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Zhou et al.

(10) **Patent No.: US 12,395,931 B2**
(45) **Date of Patent: *Aug. 19, 2025**

(54) **POWER SAVING OPERATIONS FOR COMMUNICATION SYSTEMS**

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(73) Assignee: **Comcast Cable Communications, LLC**, Philadelphia, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/392,264**

(22) Filed: **Dec. 21, 2023**

(65) **Prior Publication Data**

US 2024/0137864 A1 Apr. 25, 2024

Related U.S. Application Data

(63) Continuation of application No. 17/526,618, filed on Nov. 15, 2021, now Pat. No. 11,895,584, which is a continuation of application No. 16/829,144, filed on Mar. 25, 2020, now Pat. No. 11,212,747.

(60) Provisional application No. 62/823,528, filed on Mar. 25, 2019.

(51) **Int. Cl.**
H04W 52/02 (2009.01)
H04W 52/14 (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04W 52/0216*** (2013.01); ***H04W 52/143*** (2013.01); ***H04W 72/0446*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04W 52/0216; H04W 72/23; H04W 52/143; H04W 72/0446; H04W 72/1273; H04W 52/0129
See application file for complete search history.

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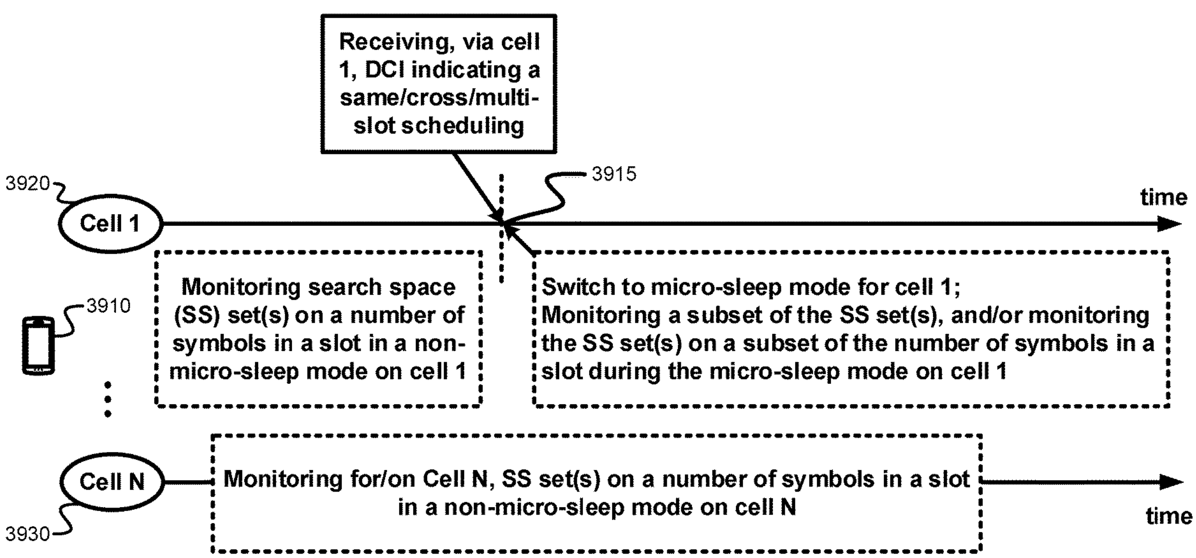
Primary Examiner — John J Lee
(74) *Attorney, Agent, or Firm* — Banner & Witcoff, Ltd.

(57) **ABSTRACT**

Base stations and wireless devices may use cross-slot scheduling for each of a plurality of cells. Base stations and wireless devices may communicate regarding the cross-slot scheduling, including for example, one or more indications associated with cross-slot scheduling for one or more cells. A wireless device may determine cross-slot scheduling for one or more transmissions associated with the one or more cells. The wireless device may save power by switching to a power saving mode for at least one cell during one or more slots, based on the cross-slot scheduling.

24 Claims, 43 Drawing Sheets



(51) **Int. Cl.**
H04W 72/0446 (2023.01)
H04W 72/1273 (2023.01)
H04W 72/23 (2023.01)

(52) **U.S. Cl.**
CPC ***H04W 72/1273*** (2013.01); ***H04W 72/23*** (2023.01); *H04W 52/0219* (2013.01)

(56) **References Cited**

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Aug. 11, 2021—European Office Action—EP 20165542.0.

Aug. 11, 2022—EP Office Action—EP App. No. 20165542.0.

* cited by examiner

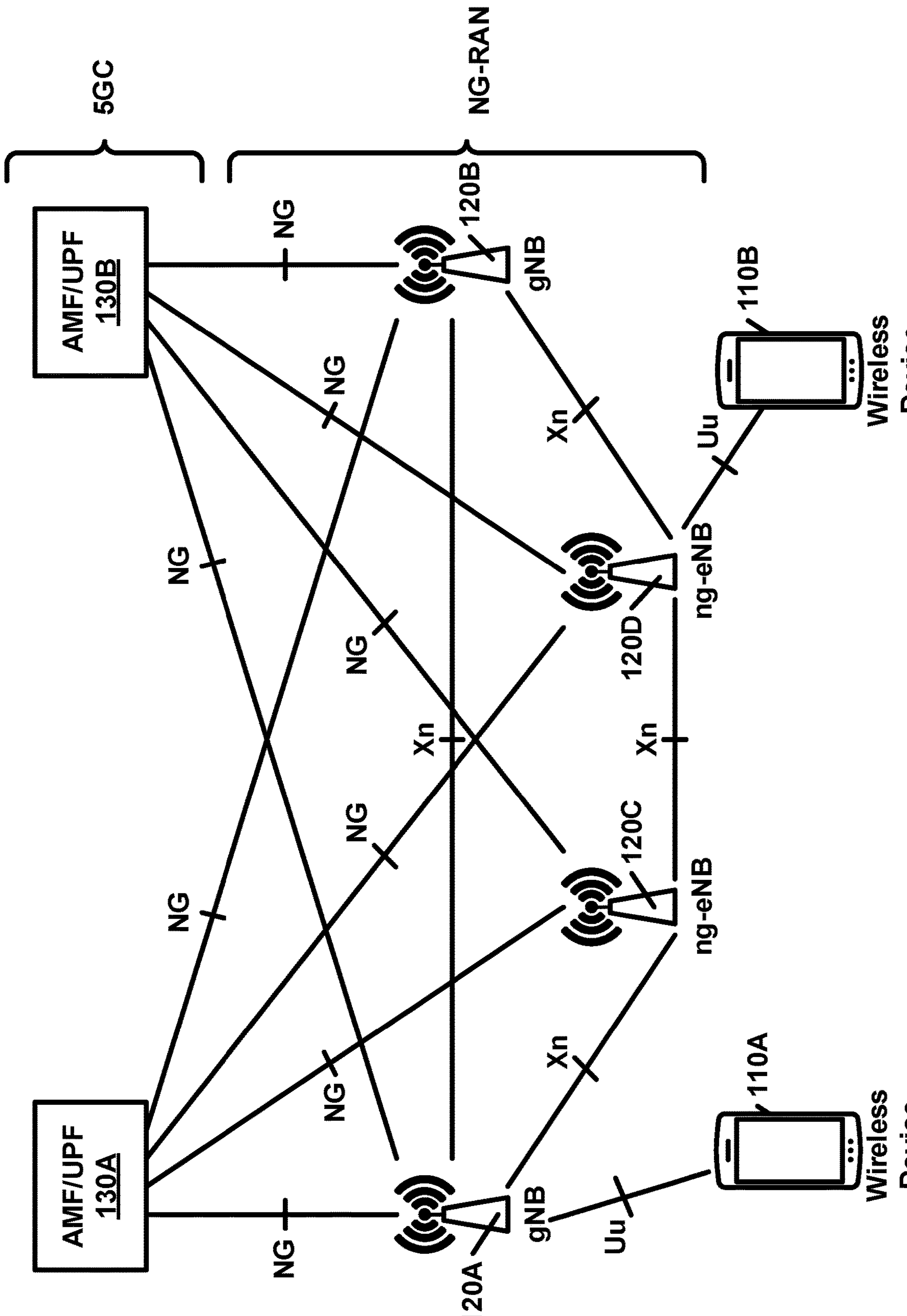
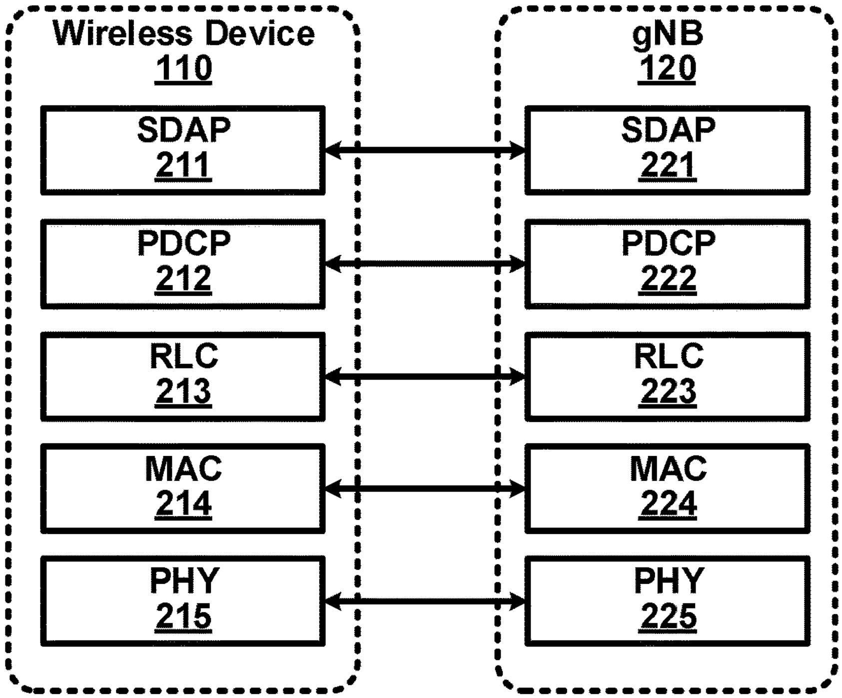
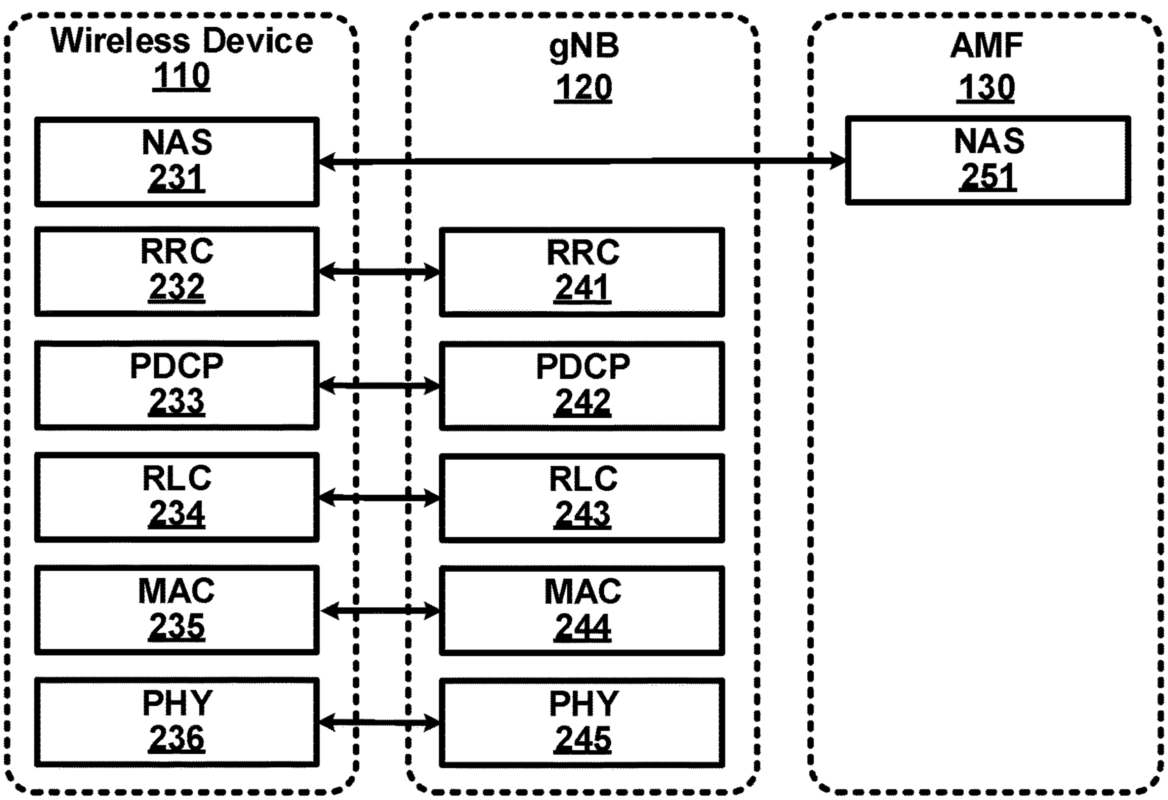

5GC
NG-RAN
AMF/UPF
130B
AMF/UPF
130A
NG
Xn
Uu
gNB
120A
gNB
120B
ng-eNB
120C
ng-eNB
120D
110A
Wireless Device
110B
Wireless Device

FIG. 1



User Plane Protocol Stack

FIG. 2A



Control Plane Protocol Stack

FIG. 2B

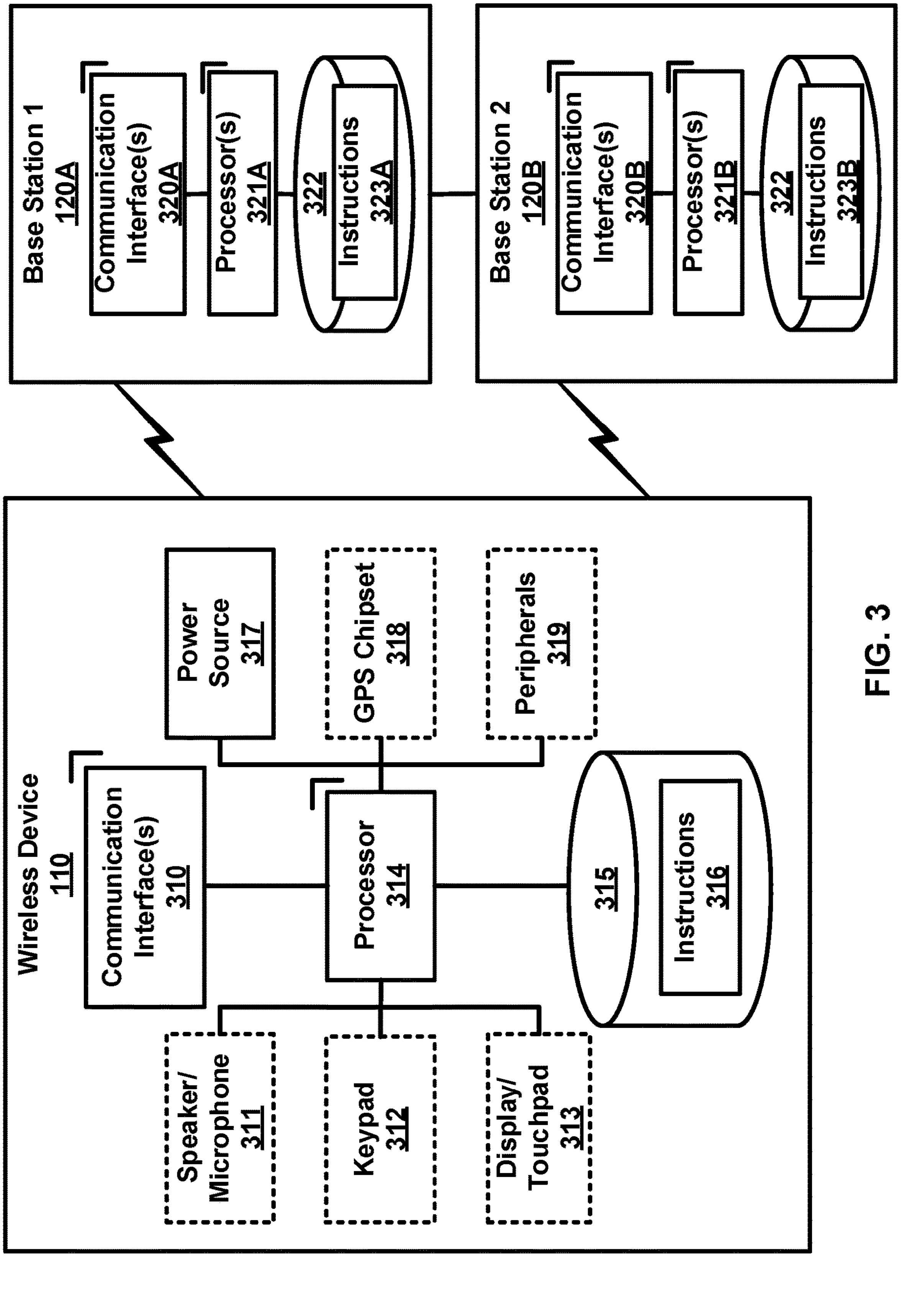

Base Station 1
120A
Communication Interface(s)
320A
Processor(s)
321A
322
Instructions
323A
Base Station 2
120B
Communication Interface(s)
320B
Processor(s)
321B
322
Instructions
323B
Wireless Device
110
Communication Interface(s)
310
Processor
314
315
Instructions
316
Power Source
317
GPS Chipset
318
Peripherals
319
Speaker/ Microphone
311
Keypad
312
Display/ Touchpad
313

FIG. 3

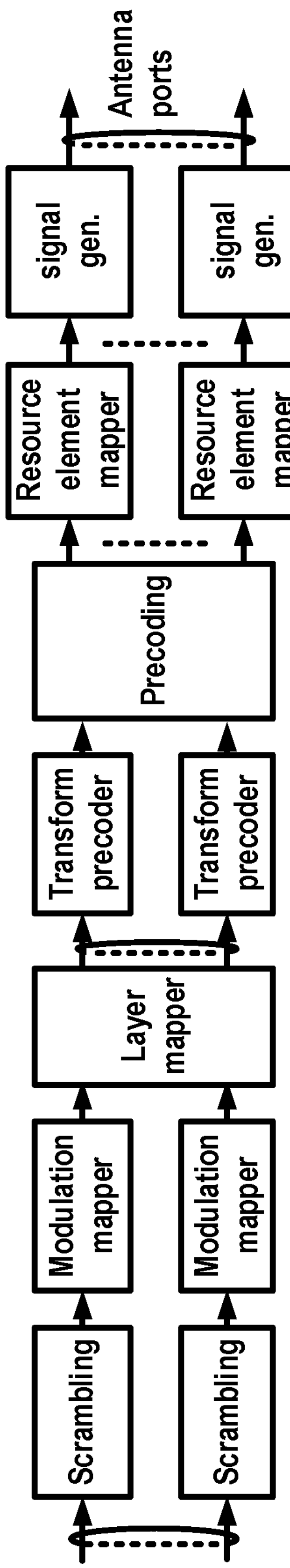


FIG. 4A

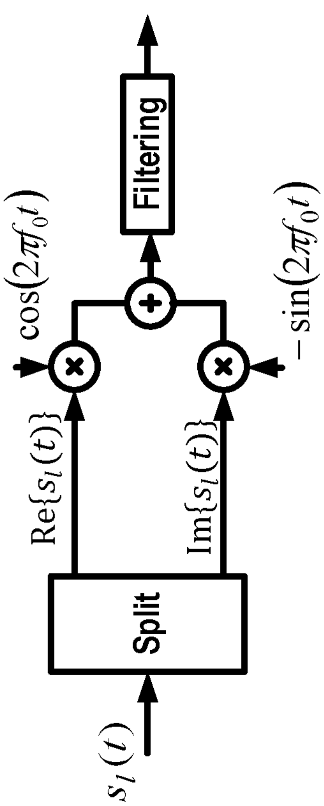


FIG. 4B

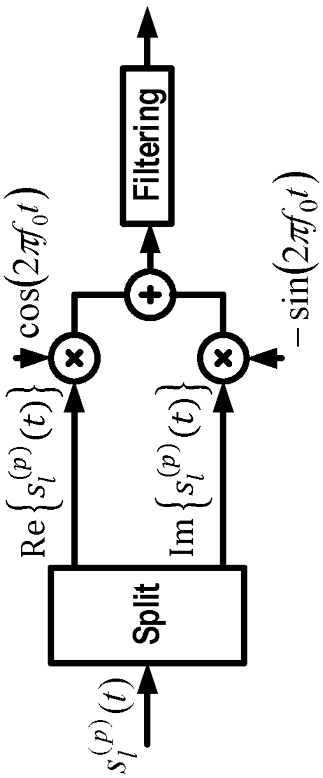


FIG. 4D

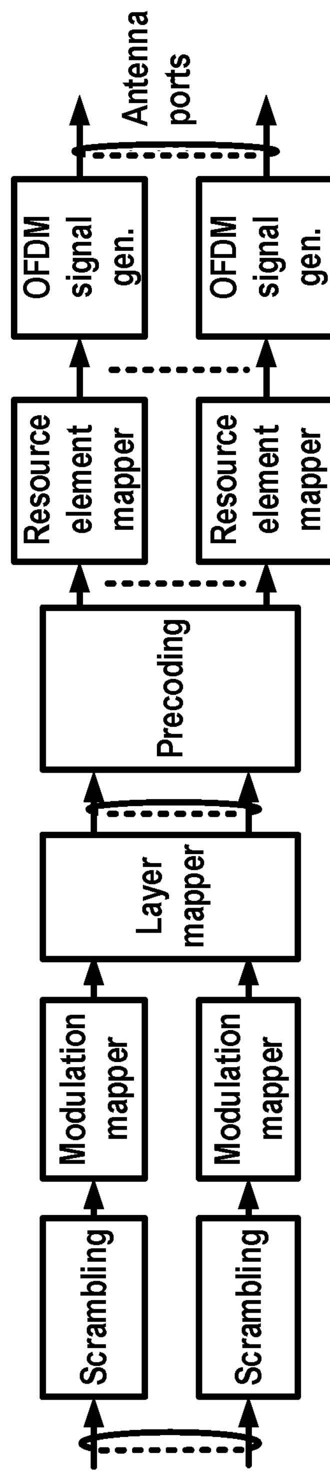


FIG. 4C

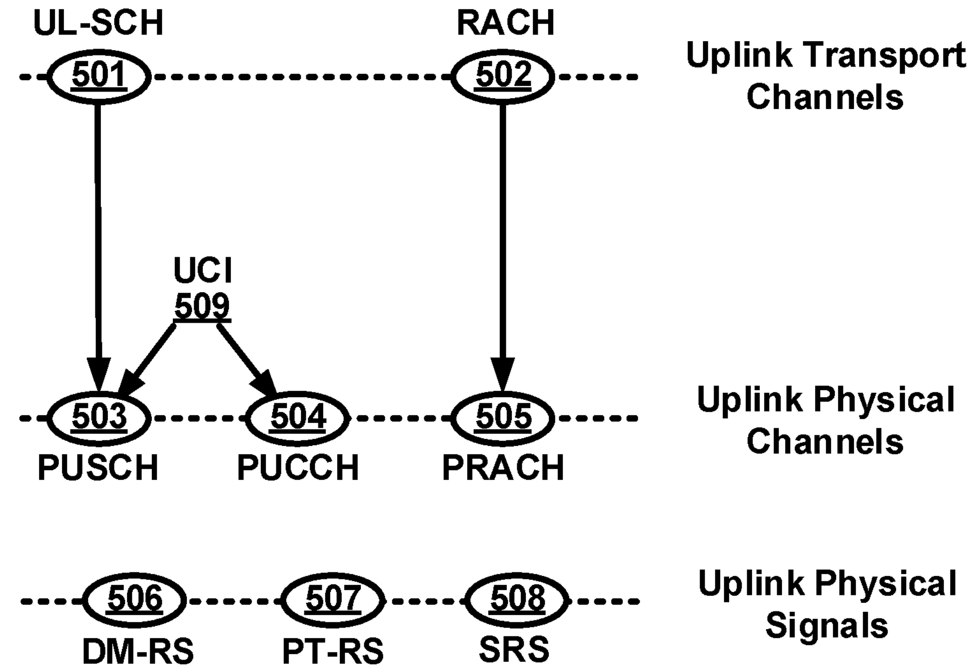

UL-SCH
501
RACH
502
Uplink Transport Channels
UCI
509
503
PUSCH
504
PUCCH
505
PRACH
Uplink Physical Channels
506
DM-RS
507
PT-RS
508
SRS
Uplink Physical Signals

FIG. 5A

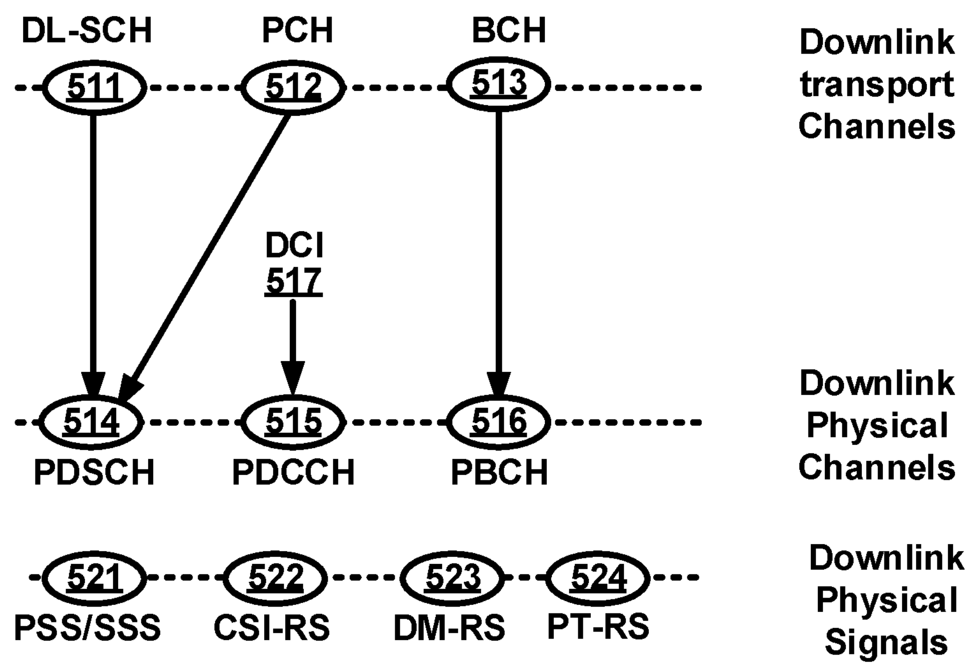
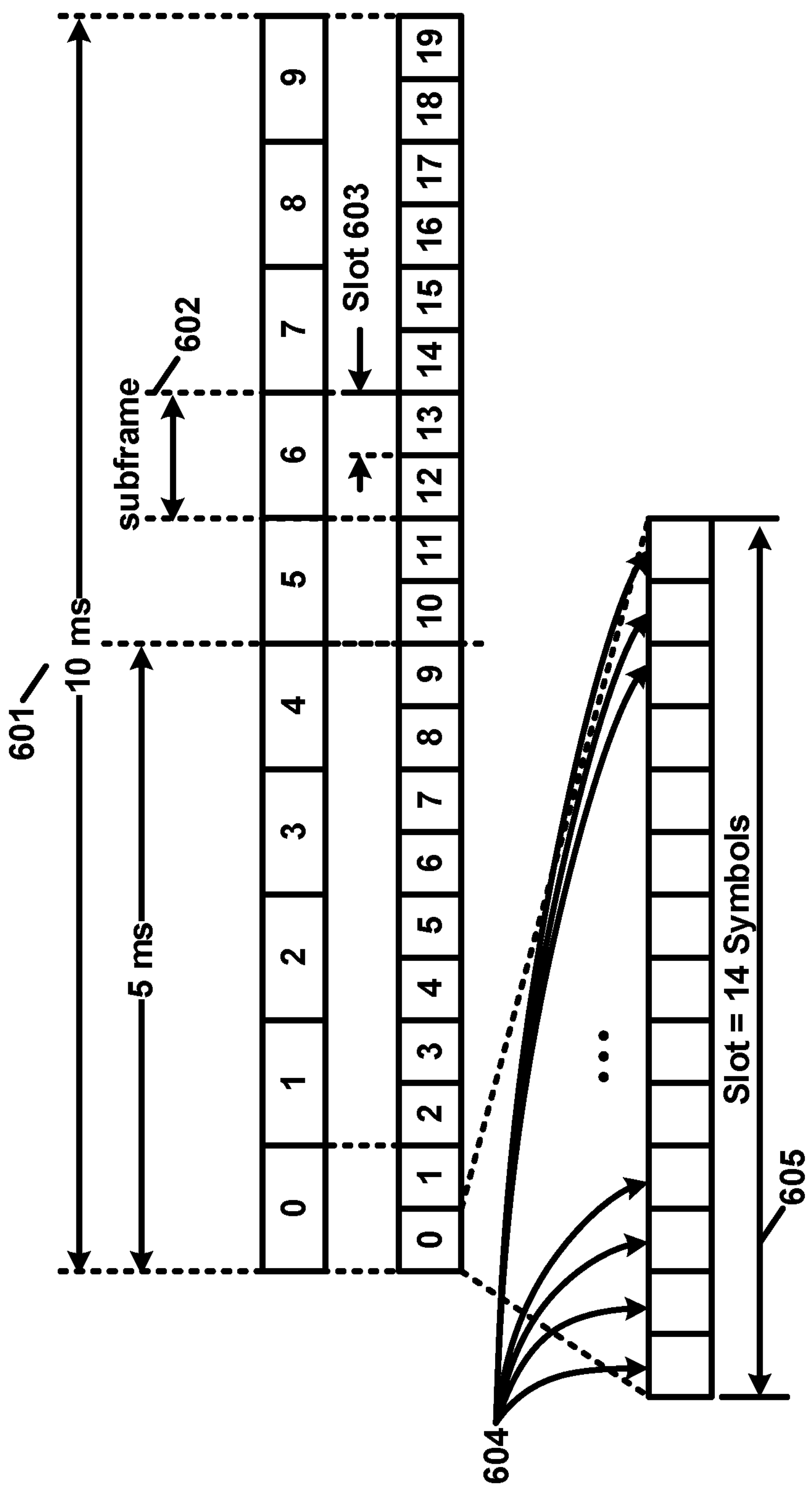

DL-SCH
511
PCH
512
BCH
513
Downlink transport Channels
DCI
517
514
PDSCH
515
PDCCH
516
PBCH
Downlink Physical Channels
521
PSS/SSS
522
CSI-RS
523
DM-RS
524
PT-RS
Downlink Physical Signals

FIG. 5B



601
10 ms
5 ms
subframe
602
Slot 603
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
604
Slot = 14 Symbols
605

FIG. 6

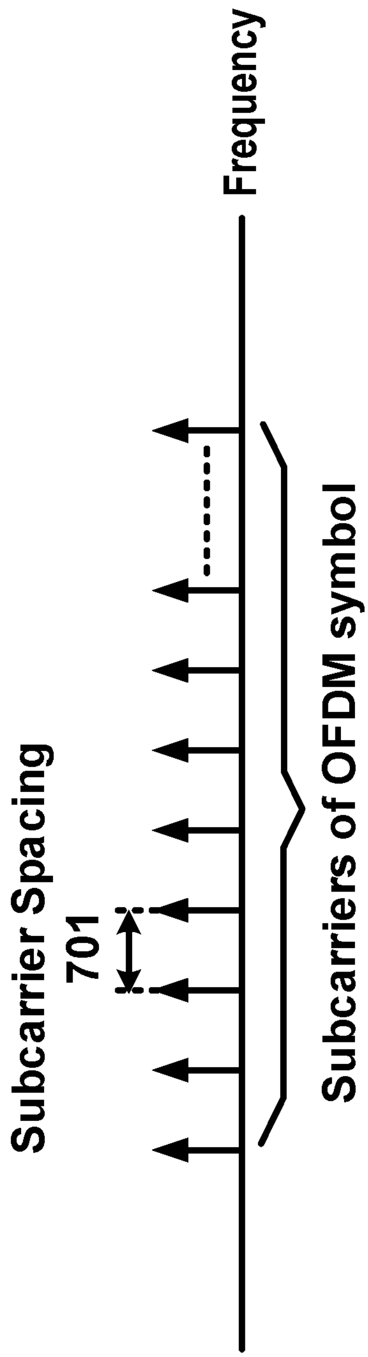

Subcarrier Spacing
701
Subcarriers of OFDM symbol
702
Frequency

FIG. 7A

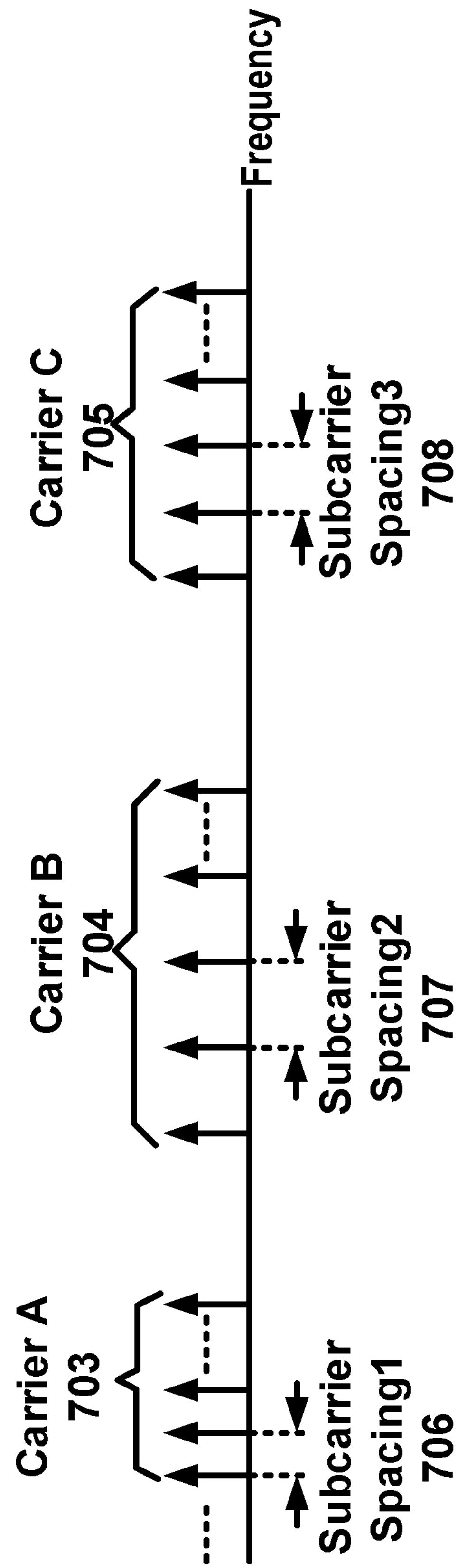

Carrier A
703
Carrier B
704
Carrier C
705
Subcarrier
Spacing1
706
Subcarrier
Spacing2
707
Subcarrier
Spacing3
708
Frequency

FIG. 7B

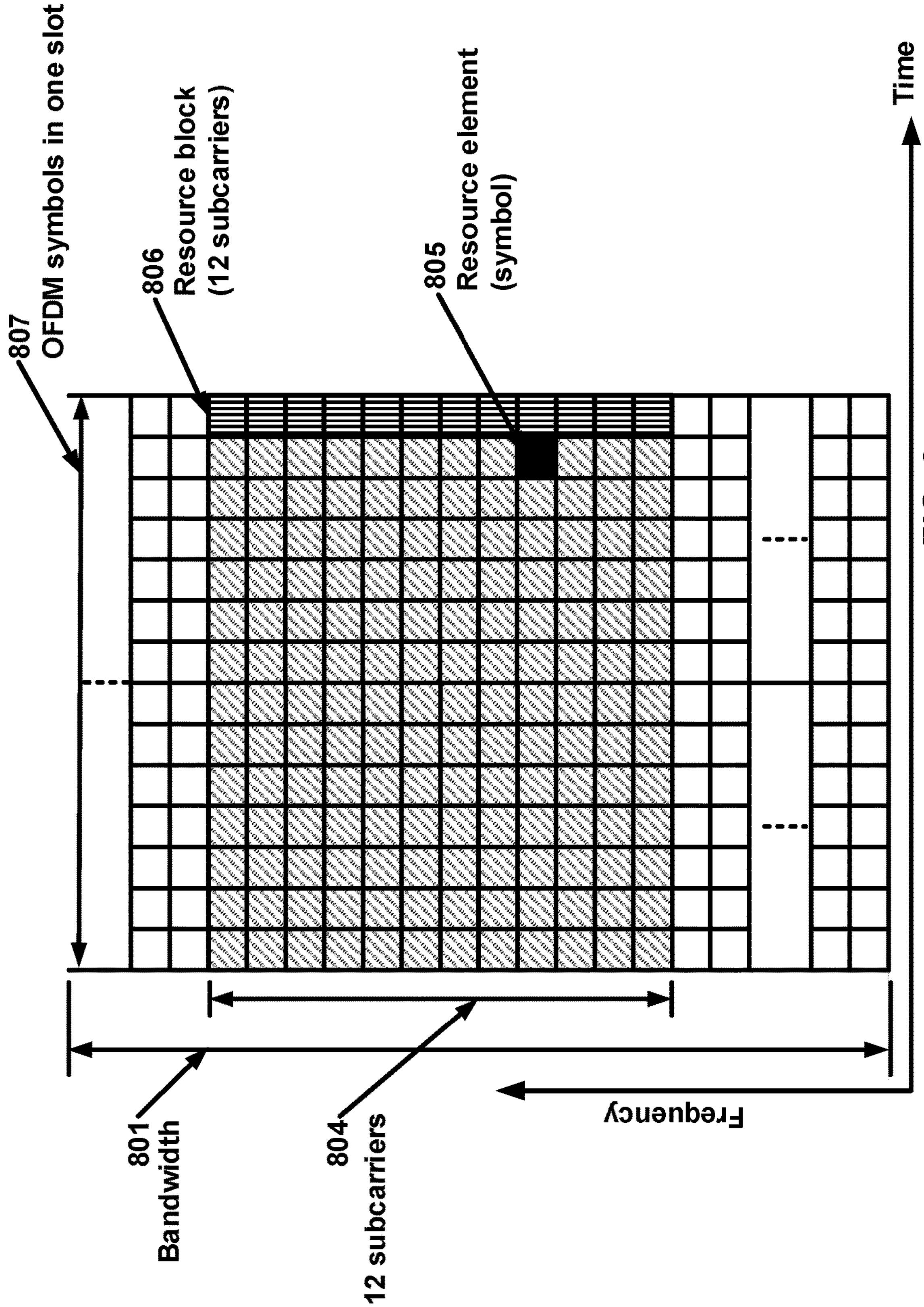
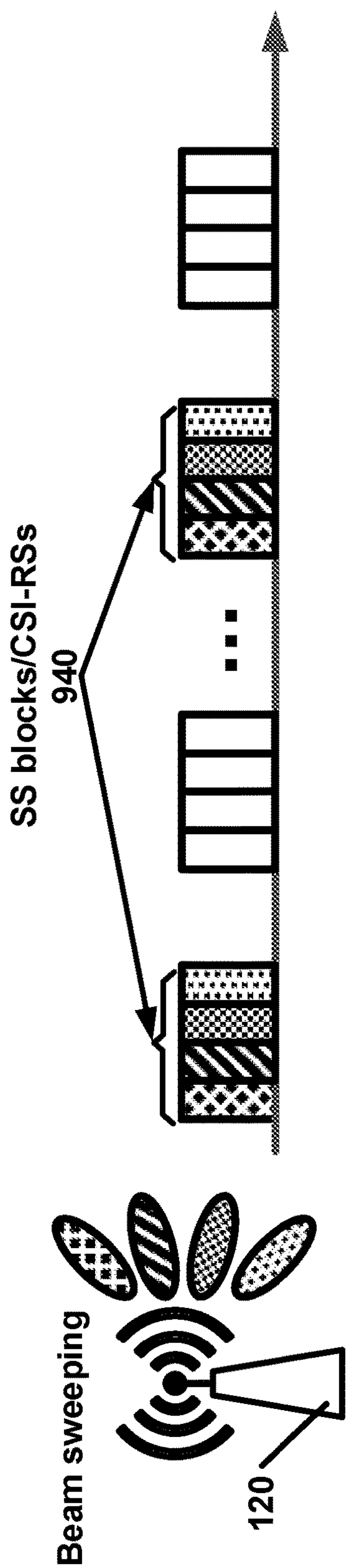
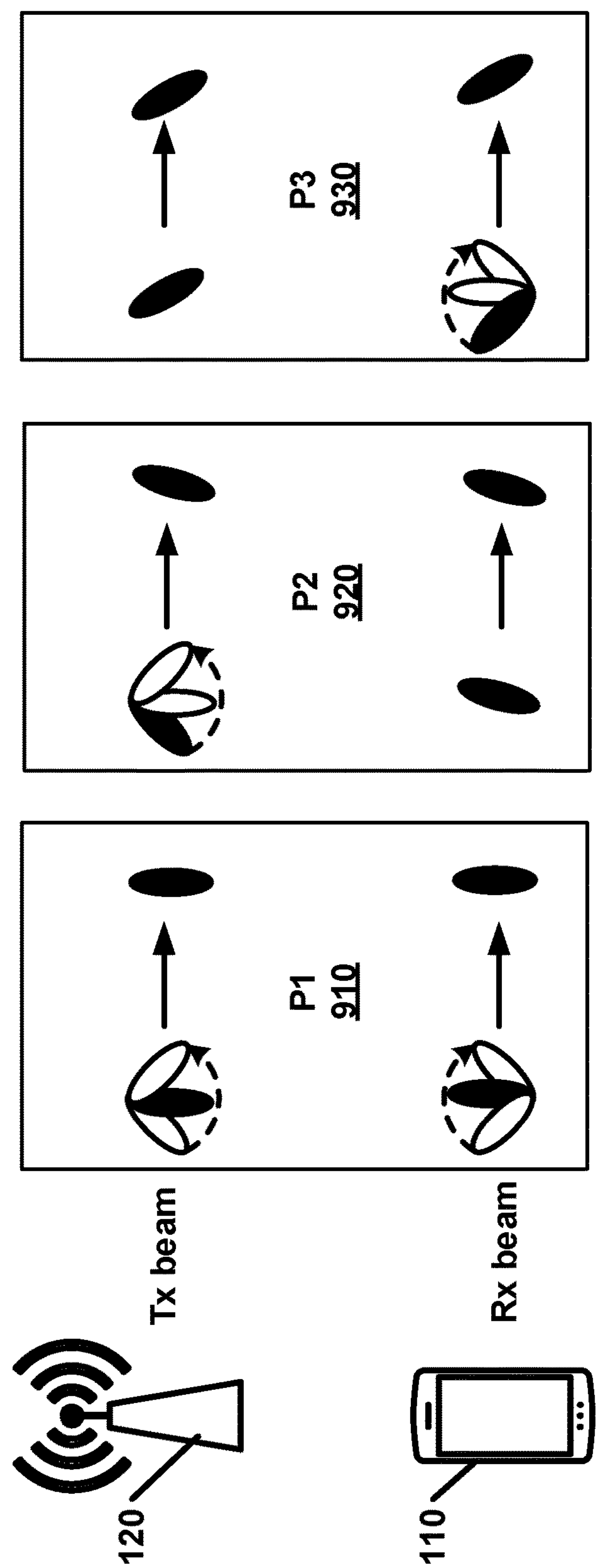

807
OFDM symbols in one slot
806
Resource block
(12 subcarriers)
805
Resource element
(symbol)
Time
801
Bandwidth
804
12 subcarriers
Frequency

FIG. 8



Beam sweeping
120
SS blocks/CSI-RSs
940

FIG. 9A



Tx beam
Rx beam
120
110
P1
910
P2
920
P3
930

FIG. 9B

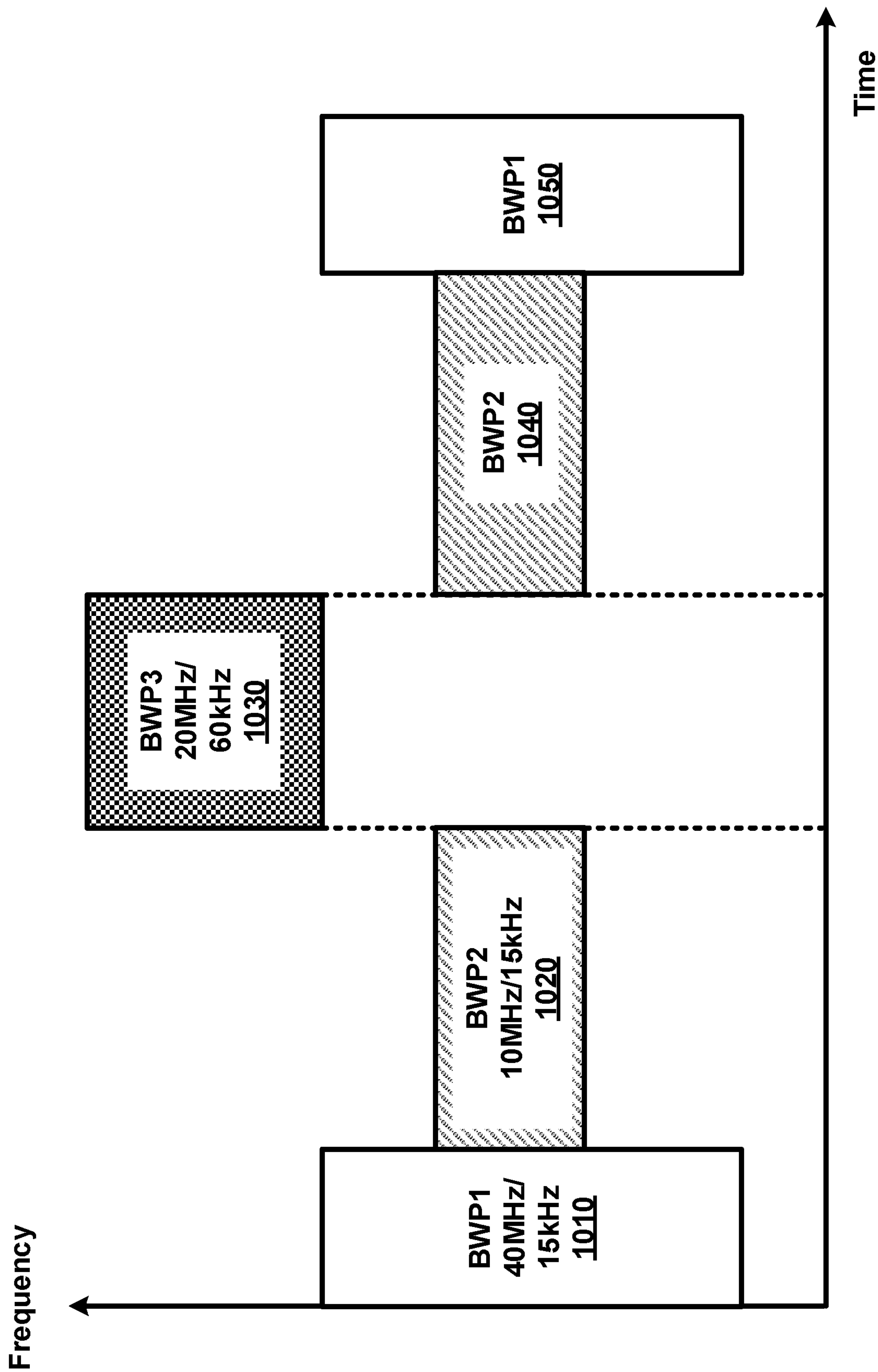

Time
BWP1
1050
BWP2
1040
BWP3
20MHz/
60kHz
1030
BWP2
10MHz/15kHz
1020
BWP1
40MHz/
15kHz
1010
Frequency

FIG. 10

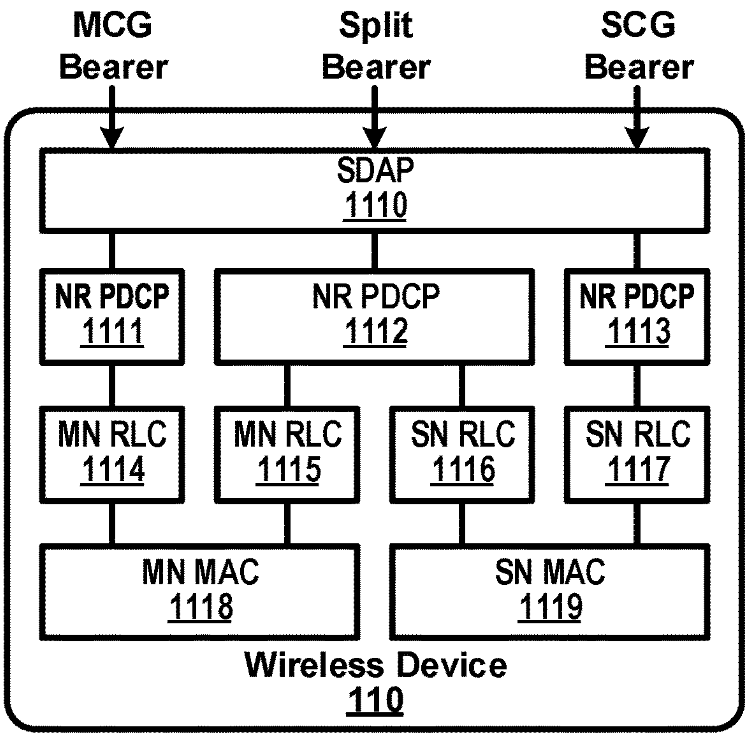


FIG. 11A

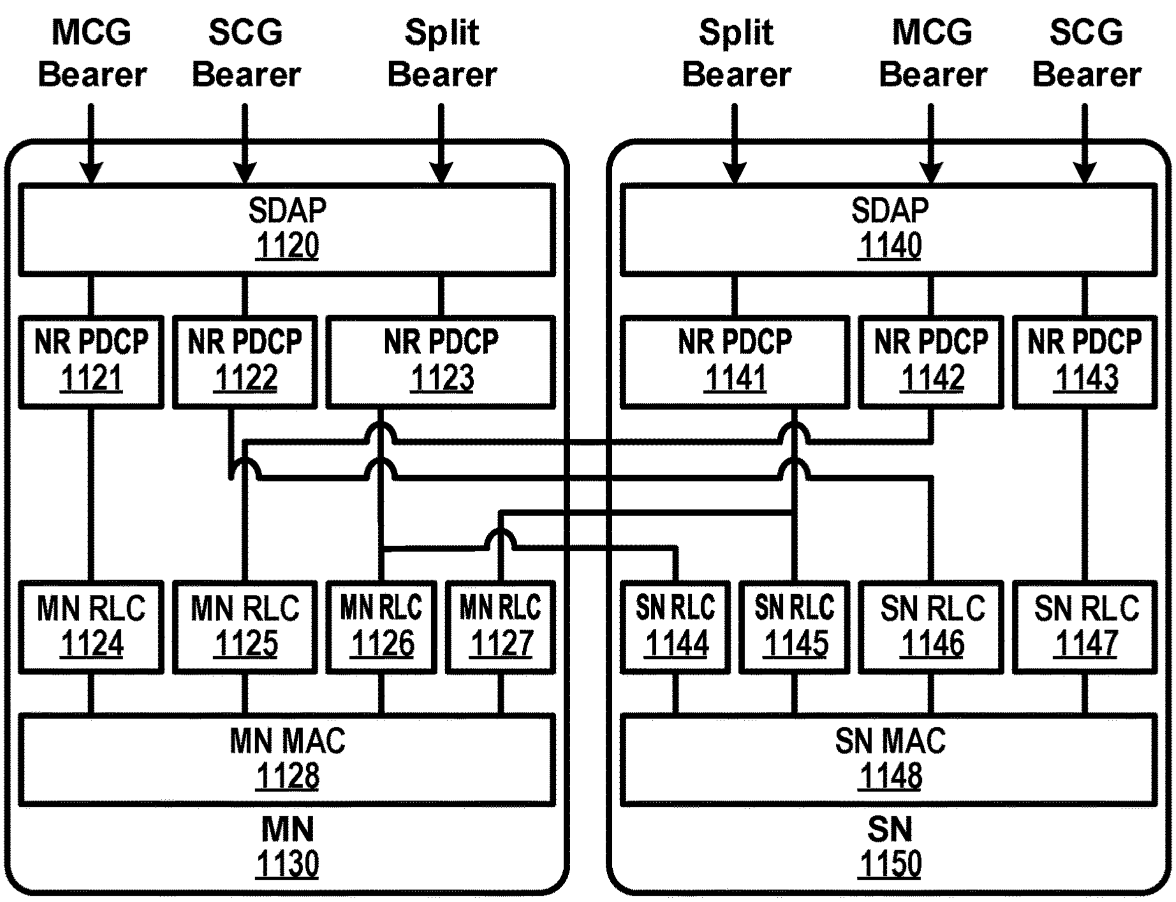


FIG. 11B

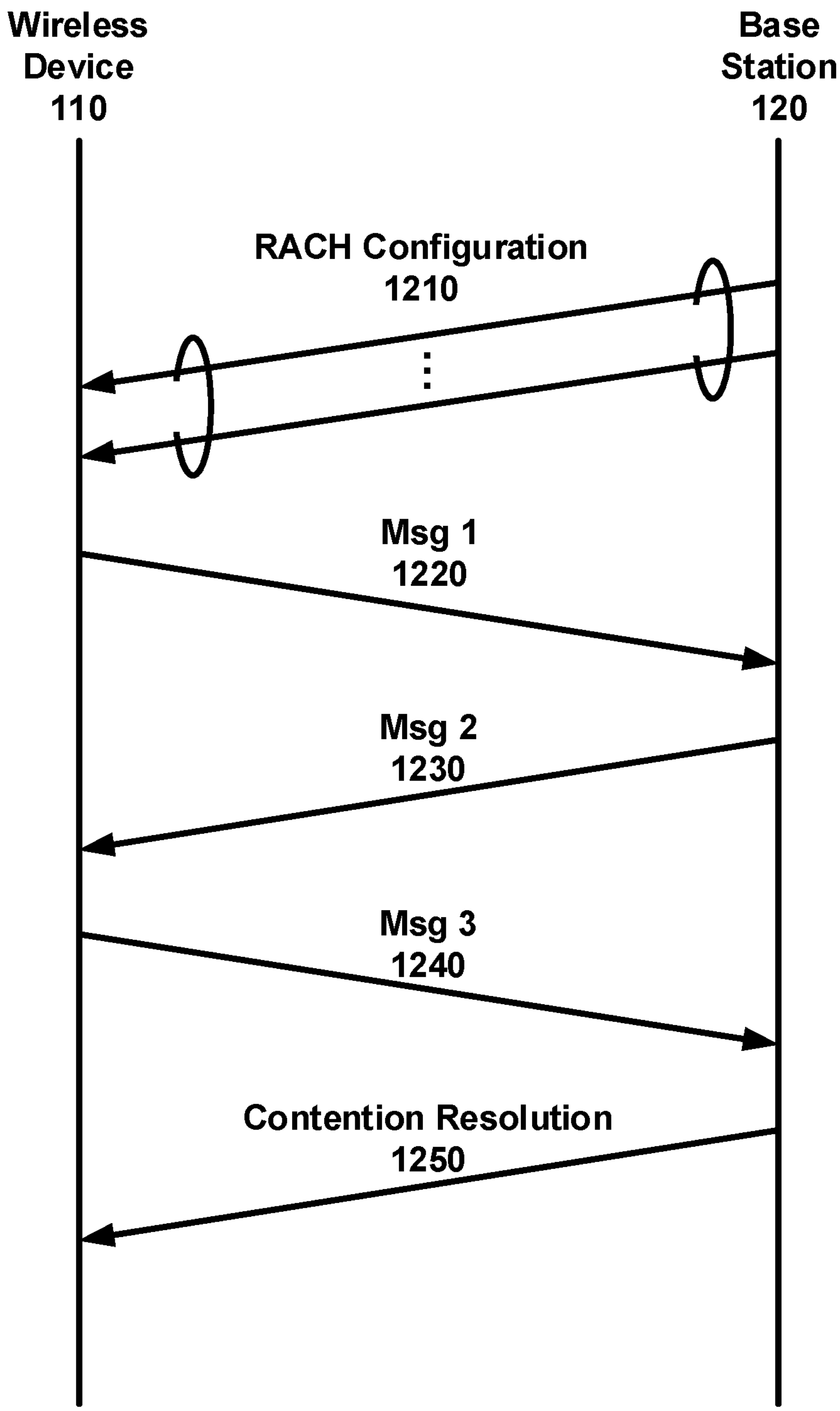

Wireless Device 110
Base Station 120
RACH Configuration 1210
Msg 1 1220
Msg 2 1230
Msg 3 1240
Contention Resolution 1250

FIG. 12

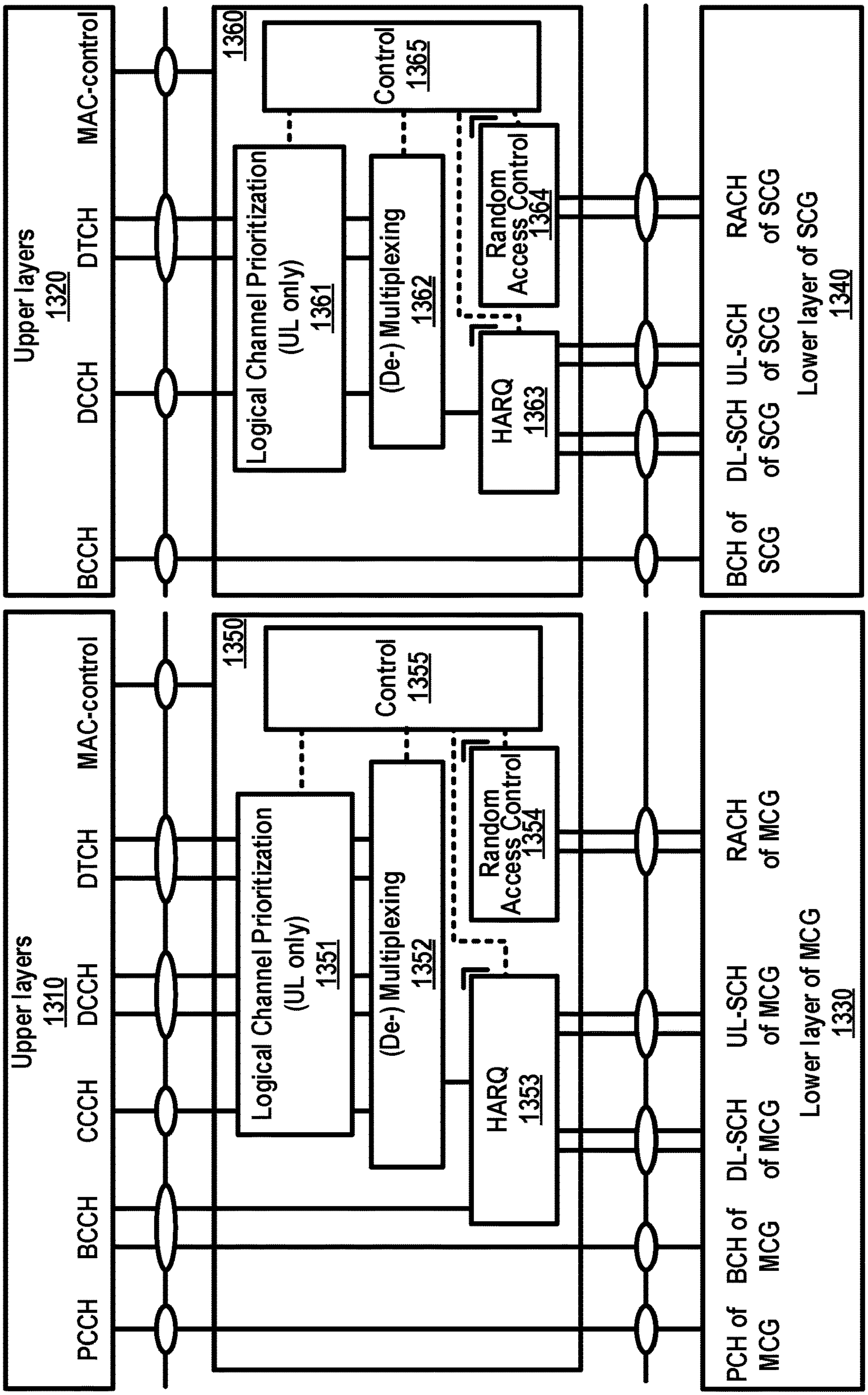
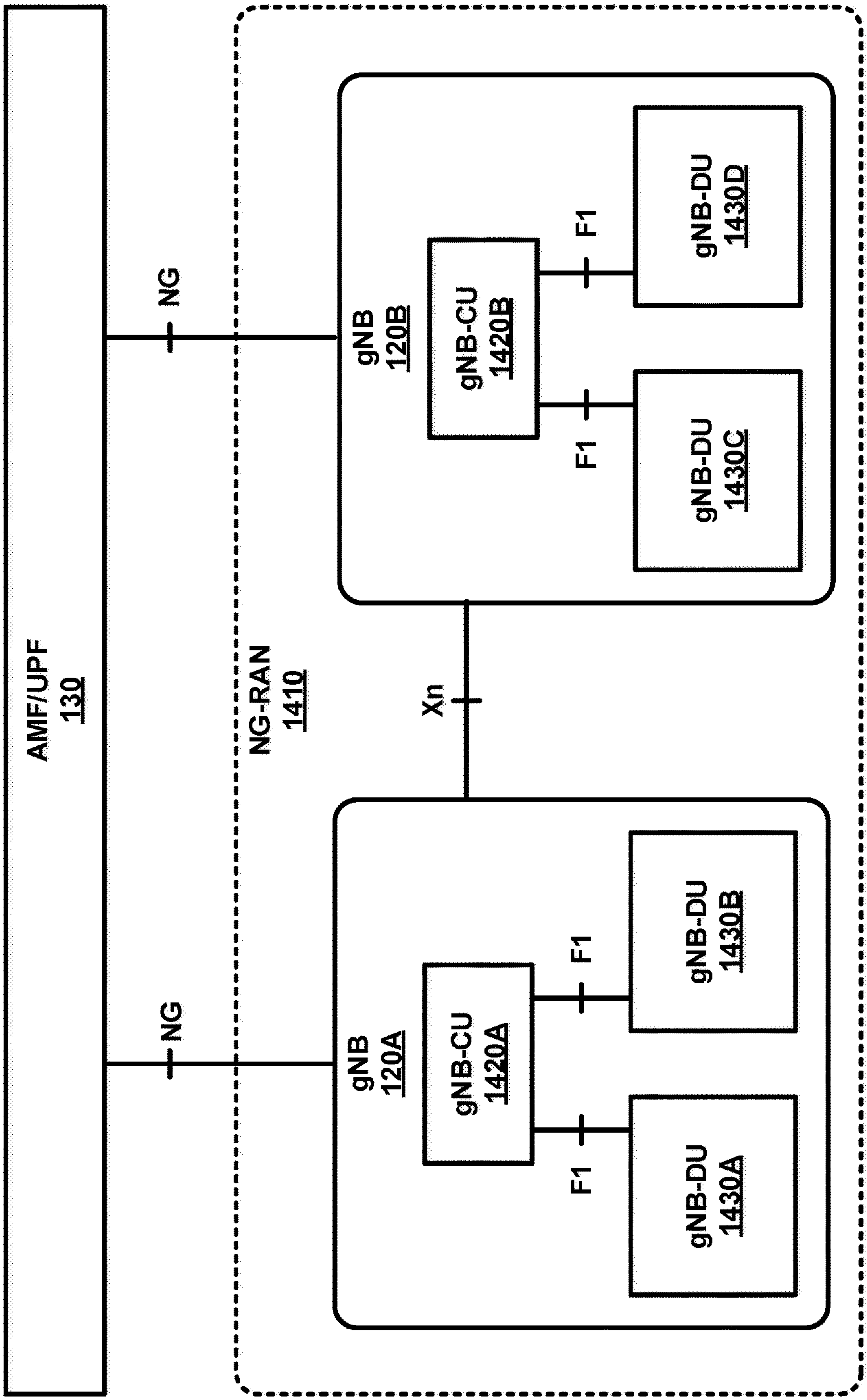

Upper layers
1310
PCCH
BCCH
CCCH
DCCH
DTCH
MAC-control
1350
Logical Channel Prioritization
(UL only)
1351
(De-) Multiplexing
1352
HARQ
1353
Random
Access Control
1354
Control
1355
PCH of
MCG
BCH of
MCG
DL-SCH
of MCG
UL-SCH
of MCG
RACH
of MCG
Lower layer of MCG
1330
Upper layers
1320
BCCH
DCCH
DTCH
MAC-control
1360
Logical Channel Prioritization
(UL only)
1361
(De-) Multiplexing
1362
HARQ
1363
Random
Access Control
1364
Control
1365
BCH of
SCG
DL-SCH
of SCG
UL-SCH
of SCG
RACH
of SCG
Lower layer of SCG
1340

FIG. 13



AMF/UPF
130
NG
NG
NG-RAN
1410
gNB
120A
gNB-CU
1420A
F1
F1
gNB-DU
1430A
gNB-DU
1430B
Xn
gNB
120B
gNB-CU
1420B
F1
F1
gNB-DU
1430C
gNB-DU
1430D

FIG. 14

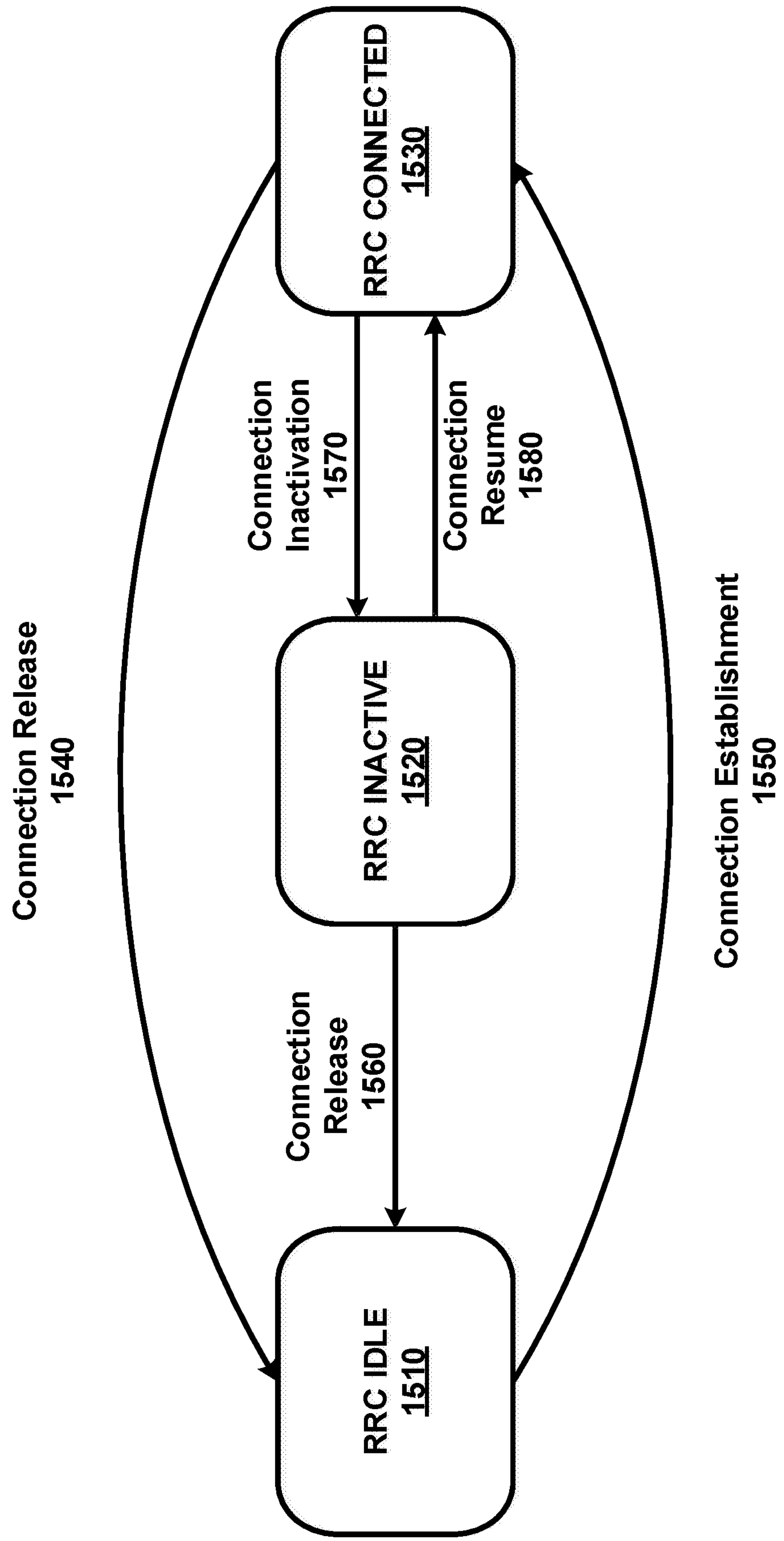

RRC CONNECTED
1530
Connection Inactivation
1570
Connection Resume
1580
Connection Release
1540
RRC INACTIVE
1520
Connection Establishment
1550
Connection Release
1560
RRC IDLE
1510

FIG. 15

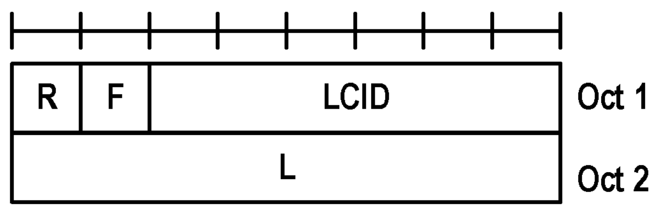


FIG. 16A

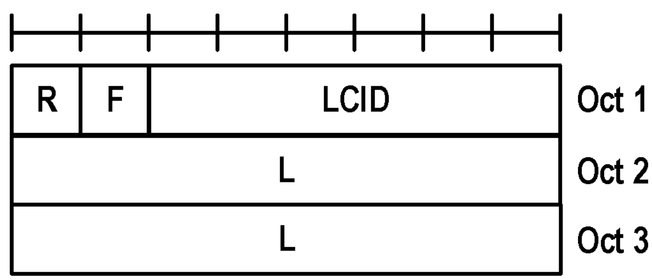


FIG. 16B

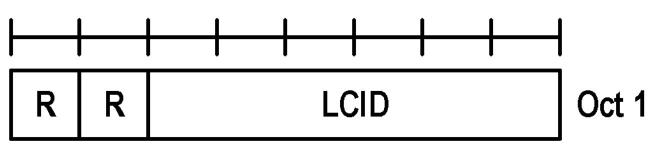


FIG. 16C

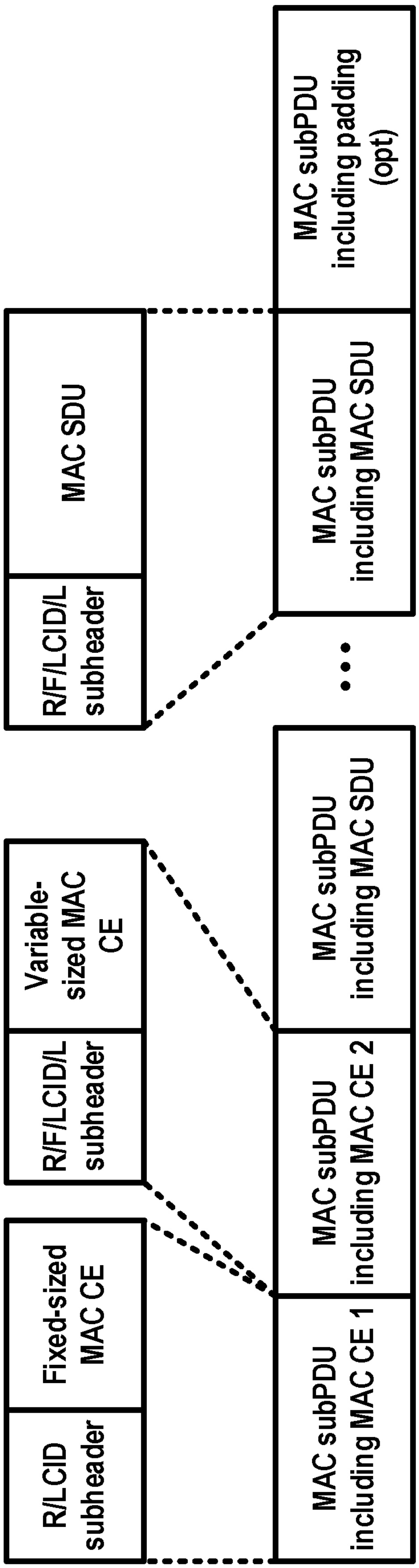


FIG. 17A

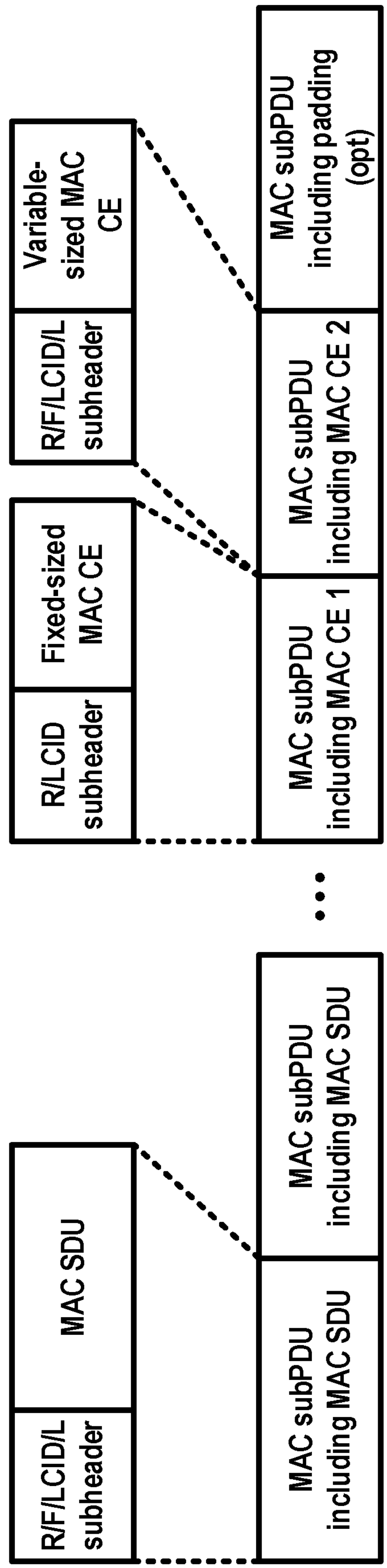


FIG. 17B

Index	LCID values
000000	CCCH
000001-100000	Identity of a logical channel
100001-101111	Reserved
110000	SP ZP CSI-RS Resource Set Act./Deact.
110001	PUCCH spatial relation Act./Deact.
110010	SP SRS Act./Deact.
110011	SP CSI reporting on PUCCH Act./Deact.
110100	TCI State Indication for UE-specific PDCCH
110101	TCI State Indication for UE-specific PDSCH
110110	Aperiodic CSI Trigger State Subselection
110111	SP CSI-RS/CSI-IM Resource Set Act./Deact.
111000	Duplication Activation/deactivation
111001	SCell activation/deactivation (4 Octet)
111010	SCell activation/deactivation (1 Octet)
111011	Long DRX Command
111100	DRX Command
111101	Timing Advance Command
111110	UE Contention Resolution Identity
111111	Padding

FIG. 18

Index	LCID values
000000	CCCH
000001-100000	Identity of a logical channel
100001-110110	Reserved
110111	Configured Grant Confirmation
111000	Multiple Entry PHR
111001	Single Entry PHR
111010	C-RNTI
111011	Short Truncated BSR
111100	Long Truncated BSR
111101	Short BSR
111110	Long BSR
111111	Padding

FIG. 19

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R	Oct 1

FIG. 20A

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R	Oct 1
C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	Oct 2
C_{23}	C_{22}	C_{21}	C_{20}	C_{19}	C_{18}	C_{17}	C_{16}	Oct 3
C_{31}	C_{30}	C_{29}	C_{28}	C_{27}	C_{26}	C_{25}	C_{24}	Oct 4

FIG. 20B

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R	Oct 1

FIG. 21A

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R	Oct 1
C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	Oct 2
C_{23}	C_{22}	C_{21}	C_{20}	C_{19}	C_{18}	C_{17}	C_{16}	Oct 3
C_{31}	C_{30}	C_{29}	C_{28}	C_{27}	C_{26}	C_{25}	C_{24}	Oct 4

FIG. 21B

Hibernation MAC CE C_i	Activation/ Deactivation MAC CE C_i	SCell may be
0	0	Deactivated
0	1	Activated
1	0	Reserved MAC CE combination
1	1	Dormant

FIG. 21C

	DCI format	Example size (Bits)	Usage
Uplink	0	45	Uplink scheduling grant
	4	53	Uplink scheduling grant with spatial multiplexing
	6-0A, 6-0B	46, 36	Uplink scheduling grant for eMTC devices
Downlink	1C	31	Special purpose compact assignment
	1A	45	Contiguous allocation only
	1B	46	Codebook-based beamforming using CRS
	1D	46	MU-MIMO using CRS
	1	55	Flexible allocations
	2A	64	Open-loop spatial multiplexing using CRS
	2B	64	Dual-layer transmission using DM-RS (TM8)
	2C	66	Multi-layer transmission using DM-RS (TM9)
	2D	68	Multi-layer transmission using DM-RS (TM9)
	2	67	Closed-loop spatial multiplexing using CRS
	6-1A, 6-1B	46, 36	Downlink scheduling grants for eMTC devices
Special	3, 3A	45	Power control commands
	5		Sidelink operation
	6-2		Paging/direct indication for eMTC devices

FIG. 22

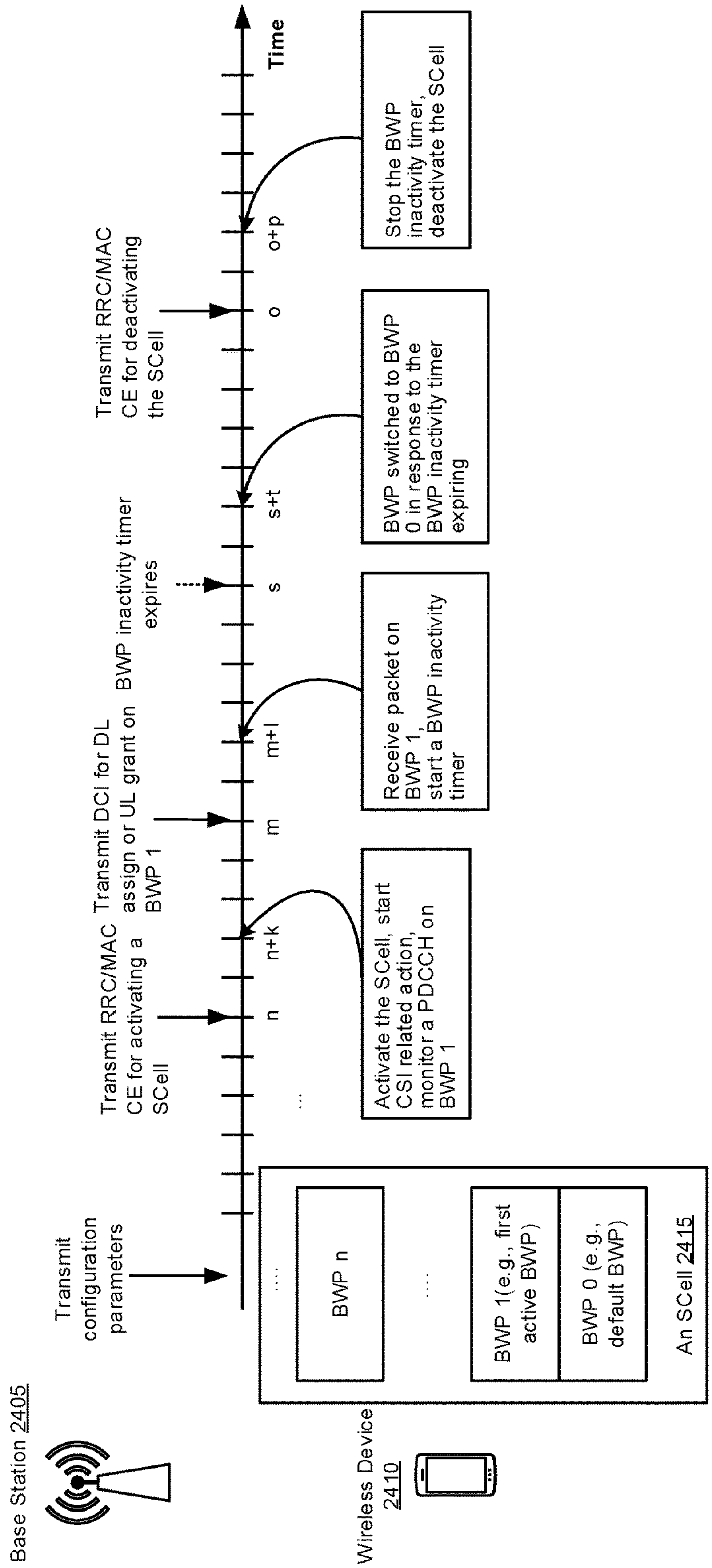
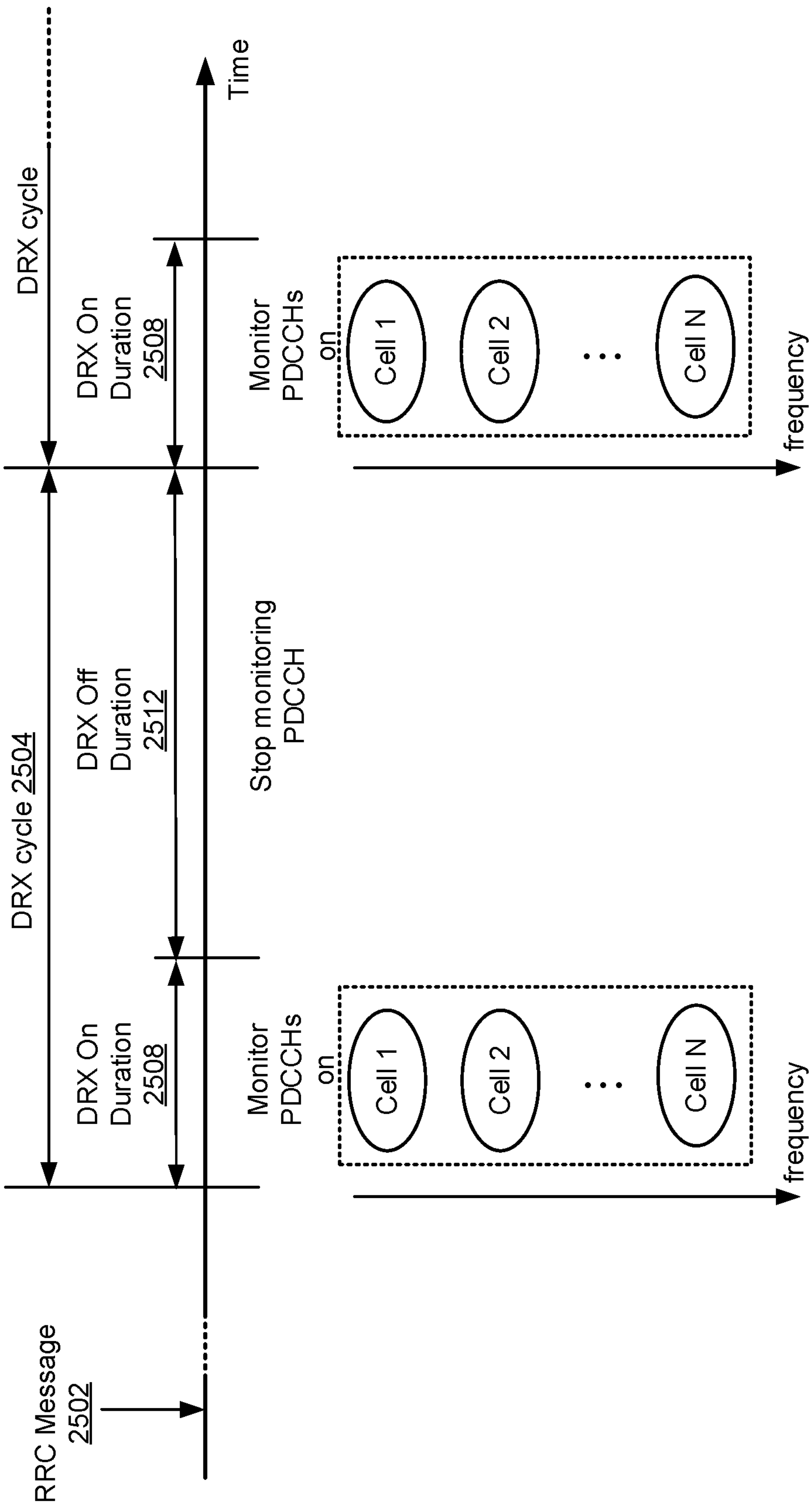

Base Station 2405
Wireless Device 2410
Transmit configuration parameters
Transmit RRC/MAC CE for activating a SCell
Transmit DCI for DL assign or UL grant on BWP 1
BWP inactivity timer expires
Transmit RRC/MAC CE for deactivating the SCell
Time
n
n+k
m
m+l
s
s+t
o
o+p
Activate the SCell, start CSI related action, monitor a PDCCH on BWP 1
Receive packet on BWP 1, start a BWP inactivity timer
BWP switched to BWP 0 in response to the BWP inactivity timer expiring
Stop the BWP inactivity timer, deactivate the SCell
BWP n
BWP 1(e.g., first active BWP)
BWP 0 (e.g., default BWP)
An SCell 2415

FIG. 23



RRC Message 2502
DRX cycle 2504
DRX On Duration 2508
DRX Off Duration 2512
DRX On Duration 2508
DRX cycle
Time
Monitor PDCCHs on
Stop monitoring PDCCH
Monitor PDCCHs on
Cell 1
Cell 2
Cell N
frequency
Cell 1
Cell 2
Cell N
frequency

FIG. 24

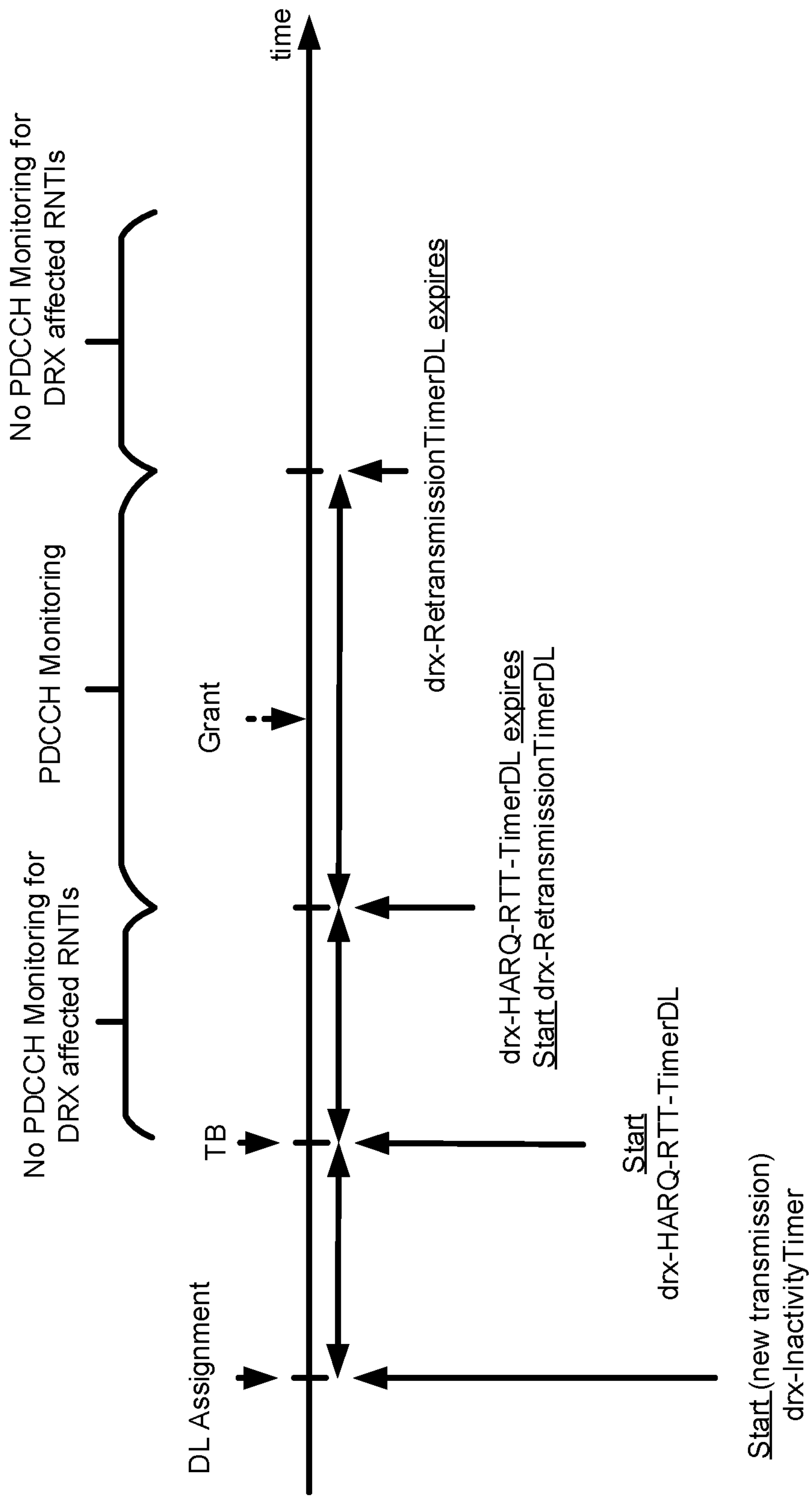

time
No PDCCH Monitoring for
DRX affected RNTIs
PDCCH Monitoring
No PDCCH Monitoring for
DRX affected RNTIs
DL Assignment
TB
Grant
drx-RetransmissionTimerDL expires
drx-HARQ-RTT-TimerDL expires
Start drx-RetransmissionTimerDL
Start
drx-HARQ-RTT-TimerDL
Start (new transmission)
drx-InactivityTimer

FIG. 25

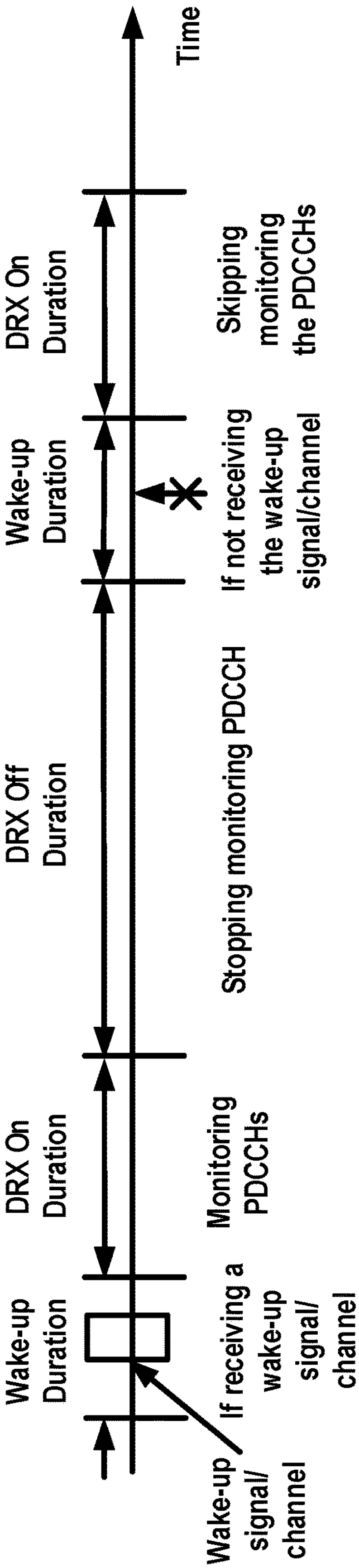


FIG. 26A

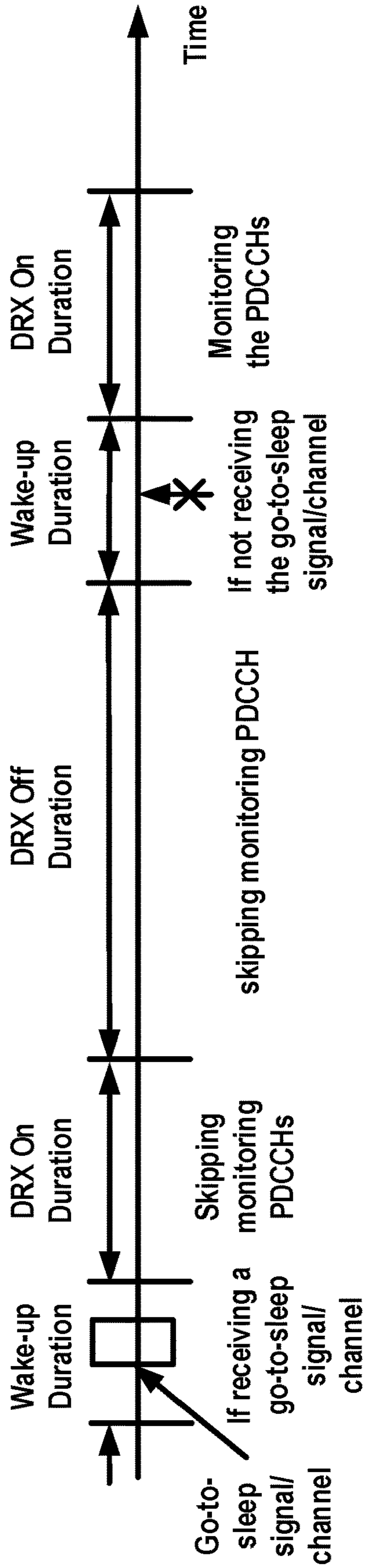


FIG. 26B

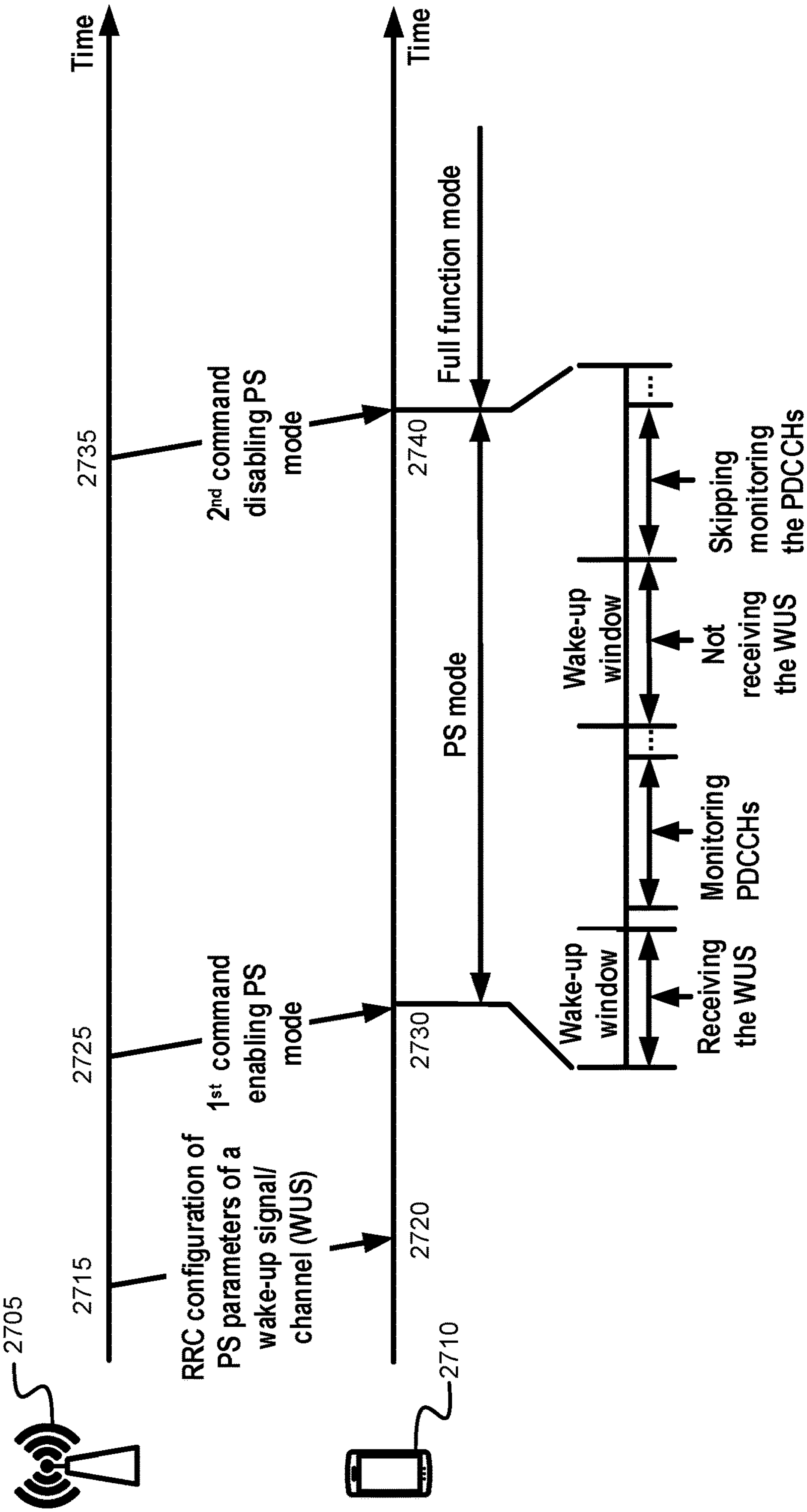

2705
2710
Time
Time
2715
RRC configuration of PS parameters of a wake-up signal/ channel (WUS)
2720
2725
1st command enabling PS mode
2730
2735
2nd command disabling PS mode
2740
PS mode
Full function mode
Wake-up window
Wake-up window
Receiving the WUS
Monitoring PDCCHs
Not receiving the WUS
Skipping monitoring the PDCCHs
...
...

FIG. 27

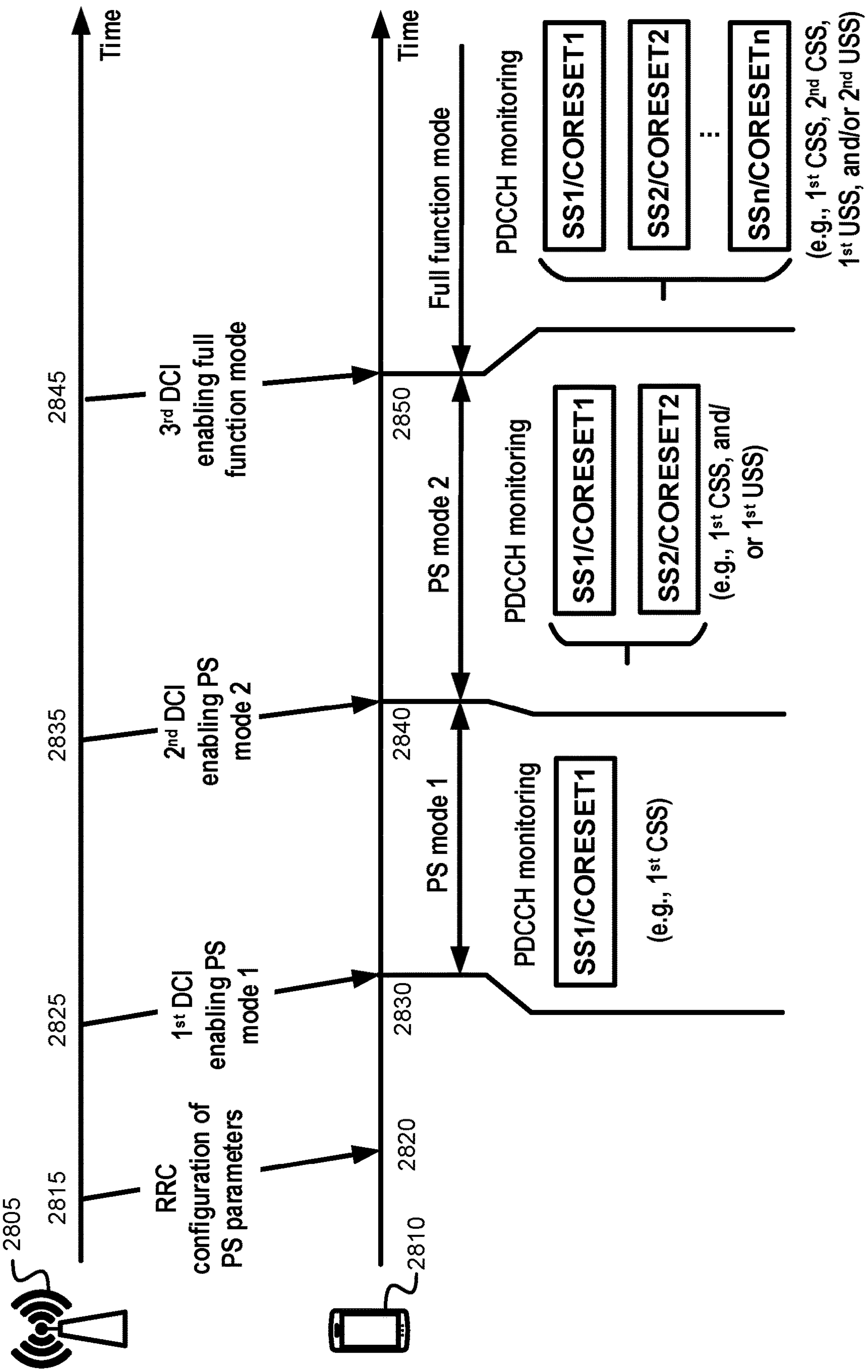

2805
2810
Time
Time
2815
RRC configuration of PS parameters
2820
2825
1st DCI enabling PS mode 1
2830
PS mode 1
PDCCH monitoring
SS1/CORESET1
(e.g., 1st CSS)
2835
2nd DCI enabling PS mode 2
2840
PS mode 2
PDCCH monitoring
SS1/CORESET1
SS2/CORESET2
(e.g., 1st CSS, and/or 1st USS)
2845
3rd DCI enabling full function mode
2850
Full function mode
PDCCH monitoring
SS1/CORESET1
SS2/CORESET2
...
SSn/CORESETn
(e.g., 1st CSS, 2nd CSS, 1st USS, and/or 2nd USS)

FIG. 28

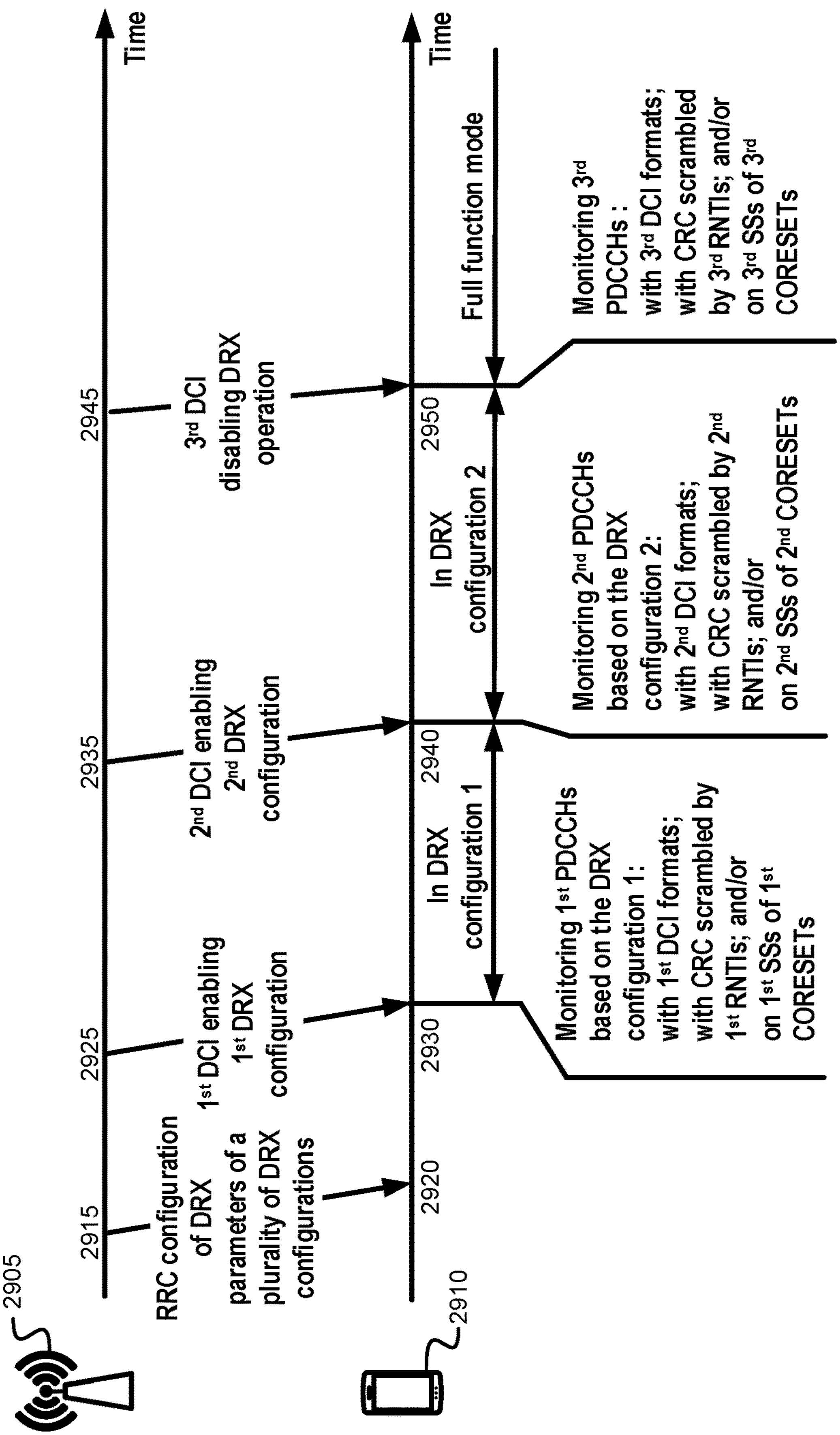

2905
2910
Time
Time
2915
RRC configuration of DRX parameters of a plurality of DRX configurations
2920
2925
1st DCI enabling 1st DRX configuration
2930
In DRX configuration 1
Monitoring 1st PDCCHs based on the DRX configuration 1: with 1st DCI formats; with CRC scrambled by 1st RNTIs; and/or on 1st SSs of 1st CORESETs
2935
2nd DCI enabling 2nd DRX configuration
2940
In DRX configuration 2
Monitoring 2nd PDCCHs based on the DRX configuration 2: with 2nd DCI formats; with CRC scrambled by 2nd RNTIs; and/or on 2nd SSs of 2nd CORESETs
2945
3rd DCI disabling DRX operation
2950
Full function mode
Monitoring 3rd PDCCHs : with 3rd DCI formats; with CRC scrambled by 3rd RNTIs; and/or on 3rd SSs of 3rd CORESETs

FIG. 29

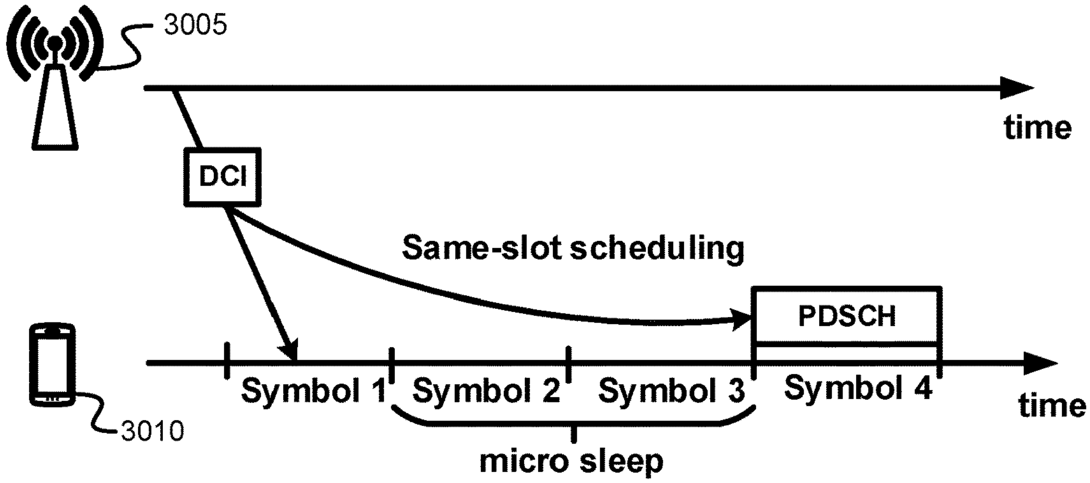


FIG. 30A

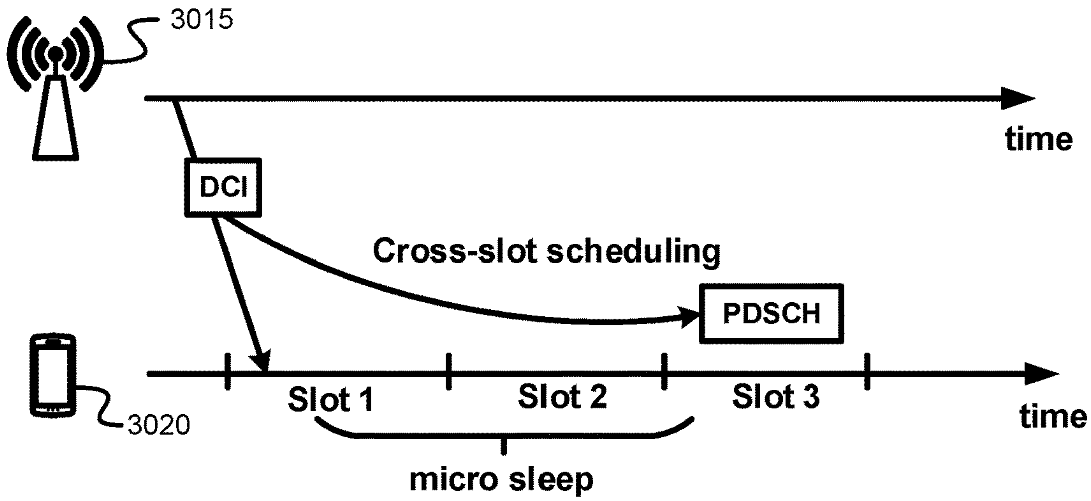


FIG. 30B

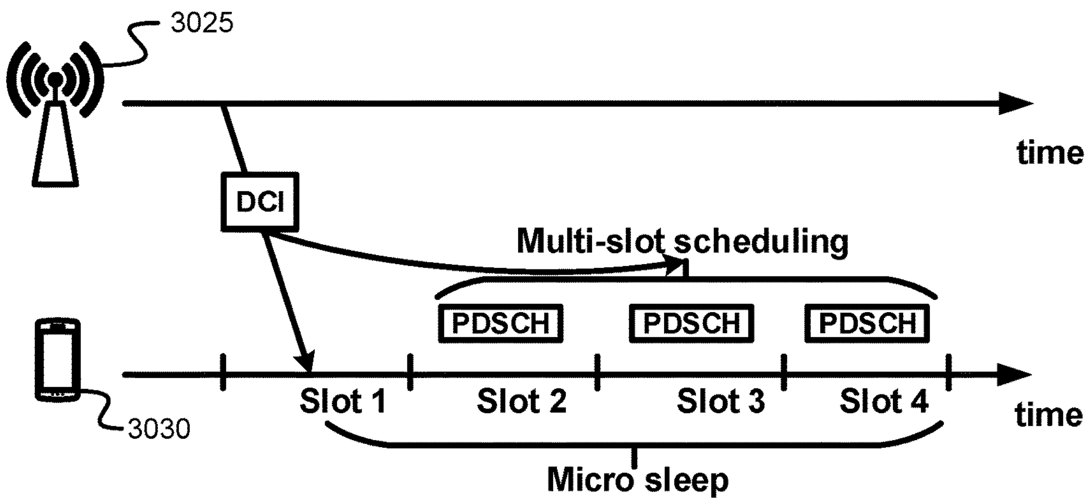


FIG. 30C

DCI format	CRC scrambled by	DCI contents	Usage of the DCI
DCI format 2_0	SFI-RNTI	Slot format indicator 1 ← for cell 1; Slot format indicator 2 ← for cell 2 ••• Slot format indicator N ← for cell N	Notifying a group of UE's of the slot format
DCI format 2_1	INT-RNTI	Pre-emption indication 1 ← for cell 1; Pre-emption indication 2 ← for cell 2 ••• Pre-emption indication N ← for cell N	Notifying a group of UE of PDSCH resources where UE may assume no transmission is intended for the UE
DCI format 2_2	TPC-PUSCH-RNTI or TPC-PUCCH-RNTI	Block number 1 ← for cell 1; Block number 2 ← for cell 2 ••• Block number N ← for cell N	Transmission of TPC commands for PUCCH/ PUSCH
DCI format 2_3	TPC-SRS-RNTI	Block number 1 ← for cell 1 or UE 1; Block number 2 ← for cell 2 or UE 2 ••• Block number N ← for cell N or UE N	Transmission of a group of TPC commands for SRS transmissions by one or more UEs

FIG. 31

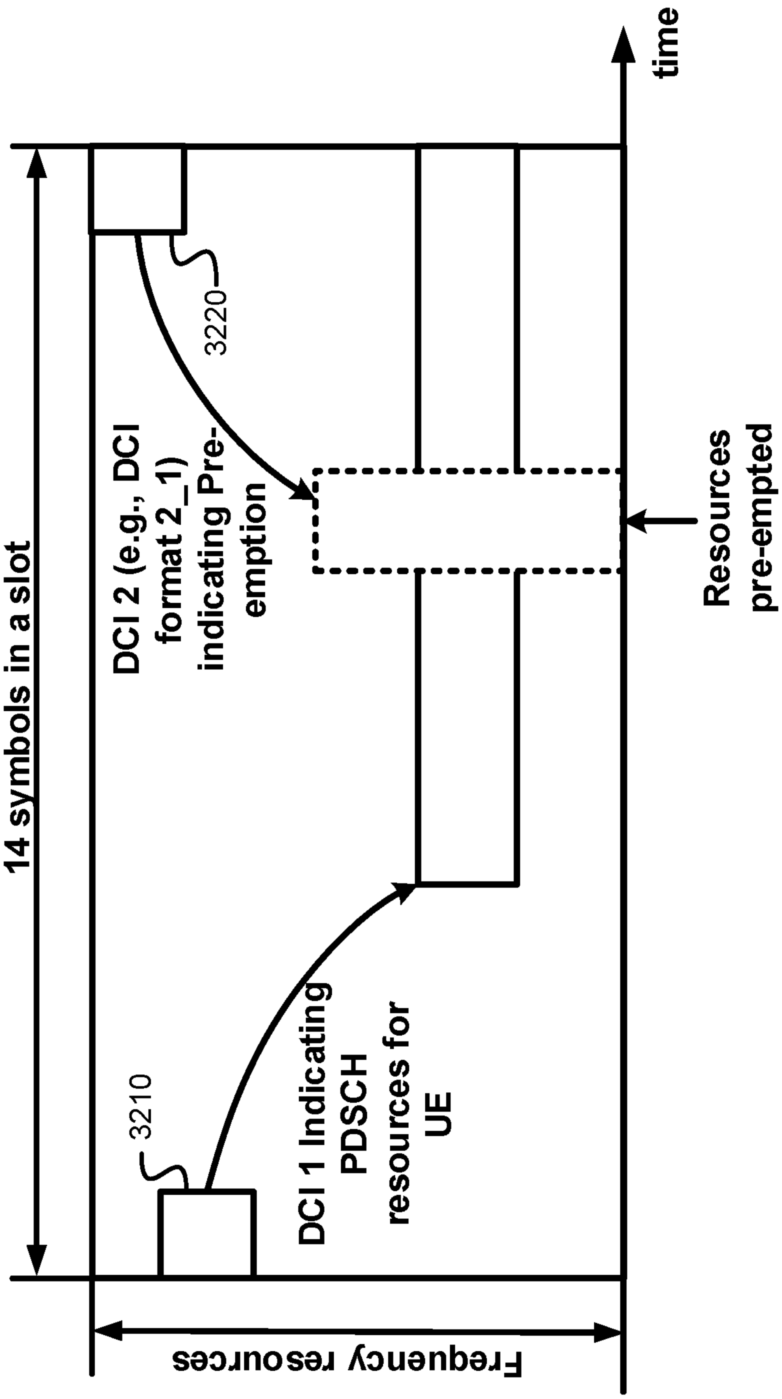

time
14 symbols in a slot
DCI 2 (e.g., DCI format 2_1) indicating Pre-emption
3220
Resources pre-empted
DCI 1 Indicating PDSCH resources for UE
3210
Frequency resources

FIG. 32

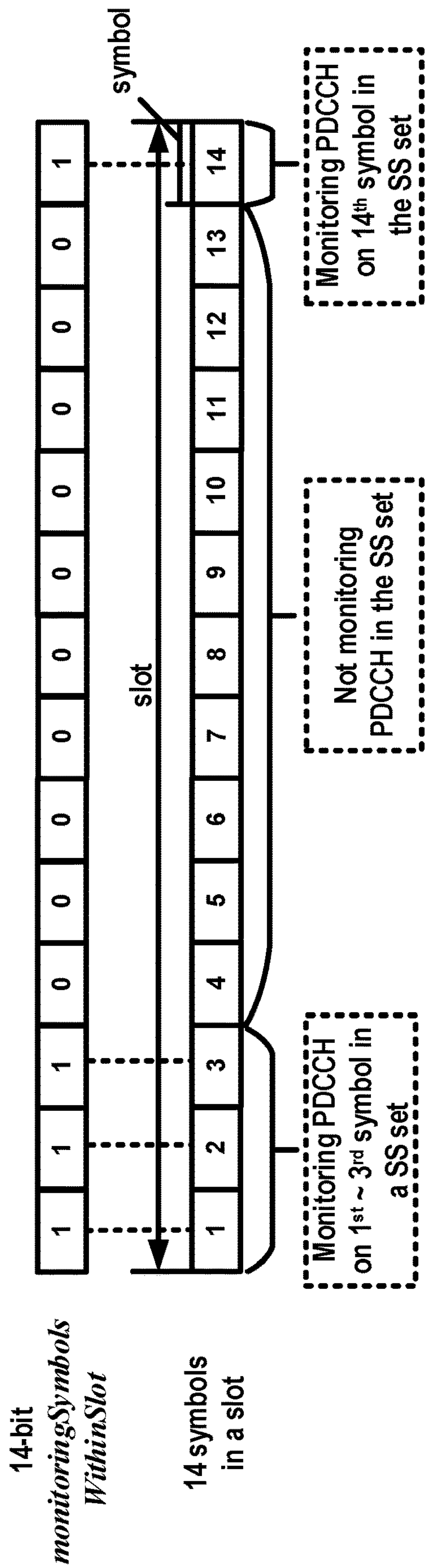
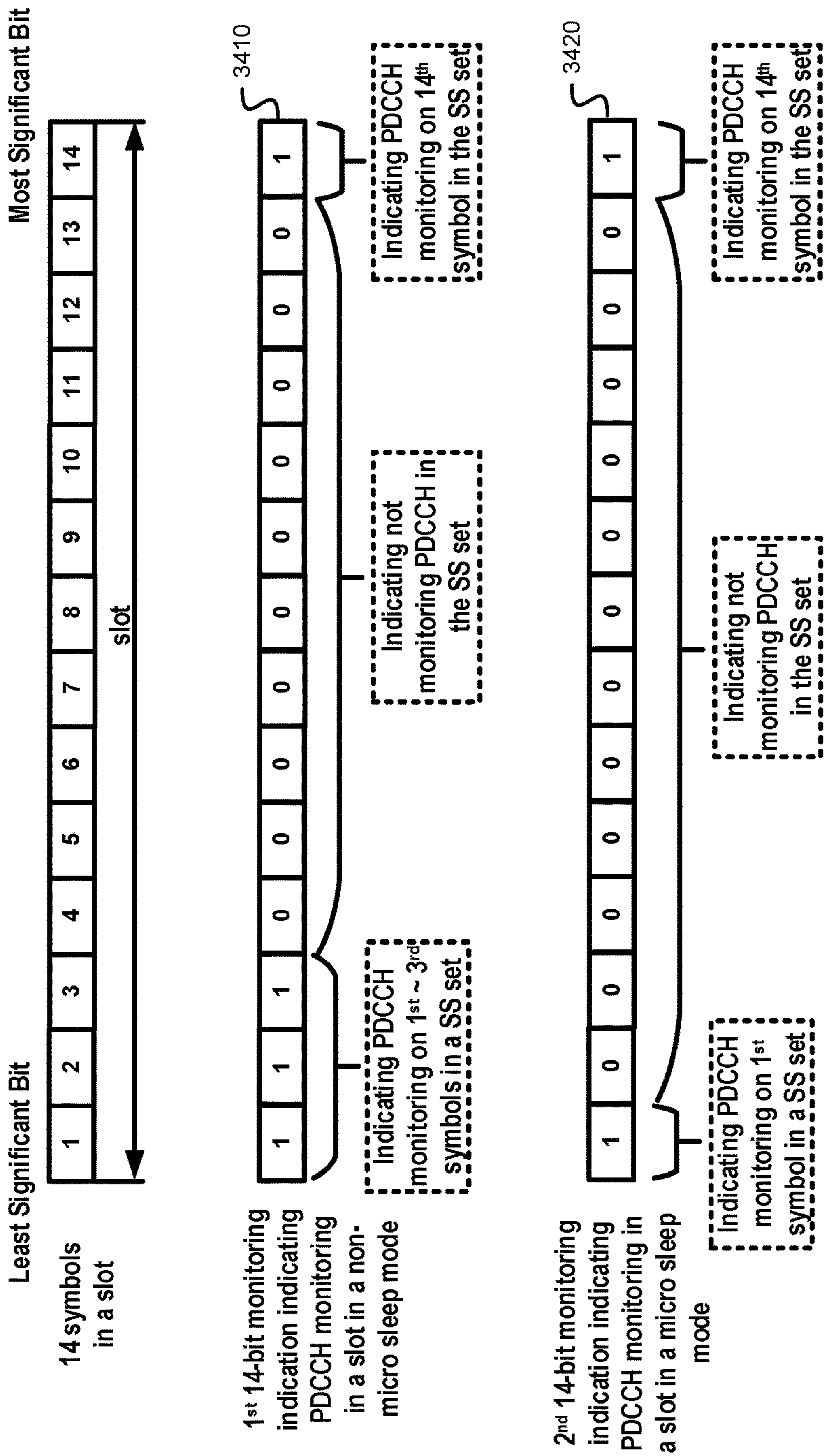

14-bit *monitoringSymbolsWithinSlot*
14 symbols in a slot
1 1 1 0 0 0 0 0 0 0 0 0 0 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14
slot
symbol
Monitoring PDCCH on 1st ~ 3rd symbol in a SS set
Not monitoring PDCCH in the SS set
Monitoring PDCCH on 14th symbol in the SS set

FIG. 33



Least Significant Bit
Most Significant Bit
14 symbols in a slot
1 2 3 4 5 6 7 8 9 10 11 12 13 14
slot
3410
1st 14-bit monitoring indication indicating PDCCH monitoring in a slot in a non-micro sleep mode
1 1 1 0 0 0 0 0 0 0 0 0 0 1
Indicating PDCCH monitoring on 1st ~ 3rd symbols in a SS set
Indicating not monitoring PDCCH in the SS set
Indicating PDCCH monitoring on 14th symbol in the SS set
3420
2nd 14-bit monitoring indication indicating PDCCH monitoring in a slot in a micro sleep mode
1 0 0 0 0 0 0 0 0 0 0 0 0 1
Indicating PDCCH monitoring on 1st symbol in a SS set
Indicating not monitoring PDCCH in the SS set
Indicating PDCCH monitoring on 14th symbol in the SS set

FIG. 34

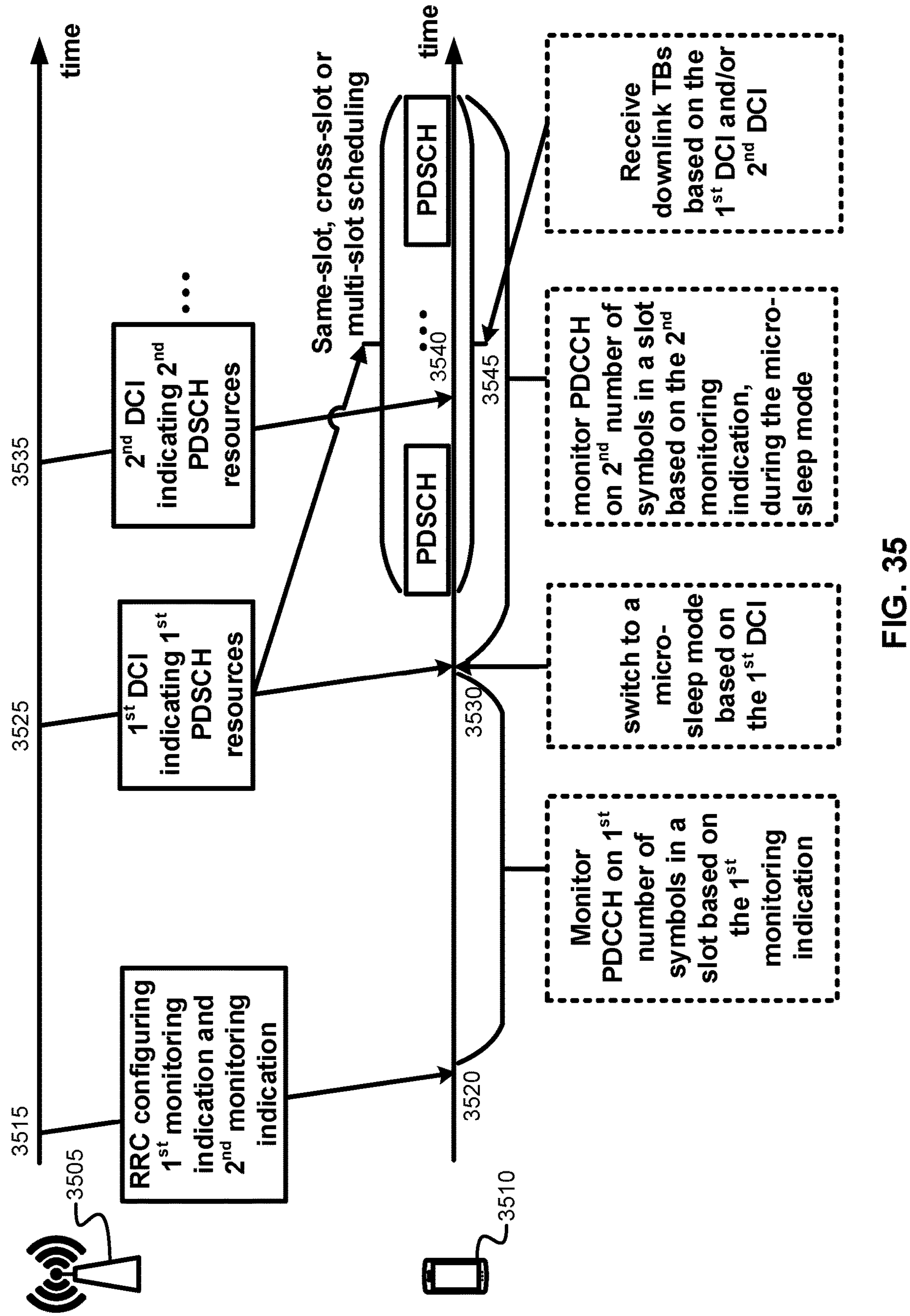

3505
3510
3515
RRC configuring 1st monitoring indication and 2nd monitoring indication
3520
Monitor PDCCH on 1st number of symbols in a slot based on the 1st monitoring indication
3525
1st DCI indicating 1st PDSCH resources
3530
switch to a micro-sleep mode based on the 1st DCI
3535
2nd DCI indicating 2nd PDSCH resources
Same-slot, cross-slot or multi-slot scheduling
PDSCH
PDSCH
3540
3545
monitor PDCCH on 2nd number of symbols in a slot based on the 2nd monitoring indication, during the micro-sleep mode
Receive downlink TBs based on the 1st DCI and/or 2nd DCI
time
time

FIG. 35

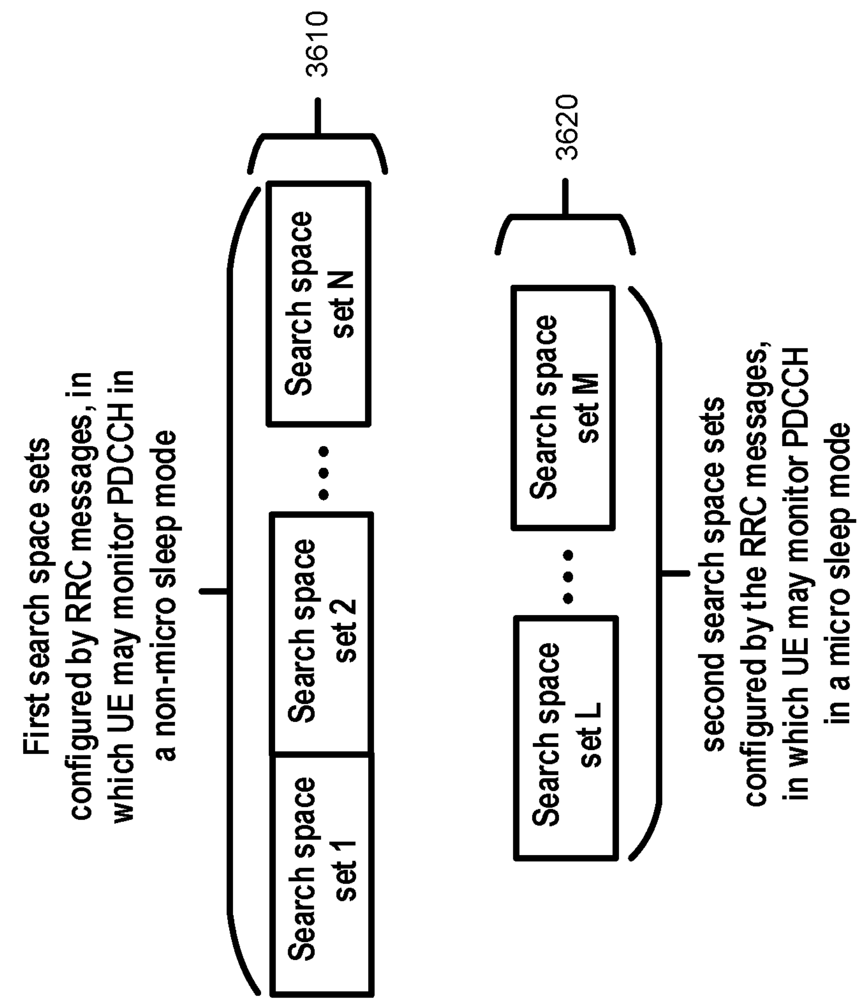

First search space sets configured by RRC messages, in which UE may monitor PDCCH in a non-micro sleep mode
3610
Search space set 1
Search space set 2
Search space set N
3620
Search space set L
Search space set M
second search space sets configured by the RRC messages, in which UE may monitor PDCCH in a micro sleep mode

FIG. 36

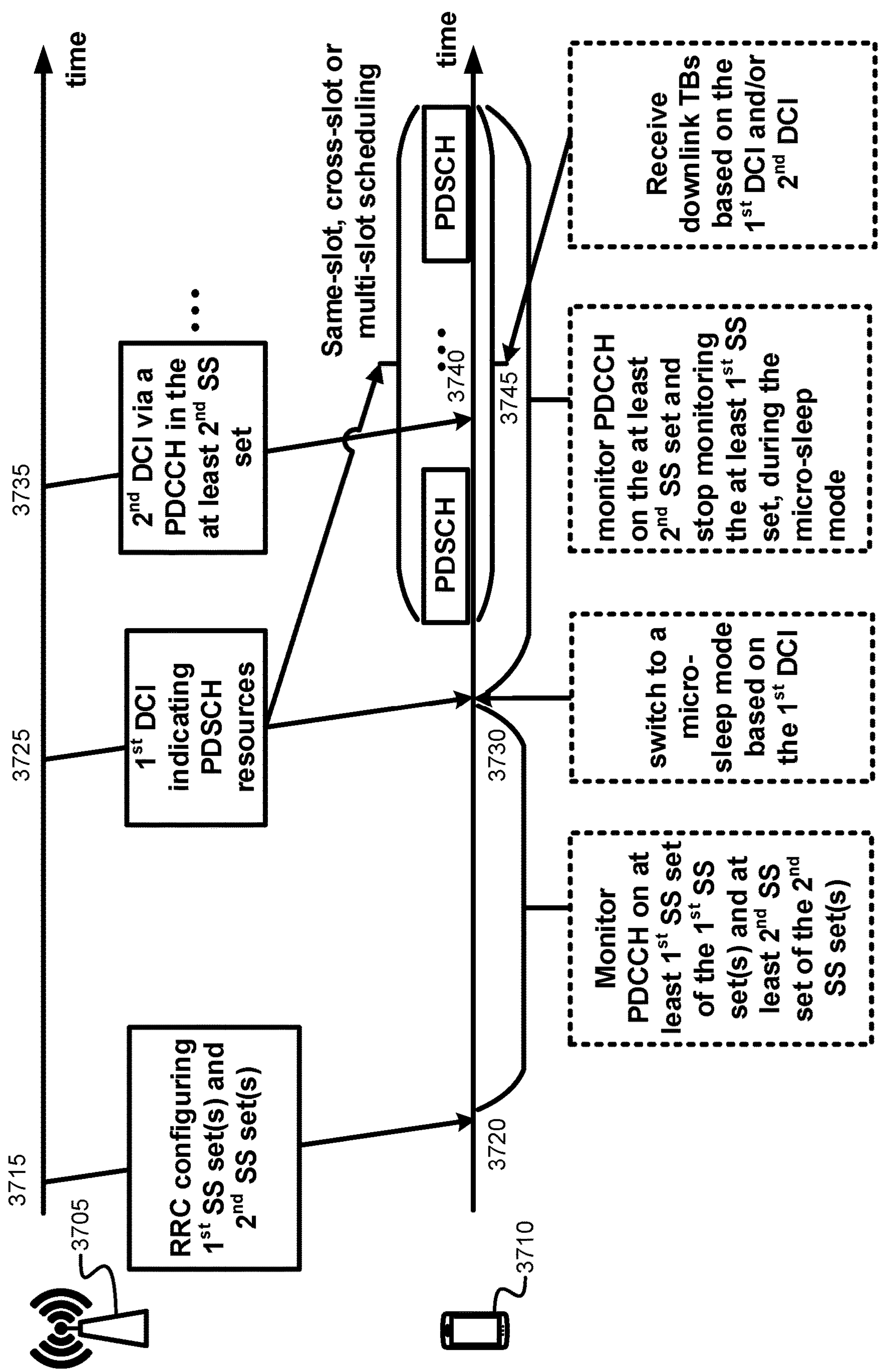

3705
3710
3715
3725
3735
time
RRC configuring 1st SS set(s) and 2nd SS set(s)
1st DCI indicating PDSCH resources
2nd DCI via a PDCCH in the at least 2nd SS set
Same-slot, cross-slot or multi-slot scheduling
time
PDSCH
PDSCH
3720
3730
3740
3745
Monitor PDCCH on at least 1st SS set of the 1st SS set(s) and at least 2nd SS set of the 2nd SS set(s)
switch to a micro-sleep mode based on the 1st DCI
monitor PDCCH on the at least 2nd SS set and stop monitoring the at least 1st SS set, during the micro-sleep mode
Receive downlink TBs based on the 1st DCI and/or 2nd DCI

FIG. 37

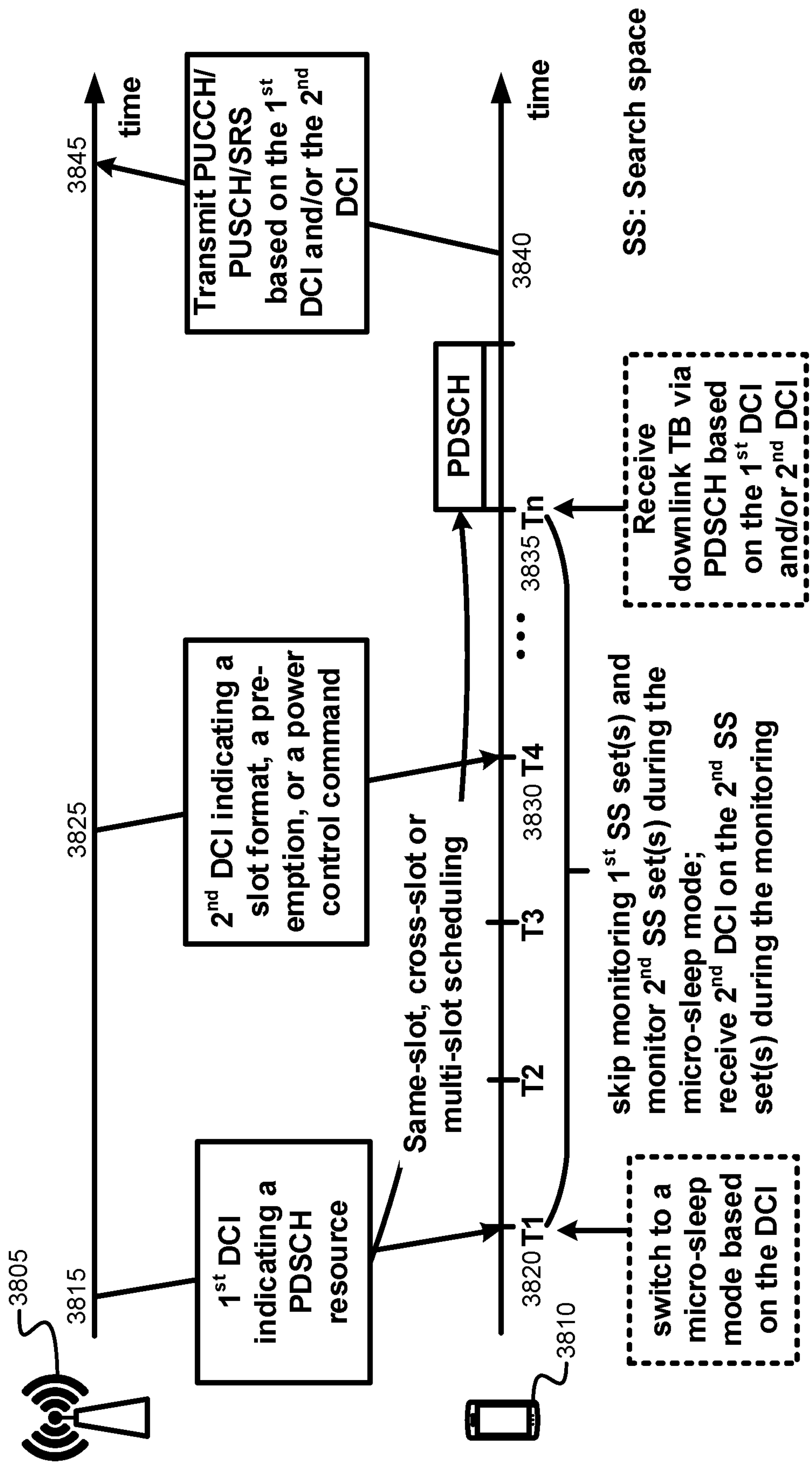
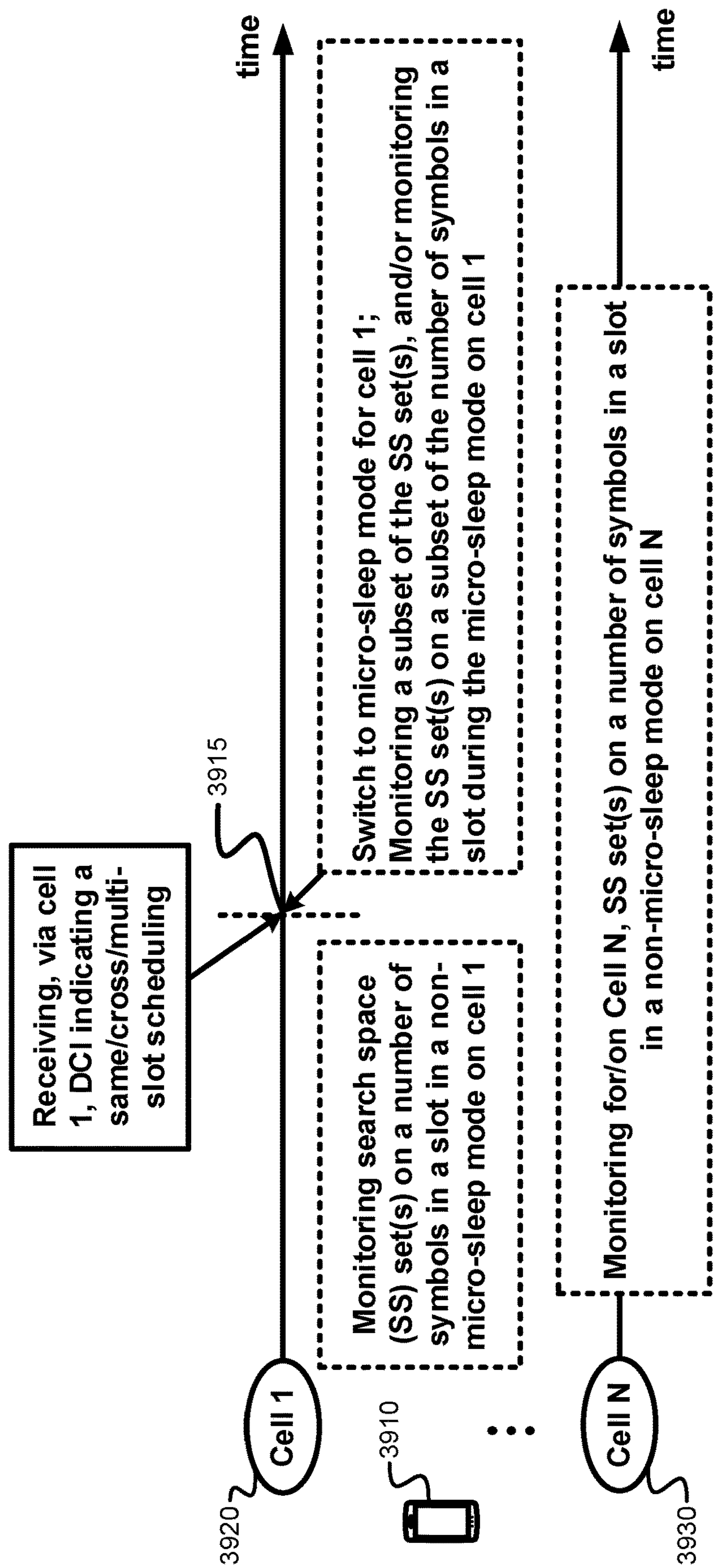
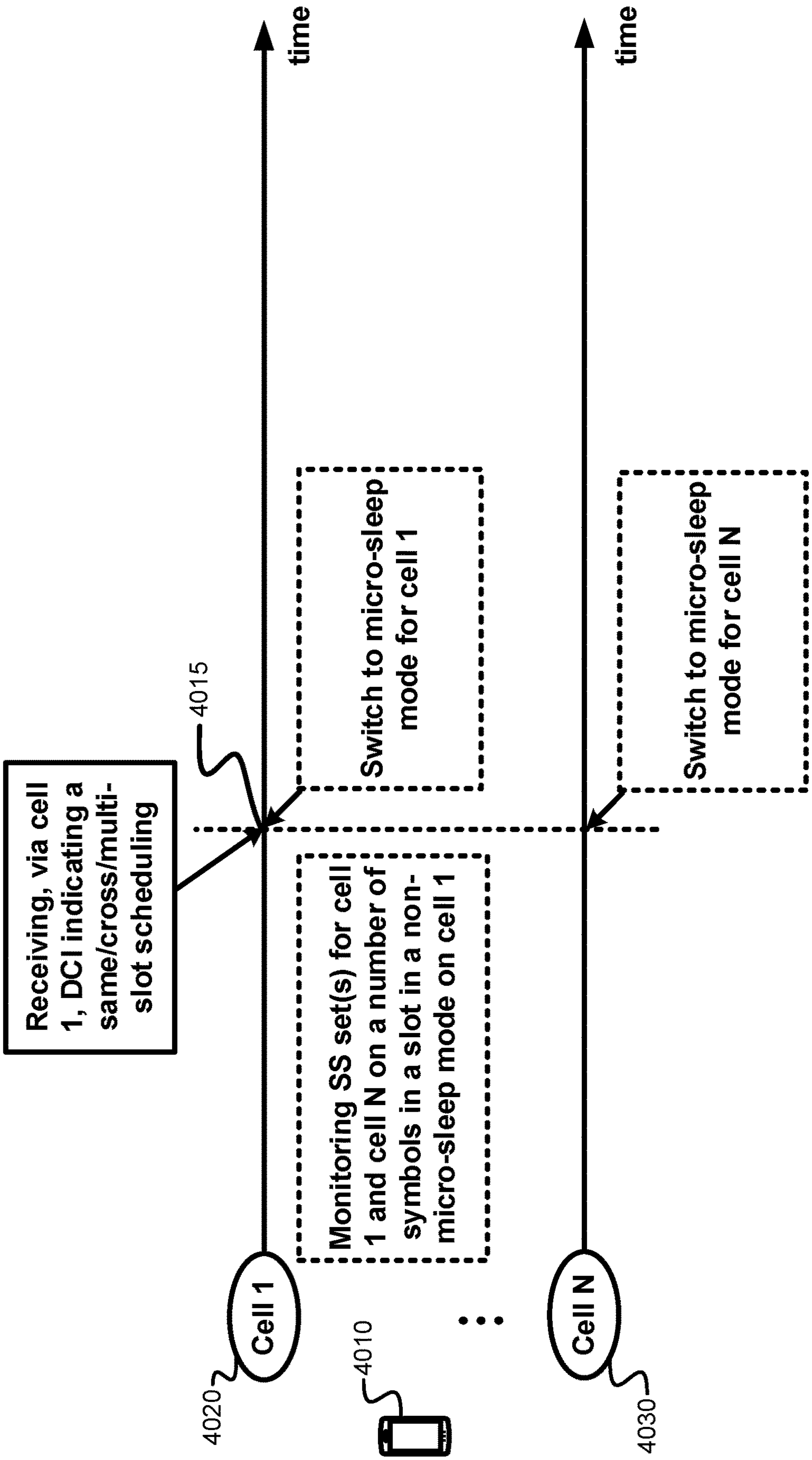

3805
3810
3815
3825
3845
time
1st DCI indicating a PDSCH resource
2nd DCI indicating a slot format, a pre-emption, or a power control command
Transmit PUCCH/PUSCH/SRS based on the 1st DCI and/or the 2nd DCI
Same-slot, cross-slot or multi-slot scheduling
PDSCH
3820 T1
T2
T3
3830 T4
3835 Tn
3840
time
switch to a micro-sleep mode based on the DCI
skip monitoring 1st SS set(s) and monitor 2nd SS set(s) during the micro-sleep mode; receive 2nd DCI on the 2nd SS set(s) during the monitoring
Receive downlink TB via PDSCH based on the 1st DCI and/or 2nd DCI
SS: Search space

FIG. 38



time
time
Receiving, via cell 1, DCI indicating a same/cross/multi-slot scheduling
3915
Monitoring search space (SS) set(s) on a number of symbols in a slot in a non-micro-sleep mode on cell 1
Switch to micro-sleep mode for cell 1;
Monitoring a subset of the SS set(s), and/or monitoring the SS set(s) on a subset of the number of symbols in a slot during the micro-sleep mode on cell 1
Monitoring for/on Cell N, SS set(s) on a number of symbols in a slot in a non-micro-sleep mode on cell N
Cell 1
3920
3910
Cell N
3930

FIG. 39



4020
Cell 1
4010
Cell N
4030
Receiving, via cell 1, DCI indicating a same/cross/multi-slot scheduling
4015
Monitoring SS set(s) for cell 1 and cell N on a number of symbols in a slot in a non-micro-sleep mode on cell 1
Switch to micro-sleep mode for cell 1
Switch to micro-sleep mode for cell N
time
time

FIG. 40

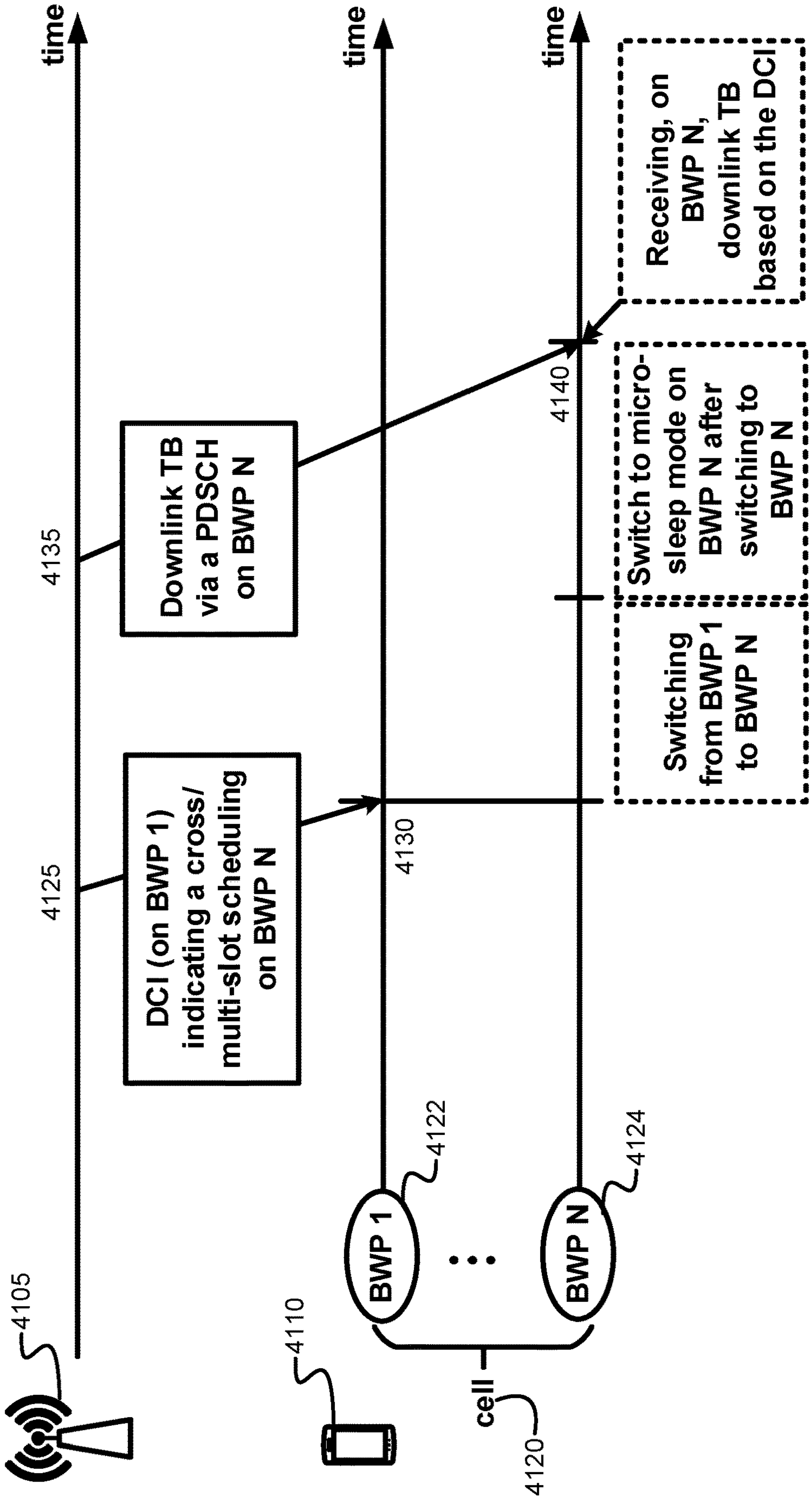

4105
4110
cell
4120
BWP 1
4122
BWP N
4124
time
time
time
4125
DCI (on BWP 1) indicating a cross/ multi-slot scheduling on BWP N
4130
Switching from BWP 1 to BWP N
Switch to micro-sleep mode on BWP N after switching to BWP N
4135
Downlink TB via a PDSCH on BWP N
4140
Receiving, on BWP N, downlink TB based on the DCI

FIG. 41

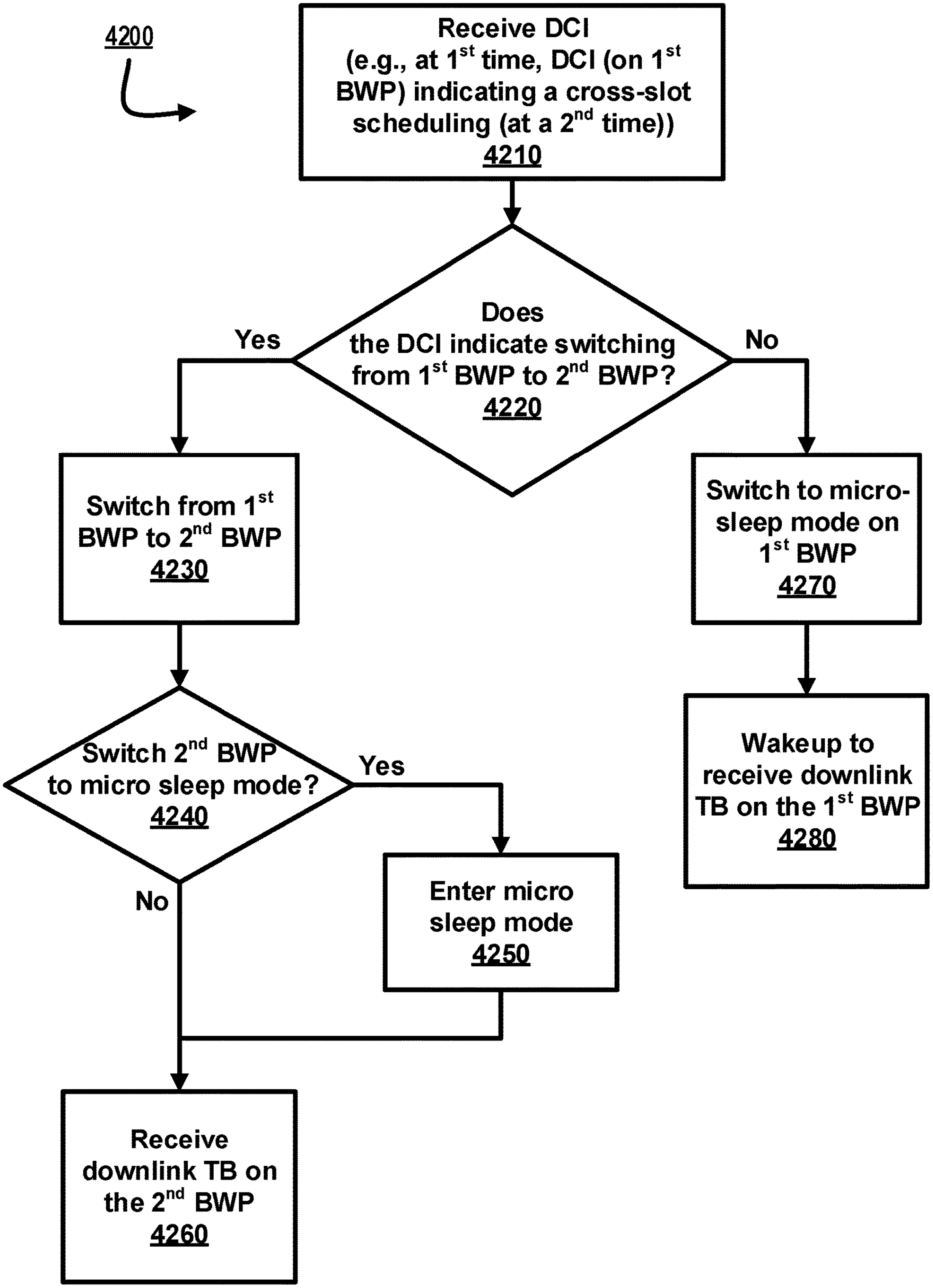

4200
Receive DCI
(e.g., at 1st time, DCI (on 1st BWP) indicating a cross-slot scheduling (at a 2nd time))
4210
Does the DCI indicate switching from 1st BWP to 2nd BWP?
4220
Yes
No
Switch from 1st BWP to 2nd BWP
4230
Switch 2nd BWP to micro sleep mode?
4240
Yes
No
Enter micro sleep mode
4250
Receive downlink TB on the 2nd BWP
4260
Switch to micro-sleep mode on 1st BWP
4270
Wakeup to receive downlink TB on the 1st BWP
4280

FIG. 42

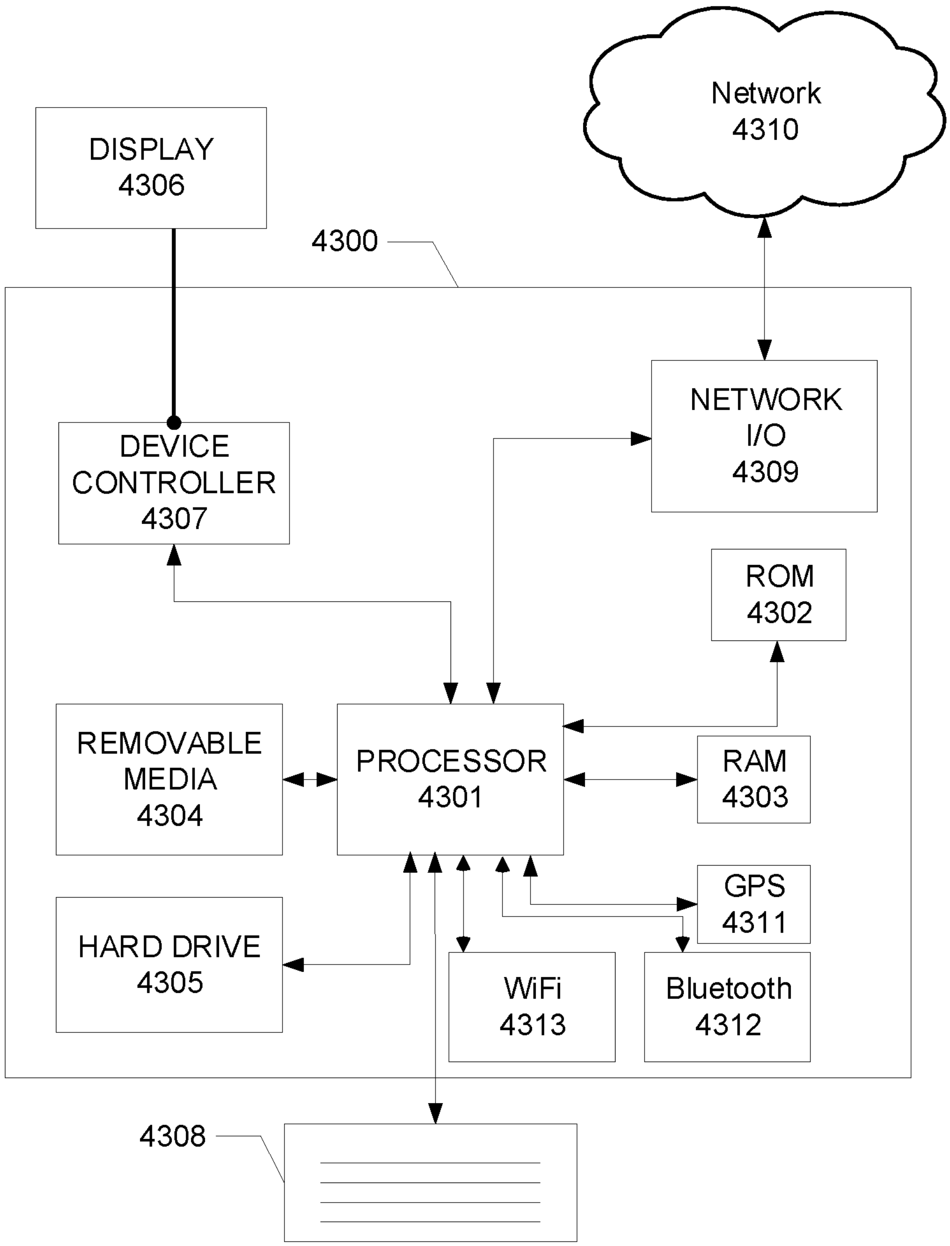

Network
4310
DISPLAY
4306
4300
NETWORK
I/O
4309
DEVICE
CONTROLLER
4307
ROM
4302
REMOVABLE
MEDIA
4304
PROCESSOR
4301
RAM
4303
GPS
4311
HARD DRIVE
4305
WiFi
4313
Bluetooth
4312
4308

FIG. 43

POWER SAVING OPERATIONS FOR COMMUNICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of and claims priority to U.S. patent application Ser. No. 17/526,618, filed Nov. 15, 2021, which is a continuation of U.S. patent application Ser. No. 16/829,144, filed on Mar. 25, 2020 (now U.S. Pat. No. 11,212,747), which claims the benefit of U.S. Provisional Application No. 62/823,528, filed on Mar. 25, 2019, each of which is hereby incorporated by reference in its entirety.

BACKGROUND

A wireless device may use discontinuous reception (DRX) to turn on and/or off one or more cells. A base station may send downlink control information (DCI) indicating same-slot scheduling. Same-slot scheduling may comprise the DCI, that schedules a physical downlink shared channel (PDSCH) transmission, occurring in a same slot as the PDSCH transmission.

SUMMARY

The following summary presents a simplified summary of certain features. The summary is not an extensive overview and is not intended to identify key or critical elements.

Base stations and wireless devices may use cross-slot scheduling for each of a plurality of cells. Base stations and wireless devices may communicate regarding the cross-slot scheduling, including for example, one or more indications associated with cross-slot scheduling for one or more cells. A wireless device may determine cross-slot scheduling for one or more transmissions associated with the one or more cells, for example, based on an indication that cross-slot scheduling is to be applied for receiving data packets. The wireless device may apply cross-slot scheduling for a first cell used to receive the indication. The wireless device may not apply cross-slot scheduling for one or more second cells different from the first cell used to receive the indication. The wireless device may save power by during a power saving mode, for example, by reducing a quantity of symbols to monitor on the first cell, based on the cross-slot scheduling, while maintaining a non-power saving mode on the second cell. By applying cross-slot scheduling as described herein, the wireless device may be able to achieve improved power savings.

These and other features and advantages are described in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

Some features are shown by way of example, and not by limitation, in the accompanying drawings. In the drawings, like numerals reference similar elements.

FIG. **1** shows an example radio access network (RAN) architecture.

FIG. **2**A shows an example user plane protocol stack.

FIG. **2**B shows an example control plane protocol stack.

FIG. **3** shows an example wireless device and two base stations.

FIG. **4**A, FIG. **4**B, FIG. **4**C, and FIG. **4**D show examples of uplink and downlink signal transmission.

FIG. **5**A shows an example uplink channel mapping and example uplink physical signals.

FIG. **5**B shows an example downlink channel mapping and example downlink physical signals.

FIG. **6** shows an example transmission time and/or reception time for a carrier.

FIG. **7**A and FIG. **7**B show example sets of orthogonal frequency division multiplexing (OFDM) subcarriers.

FIG. **8** shows example OFDM radio resources.

FIG. **9**A shows an example channel state information reference signal (CSI-RS) and/or synchronization signal (SS) block transmission in a multi-beam system.

FIG. **9**B shows an example downlink beam management procedure.

FIG. **10** shows an example of configured bandwidth parts (BWPs).

FIG. **11**A and FIG. **11**B show examples of multi connectivity.

FIG. **12** shows an example of a random access procedure.

FIG. **13** shows example medium access control (MAC) entities.

FIG. **14** shows an example RAN architecture.

FIG. **15** shows example radio resource control (RRC) states.

FIG. **16**A, FIG. **16**B and FIG. **16**C show an example of MAC subheader formats.

FIG. **17**A and FIG. **17**B show examples MAC data unit formats.

FIG. **18** shows example logical channel identifier (LCID) values.

FIG. **19** shows example LCID values.

FIG. **20**A and FIG. **20**B show example secondary cell (SCell) activation/deactivation MAC control element (CE) formats.

FIG. **21**A shows an example of an SCell hibernation MAC CE format.

FIG. **21**B shows an example of an SCell hibernation MAC CE format.

FIG. **21**C shows example MAC CEs for SCell state transitions.

FIG. **22** shows example downlink control information (DCI) formats.

FIG. **23** shows example BWP management on an SCell.

FIG. **24** shows an example of discontinuous reception (DRX) operation.

FIG. **25** shows an example of DRX operation.

FIG. **26**A shows an example of a wake-up signal/channel-based power saving operation.

FIG. **26**B shows an example of a go-to-sleep signal/channel-based power saving operation.

FIG. **27** shows an example of power saving enabling/disabling.

FIG. **28** shows an example of DCI for power saving enabling (or activating).

FIG. **29** shows an example of DCI for power saving disabling (or deactivating).

FIG. **30**A shows an example of a power saving mode (e.g., micro sleep mode) in a same-slot scheduling.

FIG. **30**B shows an example of a power saving mode (e.g., micro sleep mode) in a cross-slot scheduling.

FIG. **30**C shows an example of a power saving mode (e.g., micro sleep mode) in a multi-slot scheduling.

FIG. **31** shows an example of a plurality of group common DCI formats.

FIG. **32** shows an example of transmission of a downlink pre-emption indication DCI.

FIG. **33** shows an example of monitoring a PDCCH in one or more symbols of a slot.

FIG. **34** shows an example of monitoring PDCCH monitoring.

FIG. **35** shows an example of a power saving mode (e.g., micro sleep mode).

FIG. **36** shows an example of search spaces in a power-saving mode (e.g., micro sleep mode).

FIG. **37** shows an example of a power saving mode (e.g., micro sleep mode).

FIG. **38** shows an example of a power saving mode (e.g., micro sleep mode).

FIG. **39** shows an example of a power saving mode (e.g., micro sleep mode) such as in carrier aggregation and/or dual-connectivity.

FIG. **40** shows an example of a power saving mode (e.g., micro sleep mode) such as in carrier aggregation and/or dual connectivity.

FIG. **41** shows an example of a power saving mode (e.g., micro sleep mode) such as in in bandwidth part switching.

FIG. **42** shows an example of a power saving mode (e.g., micro sleep mode) such as in bandwidth part switching.

FIG. **43** shows example elements of a computing device that may be used to implement any of the various devices described herein.

DETAILED DESCRIPTION

The accompanying drawings and descriptions provide examples. It is to be understood that the examples shown in the drawings and/or described are non-exclusive and that there are other examples of how features shown and described may be practiced.

Examples are provided for operation of wireless communication systems which may be used in the technical field of multicarrier communication systems. More particularly, the technology described herein may relate to power saving in wireless communications.

The following acronyms are used throughout the drawings and/or descriptions, and are provided below for convenience although other acronyms may be introduced in the detailed description:

3GPP 3rd Generation Partnership Project
5GC 5G Core Network
ACK Acknowledgement
AMF Access and Mobility Management Function
ARQ Automatic Repeat Request
AS Access Stratum
ASIC Application-Specific Integrated Circuit
BA Bandwidth Adaptation
BCCH Broadcast Control Channel
BCH Broadcast Channel
BPSK Binary Phase Shift Keying
BWP Bandwidth Part
CA Carrier Aggregation
CC Component Carrier
CCCH Common Control CHannel
CDMA Code Division Multiple Access
CE Control Element
CN Core Network
CORESET Control Resource Set
CP Cyclic Prefix
CP-OFDM Cyclic Prefix-Orthogonal Frequency Division Multiplex
C-RNTI Cell-Radio Network Temporary Identifier
MCS Modulation and Coding Scheme
MeNB Master evolved Node B
MIB Master Information Block
MME Mobility Management Entity
MN Master Node j
NACK Negative Acknowledgement
NAS Non-Access Stratum
NDI New Data Indicator
NG CP Next Generation Control Plane
NGC Next Generation Core
NG-C NG-Control plane
ng-eNB next generation evolved Node B
NG-U NG-User plane
NR New Radio
NR MAC New Radio MAC
NR PDCP New Radio PDCP
NR PHY New Radio PHYsical
NR RLC New Radio RLC
NR RRC New Radio RRC
NSSAI Network Slice Selection Assistance Information
O&M Operation and Maintenance
OFDM Orthogonal Frequency Division Multiplexing
PBCH Physical Broadcast CHannel
PCC Primary Component Carrier
PCCH Paging Control CHannel
PCell Primary Cell
PCH Paging CHannel
PDCCH Physical Downlink Control CHannel
PDCP Packet Data Convergence Protocol
PDSCH Physical Downlink Shared CHannel
PDU Protocol Data Unit
PHICH Physical HARQ Indicator CHannel
PHY PHYsical
PLMN Public Land Mobile Network
PMI Precoding Matrix Indicator
PRACH Physical Random Access CHannel
PRB Physical Resource Block
PSCell Primary Secondary Cell
PSS Primary Synchronization Signal
pTAG primary Timing Advance Group
PT-RS Phase Tracking Reference Signal
PUCCH Physical Uplink Control CHannel
PUSCH Physical Uplink Shared CHannel
QAM Quadrature Amplitude Modulation
QCLed Quasi-Co-Located
QCL Quasi-Co-Location
QFI Quality of Service Indicator
QoS Quality of Service
QPSK Quadrature Phase Shift Keying
RA Random Access
RACH Random Access CHannel
RAN Radio Access Network
RAT Radio Access Technology
RA-RNTI Random Access-Radio Network Temporary Identifier
RB Resource Blocks
RBG Resource Block Groups
RI Rank indicator
RLC Radio Link Control
RLM Radio Link Monitoring
RNTI Radio Network Temporary Identifier
RRC Radio Resource Control
RRM Radio Resource Management
RS Reference Signal
RV Redundancy Version
RSRP Reference Signal Received Power
SCC Secondary Component Carrier
SCell Secondary Cell
SCG Secondary Cell Group
SC-FDMA Single Carrier-Frequency Division Multiple Access

SDAP Service Data Adaptation Protocol
SDU Service Data Unit
SeNB Secondary evolved Node B
SFN System Frame Number
S-GW Serving GateWay
SI System Information
SIB System Information Block
SINR Signal-to-Interference-plus-Noise Ratio
SMF Session Management Function
SN Secondary Node
SpCell Special Cell
SRB Signaling Radio Bearer
SRS Sounding Reference Signal
SS Synchronization Signal
SSB Synchronization Signal Block
SSBRI Synchronization Signal Block Resource Indicator
SSS Secondary Synchronization Signal
sTAG secondary Timing Advance Group
TA Timing Advance
TAG Timing Advance Group
TAI Tracking Area Identifier
TAT Time Alignment Timer
TB Transport Block
TC-RNTI Temporary Cell-Radio Network Temporary Identifier
TCI Transmission Configuration Indication
TDD Time Division Duplex
TDMA Time Division Multiple Access
TRP Transmission Reception Point
TTI Transmission Time Interval
UCI Uplink Control Information
UE User Equipment
UL Uplink
UL-SCH Uplink Shared CHannel
UPF User Plane Function
UPGW User Plane Gateway
URLLC Ultra-Reliable Low-Latency Communication
V2X Vehicle-to-everything
VHDL VHSIC Hardware Description Language
Xn-C Xn-Control plane
Xn-U Xn-User plane

Examples described herein may be implemented using various physical layer modulation and transmission mechanisms. Example transmission mechanisms may include, but are not limited to: Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), Time Division Multiple Access (TDMA), Wavelet technologies, and/or the like. Hybrid transmission mechanisms such as TDMA/CDMA, and/or OFDM/CDMA may be used. Various modulation schemes may be used for signal transmission in the physical layer. Examples of modulation schemes include, but are not limited to: phase, amplitude, code, a combination of these, and/or the like. An example radio transmission method may implement Quadrature Amplitude Modulation (QAM) using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16-QAM, 64-QAM, 256-QAM, 1024-QAM and/or the like. Physical radio transmission may be enhanced by dynamically or semi-dynamically changing the modulation and coding scheme, for example, depending on transmission requirements and/or radio conditions.

FIG. **1** shows an example Radio Access Network (RAN) architecture. A RAN node may comprise a next generation Node B (gNB) (e.g., **120**A, **120**B) providing New Radio (NR) user plane and control plane protocol terminations towards a first wireless device (e.g., **110**A). A RAN node may comprise a base station such as a next generation evolved Node B (ng-eNB) (e.g., **120**C, **120**D), providing Evolved UMTS Terrestrial Radio Access (E-UTRA) user plane and control plane protocol terminations towards a second wireless device (e.g., **110**B). A first wireless device **110**A may communicate with a base station, such as a gNB **120**A, over a Uu interface. A second wireless device **110**B may communicate with a base station, such as an ng-eNB **120**D, over a Uu interface. The wireless devices **110**A and/or **110**B may be structurally similar to wireless devices shown in and/or described in connection with other drawing figures. The Node B **120**A, the Node B **120**B, the Node B **120**C, and/or the Node B **120**D may be structurally similar to Nodes B and/or base stations shown in and/or described in connection with other drawing figures.

A base station, such as a gNB (e.g., **120**A, **120**B, etc.) and/or an ng-eNB (e.g., **120**C, **120**D, etc.) may host functions such as radio resource management and scheduling, IP header compression, encryption and integrity protection of data, selection of Access and Mobility Management Function (AMF) at wireless device (e.g., User Equipment (UE)) attachment, routing of user plane and control plane data, connection setup and release, scheduling and transmission of paging messages (e.g., originated from the AMF), scheduling and transmission of system broadcast information (e.g., originated from the AMF or Operation and Maintenance (O&M)), measurement and measurement reporting configuration, transport level packet marking in the uplink, session management, support of network slicing, Quality of Service (QoS) flow management and mapping to data radio bearers, support of wireless devices in an inactive state (e.g., RRC_INACTIVE state), distribution function for Non-Access Stratum (NAS) messages, RAN sharing, dual connectivity, and/or tight interworking between NR and E-UTRA.

One or more first base stations (e.g., gNBs **120**A and **120**B) and/or one or more second base stations (e.g., ng-eNBs **120**C and **120**D) may be interconnected with each other via Xn interface. A first base station (e.g., gNB **120**A, **120**B, etc.) or a second base station (e.g., ng-eNB **120**C, **120**D, etc.) may be connected via NG interfaces to a network, such as a 5G Core Network (5GC). A 5GC may comprise one or more AMF/User Plan Function (UPF) functions (e.g., **130**A and/or **130**B). A base station (e.g., a gNB and/or an ng-eNB) may be connected to a UPF via an NG-User plane (NG-U) interface. The NG-U interface may provide delivery (e.g., non-guaranteed delivery) of user plane Protocol Data Units (PDUs) between a RAN node and the UPF. A base station (e.g., a gNB and/or an ng-eNB) may be connected to an AMF via an NG-Control plane (NG-C) interface. The NG-C interface may provide functions such as NG interface management, wireless device (e.g., UE) context management, wireless device (e.g., UE) mobility management, transport of NAS messages, paging, PDU session management, configuration transfer, and/or warning message transmission.

A UPF may host functions such as anchor point for intra-/inter-Radio Access Technology (RAT) mobility (e.g., if applicable), external PDU session point of interconnect to data network, packet routing and forwarding, packet inspection and user plane part of policy rule enforcement, traffic usage reporting, uplink classifier to support routing traffic flows to a data network, branching point to support multi-homed PDU session, quality of service (QoS) handling for user plane, packet filtering, gating, Uplink (UL)/Downlink (DL) rate enforcement, uplink traffic verification (e.g., Service Data Flow (SDF) to QoS flow mapping), downlink packet buffering, and/or downlink data notification triggering.

An AMF may host functions such as NAS signaling termination, NAS signaling security, Access Stratum (AS) security control, inter Core Network (CN) node signaling (e.g., for mobility between 3rd Generation Partnership Project (3GPP) access networks), idle mode wireless device reachability (e.g., control and execution of paging retransmission), registration area management, support of intra-system and inter-system mobility, access authentication, access authorization including check of roaming rights, mobility management control (e.g., subscription and/or policies), support of network slicing, and/or Session Management Function (SMF) selection.

FIG. **2**A shows an example user plane protocol stack. A Service Data Adaptation Protocol (SDAP) (e.g., **211** and **221**), Packet Data Convergence Protocol (PDCP) (e.g., **212** and **222**), Radio Link Control (RLC) (e.g., **213** and **223**), and Medium Access Control (MAC) (e.g., **214** and **224**) sublayers, and a Physical (PHY) (e.g., **215** and **225**) layer, may be terminated in a wireless device (e.g., **110**) and in a base station (e.g., **120**) on a network side. A PHY layer may provide transport services to higher layers (e.g., MAC, RRC, etc.). Services and/or functions of a MAC sublayer may comprise mapping between logical channels and transport channels, multiplexing and/or demultiplexing of MAC Service Data Units (SDUs) belonging to the same or different logical channels into and/or from Transport Blocks (TB s) delivered to and/or from the PHY layer, scheduling information reporting, error correction through Hybrid Automatic Repeat request (HARQ) (e.g., one HARQ entity per carrier for Carrier Aggregation (CA)), priority handling between wireless devices such as by using dynamic scheduling, priority handling between logical channels of a wireless device such as by using logical channel prioritization, and/or padding. A MAC entity may support one or multiple numerologies and/or transmission timings. Mapping restrictions in a logical channel prioritization may control which numerology and/or transmission timing a logical channel may use. An RLC sublayer may support transparent mode (TM), unacknowledged mode (UM), and/or acknowledged mode (AM) transmission modes. The RLC configuration may be per logical channel with no dependency on numerologies and/or Transmission Time Interval (TTI) durations. Automatic Repeat Request (ARQ) may operate on any of the numerologies and/or TTI durations with which the logical channel is configured. Services and functions of the PDCP layer for the user plane may comprise, for example, sequence numbering, header compression and decompression, transfer of user data, reordering and duplicate detection, PDCP PDU routing (e.g., such as for split bearers), retransmission of PDCP SDUs, ciphering, deciphering and integrity protection, PDCP SDU discard, PDCP re-establishment and data recovery for RLC AM, and/or duplication of PDCP PDUs. Services and/or functions of SDAP may comprise, for example, mapping between a QoS flow and a data radio bearer. Services and/or functions of SDAP may comprise mapping a Quality of Service Indicator (QFI) in DL and UL packets. A protocol entity of SDAP may be configured for an individual PDU session.

FIG. **2**B shows an example control plane protocol stack. A PDCP (e.g., **233** and **242**), RLC (e.g., **234** and **243**), and MAC (e.g., **235** and **244**) sublayers, and a PHY (e.g., **236** and **245**) layer, may be terminated in a wireless device (e.g., **110**), and in a base station (e.g., **120**) on a network side, and perform service and/or functions described above. RRC (e.g., **232** and **241**) may be terminated in a wireless device and a base station on a network side. Services and/or functions of RRC may comprise broadcast of system information related to AS and/or NAS; paging (e.g., initiated by a 5GC or a RAN); establishment, maintenance, and/or release of an RRC connection between the wireless device and RAN; security functions such as key management, establishment, configuration, maintenance, and/or release of Signaling Radio Bearers (SRBs) and Data Radio Bearers (DRBs); mobility functions; QoS management functions; wireless device measurement reporting and control of the reporting; detection of and recovery from radio link failure; and/or NAS message transfer to/from NAS from/to a wireless device. NAS control protocol (e.g., **231** and **251**) may be terminated in the wireless device and AMF (e.g., **130**) on a network side. NAS control protocol may perform functions such as authentication, mobility management between a wireless device and an AMF (e.g., for 3GPP access and non-3GPP access), and/or session management between a wireless device and an SMF (e.g., for 3GPP access and non-3GPP access).

A base station may configure a plurality of logical channels for a wireless device. A logical channel of the plurality of logical channels may correspond to a radio bearer. The radio bearer may be associated with a QoS requirement. A base station may configure a logical channel to be mapped to one or more TTIs and/or numerologies in a plurality of TTIs and/or numerologies. The wireless device may receive Downlink Control Information (DCI) via a Physical Downlink Control CHannel (PDCCH) indicating an uplink grant. The uplink grant may be for a first TTI and/or a first numerology and may indicate uplink resources for transmission of a transport block. The base station may configure each logical channel in the plurality of logical channels with one or more parameters to be used by a logical channel prioritization procedure at the MAC layer of the wireless device. The one or more parameters may comprise, for example, priority, prioritized bit rate, etc. A logical channel in the plurality of logical channels may correspond to one or more buffers comprising data associated with the logical channel. The logical channel prioritization procedure may allocate the uplink resources to one or more first logical channels in the plurality of logical channels and/or to one or more MAC Control Elements (CEs). The one or more first logical channels may be mapped to the first TTI and/or the first numerology. The MAC layer at the wireless device may multiplex one or more MAC CEs and/or one or more MAC SDUs (e.g., logical channel) in a MAC PDU (e.g., transport block). The MAC PDU may comprise a MAC header comprising a plurality of MAC sub-headers. A MAC sub-header in the plurality of MAC sub-headers may correspond to a MAC CE or a MAC SUD (e.g., logical channel) in the one or more MAC CEs and/or in the one or more MAC SDUs. A MAC CE and/or a logical channel may be configured with a Logical Channel IDentifier (LCID). An LCID for a logical channel and/or a MAC CE may be fixed and/or pre-configured. An LCID for a logical channel and/or MAC CE may be configured for the wireless device by the base station. The MAC sub-header corresponding to a MAC CE and/or a MAC SDU may comprise an LCID associated with the MAC CE and/or the MAC SDU.

A base station may activate, deactivate, and/or impact one or more processes (e.g., set values of one or more parameters of the one or more processes or start and/or stop one or more timers of the one or more processes) at the wireless device, for example, by using one or more MAC commands. The one or more MAC commands may comprise one or more MAC control elements. The one or more processes may comprise activation and/or deactivation of PDCP packet duplication for one or more radio bearers. The base station may send (e.g., transmit) a MAC CE comprising one or more fields. The values of the fields may indicate activation and/or deactivation of PDCP duplication for the one or more radio bearers. The one or more processes may comprise Channel State Information (CSI) transmission of on one or more cells. The base station may send (e.g., transmit) one or more MAC CEs indicating activation and/or deactivation of the CSI transmission on the one or more cells. The one or more processes may comprise activation and/or deactivation of one or more secondary cells. The base station may send (e.g., transmit) a MAC CE indicating activation and/or deactivation of one or more secondary cells. The base station may send (e.g., transmit) one or more MAC CEs indicating starting and/or stopping of one or more Discontinuous Reception (DRX) timers at the wireless device. The base station may send (e.g., transmit) one or more MAC CEs indicating one or more timing advance values for one or more Timing Advance Groups (TAGs).

FIG. **3** shows an example of base stations (base station 1, **120**A, and base station 2, **120**B) and a wireless device **110**. The wireless device **110** may comprise a UE or any other wireless device. The base station (e.g., **120**A, **120**B) may comprise a Node B, eNB, gNB, ng-eNB, one or more transmission and reception points, or any other base station. A wireless device and/or a base station may perform one or more functions of a relay node. The base station 1, **120**A, may comprise at least one communication interface **320**A (e.g., a wireless modem, an antenna, a wired modem, and/or the like), at least one processor **321**A, and at least one set of program code instructions **323**A that may be stored in non-transitory memory **322**A and executable by the at least one processor **321**A. The base station 2, **120**B, may comprise at least one communication interface **320**B, at least one processor **321**B, and at least one set of program code instructions **323**B that may be stored in non-transitory memory **322**B and executable by the at least one processor **321**B.

A base station may comprise any number of sectors, for example: 1, 2, 3, 4, or 6 sectors. A base station may comprise any number of cells, for example, ranging from 1 to 50 cells or more. A cell may be categorized, for example, as a primary cell or secondary cell. At Radio Resource Control (RRC) connection establishment, re-establishment, handover, etc., a serving cell may provide NAS (non-access stratum) mobility information (e.g., Tracking Area Identifier (TAI)). At RRC connection re-establishment and/or handover, a serving cell may provide security input. This serving cell may be referred to as the Primary Cell (PCell). In the downlink, a carrier corresponding to the PCell may be a DL Primary Component Carrier (PCC). In the uplink, a carrier may be an UL PCC. Secondary Cells (SCells) may be configured to form together with a PCell a set of serving cells, for example, depending on wireless device capabilities. In a downlink, a carrier corresponding to an SCell may be a downlink secondary component carrier (DL SCC). In an uplink, a carrier may be an uplink secondary component carrier (UL SCC). An SCell may or may not have an uplink carrier.

A cell, comprising a downlink carrier and optionally an uplink carrier, may be assigned a physical cell ID and/or a cell index. A carrier (downlink and/or uplink) may belong to one cell. The cell ID and/or cell index may identify the downlink carrier and/or uplink carrier of the cell (e.g., depending on the context it is used). A cell ID may be equally referred to as a carrier ID, and a cell index may be referred to as a carrier index. A physical cell ID and/or a cell index may be assigned to a cell. A cell ID may be determined using a synchronization signal transmitted via a downlink carrier. A cell index may be determined using RRC messages. A first physical cell ID for a first downlink carrier may indicate that the first physical cell ID is for a cell comprising the first downlink carrier. The same concept may be used, for example, with carrier activation and/or deactivation (e.g., secondary cell activation and/or deactivation). A first carrier that is activated may indicate that a cell comprising the first carrier is activated.

A base station may send (e.g., transmit) to a wireless device one or more messages (e.g., RRC messages) comprising a plurality of configuration parameters for one or more cells. One or more cells may comprise at least one primary cell and at least one secondary cell. An RRC message may be broadcasted and/or unicasted to the wireless device. Configuration parameters may comprise common parameters and dedicated parameters.

Services and/or functions of an RRC sublayer may comprise at least one of: broadcast of system information related to AS and/or NAS; paging initiated by a 5GC and/or an NG-RAN; establishment, maintenance, and/or release of an RRC connection between a wireless device and an NG-RAN, which may comprise at least one of addition, modification, and/or release of carrier aggregation; and/or addition, modification, and/or release of dual connectivity in NR or between E-UTRA and NR. Services and/or functions of an RRC sublayer may comprise at least one of security functions comprising key management; establishment, configuration, maintenance, and/or release of Signaling Radio Bearers (SRBs) and/or Data Radio Bearers (DRBs); mobility functions which may comprise at least one of a handover (e.g., intra NR mobility or inter-RAT mobility) and/or a context transfer; and/or a wireless device cell selection and/or reselection and/or control of cell selection and reselection. Services and/or functions of an RRC sublayer may comprise at least one of QoS management functions; a wireless device measurement configuration/reporting; detection of and/or recovery from radio link failure; and/or NAS message transfer to and/or from a core network entity (e.g., AMF, Mobility Management Entity (MME)) from and/or to the wireless device.

An RRC sublayer may support an RRC_Idle state, an RRC_Inactive state, and/or an RRC_Connected state for a wireless device. In an RRC_Idle state, a wireless device may perform at least one of: Public Land Mobile Network (PLMN) selection; receiving broadcasted system information; cell selection and/or re-selection; monitoring and/or receiving a paging for mobile terminated data initiated by 5GC; paging for mobile terminated data area managed by 5GC; and/or DRX for CN paging configured via NAS. In an RRC_Inactive state, a wireless device may perform at least one of: receiving broadcasted system information; cell selection and/or re-selection; monitoring and/or receiving a RAN and/or CN paging initiated by an NG-RAN and/or a 5GC; RAN-based notification area (RNA) managed by an NG-RAN; and/or DRX for a RAN and/or CN paging configured by NG-RAN/NAS. In an RRC_Idle state of a wireless device, a base station (e.g., NG-RAN) may keep a 5GC-NG-RAN connection (e.g., both C/U-planes) for the wireless device; and/or store a wireless device AS context for the wireless device. In an RRC_Connected state of a wireless device, a base station (e.g., NG-RAN) may perform at least one of: establishment of 5GC-NG-RAN connection (both C/U-planes) for the wireless device; storing a UE AS context for the wireless device; send (e.g., transmit) and/or receive of unicast data to and/or from the wireless device; and/or network-controlled mobility based on measurement results received from the wireless device. In an RRC_Connected state of a wireless device, an NG-RAN may know a cell to which the wireless device belongs.

System information (SI) may be divided into minimum SI and other SI. The minimum SI may be periodically broadcast. The minimum SI may comprise basic information required for initial access and/or information for acquiring any other SI broadcast periodically and/or provisioned on-demand (e.g., scheduling information). The other SI may either be broadcast, and/or be provisioned in a dedicated manner, such as either triggered by a network and/or upon request from a wireless device. A minimum SI may be transmitted via two different downlink channels using different messages (e.g., MasterinformationBlock and SystemInformationBlockType1). Another SI may be transmitted via SystemInformationBlockType2. For a wireless device in an RRC_Connected state, dedicated RRC signaling may be used for the request and delivery of the other SI. For the wireless device in the RRC_Idle state and/or in the RRC_Inactive state, the request may trigger a random access procedure.

A wireless device may report its radio access capability information, which may be static. A base station may request one or more indications of capabilities for a wireless device to report based on band information. A temporary capability restriction request may be sent by the wireless device (e.g., if allowed by a network) to signal the limited availability of some capabilities (e.g., due to hardware sharing, interference, and/or overheating) to the base station. The base station may confirm or reject the request. The temporary capability restriction may be transparent to 5GC (e.g., static capabilities may be stored in 5GC).

A wireless device may have an RRC connection with a network, for example, if CA is configured. At RRC connection establishment, re-establishment, and/or handover procedures, a serving cell may provide NAS mobility information. At RRC connection re-establishment and/or handover, a serving cell may provide a security input. This serving cell may be referred to as the PCell. SCells may be configured to form together with the PCell a set of serving cells, for example, depending on the capabilities of the wireless device. The configured set of serving cells for the wireless device may comprise a PCell and one or more SCells.

The reconfiguration, addition, and/or removal of SCells may be performed by RRC messaging. At intra-NR handover, RRC may add, remove, and/or reconfigure SCells for usage with the target PCell. Dedicated RRC signaling may be used (e.g., if adding a new SCell) to send all required system information of the SCell (e.g., if in connected mode, wireless devices may not acquire broadcasted system information directly from the SCells).

The purpose of an RRC connection reconfiguration procedure may be to modify an RRC connection, (e.g., to establish, modify, and/or release RBs; to perform handover; to setup, modify, and/or release measurements, for example, to add, modify, and/or release SCells and cell groups). NAS dedicated information may be transferred from the network to the wireless device, for example, as part of the RRC connection reconfiguration procedure. The RRCConnectionReconfiguration message may be a command to modify an RRC connection. One or more RRC messages may convey information for measurement configuration, mobility control, and/or radio resource configuration (e.g., RBs, MAC main configuration, and/or physical channel configuration), which may comprise any associated dedicated NAS information and/or security configuration. The wireless device may perform an SCell release, for example, if the received RRC Connection Reconfiguration message includes the sCellToReleaseList. The wireless device may perform SCell additions or modification, for example, if the received RRC Connection Reconfiguration message includes the sCellToAddModList.

An RRC connection establishment, reestablishment, and/or resume procedure may be to establish, reestablish, and/or resume an RRC connection, respectively. An RRC connection establishment procedure may comprise SRB1 establishment. The RRC connection establishment procedure may be used to transfer the initial NAS dedicated information and/or message from a wireless device to an E-UTRAN. The RRCConnectionReestablishment message may be used to re-establish SRB1.

A measurement report procedure may be used to transfer measurement results from a wireless device to an NG-RAN. The wireless device may initiate a measurement report procedure, for example, after successful security activation. A measurement report message may be used to send (e.g., transmit) measurement results.

The wireless device **110** may comprise at least one communication interface **310** (e.g., a wireless modem, an antenna, and/or the like), at least one processor **314**, and at least one set of program code instructions **316** that may be stored in non-transitory memory **315** and executable by the at least one processor **314**. The wireless device **110** may further comprise at least one of at least one speaker and/or microphone **311**, at least one keypad **312**, at least one display and/or touchpad **313**, at least one power source **317**, at least one global positioning system (GPS) chipset **318**, and/or other peripherals **319**.

The processor **314** of the wireless device **110**, the processor **321**A of the base station 1 **120**A, and/or the processor **321**B of the base station 2 **120**B may comprise at least one of a general-purpose processor, a digital signal processor (DSP), a controller, a microcontroller, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) and/or other programmable logic device, discrete gate and/or transistor logic, discrete hardware components, and/or the like. The processor **314** of the wireless device **110**, the processor **321**A in base station 1 **120**A, and/or the processor **321**B in base station 2 **120**B may perform at least one of signal coding and/or processing, data processing, power control, input/output processing, and/or any other functionality that may enable the wireless device **110**, the base station 1 **120**A and/or the base station 2 **120**B to operate in a wireless environment.

The processor **314** of the wireless device **110** may be connected to and/or in communication with the speaker and/or microphone **311**, the keypad **312**, and/or the display and/or touchpad **313**. The processor **314** may receive user input data from and/or provide user output data to the speaker and/or microphone **311**, the keypad **312**, and/or the display and/or touchpad **313**. The processor **314** in the wireless device **110** may receive power from the power source **317** and/or may be configured to distribute the power to the other components in the wireless device **110**. The power source **317** may comprise at least one of one or more dry cell batteries, solar cells, fuel cells, and/or the like. The processor **314** may be connected to the GPS chipset **318**. The GPS chipset **318** may be configured to provide geographic location information of the wireless device **110**.

The processor **314** of the wireless device **110** may further be connected to and/or in communication with other peripherals **319**, which may comprise one or more software and/or hardware modules that may provide additional features and/or functionalities. For example, the peripherals **319** may comprise at least one of an accelerometer, a satellite transceiver, a digital camera, a universal serial bus (USB) port, a hands-free headset, a frequency modulated (FM) radio unit, a media player, an Internet browser, and/or the like.

The communication interface **320**A of the base station 1, **120**A, and/or the communication interface **320**B of the base station 2, **120**B, may be configured to communicate with the communication interface **310** of the wireless device **110**, for example, via a wireless link **330**A and/or via a wireless link **330**B, respectively. The communication interface **320**A of the base station 1, **120**A, may communicate with the communication interface **320**B of the base station 2, **120**B, and/or other RAN and/or core network nodes.

The wireless link **330**A and/or the wireless link **330**B may comprise at least one of a bi-directional link and/or a directional link. The communication interface **310** of the wireless device **110** may be configured to communicate with the communication interface **320**A of the base station 1 **120**A and/or with the communication interface **320**B of the base station 2 **120**B. The base station 1 **120**A and the wireless device **110**, and/or the base station 2 **120**B and the wireless device **110**, may be configured to send and receive transport blocks, for example, via the wireless link **330**A and/or via the wireless link **330**B, respectively. The wireless link **330**A and/or the wireless link **330**B may use at least one frequency carrier. Transceiver(s) may be used. A transceiver may be a device that comprises both a transmitter and a receiver. Transceivers may be used in devices such as wireless devices, base stations, relay nodes, computing devices, and/or the like. Radio technology may be implemented in the communication interface **310**, **320**A, and/or **320**B, and the wireless link **330**A and/or **330**B. The radio technology may comprise one or more elements shown in FIG. **4**A, FIG. **4**B, FIG. **4**C, FIG. **4**D, FIG. **6**, FIG. **7**A, FIG. **7**B, FIG. **8**, and associated text, described below.

Other nodes in a wireless network (e.g. AMF, UPF, SMF, etc.) may comprise one or more communication interfaces, one or more processors, and memory storing instructions. A node (e.g., wireless device, base station, AMF, SMF, UPF, servers, switches, antennas, and/or the like) may comprise one or more processors, and memory storing instructions that when executed by the one or more processors causes the node to perform certain processes and/or functions. Single-carrier and/or multi-carrier communication operation may be performed. A non-transitory tangible computer readable media may comprise instructions executable by one or more processors to cause operation of single-carrier and/or multi-carrier communications. An article of manufacture may comprise a non-transitory tangible computer readable machine-accessible medium having instructions encoded thereon for enabling programmable hardware to cause a node to enable operation of single-carrier and/or multi-carrier communications. The node may include processors, memory, interfaces, and/or the like.

An interface may comprise at least one of a hardware interface, a firmware interface, a software interface, and/or a combination thereof. The hardware interface may comprise connectors, wires, and/or electronic devices such as drivers, amplifiers, and/or the like. The software interface may comprise code stored in a memory device to implement protocol(s), protocol layers, communication drivers, device drivers, combinations thereof, and/or the like. The firmware interface may comprise a combination of embedded hardware and/or code stored in (and/or in communication with) a memory device to implement connections, electronic device operations, protocol(s), protocol layers, communication drivers, device drivers, hardware operations, combinations thereof, and/or the like.

A communication network may comprise the wireless device **110**, the base station 1, **120**A, the base station 2, **120**B, and/or any other device. The communication network may comprise any number and/or type of devices, such as, for example, computing devices, wireless devices, mobile devices, handsets, tablets, laptops, internet of things (IoT) devices, hotspots, cellular repeaters, computing devices, and/or, more generally, user equipment (e.g., UE). Although one or more of the above types of devices may be referenced herein (e.g., UE, wireless device, computing device, etc.), it should be understood that any device herein may comprise any one or more of the above types of devices or similar devices. The communication network, and any other network referenced herein, may comprise an LTE network, a 5G network, or any other network for wireless communications. Apparatuses, systems, and/or methods described herein may generally be described as implemented on one or more devices (e.g., wireless device, base station, eNB, gNB, computing device, etc.), in one or more networks, but it will be understood that one or more features and steps may be implemented on any device and/or in any network. As used throughout, the term "base station" may comprise one or more of: a base station, a node, a Node B, a gNB, an eNB, an ng-eNB, a relay node (e.g., an integrated access and backhaul (IAB) node), a donor node (e.g., a donor eNB, a donor gNB, etc.), an access point (e.g., a WiFi access point), a computing device, a device capable of wirelessly communicating, or any other device capable of sending and/or receiving signals. As used throughout, the term "wireless device" may comprise one or more of: a UE, a handset, a mobile device, a computing device, a node, a device capable of wirelessly communicating, or any other device capable of sending and/or receiving signals. Any reference to one or more of these terms/devices also considers use of any other term/device mentioned above.

FIG. **4**A, FIG. **4**B, FIG. **4**C and FIG. **4**D show examples of uplink and downlink signal transmission. FIG. **4**A shows an example uplink transmitter for at least one physical channel. A baseband signal representing a physical uplink shared channel may perform one or more functions. The one or more functions may comprise at least one of: scrambling (e.g., by Scrambling); modulation of scrambled bits to generate complex-valued symbols (e.g., by a Modulation mapper); mapping of the complex-valued modulation symbols onto one or several transmission layers (e.g., by a Layer mapper); transform precoding to generate complex-valued symbols (e.g., by a Transform precoder); precoding of the complex-valued symbols (e.g., by a Precoder); mapping of precoded complex-valued symbols to resource elements (e.g., by a Resource element mapper); generation of complex-valued time-domain Single Carrier-Frequency Division Multiple Access (SC-FDMA) or CP-OFDM signal for an antenna port (e.g., by a signal gen.); and/or the like. A SC-FDMA signal for uplink transmission may be generated, for example, if transform precoding is enabled. A CP-OFDM signal for uplink transmission may be generated by FIG. **4**A, for example, if transform precoding is not enabled. These functions are shown as examples and other mechanisms may be implemented.

FIG. **4**B shows an example of modulation and up-conversion to the carrier frequency of a complex-valued SC-FDMA or CP-OFDM baseband signal for an antenna port and/or for the complex-valued Physical Random Access CHannel (PRACH) baseband signal. Filtering may be performed prior to transmission.

FIG. 4C shows an example of downlink transmissions. The baseband signal representing a downlink physical channel may perform one or more functions. The one or more functions may comprise: scrambling of coded bits in a codeword to be transmitted on a physical channel (e.g., by Scrambling); modulation of scrambled bits to generate complex-valued modulation symbols (e.g., by a Modulation mapper); mapping of the complex-valued modulation symbols onto one or several transmission layers (e.g., by a Layer mapper); precoding of the complex-valued modulation symbols on a layer for transmission on the antenna ports (e.g., by Precoding); mapping of complex-valued modulation symbols for an antenna port to resource elements (e.g., by a Resource element mapper); generation of complex-valued time-domain OFDM signal for an antenna port (e.g., by an OFDM signal gen.); and/or the like. These functions are shown as examples and other mechanisms may be implemented.

A base station may send (e.g., transmit) a first symbol and a second symbol on an antenna port, to a wireless device. The wireless device may infer the channel (e.g., fading gain, multipath delay, etc.) for conveying the second symbol on the antenna port, from the channel for conveying the first symbol on the antenna port. A first antenna port and a second antenna port may be quasi co-located, for example, if one or more large-scale properties of the channel over which a first symbol on the first antenna port is conveyed may be inferred from the channel over which a second symbol on a second antenna port is conveyed. The one or more large-scale properties may comprise at least one of: delay spread; Doppler spread; Doppler shift; average gain; average delay; and/or spatial receiving (Rx) parameters.

FIG. 4D shows an example modulation and up-conversion to the carrier frequency of the complex-valued OFDM baseband signal for an antenna port. Filtering may be performed prior to transmission.

FIG. 5A shows example uplink channel mapping and example uplink physical signals. A physical layer may provide one or more information transfer services to a MAC and/or one or more higher layers. The physical layer may provide the one or more information transfer services to the MAC via one or more transport channels. An information transfer service may indicate how and/or with what characteristics data is transferred over the radio interface.

Uplink transport channels may comprise an Uplink-Shared CHannel (UL-SCH) **501** and/or a Random Access CHannel (RACH) **502**. A wireless device may send (e.g., transmit) one or more uplink DM-RSs **506** to a base station for channel estimation, for example, for coherent demodulation of one or more uplink physical channels (e.g., PUSCH **503** and/or PUCCH **504**). The wireless device may send (e.g., transmit) to a base station at least one uplink DM-RS **506** with PUSCH **503** and/or PUCCH **504**, wherein the at least one uplink DM-RS **506** may be spanning a same frequency range as a corresponding physical channel. The base station may configure the wireless device with one or more uplink DM-RS configurations. At least one DM-RS configuration may support a front-loaded DM-RS pattern. A front-loaded DM-RS may be mapped over one or more OFDM symbols (e.g., 1 or 2 adjacent OFDM symbols). One or more additional uplink DM-RS may be configured to send (e.g., transmit) at one or more symbols of a PUSCH and/or PUCCH. The base station may semi-statically configure the wireless device with a maximum number of front-loaded DM-RS symbols for PUSCH and/or PUCCH. The wireless device may schedule a single-symbol DM-RS and/or double symbol DM-RS based on a maximum number of front-loaded DM-RS symbols, wherein the base station may configure the wireless device with one or more additional uplink DM-RS for PUSCH and/or PUCCH. A new radio network may support, for example, at least for CP-OFDM, a common DM-RS structure for DL and UL, wherein a DM-RS location, DM-RS pattern, and/or scrambling sequence may be same or different.

Whether or not an uplink PT-RS **507** is present may depend on an RRC configuration. A presence of the uplink PT-RS may be wireless device-specifically configured. A presence and/or a pattern of the uplink PT-RS **507** in a scheduled resource may be wireless device-specifically configured by a combination of RRC signaling and/or association with one or more parameters used for other purposes (e.g., Modulation and Coding Scheme (MCS)) which may be indicated by DCI. If configured, a dynamic presence of uplink PT-RS **507** may be associated with one or more DCI parameters comprising at least a MCS. A radio network may support a plurality of uplink PT-RS densities defined in time/frequency domain. If present, a frequency domain density may be associated with at least one configuration of a scheduled bandwidth. A wireless device may assume a same precoding for a DMRS port and a PT-RS port. A number of PT-RS ports may be less than a number of DM-RS ports in a scheduled resource. The uplink PT-RS **507** may be confined in the scheduled time/frequency duration for a wireless device.

A wireless device may send (e.g., transmit) an SRS **508** to a base station for channel state estimation, for example, to support uplink channel dependent scheduling and/or link adaptation. The SRS **508** sent (e.g., transmitted) by the wireless device may allow for the base station to estimate an uplink channel state at one or more different frequencies. A base station scheduler may use an uplink channel state to assign one or more resource blocks of a certain quality (e.g., above a quality threshold) for an uplink PUSCH transmission from the wireless device. The base station may semi-statically configure the wireless device with one or more SRS resource sets. For an SRS resource set, the base station may configure the wireless device with one or more SRS resources. An SRS resource set applicability may be configured by a higher layer (e.g., RRC) parameter. An SRS resource in each of one or more SRS resource sets may be sent (e.g., transmitted) at a time instant, for example, if a higher layer parameter indicates beam management. The wireless device may send (e.g., transmit) one or more SRS resources in different SRS resource sets simultaneously. A new radio network may support aperiodic, periodic, and/or semi-persistent SRS transmissions. The wireless device may send (e.g., transmit) SRS resources, for example, based on one or more trigger types. The one or more trigger types may comprise higher layer signaling (e.g., RRC) and/or one or more DCI formats (e.g., at least one DCI format may be used for a wireless device to select at least one of one or more configured SRS resource sets). An SRS trigger type 0 may refer to an SRS triggered based on a higher layer signaling. An SRS trigger type 1 may refer to an SRS triggered based on one or more DCI formats. The wireless device may be configured to send (e.g., transmit) the SRS **508** after a transmission of PUSCH **503** and corresponding uplink DM-RS **506**, for example, if PUSCH **503** and the SRS **508** are transmitted in a same slot.

A base station may semi-statically configure a wireless device with one or more SRS configuration parameters indicating at least one of following: an SRS resource configuration identifier, a number of SRS ports, time domain behavior of SRS resource configuration (e.g., an indication of periodic, semi-persistent, or aperiodic SRS), slot (mini-slot, and/or subframe) level periodicity and/or offset for a periodic and/or aperiodic SRS resource, a number of OFDM symbols in a SRS resource, starting OFDM symbol of a SRS resource, an SRS bandwidth, a frequency hopping bandwidth, a cyclic shift, and/or an SRS sequence ID.

FIG. 5B shows an example downlink channel mapping and downlink physical signals. Downlink transport channels may comprise a Downlink-Shared CHannel (DL-SCH) **511**, a Paging CHannel (PCH) **512**, and/or a Broadcast CHannel (BCH) **513**. A transport channel may be mapped to one or more corresponding physical channels. A UL-SCH **501** may be mapped to a Physical Uplink Shared CHannel (PUSCH) **503**. A RACH **502** may be mapped to a PRACH **505**. A DL-SCH **511** and a PCH **512** may be mapped to a Physical Downlink Shared CHannel (PDSCH) **514**. A BCH **513** may be mapped to a Physical Broadcast CHannel (PBCH) **516**.

A radio network may comprise one or more downlink and/or uplink transport channels. The radio network may comprise one or more physical channels without a corresponding transport channel. The one or more physical channels may be used for an Uplink Control Information (UCI) **509** and/or a Downlink Control Information (DCI) **517**. A Physical Uplink Control CHannel (PUCCH) **504** may carry UCI **509** from a wireless device to a base station. A Physical Downlink Control CHannel (PDCCH) **515** may carry the DCI **517** from a base station to a wireless device. The radio network (e.g., NR) may support the UCI **509** multiplexing in the PUSCH **503**, for example, if the UCI **509** and the PUSCH **503** transmissions may coincide in a slot (e.g., at least in part). The UCI **509** may comprise at least one of a CSI, an Acknowledgement (ACK)/Negative Acknowledgement (NACK), and/or a scheduling request. The DCI **517** via the PDCCH **515** may indicate at least one of following: one or more downlink assignments and/or one or more uplink scheduling grants.

In uplink, a wireless device may send (e.g., transmit) one or more Reference Signals (RSs) to a base station. The one or more RSs may comprise at least one of a Demodulation-RS (DM-RS) **506**, a Phase Tracking-RS (PT-RS) **507**, and/or a Sounding RS (SRS) **508**. In downlink, a base station may send (e.g., transmit, unicast, multicast, and/or broadcast) one or more RSs to a wireless device. The one or more RSs may comprise at least one of a Primary Synchronization Signal (PSS)/Secondary Synchronization Signal (SSS) **521**, a CSI-RS **522**, a DM-RS **523**, and/or a PT-RS **524**.

In a time domain, an SS/PBCH block may comprise one or more OFDM symbols (e.g., 4 OFDM symbols numbered in increasing order from 0 to 3) within the SS/PBCH block. An SS/PBCH block may comprise the PSS/SSS **521** and/or the PBCH **516**. In the frequency domain, an SS/PBCH block may comprise one or more contiguous subcarriers (e.g., 240 contiguous subcarriers with the subcarriers numbered in increasing order from 0 to 239) within the SS/PBCH block. The PSS/SSS **521** may occupy, for example, 1 OFDM symbol and 127 subcarriers. The PBCH **516** may span across, for example, 3 OFDM symbols and 240 subcarriers. A wireless device may assume that one or more SS/PBCH blocks transmitted with a same block index may be quasi co-located, for example, with respect to Doppler spread, Doppler shift, average gain, average delay, and/or spatial Rx parameters. A wireless device may not assume quasi co-location for other SS/PBCH block transmissions. A periodicity of an SS/PBCH block may be configured by a radio network (e.g., by an RRC signaling). One or more time locations in which the SS/PBCH block may be sent may be determined by sub-carrier spacing. A wireless device may assume a band-specific sub-carrier spacing for an SS/PBCH block, for example, unless a radio network has configured the wireless device to assume a different sub-carrier spacing.

The downlink CSI-RS **522** may be used for a wireless device to acquire channel state information. A radio network may support periodic, aperiodic, and/or semi-persistent transmission of the downlink CSI-RS **522**. A base station may semi-statically configure and/or reconfigure a wireless device with periodic transmission of the downlink CSI-RS **522**. A configured CSI-RS resources may be activated and/or deactivated. For semi-persistent transmission, an activation and/or deactivation of a CSI-RS resource may be triggered dynamically. A CSI-RS configuration may comprise one or more parameters indicating at least a number of antenna ports. A base station may configure a wireless device with 32 ports, or any other number of ports. A base station may semi-statically configure a wireless device with one or more CSI-RS resource sets. One or more CSI-RS resources may be allocated from one or more CSI-RS resource sets to one or more wireless devices. A base station may semi-statically configure one or more parameters indicating CSI RS resource mapping, for example, time-domain location of one or more CSI-RS resources, a bandwidth of a CSI-RS resource, and/or a periodicity. A wireless device may be configured to use the same OFDM symbols for the downlink CSI-RS **522** and the Control Resource Set (CORESET), for example, if the downlink CSI-RS **522** and the CORESET are spatially quasi co-located and resource elements associated with the downlink CSI-RS **522** are the outside of PRBs configured for the CORESET. A wireless device may be configured to use the same OFDM symbols for downlink CSI-RS **522** and SS/PBCH blocks, for example, if the downlink CSI-RS **522** and SS/PBCH blocks are spatially quasi co-located and resource elements associated with the downlink CSI-RS **522** are outside of the PRBs configured for the SS/PBCH blocks.

A wireless device may send (e.g., transmit) one or more downlink DM-RSs **523** to a base station for channel estimation, for example, for coherent demodulation of one or more downlink physical channels (e.g., PDSCH **514**). A radio network may support one or more variable and/or configurable DM-RS patterns for data demodulation. At least one downlink DM-RS configuration may support a front-loaded DM-RS pattern. A front-loaded DM-RS may be mapped over one or more OFDM symbols (e.g., 1 or 2 adjacent OFDM symbols). A base station may semi-statically configure a wireless device with a maximum number of front-loaded DM-RS symbols for PDSCH **514**. A DM-RS configuration may support one or more DM-RS ports. A DM-RS configuration may support at least 8 orthogonal downlink DM-RS ports, for example, for single user-MIMO. ADM-RS configuration may support 12 orthogonal downlink DM-RS ports, for example, for multiuser-MIMO. A radio network may support, for example, at least for CP-OFDM, a common DM-RS structure for DL and UL, wherein a DM-RS location, DM-RS pattern, and/or scrambling sequence may be the same or different.

Whether or not the downlink PT-RS **524** is present may depend on an RRC configuration. A presence of the downlink PT-RS **524** may be wireless device-specifically configured. A presence and/or a pattern of the downlink PT-RS **524** in a scheduled resource may be wireless device-specifically configured, for example, by a combination of RRC signaling and/or an association with one or more parameters used for other purposes (e.g., MCS) which may be indicated by the DCI. If configured, a dynamic presence of the downlink PT-RS **524** may be associated with one or more DCI parameters comprising at least MCS. A radio network may support a plurality of PT-RS densities in a time/frequency domain. If present, a frequency domain density may be associated with at least one configuration of a scheduled bandwidth. A wireless device may assume the same precoding for a DMRS port and a PT-RS port. A number of PT-RS ports may be less than a number of DM-RS ports in a scheduled resource. The downlink PT-RS **524** may be confined in the scheduled time/frequency duration for a wireless device.

FIG. **6** shows an example transmission time and reception time for a carrier. A multicarrier OFDM communication system may include one or more carriers, for example, ranging from 1 to 32 carriers (such as for carrier aggregation) or ranging from 1 to 64 carriers (such as for dual connectivity). Different radio frame structures may be supported (e.g., for FDD and/or for TDD duplex mechanisms). FIG. **6** shows an example frame timing. Downlink and uplink transmissions may be organized into radio frames **601**. Radio frame duration may be 10 milliseconds (ms). A 10 ms radio frame **601** may be divided into ten equally sized subframes **602**, each with a 1 ms duration. Subframe(s) may comprise one or more slots (e.g., slots **603** and **605**) depending on subcarrier spacing and/or CP length. For example, a subframe with 15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz and 480 kHz subcarrier spacing may comprise one, two, four, eight, sixteen and thirty-two slots, respectively. In FIG. **6**, a subframe may be divided into two equally sized slots **603** with 0.5 ms duration. For example, 10 subframes may be available for downlink transmission and 10 subframes may be available for uplink transmissions in a 10 ms interval. Other subframe durations such as, for example, 0.5 ms, 1 ms, 2 ms, and 5 ms may be supported. Uplink and downlink transmissions may be separated in the frequency domain Slot(s) may include a plurality of OFDM symbols **604**. The number of OFDM symbols **604** in a slot **605** may depend on the cyclic prefix length. A slot may be 14 OFDM symbols for the same subcarrier spacing of up to 480 kHz with normal CP. A slot may be 12 OFDM symbols for the same subcarrier spacing of 60 kHz with extended CP. A slot may comprise downlink, uplink, and/or a downlink part and an uplink part, and/or alike.

FIG. **7**A shows example sets of OFDM subcarriers. A base station may communicate with a wireless device using a carrier having an example channel bandwidth **700**. Arrow(s) in the example may depict a subcarrier in a multicarrier OFDM system. The OFDM system may use technology such as OFDM technology, SC-FDMA technology, and/or the like. An arrow **701** shows a subcarrier transmitting information symbols. A subcarrier spacing **702**, between two contiguous subcarriers in a carrier, may be any one of 15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz, or any other frequency. Different subcarrier spacing may correspond to different transmission numerologies. A transmission numerology may comprise at least: a numerology index; a value of subcarrier spacing; and/or a type of cyclic prefix (CP). A base station may send (e.g., transmit) to and/or receive from a wireless device via a number of subcarriers **703** in a carrier. A bandwidth occupied by a number of subcarriers **703** (e.g., transmission bandwidth) may be smaller than the channel bandwidth **700** of a carrier, for example, due to guard bands **704** and **705**. Guard bands **704** and **705** may be used to reduce interference to and from one or more neighbor carriers. A number of subcarriers (e.g., transmission bandwidth) in a carrier may depend on the channel bandwidth of the carrier and/or the subcarrier spacing. A transmission bandwidth, for a carrier with a 20 MHz channel bandwidth and a 15 kHz subcarrier spacing, may be in number of 1024 subcarriers.

A base station and a wireless device may communicate with multiple component carriers (CCs), for example, if configured with CA. Different component carriers may have different bandwidth and/or different subcarrier spacing, for example, if CA is supported. A base station may send (e.g., transmit) a first type of service to a wireless device via a first component carrier. The base station may send (e.g., transmit) a second type of service to the wireless device via a second component carrier. Different types of services may have different service requirements (e.g., data rate, latency, reliability), which may be suitable for transmission via different component carriers having different subcarrier spacing and/or different bandwidth.

FIG. **7**B shows examples of component carriers. A first component carrier may comprise a first number of subcarriers **706** having a first subcarrier spacing **709**. A second component carrier may comprise a second number of subcarriers **707** having a second subcarrier spacing **710**. A third component carrier may comprise a third number of subcarriers **708** having a third subcarrier spacing **711**. Carriers in a multicarrier OFDM communication system may be contiguous carriers, non-contiguous carriers, or a combination of both contiguous and non-contiguous carriers.

FIG. **8** shows an example of OFDM radio resources. A carrier may have a transmission bandwidth **801**. A resource grid may be in a structure of frequency domain **802** and time domain **803**. A resource grid may comprise a first number of OFDM symbols in a subframe and a second number of resource blocks, starting from a common resource block indicated by higher-layer signaling (e.g., RRC signaling), for a transmission numerology and a carrier. In a resource grid, a resource element **805** may comprise a resource unit that may be identified by a subcarrier index and a symbol index. A subframe may comprise a first number of OFDM symbols **807** that may depend on a numerology associated with a carrier. A subframe may have 14 OFDM symbols for a carrier, for example, if a subcarrier spacing of a numerology of a carrier is 15 kHz. A subframe may have 28 OFDM symbols, for example, if a subcarrier spacing of a numerology is 30 kHz. A subframe may have 56 OFDM symbols, for example, if a subcarrier spacing of a numerology is 60 kHz. A subcarrier spacing of a numerology may comprise any other frequency. A second number of resource blocks comprised in a resource grid of a carrier may depend on a bandwidth and a numerology of the carrier.

A resource block **806** may comprise 12 subcarriers. Multiple resource blocks may be grouped into a Resource Block Group (RBG) **804**. A size of a RBG may depend on at least one of: a RRC message indicating a RBG size configuration; a size of a carrier bandwidth; and/or a size of a bandwidth part of a carrier. A carrier may comprise multiple bandwidth parts. A first bandwidth part of a carrier may have a different frequency location and/or a different bandwidth from a second bandwidth part of the carrier.

A base station may send (e.g., transmit), to a wireless device, a downlink control information comprising a downlink or uplink resource block assignment. A base station may send (e.g., transmit) to and/or receive from, a wireless device, data packets (e.g., transport blocks). The data packets may be scheduled on and transmitted via one or more resource blocks and one or more slots indicated by parameters in downlink control information and/or RRC message(s). A starting symbol relative to a first slot of the one or more slots may be indicated to the wireless device. A base station may send (e.g., transmit) to and/or receive from, a wireless device, data packets. The data packets may be scheduled for transmission on one or more RBGs and in one or more slots.

A base station may send (e.g., transmit), to a wireless device, downlink control information comprising a downlink assignment. The base station may send (e.g., transmit) the DCI via one or more PDCCHs. The downlink assignment may comprise parameters indicating at least one of a modulation and coding format; resource allocation; and/or HARQ information related to the DL-SCH. The resource allocation may comprise parameters of resource block allocation; and/or slot allocation. A base station may allocate (e.g., dynamically) resources to a wireless device, for example, via a Cell-Radio Network Temporary Identifier (C-RNTI) on one or more PDCCHs. The wireless device may monitor the one or more PDCCHs, for example, in order to find possible allocation if its downlink reception is enabled. The wireless device may receive one or more downlink data packets on one or more PDSCH scheduled by the one or more PDCCHs, for example, if the wireless device successfully detects the one or more PDCCHs.

A base station may allocate Configured Scheduling (CS) resources for down link transmission to a wireless device. The base station may send (e.g., transmit) one or more RRC messages indicating a periodicity of the CS grant. The base station may send (e.g., transmit) DCI via a PDCCH addressed to a Configured Scheduling-RNTI (CS-RNTI) activating the CS resources. The DCI may comprise parameters indicating that the downlink grant is a CS grant. The CS grant may be implicitly reused according to the periodicity defined by the one or more RRC messages. The CS grant may be implicitly reused, for example, until deactivated.

A base station may send (e.g., transmit), to a wireless device via one or more PDCCHs, downlink control information comprising an uplink grant. The uplink grant may comprise parameters indicating at least one of a modulation and coding format; a resource allocation; and/or HARQ information related to the UL-SCH. The resource allocation may comprise parameters of resource block allocation; and/or slot allocation. The base station may dynamically allocate resources to the wireless device via a C-RNTI on one or more PDCCHs. The wireless device may monitor the one or more PDCCHs, for example, in order to find possible resource allocation. The wireless device may send (e.g., transmit) one or more uplink data packets via one or more PUSCH scheduled by the one or more PDCCHs, for example, if the wireless device successfully detects the one or more PDCCHs.

The base station may allocate CS resources for uplink data transmission to a wireless device. The base station may transmit one or more RRC messages indicating a periodicity of the CS grant. The base station may send (e.g., transmit) DCI via a PDCCH addressed to a CS-RNTI to activate the CS resources. The DCI may comprise parameters indicating that the uplink grant is a CS grant. The CS grant may be implicitly reused according to the periodicity defined by the one or more RRC message, The CS grant may be implicitly reused, for example, until deactivated.

A base station may send (e.g., transmit) DCI and/or control signaling via a PDCCH. The DCI may comprise a format of a plurality of formats. The DCI may comprise downlink and/or uplink scheduling information (e.g., resource allocation information, HARQ related parameters, MCS), request(s) for CSI (e.g., aperiodic CQI reports), request(s) for an SRS, uplink power control commands for one or more cells, one or more timing information (e.g., TB transmission/reception timing, HARQ feedback timing, etc.), and/or the like. The DCI may indicate an uplink grant comprising transmission parameters for one or more transport blocks. The DCI may indicate a downlink assignment indicating parameters for receiving one or more transport blocks. The DCI may be used by the base station to initiate a contention-free random access at the wireless device. The base station may send (e.g., transmit) DCI comprising a slot format indicator (SFI) indicating a slot format. The base station may send (e.g., transmit) DCI comprising a pre-emption indication indicating the PRB(s) and/or OFDM symbol(s) in which a wireless device may assume no transmission is intended for the wireless device. The base station may send (e.g., transmit) DCI for group power control of the PUCCH, the PUSCH, and/or an SRS. DCI may correspond to an RNTI. The wireless device may obtain an RNTI after or in response to completing the initial access (e.g., C-RNTI). The base station may configure an RNTI for the wireless (e.g., CS-RNTI, TPC-CS-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, TPC-SRS-RNTI, etc.). The wireless device may determine (e.g., compute) an RNTI (e.g., the wireless device may determine the RA-RNTI based on resources used for transmission of a preamble). An RNTI may have a pre-configured value (e.g., P-RNTI or SI-RNTI). The wireless device may monitor a group common search space which may be used by the base station for sending (e.g., transmitting) DCIs that are intended for a group of wireless devices. A group common DCI may correspond to an RNTI which is commonly configured for a group of wireless devices. The wireless device may monitor a wireless device-specific search space. A wireless device specific DCI may correspond to an RNTI configured for the wireless device.

A communications system (e.g., an NR system) may support a single beam operation and/or a multi-beam operation. In a multi-beam operation, a base station may perform a downlink beam sweeping to provide coverage for common control channels and/or downlink SS blocks, which may comprise at least a PSS, a SSS, and/or PBCH. A wireless device may measure quality of a beam pair link using one or more RSs. One or more SS blocks, or one or more CSI-RS resources (e.g., which may be associated with a CSI-RS resource index (CRI)), and/or one or more DM-RSs of a PBCH, may be used as an RS for measuring a quality of a beam pair link. The quality of a beam pair link may be based on a reference signal received power (RSRP) value, a reference signal received quality (RSRQ) value, and/or a CSI value measured on RS resources. The base station may indicate whether an RS resource, used for measuring a beam pair link quality, is quasi-co-located (QCLed) with DM-RSs of a control channel. An RS resource and DM-RSs of a control channel may be called QCLed, for example, if channel characteristics from a transmission on an RS to a wireless device, and that from a transmission on a control channel to a wireless device, are similar or the same under a configured criterion. In a multi-beam operation, a wireless device may perform an uplink beam sweeping to access a cell.

A wireless device may be configured to monitor a PDCCH on one or more beam pair links simultaneously, for example, depending on a capability of the wireless device. This monitoring may increase robustness against beam pair link blocking. A base station may send (e.g., transmit) one or more messages to configure the wireless device to monitor the PDCCH on one or more beam pair links in different PDCCH OFDM symbols. A base station may send (e.g., transmit) higher layer signaling (e.g., RRC signaling) and/or a MAC CE comprising parameters related to the Rx beam setting of the wireless device for monitoring the PDCCH on one or more beam pair links. The base station may send (e.g., transmit) an indication of a spatial QCL assumption between an DL RS antenna port(s) (e.g., a cell-specific CSI-RS, a wireless device-specific CSI-RS, an SS block, and/or a PBCH with or without DM-RSs of the PBCH) and/or DL RS antenna port(s) for demodulation of a DL control channel. Signaling for beam indication for a PDCCH may comprise MAC CE signaling, RRC signaling, DCI signaling, and/or specification-transparent and/or implicit method, and/or any combination of signaling methods.

A base station may indicate spatial QCL parameters between DL RS antenna port(s) and DM-RS antenna port(s) of a DL data channel, for example, for reception of a unicast DL data channel. The base station may send (e.g., transmit) DCI (e.g., downlink grants) comprising information indicating the RS antenna port(s). The information may indicate RS antenna port(s) that may be QCL-ed with the DM-RS antenna port(s). A different set of DM-RS antenna port(s) for a DL data channel may be indicated as QCL with a different set of the RS antenna port(s).

FIG. **9**A shows an example of beam sweeping in a DL channel. In an RRC_INACTIVE state or RRC_IDLE state, a wireless device may assume that SS blocks form an SS burst **940**, and an SS burst set **950**. The SS burst set **950** may have a given periodicity. A base station **120** may send (e.g., transmit) SS blocks in multiple beams, together forming a SS burst **940**, for example, in a multi-beam operation. One or more SS blocks may be sent (e.g., transmitted) on one beam. If multiple SS bursts **940** are transmitted with multiple beams, SS bursts together may form SS burst set **950**.

A wireless device may use CSI-RS for estimating a beam quality of a link between a wireless device and a base station, for example, in the multi beam operation. A beam may be associated with a CSI-RS. A wireless device may (e.g., based on a RSRP measurement on CSI-RS) report a beam index, which may be indicated in a CRI for downlink beam selection and/or associated with an RSRP value of a beam. A CSI-RS may be sent (e.g., transmitted) on a CSI-RS resource, which may comprise at least one of: one or more antenna ports and/or one or more time and/or frequency radio resources. A CSI-RS resource may be configured in a cell-specific way such as by common RRC signaling, or in a wireless device-specific way such as by dedicated RRC signaling and/or L1/L2 signaling. Multiple wireless devices covered by a cell may measure a cell-specific CSI-RS resource. A dedicated subset of wireless devices covered by a cell may measure a wireless device-specific CSI-RS resource.

A CSI-RS resource may be sent (e.g., transmitted) periodically, using aperiodic transmission, or using a multi-shot or semi-persistent transmission. In a periodic transmission in FIG. **9**A, a base station **120** may send (e.g., transmit) configured CSI-RS resources **940** periodically using a configured periodicity in a time domain. In an aperiodic transmission, a configured CSI-RS resource may be sent (e.g., transmitted) in a dedicated time slot. In a multi-shot and/or semi-persistent transmission, a configured CSI-RS resource may be sent (e.g., transmitted) within a configured period. Beams used for CSI-RS transmission may have a different beam width than beams used for SS-blocks transmission.

FIG. **9**B shows an example of a beam management procedure, such as new radio network. The base station **120** and/or the wireless device **110** may perform a downlink L1/L2 beam management procedure. One or more of the following downlink L1/L2 beam management procedures may be performed within one or more wireless devices **110** and one or more base stations **120**. A P1 procedure **910** may be used to enable the wireless device **110** to measure one or more Transmission (Tx) beams associated with the base station **120**, for example, to support a selection of a first set of Tx beams associated with the base station **120** and a first set of Rx beam(s) associated with the wireless device **110**. A base station **120** may sweep a set of different Tx beams, for example, for beamforming at a base station **120** (such as shown in the top row, in a counter-clockwise direction). A wireless device **110** may sweep a set of different Rx beams, for example, for beamforming at a wireless device **110** (such as shown in the bottom row, in a clockwise direction). A P2 procedure **920** may be used to enable a wireless device **110** to measure one or more Tx beams associated with a base station **120**, for example, to possibly change a first set of Tx beams associated with a base station **120**. A P2 procedure **920** may be performed on a possibly smaller set of beams (e.g., for beam refinement) than in the P1 procedure **910**. A P2 procedure **920** may be a special example of a P1 procedure **910**. A P3 procedure **930** may be used to enable a wireless device **110** to measure at least one Tx beam associated with a base station **120**, for example, to change a first set of Rx beams associated with a wireless device **110**.

A wireless device **110** may send (e.g., transmit) one or more beam management reports to a base station **120**. In one or more beam management reports, a wireless device **110** may indicate one or more beam pair quality parameters comprising one or more of: a beam identification; an RSRP; a Precoding Matrix Indicator (PMI), Channel Quality Indicator (CQI), and/or Rank Indicator (RI) of a subset of configured beams. Based on one or more beam management reports, the base station **120** may send (e.g., transmit) to a wireless device **110** a signal indicating that one or more beam pair links are one or more serving beams. The base station **120** may send (e.g., transmit) the PDCCH and the PDSCH for a wireless device **110** using one or more serving beams.

A communications network (e.g., a new radio network) may support a Bandwidth Adaptation (BA). Receive and/or transmit bandwidths that may be configured for a wireless device using a BA may not be large. Receive and/or transmit bandwidth may not be as large as a bandwidth of a cell. Receive and/or transmit bandwidths may be adjustable. A wireless device may change receive and/or transmit bandwidths, for example, to reduce (e.g., shrink) the bandwidth(s) at (e.g., during) a period of low activity such as to save power. A wireless device may change a location of receive and/or transmit bandwidths in a frequency domain, for example, to increase scheduling flexibility. A wireless device may change a subcarrier spacing, for example, to allow different services.

A Bandwidth Part (BWP) may comprise a subset of a total cell bandwidth of a cell. A base station may configure a wireless device with one or more BWPs, for example, to achieve a BA. A base station may indicate, to a wireless device, which of the one or more (configured) BWPs is an active BWP.

FIG. **10** shows an example of BWP configurations. BWPs may be configured as follows: BWP1 (**1010** and **1050**) with a width of 40 MHz and subcarrier spacing of 15 kHz; BWP2 (**1020** and **1040**) with a width of 10 MHz and subcarrier spacing of 15 kHz; BWP3 **1030** with a width of 20 MHz and subcarrier spacing of 60 kHz. Any number of BWP configurations may comprise any other width and subcarrier spacing combination.

A wireless device, configured for operation in one or more BWPs of a cell, may be configured by one or more higher layers (e.g., RRC layer). The wireless device may be configured for a cell with: a set of one or more BWPs (e.g., at most four BWPs) for reception (e.g., a DL BWP set) in a DL bandwidth by at least one parameter DL-BWP; and a set of one or more BWPs (e.g., at most four BWPs) for transmissions (e.g., UL BWP set) in an UL bandwidth by at least one parameter UL-BWP. BWPs are described as example resources. Any wireless resource may be applicable to one or more procedures described herein.

A base station may configure a wireless device with one or more UL and DL BWP pairs, for example, to enable BA on the PCell. To enable BA on SCells (e.g., for CA), a base station may configure a wireless device at least with one or more DL BWPs (e.g., there may be none in an UL).

An initial active DL BWP may comprise at least one of a location and number of contiguous PRBs, a subcarrier spacing, or a cyclic prefix, for example, for a control resource set for at least one common search space. For operation on the PCell, one or more higher layer parameters may indicate at least one initial UL BWP for a random access procedure. If a wireless device is configured with a secondary carrier on a primary cell, the wireless device may be configured with an initial BWP for random access procedure on a secondary carrier.

A wireless device may expect that a center frequency for a DL BWP may be same as a center frequency for a UL BWP, for example, for unpaired spectrum operation. A base station may semi-statically configure a wireless device for a cell with one or more parameters, for example, for a DL BWP or an UL BWP in a set of one or more DL BWPs or one or more UL BWPs, respectively. The one or more parameters may indicate one or more of following: a subcarrier spacing; a cyclic prefix; a number of contiguous PRBs; an index in the set of one or more DL BWPs and/or one or more UL BWPs; a link between a DL BWP and an UL BWP from a set of configured DL BWPs and UL BWPs; a DCI detection to a PDSCH reception timing; a PDSCH reception to a HARQ-ACK transmission timing value; a DCI detection to a PUSCH transmission timing value; and/or an offset of a first PRB of a DL bandwidth or an UL bandwidth, respectively, relative to a first PRB of a bandwidth.

For a DL BWP in a set of one or more DL BWPs on a PCell, a base station may configure a wireless device with one or more control resource sets for at least one type of common search space and/or one wireless device-specific search space. A base station may refrain from configuring a wireless device without a common search space on a PCell, or on a PSCell, in an active DL BWP. For an UL BWP in a set of one or more UL BWPs, a base station may configure a wireless device with one or more resource sets for one or more PUCCH transmissions.

DCI may comprise a BWP indicator field. The BWP indicator field value may indicate an active DL BWP, from a configured DL BWP set, for one or more DL receptions. The BWP indicator field value may indicate an active UL BWP, from a configured UL BWP set, for one or more UL transmissions.

For a PCell, a base station may semi-statically configure a wireless device with a default DL BWP among configured DL BWPs. If a wireless device is not provided with a default DL BWP, a default BWP may be an initial active DL BWP. A default BWP may not be configured for one or more wireless devices. A first (or initial) BWP may serve as a default BWP, for example, if a default BWP is not configured.

A base station may configure a wireless device with a timer value for a PCell. A wireless device may start a timer (e.g., a BWP inactivity timer), for example, if a wireless device detects DCI indicating an active DL BWP, other than a default DL BWP, for a paired spectrum operation, and/or if a wireless device detects DCI indicating an active DL BWP or UL BWP, other than a default DL BWP or UL BWP, for an unpaired spectrum operation. The wireless device may increment the timer by an interval of a first value (e.g., the first value may be 1 millisecond, 0.5 milliseconds, or any other time duration), for example, if the wireless device does not detect DCI at (e.g., during) the interval for a paired spectrum operation or for an unpaired spectrum operation. The timer may expire at a time that the timer is equal to the timer value. A wireless device may switch to the default DL BWP from an active DL BWP, for example, if the timer expires.

A base station may semi-statically configure a wireless device with one or more BWPs. A wireless device may switch an active BWP from a first BWP to a second BWP, for example, after or in response to receiving DCI indicating the second BWP as an active BWP, and/or after or in response to an expiry of BWP inactivity timer (e.g., the second BWP may be a default BWP). FIG. **10** shows an example of three BWPs configured, BWP1 (**1010** and **1050**), BWP2 (**1020** and **1040**), and BWP3 (**1030**). BWP2 (**1020** and **1040**) may be a default BWP. BWP1 (**1010**) may be an initial active BWP. A wireless device may switch an active BWP from BWP1 **1010** to BWP2 **1020**, for example, after or in response to an expiry of the BWP inactivity timer. A wireless device may switch an active BWP from BWP2 **1020** to BWP3 **1030**, for example, after or in response to receiving DCI indicating BWP3 **1030** as an active BWP. Switching an active BWP from BWP3 **1030** to BWP2 **1040** and/or from BWP2 **1040** to BWP1 **1050** may be after or in response to receiving DCI indicating an active BWP, and/or after or in response to an expiry of BWP inactivity timer.

Wireless device procedures on a secondary cell may be same as on a primary cell using the timer value for the secondary cell and the default DL BWP for the secondary cell, for example, if a wireless device is configured for a secondary cell with a default DL BWP among configured DL BWPs and a timer value. A wireless device may use an indicated DL BWP and an indicated UL BWP on a secondary cell as a respective first active DL BWP and first active UL BWP on a secondary cell or carrier, for example, if a base station configures a wireless device with a first active DL BWP and a first active UL BWP on a secondary cell or carrier.

FIG. **11**A and FIG. **11**B show packet flows using a multi connectivity (e.g., dual connectivity, multi connectivity, tight interworking, and/or the like). FIG. **11**A shows an example of a protocol structure of a wireless device **110** (e.g., UE) with CA and/or multi connectivity. FIG. **11**B shows an example of a protocol structure of multiple base stations with CA and/or multi connectivity. The multiple base stations may comprise a master node, MN **1130** (e.g., a master node, a master base station, a master gNB, a master eNB, and/or the like) and a secondary node, SN **1150** (e.g., a secondary node, a secondary base station, a secondary gNB, a secondary eNB, and/or the like). A master node **1130** and a secondary node **1150** may co-work to communicate with a wireless device **110**.

If multi connectivity is configured for a wireless device **110**, the wireless device **110**, which may support multiple reception and/or transmission functions in an RRC connected state, may be configured to utilize radio resources provided by multiple schedulers of a multiple base stations. Multiple base stations may be inter-connected via a non-ideal or ideal backhaul (e.g., Xn interface, X2 interface, and/or the like). A base station involved in multi connectivity for a certain wireless device may perform at least one of two different roles: a base station may act as a master base station or act as a secondary base station. In multi connectivity, a wireless device may be connected to one master base station and one or more secondary base stations. A master base station (e.g., the MN **1130**) may provide a master cell group (MCG) comprising a primary cell and/or one or more secondary cells for a wireless device (e.g., the wireless device **110**). A secondary base station (e.g., the SN **1150**) may provide a secondary cell group (SCG) comprising a primary secondary cell (PSCell) and/or one or more secondary cells for a wireless device (e.g., the wireless device **110**).

In multi connectivity, a radio protocol architecture that a bearer uses may depend on how a bearer is setup. Three different types of bearer setup options may be supported: an MCG bearer, an SCG bearer, and/or a split bearer. A wireless device may receive and/or send (e.g., transmit) packets of an MCG bearer via one or more cells of the MCG. A wireless device may receive and/or send (e.g., transmit) packets of an SCG bearer via one or more cells of an SCG. Multi-connectivity may indicate having at least one bearer configured to use radio resources provided by the secondary base station. Multi-connectivity may or may not be configured and/or implemented.

A wireless device (e.g., wireless device **110**) may send (e.g., transmit) and/or receive: packets of an MCG bearer via an SDAP layer (e.g., SDAP **1110**), a PDCP layer (e.g., NR PDCP **1111**), an RLC layer (e.g., MN RLC **1114**), and a MAC layer (e.g., MN MAC **1118**); packets of a split bearer via an SDAP layer (e.g., SDAP **1110**), a PDCP layer (e.g., NR PDCP **1112**), one of a master or secondary RLC layer (e.g., MN RLC **1115**, SN RLC **1116**), and one of a master or secondary MAC layer (e.g., MN MAC **1118**, SN MAC **1119**); and/or packets of an SCG bearer via an SDAP layer (e.g., SDAP **1110**), a PDCP layer (e.g., NR PDCP **1113**), an RLC layer (e.g., SN RLC **1117**), and a MAC layer (e.g., MN MAC **1118**).

A master base station (e.g., MN **1130**) and/or a secondary base station (e.g., SN **1150**) may send (e.g., transmit) and/or receive: packets of an MCG bearer via a master or secondary node SDAP layer (e.g., SDAP **1120**, SDAP **1140**), a master or secondary node PDCP layer (e.g., NR PDCP **1121**, NR PDCP **1142**), a master node RLC layer (e.g., MN RLC **1124**, MN RLC **1125**), and a master node MAC layer (e.g., MN MAC **1128**); packets of an SCG bearer via a master or secondary node SDAP layer (e.g., SDAP **1120**, SDAP **1140**), a master or secondary node PDCP layer (e.g., NR PDCP **1122**, NR PDCP **1143**), a secondary node RLC layer (e.g., SN RLC **1146**, SN RLC **1147**), and a secondary node MAC layer (e.g., SN MAC **1148**); packets of a split bearer via a master or secondary node SDAP layer (e.g., SDAP **1120**, SDAP **1140**), a master or secondary node PDCP layer (e.g., NR PDCP **1123**, NR PDCP **1141**), a master or secondary node RLC layer (e.g., MN RLC **1126**, SN RLC **1144**, SN RLC **1145**, MN RLC **1127**), and a master or secondary node MAC layer (e.g., MN MAC **1128**, SN MAC **1148**).

In multi connectivity, a wireless device may configure multiple MAC entities, such as one MAC entity (e.g., MN MAC **1118**) for a master base station, and other MAC entities (e.g., SN MAC **1119**) for a secondary base station. In multi-connectivity, a configured set of serving cells for a wireless device may comprise two subsets: an MCG comprising serving cells of a master base station, and SCGs comprising serving cells of a secondary base station. For an SCG, one or more of following configurations may be used. At least one cell of an SCG may have a configured UL CC and at least one cell of a SCG, named as primary secondary cell (e.g., PSCell, PCell of SCG, PCell), and may be configured with PUCCH resources. If an SCG is configured, there may be at least one SCG bearer or one split bearer. After or upon detection of a physical layer problem or a random access problem on a PSCell, or a number of NR RLC retransmissions has been reached associated with the SCG, or after or upon detection of an access problem on a PSCell associated with (e.g., during) a SCG addition or an SCG change: an RRC connection re-establishment procedure may not be triggered, UL transmissions towards cells of an SCG may be stopped, a master base station may be informed by a wireless device of a SCG failure type, a DL data transfer over a master base station may be maintained (e.g., for a split bearer). An NR RLC acknowledged mode (AM) bearer may be configured for a split bearer. A PCell and/or a PSCell may not be de-activated. A PSCell may be changed with a SCG change procedure (e.g., with security key change and a RACH procedure). A bearer type change between a split bearer and a SCG bearer, and/or simultaneous configuration of a SCG and a split bearer, may or may not be supported.

With respect to interactions between a master base station and a secondary base stations for multi-connectivity, one or more of the following may be used. A master base station and/or a secondary base station may maintain Radio Resource Management (RRM) measurement configurations of a wireless device. A master base station may determine (e.g., based on received measurement reports, traffic conditions, and/or bearer types) to request a secondary base station to provide additional resources (e.g., serving cells) for a wireless device. After or upon receiving a request from a master base station, a secondary base station may create and/or modify a container that may result in a configuration of additional serving cells for a wireless device (or decide that the secondary base station has no resource available to do so). For a wireless device capability coordination, a master base station may provide (e.g., all or a part of) an AS configuration and wireless device capabilities to a secondary base station. A master base station and a secondary base station may exchange information about a wireless device configuration such as by using RRC containers (e.g., inter-node messages) carried via Xn messages. A secondary base station may initiate a reconfiguration of the secondary base station existing serving cells (e.g., PUCCH towards the secondary base station). A secondary base station may decide which cell is a PSCell within a SCG. A master base station may or may not change content of RRC configurations provided by a secondary base station. A master base station may provide recent (and/or the latest) measurement results for SCG cell(s), for example, if an SCG addition and/or an SCG SCell addition occurs. A master base station and secondary base stations may receive information of SFN and/or subframe offset of each other from an OAM and/or via an Xn interface (e.g., for a purpose of DRX alignment and/or identification of a measurement gap). Dedicated RRC signaling may be used for sending required system information of a cell as for CA, for example, if adding a new SCG SCell, except for an SFN acquired from an MIB of a PSCell of a SCG.

FIG. **12** shows an example of a random access procedure. One or more events may trigger a random access procedure. For example, one or more events may be at least one of following: initial access from RRC_IDLE, RRC connection re-establishment procedure, handover, DL or UL data arrival in (e.g., during) a state of RRC_CONNECTED (e.g., if UL synchronization status is non-synchronized), transition from RRC_Inactive, and/or request for other system information. A PDCCH order, a MAC entity, and/or a beam failure indication may initiate a random access procedure.

A random access procedure may comprise or be one of at least a contention based random access procedure and/or a contention free random access procedure. A contention based random access procedure may comprise one or more Msg 1 **1220** transmissions, one or more Msg2 **1230** transmissions, one or more Msg3 **1240** transmissions, and contention resolution **1250**. A contention free random access procedure may comprise one or more Msg 1 **1220** transmissions and one or more Msg2 **1230** transmissions. One or more of Msg 1 **1220**, Msg 2 **1230**, Msg 3 **1240**, and/or contention resolution **1250** may be transmitted in the same step. A two-step random access procedure, for example, may comprise a first transmission (e.g., Msg A) and a second transmission (e.g., Msg B). The first transmission (e.g., Msg A) may comprise transmitting, by a wireless device (e.g., wireless device **110**) to a base station (e.g., base station **120**), one or more messages indicating an equivalent and/or similar contents of Msg 1 **1220** and Msg3 **1240** of a four-step random access procedure. The second transmission (e.g., Msg B) may comprise transmitting, by the base station (e.g., base station **120**) to a wireless device (e.g., wireless device **110**) after or in response to the first message, one or more messages indicating an equivalent and/or similar content of Msg2 **1230** and contention resolution **1250** of a four-step random access procedure.

A base station may send (e.g., transmit, unicast, multicast, broadcast, etc.), to a wireless device, a RACH configuration **1210** via one or more beams. The RACH configuration **1210** may comprise one or more parameters indicating at least one of following: an available set of PRACH resources for a transmission of a random access preamble, initial preamble power (e.g., random access preamble initial received target power), an RSRP threshold for a selection of a SS block and corresponding PRACH resource, a power-ramping factor (e.g., random access preamble power ramping step), a random access preamble index, a maximum number of preamble transmissions, preamble group A and group B, a threshold (e.g., message size) to determine the groups of random access preambles, a set of one or more random access preambles for a system information request and corresponding PRACH resource(s) (e.g., if any), a set of one or more random access preambles for a beam failure recovery procedure and corresponding PRACH resource(s) (e.g., if any), a time window to monitor RA response(s), a time window to monitor response(s) on a beam failure recovery procedure, and/or a contention resolution timer.

The Msg1 **1220** may comprise one or more transmissions of a random access preamble. For a contention based random access procedure, a wireless device may select an SS block with an RSRP above the RSRP threshold. If random access preambles group B exists, a wireless device may select one or more random access preambles from a group A or a group B, for example, depending on a potential Msg3 **1240** size. If a random access preambles group B does not exist, a wireless device may select the one or more random access preambles from a group A. A wireless device may select a random access preamble index randomly (e.g., with equal probability or a normal distribution) from one or more random access preambles associated with a selected group. If a base station semi-statically configures a wireless device with an association between random access preambles and SS blocks, the wireless device may select a random access preamble index randomly with equal probability from one or more random access preambles associated with a selected SS block and a selected group.

A wireless device may initiate a contention free random access procedure, for example, based on a beam failure indication from a lower layer. A base station may semi-statically configure a wireless device with one or more contention free PRACH resources for a beam failure recovery procedure associated with at least one of SS blocks and/or CSI-RSs. A wireless device may select a random access preamble index corresponding to a selected SS block or a CSI-RS from a set of one or more random access preambles for a beam failure recovery procedure, for example, if at least one of the SS blocks with an RSRP above a first RSRP threshold amongst associated SS blocks is available, and/or if at least one of CSI-RSs with a RSRP above a second RSRP threshold amongst associated CSI-RSs is available.

A wireless device may receive, from a base station, a random access preamble index via PDCCH or RRC for a contention free random access procedure. The wireless device may select a random access preamble index, for example, if a base station does not configure a wireless device with at least one contention free PRACH resource associated with SS blocks or CSI-RS. The wireless device may select the at least one SS block and/or select a random access preamble corresponding to the at least one SS block, for example, if a base station configures the wireless device with one or more contention free PRACH resources associated with SS blocks and/or if at least one SS block with a RSRP above a first RSRP threshold amongst associated SS blocks is available. The wireless device may select the at least one CSI-RS and/or select a random access preamble corresponding to the at least one CSI-RS, for example, if a base station configures a wireless device with one or more contention free PRACH resources associated with CSI-RSs and/or if at least one CSI-RS with a RSRP above a second RSPR threshold amongst the associated CSI-RSs is available.

A wireless device may perform one or more Msg1 **1220** transmissions, for example, by sending (e.g., transmitting) the selected random access preamble. The wireless device may determine a PRACH occasion from one or more PRACH occasions corresponding to a selected SS block, for example, if the wireless device selects an SS block and is configured with an association between one or more PRACH occasions and/or one or more SS blocks. The wireless device may determine a PRACH occasion from one or more PRACH occasions corresponding to a selected CSI-RS, for example, if the wireless device selects a CSI-RS and is configured with an association between one or more PRACH occasions and one or more CSI-RSs. The wireless device may send (e.g., transmit), to a base station, a selected random access preamble via a selected PRACH occasions. The wireless device may determine a transmit power for a transmission of a selected random access preamble at least based on an initial preamble power and a power-ramping factor. The wireless device may determine an RA-RNTI associated with a selected PRACH occasion in which a selected random access preamble is sent (e.g., transmitted). The wireless device may not determine an RA-RNTI for a beam failure recovery procedure. The wireless device may determine an RA-RNTI at least based on an index of a first OFDM symbol, an index of a first slot of a selected PRACH occasions, and/or an uplink carrier index for a transmission of Msg1 **1220**.

A wireless device may receive, from a base station, a random access response, Msg 2 **1230**. The wireless device may start a time window (e.g., ra-ResponseWindow) to monitor a random access response. For a beam failure recovery procedure, the base station may configure the wireless device with a different time window (e.g., bfr-ResponseWindow) to monitor response to on a beam failure recovery request. The wireless device may start a time window (e.g., ra-ResponseWindow or bfr-ResponseWindow) at a start of a first PDCCH occasion, for example, after a fixed duration of one or more symbols from an end of a preamble transmission. If the wireless device sends (e.g., transmits) multiple preambles, the wireless device may start a time window at a start of a first PDCCH occasion after a fixed duration of one or more symbols from an end of a first preamble transmission. The wireless device may monitor a PDCCH of a cell for at least one random access response identified by a RA-RNTI, or for at least one response to a beam failure recovery request identified by a C-RNTI, at a time that a timer for a time window is running.

A wireless device may determine that a reception of random access response is successful, for example, if at least one random access response comprises a random access preamble identifier corresponding to a random access preamble sent (e.g., transmitted) by the wireless device. The wireless device may determine that the contention free random access procedure is successfully completed, for example, if a reception of a random access response is successful. The wireless device may determine that a contention free random access procedure is successfully complete, for example, if a contention free random access procedure is triggered for a beam failure recovery request and if a PDCCH transmission is addressed to a C-RNTI. The wireless device may determine that the random access procedure is successfully completed, and may indicate a reception of an acknowledgement for a system information request to upper layers, for example, if at least one random access response comprises a random access preamble identifier. The wireless device may stop sending (e.g., transmitting) remaining preambles (if any) after or in response to a successful reception of a corresponding random access response, for example, if the wireless device has signaled multiple preamble transmissions.

The wireless device may perform one or more Msg 3 **1240** transmissions, for example, after or in response to a successful reception of random access response (e.g., for a contention based random access procedure). The wireless device may adjust an uplink transmission timing, for example, based on a timing advanced command indicated by a random access response. The wireless device may send (e.g., transmit) one or more transport blocks, for example, based on an uplink grant indicated by a random access response. Subcarrier spacing for PUSCH transmission for Msg3 **1240** may be provided by at least one higher layer (e.g., RRC) parameter. The wireless device may send (e.g., transmit) a random access preamble via a PRACH, and Msg3 **1240** via PUSCH, on the same cell. A base station may indicate an UL BWP for a PUSCH transmission of Msg3 **1240** via system information block. The wireless device may use HARQ for a retransmission of Msg 3 **1240**.

Multiple wireless devices may perform Msg 1 **1220**, for example, by sending (e.g., transmitting) the same preamble to a base station. The multiple wireless devices may receive, from the base station, the same random access response comprising an identity (e.g., TC-RNTI). Contention resolution (e.g., comprising the wireless device **110** receiving contention resolution **1250**) may be used to increase the likelihood that a wireless device does not incorrectly use an identity of another wireless device. The contention resolution **1250** may be based on, for example, a C-RNTI on a PDCCH, and/or a wireless device contention resolution identity on a DL-SCH. If a base station assigns a C-RNTI to a wireless device, the wireless device may perform contention resolution (e.g., comprising receiving contention resolution **1250**), for example, based on a reception of a PDCCH transmission that is addressed to the C-RNTI. The wireless device may determine that contention resolution is successful, and/or that a random access procedure is successfully completed, for example, after or in response to detecting a C-RNTI on a PDCCH. If a wireless device has no valid C-RNTI, a contention resolution may be addressed by using a TC-RNTI. If a MAC PDU is successfully decoded and a MAC PDU comprises a wireless device contention resolution identity MAC CE that matches or otherwise corresponds with the CCCH SDU sent (e.g., transmitted) in Msg3 **1240**, the wireless device may determine that the contention resolution (e.g., comprising contention resolution **1250**) is successful and/or the wireless device may determine that the random access procedure is successfully completed.

FIG. **13** shows an example structure for MAC entities. A wireless device may be configured to operate in a multi-connectivity mode. A wireless device in RRC_CONNECTED with multiple Rx/Tx may be configured to utilize radio resources provided by multiple schedulers that may be located in a plurality of base stations. The plurality of base stations may be connected via a non-ideal or ideal backhaul over the Xn interface. A base station in a plurality of base stations may act as a master base station or as a secondary base station. A wireless device may be connected to and/or in communication with, for example, one master base station and one or more secondary base stations. A wireless device may be configured with multiple MAC entities, for example, one MAC entity for a master base station, and one or more other MAC entities for secondary base station(s). A configured set of serving cells for a wireless device may comprise two subsets: an MCG comprising serving cells of a master base station, and one or more SCGs comprising serving cells of a secondary base station(s). FIG. **13** shows an example structure for MAC entities in which a MCG and a SCG are configured for a wireless device.

At least one cell in a SCG may have a configured UL CC. A cell of the at least one cell may comprise a PSCell or a PCell of a SCG, or a PCell. A PSCell may be configured with PUCCH resources. There may be at least one SCG bearer, or one split bearer, for a SCG that is configured. After or upon detection of a physical layer problem or a random access problem on a PSCell, after or upon reaching a number of RLC retransmissions associated with the SCG, and/or after or upon detection of an access problem on a PSCell associated with (e.g., during) a SCG addition or a SCG change: an RRC connection re-establishment procedure may not be triggered, UL transmissions towards cells of a SCG may be stopped, and/or a master base station may be informed by a wireless device of a SCG failure type and DL data transfer over a master base station may be maintained.

A MAC sublayer may provide services such as data transfer and radio resource allocation to upper layers (e.g., 1310 or 1320). A MAC sublayer may comprise a plurality of MAC entities (e.g., 1350 and 1360). A MAC sublayer may provide data transfer services on logical channels. To accommodate different kinds of data transfer services, multiple types of logical channels may be defined. A logical channel may support transfer of a particular type of information. A logical channel type may be defined by what type of information (e.g., control or data) is transferred. BCCH, PCCH, CCCH and/or DCCH may be control channels, and DTCH may be a traffic channel. A first MAC entity (e.g., 1310) may provide services on PCCH, BCCH, CCCH, DCCH, DTCH, and/or MAC control elements. A second MAC entity (e.g., 1320) may provide services on BCCH, DCCH, DTCH, and/or MAC control elements.

A MAC sublayer may expect from a physical layer (e.g., 1330 or 1340) services such as data transfer services, signaling of HARQ feedback, and/or signaling of scheduling request or measurements (e.g., CQI). In dual connectivity, two MAC entities may be configured for a wireless device: one for a MCG and one for a SCG. A MAC entity of a wireless device may handle a plurality of transport channels. A first MAC entity may handle first transport channels comprising a PCCH of a MCG, a first BCH of the MCG, one or more first DL-SCHs of the MCG, one or more first UL-SCHs of the MCG, and/or one or more first RACHs of the MCG. A second MAC entity may handle second transport channels comprising a second BCH of a SCG, one or more second DL-SCHs of the SCG, one or more second UL-SCHs of the SCG, and/or one or more second RACHs of the SCG.

If a MAC entity is configured with one or more SCells, there may be multiple DL-SCHs, multiple UL-SCHs, and/or multiple RACHs per MAC entity. There may be one DL-SCH and/or one UL-SCH on an SpCell. There may be one DL-SCH, zero or one UL-SCH, and/or zero or one RACH for an SCell. A DL-SCH may support receptions using different numerologies and/or TTI duration within a MAC entity. A UL-SCH may support transmissions using different numerologies and/or TTI duration within the MAC entity.

A MAC sublayer may support different functions. The MAC sublayer may control these functions with a control (e.g., Control 1355 and/or Control 1365) element. Functions performed by a MAC entity may comprise one or more of: mapping between logical channels and transport channels (e.g., in uplink or downlink), multiplexing (e.g., (De-) Multiplexing 1352 and/or (De-) Multiplexing 1362) of MAC SDUs from one or different logical channels onto transport blocks (TBs) to be delivered to the physical layer on transport channels (e.g., in uplink), demultiplexing (e.g., (De-) Multiplexing 1352 and/or (De-) Multiplexing 1362) of MAC SDUs to one or different logical channels from transport blocks (TBs) delivered from the physical layer on transport channels (e.g., in downlink), scheduling information reporting (e.g., in uplink), error correction through HARQ in uplink and/or downlink (e.g., 1363), and logical channel prioritization in uplink (e.g., Logical Channel Prioritization 1351 and/or Logical Channel Prioritization 1361). A MAC entity may handle a random access process (e.g., Random Access Control 1354 and/or Random Access Control 1364).

FIG. 14 shows an example of a RAN architecture comprising one or more base stations. A protocol stack (e.g., RRC, SDAP, PDCP, RLC, MAC, and/or PHY) may be supported at a node. A base station (e.g., gNB 120A and/or 120B) may comprise a base station central unit (CU) (e.g., gNB-CU 1420A or 1420B) and at least one base station distributed unit (DU) (e.g., gNB-DU 1430A, 1430B, 1430C, and/or 1430D), for example, if a functional split is configured. Upper protocol layers of a base station may be located in a base station CU, and lower layers of the base station may be located in the base station DUs. An F1 interface (e.g., CU-DU interface) connecting a base station CU and base station DUs may be an ideal or non-ideal backhaul. F1-C may provide a control plane connection over an F1 interface, and F1-U may provide a user plane connection over the F1 interface. An Xn interface may be configured between base station CUs.

A base station CU may comprise an RRC function, an SDAP layer, and/or a PDCP layer. Base station DUs may comprise an RLC layer, a MAC layer, and/or a PHY layer. Various functional split options between a base station CU and base station DUs may be possible, for example, by locating different combinations of upper protocol layers (e.g., RAN functions) in a base station CU and different combinations of lower protocol layers (e.g., RAN functions) in base station DUs. A functional split may support flexibility to move protocol layers between a base station CU and base station DUs, for example, depending on service requirements and/or network environments.

Functional split options may be configured per base station, per base station CU, per base station DU, per wireless device, per bearer, per slice, and/or with other granularities. In a per base station CU split, a base station CU may have a fixed split option, and base station DUs may be configured to match a split option of a base station CU. In a per base station DU split, a base station DU may be configured with a different split option, and a base station CU may provide different split options for different base station DUs. In a per wireless device split, a base station (e.g., a base station CU and at least one base station DUs) may provide different split options for different wireless devices. In a per bearer split, different split options may be utilized for different bearers. In a per slice splice, different split options may be used for different slices.

FIG. 15 shows example RRC state transitions of a wireless device. A wireless device may be in at least one RRC state among an RRC connected state (e.g., RRC Connected 1530, RRC_Connected, etc.), an RRC idle state (e.g., RRC Idle 1510, RRC_Idle, etc.), and/or an RRC inactive state (e.g., RRC Inactive 1520, RRC_Inactive, etc.). In an RRC connected state, a wireless device may have at least one RRC connection with at least one base station (e.g., gNB and/or eNB), which may have a context of the wireless device (e.g., UE context). A wireless device context (e.g., UE context) may comprise at least one of an access stratum context, one or more radio link configuration parameters, bearer (e.g., data radio bearer (DRB), signaling radio bearer (SRB), logical channel, QoS flow, PDU session, and/or the like) configuration information, security information, PHY/MAC/RLC/PDCP/SDAP layer configuration information, and/or the like configuration information for a wireless device. In an RRC idle state, a wireless device may not have an RRC connection with a base station, and a context of the wireless device may not be stored in a base station. In an RRC inactive state, a wireless device may not have an RRC connection with a base station. A context of a wireless device may be stored in a base station, which may comprise an anchor base station (e.g., a last serving base station).

A wireless device may transition an RRC state (e.g., UE RRC state) between an RRC idle state and an RRC connected state in both ways (e.g., connection release 1540 or connection establishment 1550; and/or connection reestablishment) and/or between an RRC inactive state and an RRC connected state in both ways (e.g., connection inactivation

1570 or connection resume 1580). A wireless device may transition its RRC state from an RRC inactive state to an RRC idle state (e.g., connection release 1560).

An anchor base station may be a base station that may keep a context of a wireless device (e.g., UE context) at least at (e.g., during) a time period that the wireless device stays in a RAN notification area (RNA) of an anchor base station, and/or at (e.g., during) a time period that the wireless device stays in an RRC inactive state. An anchor base station may comprise a base station that a wireless device in an RRC inactive state was most recently connected to in a latest RRC connected state, and/or a base station in which a wireless device most recently performed an RNA update procedure. An RNA may comprise one or more cells operated by one or more base stations. A base station may belong to one or more RNAs. A cell may belong to one or more RNAs.

A wireless device may transition, in a base station, an RRC state (e.g., UE RRC state) from an RRC connected state to an RRC inactive state. The wireless device may receive RNA information from the base station. RNA information may comprise at least one of an RNA identifier, one or more cell identifiers of one or more cells of an RNA, a base station identifier, an IP address of the base station, an AS context identifier of the wireless device, a resume identifier, and/or the like.

An anchor base station may broadcast a message (e.g., RAN paging message) to base stations of an RNA to reach to a wireless device in an RRC inactive state. The base stations receiving the message from the anchor base station may broadcast and/or multicast another message (e.g., paging message) to wireless devices in their coverage area, cell coverage area, and/or beam coverage area associated with the RNA via an air interface.

A wireless device may perform an RNA update (RNAU) procedure, for example, if the wireless device is in an RRC inactive state and moves into a new RNA. The RNAU procedure may comprise a random access procedure by the wireless device and/or a context retrieve procedure (e.g., UE context retrieve). A context retrieve procedure may comprise: receiving, by a base station from a wireless device, a random access preamble; and requesting and/or receiving (e.g., fetching), by a base station, a context of the wireless device (e.g., UE context) from an old anchor base station. The requesting and/or receiving (e.g., fetching) may comprise: sending a retrieve context request message (e.g., UE context request message) comprising a resume identifier to the old anchor base station and receiving a retrieve context response message comprising the context of the wireless device from the old anchor base station.

A wireless device in an RRC inactive state may select a cell to camp on based on at least a measurement result for one or more cells, a cell in which a wireless device may monitor an RNA paging message, and/or a core network paging message from a base station. A wireless device in an RRC inactive state may select a cell to perform a random access procedure to resume an RRC connection and/or to send (e.g., transmit) one or more packets to a base station (e.g., to a network). The wireless device may initiate a random access procedure to perform an RNA update procedure, for example, if a cell selected belongs to a different RNA from an RNA for the wireless device in an RRC inactive state. The wireless device may initiate a random access procedure to send (e.g., transmit) one or more packets to a base station of a cell that the wireless device selects, for example, if the wireless device is in an RRC inactive state and has one or more packets (e.g., in a buffer) to send (e.g., transmit) to a network. A random access procedure may be performed with two messages (e.g., 2-stage or 2-step random access) and/or four messages (e.g., 4-stage or 4-step random access) between the wireless device and the base station.

A base station receiving one or more uplink packets from a wireless device in an RRC inactive state may request and/or receive (e.g., fetch) a context of a wireless device (e.g., UE context), for example, by sending (e.g., transmitting) a retrieve context request message for the wireless device to an anchor base station of the wireless device based on at least one of an AS context identifier, an RNA identifier, a base station identifier, a resume identifier, and/or a cell identifier received from the wireless device. A base station may send (e.g., transmit) a path switch request for a wireless device to a core network entity (e.g., AMF, MME, and/or the like), for example, after or in response to requesting and/or receiving (e.g., fetching) a context. A core network entity may update a downlink tunnel endpoint identifier for one or more bearers established for the wireless device between a user plane core network entity (e.g., UPF, S-GW, and/or the like) and a RAN node (e.g., the base station), such as by changing a downlink tunnel endpoint identifier from an address of the anchor base station to an address of the base station).

A base station may communicate with a wireless device via a wireless network using one or more technologies, such as new radio technologies (e.g., NR, 5G, etc.). The one or more radio technologies may comprise at least one of: multiple technologies related to physical layer; multiple technologies related to medium access control layer; and/or multiple technologies related to radio resource control layer. Enhancing the one or more radio technologies may improve performance of a wireless network. System throughput, and/or data rate of transmission, may be increased. Battery consumption of a wireless device may be reduced. Latency of data transmission between a base station and a wireless device may be improved. Network coverage of a wireless network may be improved. Transmission efficiency of a wireless network may be improved.

A base station may send (e.g., transmit) one or more MAC PDUs to a wireless device. A MAC PDU may comprise a bit string that may be byte aligned (e.g., multiple of eight bits) in length. Bit strings may be represented by tables in which the most significant bit is the leftmost bit of the first line of the table, and the least significant bit is the rightmost bit on the last line of the table. The bit string may be read from the left to right, and then, in the reading order of the lines. The bit order of a parameter field within a MAC PDU may be represented with the first and most significant bit in the leftmost bit, and with the last and least significant bit in the rightmost bit.

A MAC SDU may comprise a bit string that is byte aligned (e.g., multiple of eight bits) in length. A MAC SDU may be included in a MAC PDU, for example, from the first bit onward. A MAC CE may be a bit string that is byte aligned (e.g., multiple of eight bits) in length. A MAC subheader may be a bit string that is byte aligned (e.g., multiple of eight bits) in length. A MAC subheader may be placed immediately in front of the corresponding MAC SDU, MAC CE, and/or padding. A MAC entity may ignore a value of reserved bits in a DL MAC PDU.

A MAC PDU may comprise one or more MAC subPDUs. A MAC subPDU of the one or more MAC subPDUs may comprise at least one of: a MAC subheader only (e.g., including padding); a MAC subheader and a MAC SDU; a MAC subheader and a MAC CE; and/or a MAC subheader and padding. The MAC SDU may be of variable size. A MAC subheader may correspond to a MAC SDU, a MAC CE, and/or padding.

A MAC subheader may comprise: an R field comprising one bit; an F field with one bit in length; an LCID field with multiple bits in length; and/or an L field with multiple bits in length. The MAC subheader may correspond to a MAC SDU, a variable-sized MAC CE, and/or padding.

FIG. **16**A shows an example of a MAC subheader comprising an eight-bit L field. The LCID field may have six bits in length (or any other quantity of bits). The L field may have eight bits in length (or any other quantity of bits).

FIG. **16**B shows an example of a MAC subheader with a sixteen-bit L field. The LCID field may have six bits in length (or any other quantity of bits). The L field may have sixteen bits in length (or any other quantity of bits). A MAC subheader may comprise: a R field comprising two bits in length (or any other quantity of bits); and an LCID field comprising multiple bits in length (e.g., if the MAC subheader corresponds to a fixed sized MAC CE), and/or padding.

FIG. **16**C shows an example of the MAC subheader. The LCID field may comprise six bits in length (or any other quantity of bits). The R field may comprise two bits in length (or any other quantity of bits).

FIG. **17**A shows an example of a DL MAC PDU. Multiple MAC CEs may be placed together. A MAC subPDU comprising MAC CE may be placed before any MAC subPDU comprising a MAC SDU, and/or before a MAC subPDU comprising padding.

FIG. **17**B shows an example of a UL MAC PDU. Multiple MAC CEs may be placed together. A MAC subPDU comprising a MAC CE may be placed after all MAC subPDU comprising a MAC SDU. The MAC subPDU may be placed before a MAC subPDU comprising padding.

FIG. **18** shows first examples of LCIDs. FIG. **19** shows second examples of LCIDs. In each of FIG. **18** and FIG. **19**, the left columns comprise indices, and the right columns comprises corresponding LCID values for each index.

FIG. **18** shows an example of an LCID that may be associated with the one or more MAC CEs. A MAC entity of a base station may send (e.g., transmit) to a MAC entity of a wireless device one or more MAC CEs. The one or more MAC CEs may comprise at least one of: an SP ZP CSI-RS Resource Set Activation/Deactivation MAC CE; a PUCCH spatial relation Activation/Deactivation MAC CE; a SP SRS Activation/Deactivation MAC CE; a SP CSI reporting on PUCCH Activation/Deactivation MAC CE; a TCI State Indication for UE-specific PDCCH MAC CE; a TCI State Indication for UE-specific PDSCH MAC CE; an Aperiodic CSI Trigger State Subselection MAC CE; a SP CSI-RS/CSI-IM Resource Set Activation/Deactivation MAC CE; a wireless device (e.g., UE) contention resolution identity MAC CE; a timing advance command MAC CE; a DRX command MAC CE; a long DRX command MAC CE; an SCell activation and/or deactivation MAC CE (e.g., 1 Octet); an SCell activation and/or deactivation MAC CE (e.g., 4 Octet); and/or a duplication activation and/or deactivation MAC CE. A MAC CE may comprise an LCID in the corresponding MAC subheader. Different MAC CEs may have different LCID in the corresponding MAC subheader. An LCID with 111011 in a MAC subheader may indicate that a MAC CE associated with the MAC subheader is a long DRX command MAC CE.

FIG. **19** shows further examples of LCIDs associated with one or more MAC CEs. The MAC entity of the wireless device may send (e.g., transmit), to the MAC entity of the base station, one or more MAC CEs. The one or more MAC CEs may comprise at least one of: a short buffer status report (BSR) MAC CE; a long BSR MAC CE; a C-RNTI MAC CE; a configured grant confirmation MAC CE; a single entry power headroom report (PHR) MAC CE; a multiple entry PHR MAC CE; a short truncated BSR; and/or a long truncated BSR. A MAC CE may comprise an LCID in the corresponding MAC subheader. Different MAC CEs may have different LCIDs in the corresponding MAC subheader. The LCID with 111011 in a MAC subheader may indicate that a MAC CE associated with the MAC subheader is a short-truncated command MAC CE.

Two or more component carriers (CCs) may be aggregated, for example, in a carrier aggregation (CA). A wireless device may simultaneously receive and/or transmit on one or more CCs, for example, depending on capabilities of the wireless device. The CA may be supported for contiguous CCs. The CA may be supported for non-contiguous CCs.

A wireless device may have one RRC connection with a network, for example, if configured with CA. At (e.g., during) an RRC connection establishment, re-establishment and/or handover, a cell providing a NAS mobility information may be a serving cell. At (e.g., during) an RRC connection re-establishment and/or handover procedure, a cell providing a security input may be a serving cell. The serving cell may be referred to as a primary cell (PCell). A base station may send (e.g., transmit), to a wireless device, one or more messages comprising configuration parameters of a plurality of one or more secondary cells (SCells), for example, depending on capabilities of the wireless device.

A base station and/or a wireless device may use an activation and/or deactivation mechanism of an SCell for an efficient battery consumption, for example, if the base station and/or the wireless device is configured with CA. A base station may activate or deactivate at least one of the one or more SCells, for example, if the wireless device is configured with one or more SCells. The SCell may be deactivated, for example, after or upon configuration of an SCell.

A wireless device may activate and/or deactivate an SCell, for example, after or in response to receiving an SCell activation and/or deactivation MAC CE. A base station may send (e.g., transmit), to a wireless device, one or more messages comprising an sCellDeactivationTimer timer. The wireless device may deactivate an SCell, for example, after or in response to an expiry of the sCellDeactivationTimer timer.

A wireless device may activate an SCell, for example, if the wireless device receives an SCell activation/deactivation MAC CE activating an SCell. The wireless device may perform operations (e.g., after or in response to the activating the SCell) that may comprise: SRS transmissions on the SCell; CQI, PMI, RI, and/or CRI reporting for the SCell on a PCell; PDCCH monitoring on the SCell; PDCCH monitoring for the SCell on the PCell; and/or PUCCH transmissions on the SCell.

The wireless device may start and/or restart a timer (e.g., an sCellDeactivationTimer timer) associated with the SCell, for example, after or in response to activating the SCell. The wireless device may start the timer (e.g., sCellDeactivationTimer timer) in the slot, for example, if the SCell activation/deactivation MAC CE has been received. The wireless device may initialize and/or re-initialize one or more suspended configured uplink grants of a configured grant Type 1 associated with the SCell according to a stored configuration, for example, after or in response to activating the

SCell. The wireless device may trigger a PHR, for example, after or in response to activating the SCell.

The wireless device may deactivate the activated SCell, for example, if the wireless device receives an SCell activation/deactivation MAC CE deactivating an activated SCell. The wireless device may deactivate the activated SCell, for example, if a timer (e.g., an sCellDeactivationTimer timer) associated with an activated SCell expires. The wireless device may stop the timer (e.g., sCellDeactivationTimer timer) associated with the activated SCell, for example, after or in response to deactivating the activated SCell. The wireless device may clear one or more configured downlink assignments and/or one or more configured uplink grant Type 2 associated with the activated SCell, for example, after or in response to the deactivating the activated SCell. The wireless device may suspend one or more configured uplink grant Type 1 associated with the activated SCell, and/or flush HARQ buffers associated with the activated SCell, for example, after or in response to deactivating the activated SCell.

A wireless device may refrain from performing certain operations, for example, if an SCell is deactivated. The wireless device may refrain from performing one or more of the following operations if an SCell is deactivated: transmitting SRS on the SCell; reporting CQI, PMI, RI, and/or CRI for the SCell on a PCell; transmitting on UL-SCH on the SCell; transmitting on a RACH on the SCell; monitoring at least one first PDCCH on the SCell; monitoring at least one second PDCCH for the SCell on the PCell; and/or transmitting a PUCCH on the SCell.

A wireless device may restart a timer (e.g., an sCellDeactivationTimer timer) associated with the activated SCell, for example, if at least one first PDCCH on an activated SCell indicates an uplink grant or a downlink assignment. A wireless device may restart a timer (e.g., an sCellDeactivationTimer timer) associated with the activated SCell, for example, if at least one second PDCCH on a serving cell (e.g. a PCell or an SCell configured with PUCCH, such as a PUCCH SCell) scheduling the activated SCell indicates an uplink grant and/or a downlink assignment for the activated SCell. A wireless device may abort the ongoing random access procedure on the SCell, for example, if an SCell is deactivated and/or if there is an ongoing random access procedure on the SCell.

FIG. **20**A shows an example of an SCell activation/deactivation MAC CE that may comprise one octet. A first MAC PDU subheader comprising a first LCID (e.g., LCID 111010) may indicate/identify the SCell activation/deactivation MAC CE of one octet. An SCell activation/deactivation MAC CE of one octet may have a fixed size. The SCell activation/deactivation MAC CE of one octet may comprise a single octet. The single octet may comprise a first number of C-fields (e.g., seven) and a second number of R-fields (e.g., one).

FIG. **20**B shows an example of an SCell Activation/Deactivation MAC CE of four octets. A second MAC PDU subheader with a second LCID (e.g., LCID 111001) may indicate/identify the SCell Activation/Deactivation MAC CE of four octets. An SCell activation/deactivation MAC CE of four octets may have a fixed size. The SCell activation/deactivation MAC CE of four octets may comprise four octets. The four octets may comprise a third number of C-fields (e.g., 31) and a fourth number of R-fields (e.g., 1). A C_i field may indicate an activation/deactivation status of an SCell with an SCell index i, for example, if an SCell with SCell index i is configured. An SCell with an SCell index i may be activated, for example, if the C_i field is set to one. An SCell with an SCell index i may be deactivated, for example, if the C_i field is set to zero. The wireless device may ignore the C_i field, for example, if there is no SCell configured with SCell index i. An R field may indicate a reserved bit. The R field may be set to zero.

A base station and/or a wireless device may use a power saving mechanism (e.g., hibernation mechanism) for an SCell, for example, if CA is configured. A power saving mechanism may improve battery performance (e.g., run-times), reduce power consumption of the wireless device, and/or to improve latency of SCell activation and/or SCell addition. The SCell may be transitioned (e.g., switched and/or adjusted) to a dormant state if the wireless device initiates a power saving state for (e.g., hibernates) the SCell. The wireless device may, for example, if the SCell is transitioned to a dormant state: stop transmitting SRS on the SCell, report CQI/PMI/RI/PTI/CRI for the SCell according to or based on a periodicity configured for the SCell in a dormant state, not transmit on an UL-SCH on the SCell, not transmit on a RACH on the SCell, not monitor the PDCCH on the SCell, not monitor the PDCCH for the SCell, and/or not transmit PUCCH on the SCell. Not transmitting, not monitoring, not receiving, and/or not performing an action may comprise, for example, refraining from transmitting, refraining from monitoring, refraining from receiving, and/or refraining from performing an action, respectively. Reporting CSI for an SCell, that has been transitioned to a dormant state, and not monitoring the PDCCH on/for the SCell, may provide the base station an "always-updated" CSI for the SCell. The base station may use a quick and/or accurate channel adaptive scheduling on the SCell, based on the always-updated CSI, if the SCell is transitioned back to active state. Using the always-updated CSI may speed up an activation procedure of the SCell. Reporting CSI for the SCell and not monitoring the PDCCH on and/or for the SCell (e.g., that may have been transitioned to a dormant state), may provide advantages such as increased battery efficiency, reduced power consumption of the wireless device, and/or increased timeliness and/or accuracy of channel feedback information feedback. A PCell/PSCell and/or a PUCCH SCell, for example, may not be configured or transitioned to a dormant state.

A base station may activate, hibernate, or deactivate at least one of one or more configured SCells. A base station may send (e.g., transmit) to a wireless device, for example, one or more messages comprising parameters indicating at least one SCell being set to an active state, a dormant state, or an inactive state.

A base station may transmit, for example, one or more RRC messages comprising parameters indicating at least one SCell being set to an active state, a dormant state, or an inactive state. A base station may transmit, for example, one or more MAC control elements (CEs) comprising parameters indicating at least one SCell being set to an active state, a dormant state, or an inactive state.

The wireless device may perform (e.g., if the SCell is in an active state): SRS transmissions on the SCell, CQI/PMI/RI/CRI reporting for the SCell, PDCCH monitoring on the SCell, PDCCH monitoring for the SCell, and/or PUCCH/SPUCCH transmissions on the SCell. The wireless device may (e.g., if the SCell is in an inactive state): not transmit SRS on the SCell, not report CQI/PMI/RI/CRI for the SCell, not transmit on an UL-SCH on the SCell, not transmit on a RACH on the SCell, not monitor PDCCH on the SCell, not monitor a PDCCH for the SCell; and/or not transmit a PUCCH/SPUCCH on the SCell. The wireless device may (e.g., if the SCell is in a dormant state): not transmit SRS on the SCell, report CQI/PMI/RI/CRI for the SCell, not transmit on a UL-SCH on the SCell, not transmit on a RACH on the SCell, not monitor a PDCCH on the SCell, not monitor a PDCCH for the SCell, and/or not transmit a PUCCH/SPUCCH on the SCell.

A base station may send (e.g., transmit), for example, a first MAC CE (e.g., an activation/deactivation MAC CE). The first MAC CE may indicate, to a wireless device, activation or deactivation of at least one SCell. A C_i field may indicate an activation/deactivation status of an SCell with an SCell index i, for example, if an SCell with SCell index i is configured. An SCell with an SCell index i may be activated, for example, if the C_i field is set to one. An SCell with an SCell index i may be deactivated, for example, if the C_i field is set to zero. A wireless device receiving a MAC CE may ignore the C_i field, for example, if there is no SCell configured with SCell index i. An R field may indicate a reserved bit. The R field may be set to zero.

A base station may transmit a MAC CE (e.g., a hibernation MAC CE) that may generally be referred to herein as a second MAC CE. The second MAC CE may be the same as or different from other MAC CEs described herein, but is generally referred to herein as the second MAC CE. The second MAC CE may indicate activation and/or hibernation of at least one SCell to a wireless device. The second MAC CE may be associated with, for example, a second LCID different from a first LCID of the first MAC CE (e.g., the activation/deactivation MAC CE). The second MAC CE may have a fixed size. The second MAC CE may comprise a single octet comprising seven C-fields and one R-field.

FIG. **21**A shows an example of a MAC CE (e.g., the second MAC CE referenced above) comprising a single octet. The second MAC CE may comprise four octets comprising 31 C-fields and one R-field. FIG. **21**B shows an example of the second MAC CE comprising four octets. A second MAC CE (e.g., comprising four octets) may be associated with a third LCID. The third LCID may be different from the second LCID for the second MAC CE and/or the first LCID for activation/deactivation MAC CE. The second MAC CE (e.g., comprising one octet) may be used, for example, if there is no SCell with a serving cell index greater than a value (e.g., 7 or any other value). The second MAC CE (e.g., comprising four octets) may be used, for example, if there is an SCell with a serving cell index greater than a value (e.g., 7 or any other value). A second MAC CE may indicate a dormant/activated status of an SCell, for example, if a second MAC CE is received and a first MAC CE is not received. The C_i field of the second MAC CE may indicate a dormant/activated status of an SCell with SCell index i if there is an SCell configured with SCell index i, otherwise the MAC entity may ignore the C_i field. A wireless device may transition an SCell associated with SCell index i into a dormant state, for example, if C_i of the second MAC CE is set to "1". The wireless device may activate an SCell associated with SCell index i, for example, if C_i of the second MAC CE is set to "0". The wireless device may activate the SCell with SCell index i, for example, if C_i of the second MAC CE is set to "0" and the SCell with SCell index i is in a dormant state. The wireless device may ignore the C_i field of the second MAC CE, for example, if the C_i field is set to "0" and the SCell with SCell index i is not in a dormant state.

FIG. **21**C shows example configurations of a field of the first MAC CE. The field may comprise, for example, a C_i field of the first MAC CE (e.g., an activation/deactivation MAC CE), a C_i field of the second MAC CE (e.g., a hibernation MAC CE), and corresponding resulting SCell status (e.g., activated/deactivated/dormant). The wireless device may deactivate an SCell associated with SCell index i, for example, if C_i of hibernation MAC CE is set to 0, and C_i of the activation/deactivation MAC CE is set to 0. The wireless device may activate an SCell associated with SCell index i, for example, if C_i of hibernation MAC CE is set to 0, and C_i of the activation/deactivation MAC CE is set to 1. The wireless device may ignore the hibernation MAC CE and the activation/deactivation MAC CE, for example, if C_i of hibernation MAC CE is set to 1, and C_i of the activation/deactivation MAC CE is set to 0. The wireless device may transition an SCell associated with SCell index I to a dormant state, for example, if C_i of hibernation MAC CE is set to 1, and C_i of the activation/deactivation MAC CE is set to 1.

A base station may activate, hibernate, and/or deactivate at least one of one or more SCells, for example, if the base station is configured with the one or more SCells. A MAC entity of a base station and/or a wireless device may maintain an SCell deactivation timer (e.g., sCellDeactivationTimer), for example, per a configured SCell and/or except for an SCell configured with PUCCH/SPUCCH, if any. The MAC entity of the base station and/or the wireless device may deactivate an associated SCell, for example, if an SCell deactivation timer expires. A MAC entity of a base station and/or a wireless device may maintain dormant SCell deactivation timer (e.g., dormantSCellDeactivationTimer), for example, per a configured SCell and/or except for an SCell configured with PUCCH/SPUCCH, if any. The MAC entity of the base station and/or the wireless device may deactivate an associated SCell, for example, if the dormant SCell deactivation timer expires (e.g., if the SCell is in dormant state).

A base station (e.g., a MAC entity of the base station) and/or a wireless device (e.g., a MAC entity of the wireless device) may, for example, maintain an SCell hibernation timer (e.g., sCellHibernationTimer), for example, per a configured SCell and/or except for an SCell configured with PUCCH/SPUCCH, if any. The base station (e.g., the MAC entity of the base station) and/or the wireless device (e.g., the MAC entity of the wireless device) may hibernate an associated SCell, for example, if the SCell hibernation timer expires (e.g., if the SCell is in active state). The SCell hibernation timer may take priority over the SCell deactivation timer, for example, if both the SCell deactivation timer and the SCell hibernation timer are configured. A base station and/or a wireless device may ignore the SCell deactivation timer regardless of the SCell deactivation timer expiry, for example, if both the SCell deactivation timer and the SCell hibernation timer are configured.

A wireless device (e.g., MAC entity of a wireless device) may activate an SCell, for example, if the MAC entity is configured with an activated SCell at SCell configuration. A wireless device (e.g., MAC entity of a wireless device) may activate an SCell, for example, if the wireless device receives a MAC CE(s) activating the SCell. The wireless device (e.g., MAC entity of a wireless device) may start or restart an SCell deactivation timer associated with an SCell, for example, based on or in response to activating the SCell. The wireless device (e.g., MAC entity of a wireless device) may start or restart an SCell hibernation timer (e.g., if configured) associated with an SCell, for example, based on or in response to activating the SCell. A wireless device (e.g., MAC entity of a wireless device) may trigger a PHR procedure, for example, based on or in response to activating an SCell.

A wireless device (e.g., MAC entity of a wireless device) and/or a base station (e.g., a MAC entity of a base station) may (e.g., if a first PDCCH on an SCell indicates an uplink grant or downlink assignment, or a second PDCCH on a serving cell scheduling the SCell indicates an uplink grant or a downlink assignment for the SCell, or a MAC PDU is transmitted in a configured uplink grant or received in a configured downlink assignment) restart an SCell deactivation timer associated with an activated SCell and/or restart an SCell hibernation timer (e.g., if configured) associated with the SCell. An ongoing random access (RA) procedure on an SCell may be aborted, for example, if, the SCell is deactivated.

A wireless device (e.g., MAC entity of a wireless device) and/or a base station (e.g., a MAC entity of a base station) may (e.g., if configured with an SCell associated with an SCell state set to dormant state upon the SCell configuration, or if receiving MAC CE(s) indicating transitioning the SCell to a dormant state): set (e.g., transition) the SCell to a dormant state, transmit one or more CSI reports for the SCell, stop an SCell deactivation timer associated with the SCell, stop an SCell hibernation timer (if configured) associated with the SCell, start or restart a dormant SCell deactivation timer associated with the SCell, and/or flush all HARQ buffers associated with the SCell. The wireless device (e.g., MAC entity of a wireless device) and/or a base station (e.g., a MAC entity of a base station) may (e.g., if the SCell hibernation timer associated with the activated SCell expires): hibernate the SCell, stop the SCell deactivation timer associated with the SCell, stop the SCell hibernation timer associated with the SCell, and/or flush all HARQ buffers associated with the SCell. The wireless device (e.g., MAC entity of a wireless device) and/or a base station (e.g., a MAC entity of a base station) may (e.g., if a dormant SCell deactivation timer associated with a dormant SCell expires): deactivate the SCell and/or stop the dormant SCell deactivation timer associated with the SCell. Ongoing RA procedure on an SCell may be aborted, for example, if the SCell is in dormant state.

FIG. **22** shows example DCI formats. The example DCI formats may correspond to an operation such as an FDD operation (e.g., 20 MHz bandwidth, or any other bandwidth). The example DCI formats may correspond to transmissions involving two transmission antennas (or any other number of antennas) at the base station. The example DCI formats may correspond to transmissions utilizing CA or utilizing single cell. The DCI formats may comprise at least one of: DCI format 0_0/0_1 indicating scheduling of PUSCH in a cell; DCI format 1_0/1_1 indicating scheduling of PDSCH in a cell; DCI format 2_0 indicating a slot format (e.g., to a group of wireless devices); DCI format 2_1 indicating PRB(s) and/or OFDM symbol(s) to a group of wireless devices (e.g., in a scenario where a wireless device may assume no transmission is intended for the wireless device); DCI format 2_2 indicating transmission of TPC commands for PUCCH and PUSCH; and/or DCI format 2_3 indicating transmission of a group of TPC commands for SRS transmission by one or more wireless devices. A base station may transmit DCI, via a PDCCH, for scheduling decisions and/or power-control commands. The DCI may comprise at least one of: downlink scheduling assignments, uplink scheduling grants, power-control commands. The downlink scheduling assignments may comprise at least one of: PDSCH resource indication, transport format, HARQ information, control information related to multiple antenna schemes, and/or a command for power control of the PUCCH used for transmission of ACK/NACK (e.g., based on downlink scheduling assignments). The uplink scheduling grants may comprise at least one of: PUSCH resource indication, transport format, and HARQ related information, and/or a power control command of the PUSCH.

The different types of control information correspond to different DCI message sizes. Supporting spatial multiplexing with non-contiguous allocation of RBs (e.g., in the frequency domain) may require a larger scheduling message, for example, in comparison with an uplink grant that allows only contiguous allocation of RBs. The DCI may be categorized into different DCI formats. A DCI format may correspond to a certain message size and may be associated with a particular application/usage.

A wireless device may monitor one or more PDCCH candidates to detect one or more DCI with one or more DCI format. One or more PDCCH transmissions may be transmitted in a common search space or a wireless device-specific search space. A wireless device may monitor PDCCH with only a limited set of DCI formats, for example, to reduce power consumption. A wireless device may not be required to detect DCI, for example, with DCI format 6 (e.g., as used for an eMTC wireless device), and/or any other DCI format. A wireless device with a capability for detection of a higher number of DCI formats may have a higher power consumption.

The one or more PDCCH candidates that a wireless device monitors may be defined in terms of PDCCH wireless device-specific search spaces. A PDCCH wireless device-specific search space at CCE aggregation level L (e.g., $L \in \{1,2,4,8\}$) may be defined by a set of PDCCH candidates for the CCE aggregation level L. A wireless device may be configured (e.g., by one or more higher layer parameters), for a DCI format per serving cell, a number of PDCCH candidates per CCE aggregation level L.

A wireless device may monitor one or more PDCCH candidate in control resource set q based on a periodicity of symbols (e.g., $W_{PDCCH,q}$ symbols) for control resource set q. The periodicity of the symbols for the control resource set q may be configured, for example, by one or more higher layer parameters)

Information in the DCI formats used for downlink scheduling may be organized into different groups. Fields present in DCIs corresponding to different DCI formats may be different. The fields may comprise, for example, at least one of: resource information (e.g., comprising carrier indicator (e.g., 0 or 3 bits, or any other quantity of bits) and/or RB allocation); HARQ process number; MCS, new data indicator (NDI), and redundancy version (RV) (e.g., for a first TB); MCS, NDI and RV (e.g., for a second TB); MIMO related information; PDSCH resource-element mapping and QCI; downlink assignment index (DAI); TPC for PUCCH; SRS request (e.g., 1 bit, or any other quantity of bits), an indicator for triggering one-shot SRS transmission; ACK/NACK offset; DCI format 0/1A indication (e.g., used to differentiate between DCI format 1A and DCI format 0); and padding (e.g., if necessary). The MIMO related information may comprise, for example, at least one of: PMI, precoding information, transport block swap flag, power offset between PDSCH and reference signal, reference-signal scrambling sequence, number/quantity of layers, and/or antenna ports for transmission.

Information in the DCI formats used for uplink scheduling may be organized into different groups. Field present in DCIs corresponding to different DCI formats may be different. The fields may comprise, for example, at least one of: resource information (e.g., comprising carrier indicator, resource allocation type, and/or RB allocation); MCS, NDI (for a first TB); MCS, NDI (for a second TB); phase rotation of an uplink DMRS; precoding information; CSI request, an indicator requesting an aperiodic CSI report; SRS request (e.g., 2 bits, or any other quantity of bits) to trigger aperiodic SRS transmission (e.g., using one of up to three preconfigured settings); uplink index/DAI; TPC for PUSCH; DCI format 0/1A indication; and padding (e.g., if necessary).

A base station may perform cyclic redundancy check (CRC) scrambling for DCI, for example, before transmitting the DCI via a PDCCH. The base station may perform CRC scrambling, for example, by bit-wise addition (or Modulo-2 addition, exclusive OR (XOR) operation, or any other method) of multiple bits of at least one wireless device identifier (e.g., C-RNTI, CS-RNTI, TPC-CS-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, SP CSI C-RNTI, SRS-TPC-RNTI, INT-RNTI, SFI-RNTI, P-RNTI, SI-RNTI, RA-RNTI, MCS-C-RNTI, and/or any other identifier) with the CRC bits of the DCI. The wireless device may check the CRC bits of the DCI, for example, if detecting the DCI. The wireless device may receive the DCI, for example, if the CRC is scrambled by a sequence of bits that is the same as the at least one wireless device identifier.

A base station may transmit one or more PDCCH in different control resource sets, for example, to support wide bandwidth operation. A base station may transmit one or more RRC message comprising configuration parameters of one or more control resource sets. At least one of the one or more control resource sets may comprise, for example, at least one of: a first OFDM symbol; a number/quantity of consecutive OFDM symbols; a set of resource blocks; a CCE-to-REG mapping; and/or a REG bundle size (e.g., for interleaved CCE-to-REG mapping).

A base station may configure a wireless device with BWPs (e.g., UL BWPs and/or DL BWPs) to enable BA on a PCell. The base station may configure the wireless device with at least DL BWP(s) (e.g., there may be no UL BWPs in the UL) to enable BA on an SCell (e.g., if CA is configured). An initial active BWP may be a first BWP used for initial access, for example, for the PCell. A first active BWP may be a second BWP configured for the wireless device to operate on the SCell (e.g., upon the SCell being activated). A base station and/or a wireless device may independently switch a DL BWP and an UL BWP, for example, if operating in a paired spectrum (e.g., FDD). A base station and/or a wireless device may simultaneously switch a DL BWP and an UL BWP, for example, if operating in an unpaired spectrum (e.g., TDD).

A base station and/or a wireless device may switch a BWP between configured BWPs, for example, based on DCI, a BWP inactivity timer, and/or any trigger. A base station and/or a wireless device may switch an active BWP to a default BWP, for example, based on or in response to an expiry of a BWP inactivity timer, if configured, associated with a serving cell. The default BWP may be configured by the network.

One UL BWP for each uplink carrier and/or one DL BWP may be active at a time in an active serving cell, for example, for FDD systems that may be configured with BA. One DL/UL BWP pair may be active at a time in an active serving cell, for example, for TDD systems. Operating on the one UL BWP and/or the one DL BWP (or the one DL/UL BWP pair) may improve wireless device battery consumption. BWPs other than the one active UL BWP and/or the one active DL BWP that the wireless device may work on may be deactivated. On or for deactivated BWPs, the wireless device may not monitor PDCCH and/or may not transmit on a PUCCH, PRACH, and/or UL-SCH.

A serving cell may be configured with any quantity of BWPs (e.g., up to four, or up to any other quantity of BWPs). There may be, for example, one or any other quantity of active BWPs at any point in time for an activated serving cell.

BWP switching for a serving cell may be used, for example, to activate an inactive BWP and/or deactivate an active BWP (e.g., at a time t). The BWP switching may be controlled, for example, by a PDCCH indicating a downlink assignment and/or an uplink grant. The BWP switching may be controlled, for example, by a BWP inactivity timer (e.g., bwp-InactivityTimer). The BWP switching may be controlled, for example, by a base station (e.g., a MAC entity of a base station), a wireless device (e.g., a MAC entity of a wireless device), and/or a MAC entity, based on or in response to initiating an RA procedure. One or more BWPs may be initially active, without receiving a PDCCH indicating a downlink assignment or an uplink grant, for example, if an SpCell is added and/or if an SCell is activated. The active BWP for a serving cell may be indicated by RRC message and/or PDCCH. A DL BWP may be paired with an UL BWP. BWP switching may be common for both UL and DL, for example, for unpaired spectrum.

FIG. **23** shows an example of BWP switching for an SCell. A base station **2305** may send (e.g., transmit) one or more messages, to a wireless device **2310**. The one or more messages may be for configuring BWPs corresponding to the SCell **2315**. The one or more messages may comprise, for example, one or more RRC messages (e.g., RRC connection reconfiguration message, and/or RRC connection reestablishment message, and/or RRC connection setup message). The configured BWPs may comprise BWP 0, BWP 1, . . . BWP n. The BWP 0 may be configured as a default BWP. The BWP 1 may be configured as a first active BWP. At time n, the base station **2305** may send (e.g., transmit) an RRC message and/or a MAC CE for activating the SCell. At or after time n+k, and based on the reception of the RRC message and/or the MAC CE, the wireless device **2310** may activate the SCell and start monitoring a PDCCH on the BWP 1 (e.g., the first active BWP). At or after time m, the base station **2305** may send (e.g., transmit) DCI for DL assignment or UL grant on the BWP 1. At or after time m+1, the wireless device **2310** may receive a packet on the BWP 1 and may start a BWP inactivity timer (e.g., bwp-InactivityTimer). At time s, the BWP inactivity timer may expire. At or after time s+t, a BWP may switch to BWP 0 based on expiration of the BWP inactivity timer. BWP switching may comprise, for example, activating the BWP 0 and deactivating the BWP 1. At time o, the base station **2305** may send (e.g., transmit) an RRC message and/or a MAC CE for deactivating an SCell. At or after time o+p, the wireless device **2310** may stop the BWP inactivity timer and deactivate the SCell **2315**.

A wireless device may receive RRC message comprising parameters of a SCell and one or more BWP configuration associated with the SCell. The RRC message may comprise: RRC connection reconfiguration message (e.g., RRCReconfiguration); RRC connection reestablishment message (e.g., RRCRestablishment); and/or RRC connection setup message (e.g., RRCSetup). Among the one or more BWPs, at least one BWP may be configured as the first active BWP (e.g., BWP 1 in FIG. **23**), one BWP as the default BWP (e.g., BWP 0 in FIG. **23**). The wireless device may receive a MAC CE to activate the SCell at n^{th} slot. The wireless device may start a SCell deactivation timer (e.g., sCellDeactivationTimer), and start CSI related actions for the SCell, and/or start CSI related actions for the first active BWP of the

SCell. The wireless device may start monitoring a PDCCH on BWP 1 in response to activating the SCell.

The wireless device may start restart a BWP inactivity timer (e.g., bwp-InactivityTimer) at m^{th} slot in response to receiving a DCI indicating DL assignment on BWP 1. The wireless device may switch back to the default BWP (e.g., BWP 0) as an active BWP when the BWP inactivity timer expires, at s^{th} slot. The wireless device may deactivate the SCell and/or stop the BWP inactivity timer when the SCell deactivation timer expires.

Using the BWP inactivity timer may reduce a wireless device's power consumption, for example, if the wireless device is configured with multiple cells with each cell having wide bandwidth (e.g., 1 GHz bandwidth, etc.). The wireless device may only transmit on or receive from a narrow-bandwidth BWP (e.g., 5 MHz) on the PCell or SCell if there is no activity on an active BWP.

A MAC entity may perform operations, on an active BWP for an activated serving cell (e.g., configured with a BWP), comprising: transmitting on an UL-SCH; transmitting on a RACH, monitoring a PDCCH, transmitting on a PUCCH, receiving DL-SCH, and/or (re-) initializing any suspended configured uplink grants of configured grant Type 1 according to a stored configuration, if any. On an inactive BWP for each activated serving cell configured with a BWP, a MAC entity may, for example: not transmit on an UL-SCH, not transmit on a RACH, not monitor a PDCCH, not transmit on a PUCCH, not transmit an SRS, not receive a DL-SCH transmission, clear configured downlink assignment(s) and/or configured uplink grant(s) of configured grant Type 2, and/or suspend configured uplink grant(s) of configured Type 1. A wireless device may perform the BWP switching to a BWP indicated by the PDCCH, for example, if the wireless device (e.g., a MAC entity of the wireless device) receives a PDCCH for a BWP switching of a serving cell and a RA procedure associated with this serving cell is not ongoing.

A bandwidth part indicator field value may indicate an active DL BWP, from a configured DL BWP set, for DL receptions for example, if the bandwidth part indicator field is configured in DCI format 1_1. A bandwidth part indicator field value, may indicate an active UL BWP, from a configured UL BWP set, for UL transmissions, for example, if the bandwidth part indicator field is configured in DCI format 0_1.

A wireless device may be provided by a higher layer parameter a timer value corresponding to a BWP inactivity timer for the PCell (e.g., bwp-InactivityTimer). The wireless device may increment the timer, if running, for example, every interval of 1 millisecond (or any other first duration) for frequency range 1 (or any other first frequency range) or every 0.5 milliseconds (or any other second duration) for frequency range 2 (or any other second frequency range), for example, if: the wireless device does not detect DCI format 1_1 for paired spectrum operation, or the wireless device does not detect DCI format 1_1 or DCI format 0_1 for unpaired spectrum operation, in the interval.

Wireless device procedures on an SCell may be similar to or the same as procedures on a PCell, for example, if the wireless device is configured for the SCell with a higher layer parameter indicating a default DL BWP among configured DL BWPs (e.g., Default-DL-BWP), and/or if the wireless device is configured with a higher layer parameter indicating a timer value (e.g., bwp-InactivityTimer). The wireless device procedures on the SCell may use the timer value for the SCell and the default DL BWP for the SCell. The wireless device may use, as first active DL BWP and first active UL BWP on the SCell or secondary cell, an indicated DL BWP and an indicated UL BWP on the SCell, respectively, if a wireless device is configured, for example, by a higher layer parameter for the DL BWP (e.g., active-BWP-DL-SCell), and/or by a higher layer parameter for the UL BWP on the SCell or secondary cell (e.g., active-BWP-UL-SCell).

A wireless device may transmit uplink control information (UCI) via one or more PUCCH resources to a base station. The wireless device may transmit the one or more UCI, for example, as part of a DRX operation. The one or more UCI may comprise at least one of: HARQ-ACK information; scheduling request (SR); and/or CSI report. A PUCCH resource may be identified by at least: frequency location (e.g., starting PRB); and/or a PUCCH format associated with initial cyclic shift of a base sequence and time domain location (e.g., starting symbol index). A PUCCH format may be PUCCH format 0, PUCCH format 1, PUCCH format 2, PUCCH format 3, or PUCCH format 4. A PUCCH format 0 may have a length of 1 or 2 OFDM symbols and be less than or equal to 2 bits. A PUCCH format 1 may occupy a number between 4 and 14 of OFDM symbols and be less than or equal to 2 bits. A PUCCH format 2 may occupy 1 or 2 OFDM symbols and be greater than 2 bits. A PUCCH format 3 may occupy a number between 4 and 14 of OFDM symbols and be greater than 2 bits. A PUCCH format 4 may occupy a number between 4 and 14 of OFDM symbols and be greater than 2 bits. The PUCCH formats 1, 2, 3, and/or 4 may comprise any other quantity of OFDM symbols and/or any other quantity of bits. The PUCCH resource may be configured on a PCell, or a PUCCH secondary cell.

A base station may transmit to a wireless device (e.g., if the wireless device is configured with multiple uplink BWPs), one or more RRC messages comprising configuration parameters of one or more PUCCH resource sets (e.g., at most 4 sets) on an uplink BWP of the multiple uplink BWPs. Each PUCCH resource set may be configured with a PUCCH resource set index, a list of PUCCH resources with each PUCCH resource being identified by a PUCCH resource identifier (e.g., pucch-Resourceid), and/or a maximum number of UCI information bits a wireless device may transmit using one of the plurality of PUCCH resources in the PUCCH resource set.

A wireless device may select (e.g., if the wireless device is configured with multiple uplink BWPs) one of the one or more PUCCH resource sets based on a total bit length of UCI information bits (e.g., HARQ-ARQ bits, SR, and/or CSI) the wireless device will transmit. The wireless device may select a first PUCCH resource set (e.g., with the PUCCH resource set index equal to 0, or any other PUCCH resource set index), for example, if the total bit length of UCI information bits is less than or equal to 2 bits (or any other quantity of bits). The wireless device may select a second PUCCH resource set (e.g., with a PUCCH resource set index equal to 1), for example, if the total bit length of UCI information bits is greater than 2 (or any other quantity of bits) and less than or equal to a first configured value. The wireless device may select a third PUCCH resource set (e.g., with a PUCCH resource set index equal to 2), for example, if the total bit length of UCI information bits is greater than the first configured value and less than or equal to a second configured value. The wireless device may select a fourth PUCCH resource set (e.g., with a PUCCH resource set index equal to 3), for example, if the total bit length of UCI information bits is greater than the second configured value and less than or equal to a third value.

A wireless device may determine, based on a quantity of uplink symbols of UCI transmission and a quantity of UCI bits, a PUCCH format from a plurality of PUCCH formats comprising PUCCH format 0, PUCCH format 1, PUCCH format 2, PUCCH format 3 and/or PUCCH format 4. The wireless device may transmit UCI in a PUCCH using PUCCH format 0, for example, if the transmission is during, greater than, or over 1 symbol or 2 symbols and/or the quantity of HARQ-ACK information bits with positive or negative SR (HARQ-ACK/SR bits) is 1 or 2. The wireless device may transmit UCI in a PUCCH using PUCCH format 1, for example, if the transmission is during, greater than, or over 4 or more symbols and the number of HARQ-ACK/SR bits is 1 or 2. The wireless device may transmit UCI in a PUCCH using PUCCH format 2, for example, if the transmission is during, greater than, or over 1 symbol or 2 symbols and the number of UCI bits is more than 2. The wireless device may transmit UCI in a PUCCH using PUCCH format 3, for example, if the transmission is during, greater than, or over 4 or more symbols, the quantity of UCI bits is more than 2 and a PUCCH resource does not include an orthogonal cover code. The wireless device may transmit UCI in a PUCCH using PUCCH format 4, for example, if the transmission is during, greater than, or over 4 or more symbols, the quantity of UCI bits is more than 2 and the PUCCH resource includes an orthogonal cover code.

A wireless device may determine a PUCCH resource from a PUCCH resource set, for example, to transmit HARQ-ACK information on the PUCCH resource. The PUCCH resource set may be determined as described herein. The wireless device may determine the PUCCH resource based on a PUCCH resource indicator field in a DCI (e.g., with a DCI format 1_0 or DCI for 1_1) received on a PDCCH. A PUCCH resource indicator field in the DCI may indicate one of eight PUCCH resources in the PUCCH resource set. The wireless device may transmit the HARQ-ACK information in a PUCCH resource indicated by the PUCCH resource indicator field in the DCI. The PUCCH resource indicator field may be 3-bits (e.g., or any other quantity of bits) in length.

The wireless device may transmit one or more UCI bits via a PUCCH resource of an active uplink BWP of a PCell or a PUCCH secondary cell. The PUCCH resource indicated in the DCI may be a PUCCH resource on the active uplink BWP of the cell, for example, if at most one active UL BWP in a cell is supported for a wireless device.

DRX operation may be used by a wireless device, for example, to reduce power consumption, resource consumption (e.g., frequency and/or time resources), and/or improve battery lifetime of the wireless device. A wireless device may discontinuously monitor downlink control channel (e.g., PDCCH or EPDCCH), for example, if the wireless device is operating using DRX. The base station may configure DRX operation with a set of DRX parameters. The base station may configure the DRX operation using an RRC configuration. The set of DRX parameters may be selected (e.g., by the base station) based on a network use case. A wireless device may receive data packets over an extended delay, based on the configured DRX operation. The configured DRX may be used such that a base station may wait, at least until the wireless device transitions to a DRX ON state, to receive data packets. The wireless device may be in a DRX Sleep/OFF state, for example, if not receiving any data packets.

A wireless device that is configured with a DRX operation may power down at least some (or most) of its circuitry, for example, if there are no packets to be received. The wireless device may monitor PDCCH discontinuously, for example, if DRX operation is configured. The wireless device may monitor the PDCCH continuously, for example, if a DRX operation is not configured. The wireless device may listen to and/or monitor DL channels (e.g., PDCCHs) in a DRX active state, for example, if DRX is configured. The wireless device may not listen to and/or monitor the DL channels (e.g., the PDCCHs) in a DRX Sleep state, for example, if DRX is configured.

FIG. **24** shows an example of a DRX operation. A base station (e.g., a gNB) may transmit an RRC message **2502** comprising, for example, one or more DRX parameters of a DRX cycle **2504**. The RRC message may comprise: RRC connection reconfiguration message (e.g., RRCReconfiguration); RRC connection reestablishment message (e.g., RRCRestablishment); and/or RRC connection setup message (e.g., RRCSetup). The one or more parameters may comprise, for example, a first parameter and/or a second parameter. The first parameter may indicate a first time value of a DRX active state (e.g., DRX active/on duration **2508**) of the DRX cycle **2504**. The second parameter may indicate a second time of a DRX sleep state (e.g., DRX sleep/off duration **2512**) of the DRX cycle **2504**. The one or more parameters may further comprise, for example, a time duration of the DRX cycle **2504**.

The wireless device may monitor PDCCHs, for detecting one or more DCIs on a serving cell, for example, if the wireless device is in the DRX active state. The wireless device may stop monitoring PDCCHs on the serving cell, for example, if the wireless device is in the DRX sleep state. The wireless device may monitor all PDCCHs on (or for) multiple cells that are in an active state, for example, if the wireless device is in the DRX active state. The wireless device may stop monitoring all PDCCH on (or for) the multiple cells, for example, if the wireless device is in the DRX sleep state. The wireless device may repeat the DRX operations according to the one or more DRX parameters.

DRX operation may be beneficial to a base station. A wireless device may transmit periodic CSI and/or SRS frequently (e.g., based on a configuration), for example, if DRX is not configured. The wireless device may not transmit periodic CSI and/or SRS in a DRX off period, for example, if DRX is not configured. The base station may assign resources in DRX off period, that would otherwise be used for transmitting periodic CSI and/or SRS, to the other wireless devices, for example, to improve resource utilization efficiency.

A wireless device (e.g., a MAC entity of the wireless device) may be configured (e.g., by RRC) with a DRX functionality that controls downlink control channel (e.g., PDCCH) monitoring activity, of the wireless device, for a plurality of RNTIs for the wireless device. The plurality of RNTIs may comprise, for example, at least one of: C-RNTI, CS-RNTI, INT-RNTI, SP-CSI-RNTI, SFI-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, Semi-Persistent Scheduling C-RNTI, eIMTA-RNTI, SL-RNTI, SL-V-RNTI, CC-RNTI, and/or SRS-TPC-RNTI. The wireless device (e.g., based on the wireless device being RRC_CONNECTED) may monitor the PDCCH discontinuously using a DRX operation, for example, if DRX is configured. The wireless device (e.g., the MAC entity of the wireless device) may monitor the PDCCH continuously, for example, if DRX is not configured.

RRC may control DRX operation, for example, by configuring a plurality of timers. The plurality of timers may comprise, for example: a DRX ON duration timer (e.g., drx-onDurationTimer), a DRX inactivity timer (e.g., drx-

InactivityTimer), a downlink DRX HARQ RTT timer (e.g., drx-HARQ-RTT-TimerDL), an uplink DRX HARQ RTT Timer (e.g., drx-HARQ-RTT-TimerUL), a downlink retransmission timer (e.g., drx-RetransmissionTimerDL), an uplink retransmission timer (e.g., drx-RetransmissionTimerUL), one or more parameters of a short DRX configuration (e.g., drx-ShortCycle and/or drx-ShortCycleTimer)), and/or one or more parameters of a long DRX configuration (e.g., drx-LongCycle). Time granularity for DRX timers may be defined in terms of PDCCH subframes (e.g., indicated as psf in DRX configurations), or in terms of milliseconds or any other duration.

An active time of a DRX cycle may include a time duration/period in which at least one timer is running. The at least one timer may comprise: a DRX ON duration timer (e.g., drx-onDurationTimer), a DRX inactivity timer (e.g., drx-InactivityTimer), a downlink retransmission timer (e.g., drx-RetransmissionTimerDL), an uplink retransmission timer (e.g., drx-RetransmissionTimerUL), and/or a MAC contention resolution timer (e.g., mac-ContentionResolutionTimer).

A DRX inactivity timer may specify a time duration/period for which the wireless device may be active based on successfully decoding a PDCCH indicating a new transmission (UL or DL or SL). The DRX inactivity timer may be restarted upon receiving PDCCH for a new transmission (UL or DL or SL). The wireless device may transition to a DRX mode (e.g., using a short DRX cycle or a long DRX cycle), for example, based on the expiry of the DRX inactivity timer.

A DRX short cycle (e.g., drx-ShortCycle) may be a first type of DRX cycle (e.g., if configured) that may be used, for example, if a wireless device enters DRX mode. An information element (e.g., DRX-Config IE) may indicate a length of the short cycle. A DRX short cycle timer (e.g., drx-ShortCycleTimer) may be expressed as multiples of the DRX short cycle. The timer may indicate a number of initial DRX cycles to follow the short DRX cycle before a long DRX cycle is initiated.

A DRX ON duration timer may specify, for example, a time duration at the beginning of a DRX cycle (e.g., DRX ON state). The drx-onDurationTimer may indicate, for example, a time duration before entering a sleep mode (e.g., DRX OFF state).

A DL HARQ RTT timer (e.g., drx-HARQ-RTT-TimerDL) may specify a minimum duration between a time at which a new transmission (e.g., a packet) is received and a time at which the wireless device may expect a retransmission (e.g., of the packet). The DL HARQ RTT timer may be, for example, fixed and not configurable by RRC. The DRX HARQ RTT timer may be, for example, configurable by RRC. A DRX HARQ RTT timer may indicate a maximum duration for which a wireless device may monitor PDCCH, for example, if a retransmission from a base station is expected by the wireless device.

An active time of a configured DRX cycle may comprise, for example, a time at which a scheduling request (e.g., sent on PUCCH) is pending. An active time of a configured DXR cycle may comprise, for example, a time in which an uplink grant for a pending HARQ retransmission may occur, and in which data is present in a corresponding HARQ buffer for a synchronous HARQ process. An active time of a configured DRX cycle may comprise, for example, a time in which a PDCCH indicating a new transmission, addressed to the C-RNTI of the wireless device (e.g., a MAC entity of the wireless device), has not been received at the wireless device (e.g., after a successful reception of an RA response at the wireless device). The RA response may correspond to, for example, a response to a preamble that is not selected by the wireless device, (e.g., the MAC entity of the wireless device).

A DL HARQ RTT timer may expire in a subframe and data of a corresponding HARQ process may not be successfully decoded, for example, at a wireless device configured for DRX. A wireless device (e.g., a MAC entity of the wireless device) may start the drx-RetransmissionTimerDL for the corresponding HARQ process. An UL HARQ RTT timer may expire in a subframe, for example, at a wireless device configured for DRX. A wireless device (e.g., a MAC entity of the wireless device) may start the uplink retransmission timer (e.g., drx-RetransmissionTimerUL) for a corresponding HARQ process. A DRX command MAC CE or a long DRX command MAC CE may be received, for example, at a wireless device configured for DRX. A wireless device (e.g., a MAC entity of the wireless device) may stop the DRX ON duration timer (e.g., drx-onDurationTimer) and stop the DRX inactivity timer (e.g., drx-InactivityTimer).

A DRX inactivity timer (e.g., drx-InactivityTimer) may expire or a DRX command MAC CE may be received in a subframe, for example, at a wireless device configured for DRX. A wireless device (e.g., a MAC entity of the wireless device) may start or restart DRX short cycle timer (e.g., drx-ShortCycleTimer) and may use a short DRX Cycle, for example, if the short DRX cycle is configured. The wireless device (e.g., the MAC entity of the wireless device) may use a long DRX cycle, if the long DRX cycle is configured.

A DRX short cycle timer (e.g., drx-ShortCycleTimer) may expire in a subframe, for example, at a wireless device configured for DRX. A wireless device (e.g., a MAC entity of the wireless device) may use the long DRX cycle (e.g., based on expiration of the drx-ShortCycleTimer). A long DRX command MAC CE may be received. The wireless device (e.g., the MAC entity of the wireless device) may stop a DRX short cycle timer (e.g., drx-ShortCycleTimer) and may use the long DRX cycle (e.g., based on reception of the long DRX command MAC CE).

A wireless device that is configured for DRX operation may start a DRX ON duration timer (e.g., drx-onDurationTimer), for example, if a short DRX cycle is used and if equation (1) is valid.

$$[(SFN\times10)+\text{sub frame number}]\text{modulo}(drx\text{-ShortCycle})=(drx\text{StartOffset})\text{modulo}(drx\text{-ShortCycle}) \quad \text{Equation (1)}$$

is valid. A wireless device that is configured for DRX operation may start a DRX ON duration timer (e.g., drx-onDurationTimer), for example, if a long DRX Cycle is used and if equation (2) is valid

$$[(SFN*10)+\text{sub frame number}]\text{modulo}(drx\text{-longCycle})=drx\text{StartOffset} \quad \text{Equation (2)}$$

FIG. **25** shows example of DRX operation. A base station may send (e.g., transmit) an RRC message to a wireless device. The RRC message may comprise configuration parameters of DRX operation. The base station may send (e.g., transmit), via a PDCCH, DCI for downlink resource allocation, to the wireless device. The wireless device may start a DRX inactivity timer (e.g., drx-InactivityTimer) and may monitor the PDCCH. The wireless device may receive a transmission block (TB), for example, while the DRX inactivity timer is running. The wireless device may start a HARQ RTT timer (e.g., drx-HARQ-RTT-TimerDL), and may stop monitoring the PDCCH, for example, based on receiving the TB. The wireless device may transmit a NACK to the base station, for example, if the wireless device fails to receive the TB. The wireless device may monitor the PDCCH and start a HARQ retransmission timer (e.g., drx-RetransmissionTimerDL), for example, based on an expiration of the HARQ RTT Timer. The wireless device may receive second DCI, for example, while the HARQ retransmission timer is running. The second DCI may indicate, for example, a DL grant for a retransmission of the TB. The wireless device may stop monitoring the PDCCH, for example, if the wireless device fails to receive a second DCI before an expiration of the HARQ retransmission timer.

The base station may transmit first DCI for an uplink grant via a PDCCH, to the wireless device. The wireless device may start the DRX inactivity timer and monitor the PDCCH. The wireless device may start a HARQ RTT Timer (e.g., drx-HARQ-RTT-TimerUL) and stop monitoring the PDCCH, for example, based on (e.g., after or in response to) transmitting a TB via the uplink grant. The base station may transmit a NACK to the wireless device, for example, if the base station is unsuccessful in receiving the TB. The wireless device may start a HARQ retransmission timer (e.g., drx-RetransmissionTimerUL) and monitor the PDCCH for the NACK, for example, if/when the HARQ RTT Timer expires. The wireless device may receive second DCI indicating an uplink grant for the retransmission of the TB, for example, if/when the HARQ retransmission timer is running. The wireless device may stop monitoring the PDCCH, for example, if/when the wireless device does not receive the second DCI before the HARQ retransmission timer expires.

A wireless device may monitor a control channel (e.g., PDCCH) to detect control information (e.g., DCI). The wireless device may be a URLLC wireless device, or a NB-IoT wireless device, and/or an MTC wireless device. The wireless device may monitor a control channel in a variety of communication systems (e.g., LTE, LTE Advanced, NR/5G, and/or any other communication system). The wireless device may be configured for DRX operation. The wireless device may monitor the control channel (e.g., PDCCH) for one or more DCIs, for example, during a DRX Active Time of a DRX cycle. The wireless device may stop monitoring the control channel (e.g., PDCCH), for example, during the DRX Sleep/Off Time of the DRX cycle, for example, to save power consumption. The wireless device may fail to detect DCI during the DRX Active Time, for example, if the control information (e.g., DCI) is not addressed to the wireless device. Additionally or alternatively, the wireless device may not be scheduled to receive data from a base station. In these instances, waking up to monitor the control channel (e.g., PDCCH) during the DRX Active Time may result in unnecessary power consumption. A wake-up operation may be combined with DRX operations to further reduce power consumption, for example, during a DRX Active Time. FIGS. **26**A and **26**B show examples of a wake-up operation.

FIG. **26**A shows an example of a wake-up signal/channel-based power saving operation. A base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may comprise one or more parameters of at least one of a wake-up duration and/or a power saving duration. The wake-up duration may be located a quantity (e.g., number) of slots (or symbols) before a DRX On duration of a DRX cycle. The quantity (e.g., number) of slots (or symbols) between a wake-up duration and a DRX On duration may be referred to as a gap. The gap may be configured by one or more messages (e.g., RRC messages) and/or predefined as a fixed value. The gap may be used for at least one of: synchronization with the base station; measuring reference signals; and/or retuning RF parameters. The gap may be determined, for example, based on a capability of the wireless device and/or the base station. A wake-up operation may be based on a wake-up signal. The parameters of a wake-up duration may comprise at least one of: a wake-up signal format (e.g., numerology, sequence length, sequence code, etc.); a periodicity of the wake-up signal; a time duration value of the wake-up duration; and/or a frequency location of the wake-up signal. Additionally or alternatively, the wake-up signal may comprise a signal sequence (e.g., Zadoff-Chu sequence) generated based on a cell identification (e.g., cell ID) as:

$$w(m) = \theta_{n_f,n_s}(m) \cdot e^{-\frac{j\pi un(n+1)}{131}}.$$

In the equation above,

$$m = 0, 1, \ldots, 132M-1,$$

$$n = m \bmod 132,$$

$$\theta_{n_f,n_s}(m) = \begin{cases} 1, \text{ if } c_{n_f,n_s}(2m) = 0 \text{ and } c_{n_f,n_s}(2m+1) = 0 \\ -1, \text{ if } c_{n_f,n_s}(2m) = 0 \text{ and } c_{n_f,n_s}(2m+1) = 1 \\ j, \text{ if } c_{n_f,n_s}(2m) = 1 \text{ and } c_{n_f,n_s}(2m+1) = 0 \\ -j, \text{ if } c_{n_f,n_s}(2m) = 1 \text{ and } c_{n_f,n_s}(2m+1) = 1 \end{cases}, \text{ and}$$

$$u = (N_{ID}^{cell} \bmod 126) + 3.$$

N_{ID}^{cell} may be a cell ID of a serving cell. M may be a quantity (e.g., number) of subframes in which the WUS may be transmitted, $1 \le M \le M_{WUSmax}$, where M_{WUSmax} is the maximum quantity (e.g., number) of subframes in which the WUS may be transmitted. $c_{n_f,n_s}(i)$, $i=0, 1, \ldots, 2\cdot132M-1$ may be a scrambling sequence (e.g., a length-31 Gold sequence), which may be initialized at a start of the transmission of the WUS with:

$$c_{init\_WUS} = (N_{ID}^{cell}+1)\left(\left(10n_{f\_start\_PO} + \left\lfloor \frac{n_{s\_start\_PO}}{2} \right\rfloor\right) \bmod 2048 + 1\right)2^9 + N_{ID}^{cell},$$

where $n_{f\_start\_PO}$ is the first frame of a first paging occasion to which the WUS is associated, and $n_{f\_start\_PO}$ is a first slot of the first paging occasion to which the WUS is associated.

The parameters of the wake-up duration may be predefined, for example, without a wireless device receiving (and/or a base station sending) one or more messages (e.g., RRC configuration). The wake-up operation may be based on a wake-up channel (e.g., a PDCCH, DCI, etc.). The parameters of the wake-up duration may comprise at least one of: a wake-up channel format (e.g., numerology, DCI format, PDCCH format); a periodicity of the wake-up channel; and/or a control resource set and/or a search space of the wake-up channel. The wireless device may be configured with one or more wake-up duration parameters. The wireless device may monitor the wake-up channel and/or for the wake-up signal using the one or more wake-up duration parameters, for example, during the wake-up duration. The wireless device may wake-up to monitor one or more control channels (e.g., PDCCHs), for example, based on or in response to receiving the wake-up signal/channel. The wireless device may wake-up, for example, based on the DRX configuration. The wireless device may monitor one or more control channels (e.g., PDCCHs) in the DRX Active Time (e.g., if drx-onDurationTimer is running), for example, based on or in response to receiving the wake-up signal/channel. The wireless device may go back to sleep, for example, if the wireless device is not monitoring the one or more control channels (e.g., PDCCHs) during the DRX Active Time. The wireless device may stay in a sleep state, for example, during the DRX off duration of the DRX cycle. The wireless device may skip monitoring one or more control channels (e.g., PDCCHs), for example, if the wireless device does not receive the wake-up signal/channel during the wake-up duration. The wireless device may skip monitoring the one or more control channels (e.g., PDCCHs), for example, during the DRX Active Time. Skipping monitoring of the one or more control channels (e.g., PDCCHs) may reduce the wireless device's power consumption, for example during the DRX Active Time. A wireless device may only monitor the wake-up signal/channel, for example, during the wake-up duration. The wireless device may stop monitoring the one or more control channels (e.g., PDCCHs) and/or the wake-up signal/channel, for example, during the DRX off duration. The wireless device may monitor one or more control channels (e.g., PDCCHs) but not the wake-up signal/channel, for example, during the DRX active duration if the wireless device received the wake-up signal/channel during the wake-up duration. The base station and/or the wireless device may apply the wake-up operation to a paging operation, for example, if the wireless device is in an RRC_idle state, an RRC_inactive state, and/or a connected DRX operation (C-DRX) if the wireless device is in an RRC_CONNECTED state.

FIG. **26**B shows an example of a go-to-sleep signal/channel-based power saving operation. A base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may comprise parameters of a wake-up duration and/or a power saving duration. The one or more messages may comprise at least one RRC message. The at least one RRC message may comprise one or more cell-specific and/or cell-common RRC messages (e.g., ServingCellConfig IE, ServingCellConfigCommon IE, MAC-CellGroupConfig IE). The wake-up duration may be located a quantity (e.g., number) of slots (symbols) before a DRX On duration of a DRX cycle. The quantity (e.g., number) of slots (or symbols) may be configured by the one or more RRC messages and/or predefined as a fixed value. The wake-up operation may be based on a go-to-sleep signal. The parameters of the wake-up duration may comprise at least one of: a go-to-sleep signal format (e.g., numerology, sequence length, sequence code, etc.); a periodicity of the go-to-sleep signal; a time duration value of the wake-up duration; and/or a frequency location of the go-to-sleep signal. The wake-up operation may be based on a go-to-sleep channel (e.g., a PDCCH, DCI, etc.). The parameters of the wake-up duration may comprise at least one of: a go-to-sleep channel format (e.g., numerology, DCI format, PDCCH format); a periodicity of the go-to-sleep channel; a control resource set and/or a search space of the go-to-sleep channel. The wireless device may be configured with the parameters of the wake-up duration. The wireless device may monitor the go-to-sleep signal and/or the go-to-sleep channel, for example, during the wake-up duration. The wireless device may go back to sleep and/or skip monitoring the one or more control channels (e.g., PDCCHs) during the DRX Active Time, for example, based on or in response to receiving the go-to-sleep signal/channel. The wireless device may monitor one or more control channels (e.g., PDCCHs) during the DRX Active Time, for example, if the wireless device does not receive the go-to-sleep signal/channel during the wake-up duration. Skipping monitoring of the one or more control channels (e.g., PDCCHs) may reduce the wireless device's power consumption, for example, during the DRX Active Time. A go-to-sleep signal based operation may be more robust for error detection, for example, compared to a wake-up signal based wake-up operation. For example, a wireless device may improperly or incorrectly monitor one or more control channels (e.g., PDCCHs), for example, if the wireless device misdetects (e.g., does not detect) the go-to-sleep signal. This may result in the wireless device consuming extra power. However, the wireless device may miss DCI addressed to the wireless device, for example, if the wireless device misdetects (e.g., does not detect) the wake-up signal. Missing the DCI may result in a communication interruption. In at least some communication systems (e.g., involving a URLLC service, a V2X service, etc.), the wireless device and/or the base station may prefer that the devices consume extra power rather than the communication being interrupted. Thus, the go-to-sleep signal based operation may be more robust for error detection, for example, in systems that do not permit for interruptions in communications.

A first wireless device (e.g., a wireless device configured for and/or compatible with NR or another communication technology) may consume more power (e.g., if configured with multiple cells) communicating with a base station than a second wireless device (e.g., a wireless device configured for and/or compatible with LTE-Advanced or another communication technology). The first wireless device may communicate with a first base station on cells operating at one or more frequencies (e.g., 6 GHz, 30 GHz, 70 GHz, etc.) that may be higher than frequencies that cells on which a second base station communicating with the second wireless device may operate. Communicating on cells operating at higher frequencies may consume more power than the second wireless device operating at lower frequencies (e.g., <=6 GHz or other frequency/frequencies). A base station (e.g., NR base station) may send (e.g., transmit) data packets of a plurality of data services (e.g., web browsing, video streaming, industry IoT, and/or communication services for automation in a variety of vertical domains) to a wireless device. The base station may receive data packets of a plurality of data services from the wireless device. The plurality of data services may have different data traffic patterns (e.g., periodic, aperiodic, data arrival pattern, event-trigger, small data size, and/or burst type). A wireless device may enable power saving mode (e.g., a micro sleep mode) with a base station, for example, if the wireless device is accessing a first data service that has a predictable and/or periodic traffic pattern. The first data service may be better-suited for the power saving mode with the base station. The power saving mode may be more useful for the first data service, for example, if the wireless device operates at higher frequencies. The wireless device may change from the first data service to a second data service that may not be well-suited for the power saving mode. The wireless device may disable the power saving mode, for example, using an operation for semi-statically/dynamically disabling the power saving mode. This disabling may be useful for a quick data packet delivery.

FIG. **27** shows an example of power saving enabling/disabling. The power saving enabling/disabling may comprise a dynamically activating/deactivating power saving mode (e.g., a micro sleep mode). A base station **2705** may communicate with a wireless device **2710** via a cell. The base station **2705** may communicate with the wireless device **2710** using a BWP via the cell. At time **2715**, the base station **2705** may send (e.g., transmit) one or more messages (e.g., RRC messages) to the wireless device **2710**. At time **2720**, the wireless device **2710** may receive the one or more messages (e.g., RRC messages) from the base station **2705**. The one or more messages (e.g., RRC messages) may comprise configuration parameters for a power saving mode (PS mode, such as a micro sleep mode). The one or more messages (e.g., RRC messages) may comprise one or more cell-specific and/or cell-common RRC messages (e.g., ServingCellConfig IE, ServingCellConfigCommon IE, MAC-CellGroupConfig IE). The one or more messages may comprise: RRC connection reconfiguration message (e.g., RRCReconfiguration); RRC connection reestablishment message (e.g., RRCRestablishment); and/or RRC connection setup message (e.g., RRCSetup). The cell may be a primary cell (e.g., PCell), a PUCCH secondary cell (if secondary PUCCH group is configured), and/or a primary secondary cell (e.g., PSCell) (e.g., if dual connectivity is configured). The cell may be indicated (e.g., identified) by and/or associated with a cell specific identity (e.g., cell ID).

As described above, the configuration parameters may comprise configuration parameters for the PS mode (e.g., micro sleep mode). The configuration parameters may comprise at least one power saving mode configuration of the cell. Each of the at least one power saving mode configurations may be indicated (e.g., identified) by a power saving mode configuration identifier (index, indicator, ID, etc.). A power saving mode of a power saving mode configuration may be based on, for example, a power saving signal (e.g., a wake-up signal and/or a go-to-sleep as described above in FIGS. **26**A and **26**B). The parameters of a signal-based power saving mode configuration may comprise at least one of: a signal format (e.g., numerology) of the power saving signal; sequence generation parameters (e.g., a cell id, a virtual cell id, SS block index, and/or an orthogonal code index) for generating the power saving signal; a window size of a time window indicating a duration when the power saving signal may be sent (e.g., transmitted); a value of a periodicity of the transmission of the power saving signal; a time resource on which the power saving signal may be sent (e.g., transmitted); a frequency resource on which the power saving signal may be sent (e.g., transmitted); a BWP on which the wireless device may monitor the power saving signal; and/or a cell on which the wireless device may monitor the power saving signal. The power saving signal may comprise at least one of: a SS block; a CSI-RS; a DMRS; and/or a signal sequence (e.g., Zadoff-Chu, M sequence, sequence, etc.).

A power saving mode may be based on, for example, a power saving channel (e.g., a wake-up channel (WUCH)) (e.g., channel-based power saving). The power saving channel may comprise a downlink control channel (e.g., a PDCCH) for the power saving mode. The parameters of the channel-based power saving mode configuration may comprise at least one of: a time window indicating a duration when the base station may transmit a power saving information (e.g., a wake-up information and/or a go-to-sleep information) via the power saving channel; parameters of a control resource set (e.g., time, frequency resource and/or TCI state indication of the power saving channel); a periodicity of the transmission of the power saving channel; a DCI format of the power saving information; a BWP on which the wireless device may monitor the power saving channel; and/or a cell on which the wireless device may monitor the power saving channel.

The wireless device **2710** may communicate with the base station **2705** in a full function mode (or a normal function mode), for example, in an RRC connected state. The wireless device **2710** may monitor (e.g., continuously monitor) one or more control channels (e.g., PDCCHs) in the full function mode, for example, if a DRX operation is not configured for the wireless device **2710**. The wireless device **2710** may be configured for DRX operation, for example, based on one or more DRX parameters. The wireless device **2710** may periodically (e.g., discontinuously) monitor the one or more control channels (e.g., PDCCHs) in full function mode, for example, if the DRX operation is configured as described above with respect to FIGS. **24** and/or **25**. The wireless device **2710** may apply one or more DRX parameters to periodically (e.g., discontinuously) monitor the one or more control channels (e.g. PDCCHs). The wireless device **2710** may: monitor PDCCHs; send (transmit) SRS; send (e.g., transmit) on RACH and/or UL-SCH; and/or receive DL-SCH in the full function mode. As shown in FIG. **27**, the wireless device may communicate with the base station in the full function mode. At time **2725**, the base station **2705** may send (e.g., transmit) a first command to the wireless device **2710**. The first command (e.g., 1^{st} command) may include an indication enabling a power saving mode. The power saving mode may be enabled, for example, if a data service is suitable for the PS mode. Additionally or alternatively, the wireless device **2710** may operate in PS mode, for example, due to a reduction in available processing power at the wireless device **2710**. The first command may be a DCI. The DCI may be of a first DCI format (e.g., one of DCI format 0-0/0-1, 1-0/1-1, or 2-0/2-1/2-2/2-3) and/or a second DCI format. The first command may be a MAC CE and/or an RRC message.

At time **2730**, the wireless device **2710** may receive the first command from the base station **2705**. The wireless device **2710** may enable (e.g., activate) the PS mode, for example, based on or in response to receiving the first command Additionally or alternatively, the wireless device **2710** may switch to the PS mode from the full function mode, for example, based on or in response to receiving the first command. The wireless device **2710**, during PS mode, may: monitor for the PS signal/channel (e.g., WUS); not send (e.g., transmit) PUCCH/PUSCH/SRS/PRACH before detecting/receiving the PS signal/channel; not receive PDSCH before detecting/receiving the PS signal/channel; not monitor PDCCHs before detecting/receiving the PS signal/channel; and/or start monitoring the PDCCHs (e.g., based on or in response to detecting/receiving the PS signal/channel).

The wireless device **2710** may monitor a PS signal/channel (e.g., WUS) in a wake-up window, for example, based on or in response to switching to the PS mode. The PS signal/channel and/or the wake-up window may be configured using the one or more messages (e.g., RRC messages). The wireless device **2710** may receive the PS signal/channel, for example, during the wake-up window. The wireless device **2710** may monitor one or more control channels (e.g., PDCCHs) as configured (e.g., via RRC message, MAC CE, etc.), for example, based on or in response to receiving the PS signal/channel. Additionally or alternatively, the wireless device **2710** may send (e.g., transmit) and/or receive data packets via the one or more control channels (e.g., PDCCHs), for example, based on one or more DCIs and in response to receiving the PS signal/channel. The wireless device **2710** may not receive the PS signal/channel, for example, during the wake-up window. The wireless device **2710** may skip monitoring the one or more control channels (e.g., PDCCHs), for example, based on or in response to not receiving the PS signal/channel. The wireless device **2710** may continue to periodically monitor the PS signal/channel, for example, during the PS mode. The wireless device **2710** may monitor one or more wake-up windows. The one or more wake-up windows may occur periodically, for example, based on one or more configured parameters of the PS mode.

At time **2735** the base station **2705** may send (e.g., transmit) a second command (e.g., 2^{nd} command) to the wireless device **2710**. The second command may comprise an indication to disable (e.g., deactivate) the PS mode. The base station **2705** may send (e.g., transmit) the second command, for example, during one or more wake-up windows. The one or more wake-up windows may occur periodically in the time domain, for example, according to one or more configuration parameters of the PS mode.

At time **2740**, the wireless device **2710** may receive the second command from the base station **2705**. The second command may be received, for example, if the wireless device **2710** monitors the PS signal/channel during the one or more wake-up windows. The second command may be or comprise DCI. The DCI may be of a first DCI format (e.g., one of DCI format 0-0/0-1, 1-0/1-1, or 2-0/2-1/2-2/2-3) and/or a second DCI format (e.g., which may be any format different from the first DCI format). The second command may be a MAC CE and/or an RRC message. The wireless device **2710** may disable (e.g., deactivate) the PS mode, for example, based on or in response to receiving the second command. Additionally or alternatively, the wireless device **2710** may switch to the full function mode, for example, based on or in response to receiving the second command. The wireless device **2710** may monitor one or more control channels (e.g., PDCCHs) as configured, for example, based on or in response to switching to the full function mode (e.g., after time **2740**). The wireless device **2710** may monitor one or more control channels (e.g., PDCCHs) for detecting DCI with CRC bits scrambled by at least one of: C-RNTI; P-RNTI; SI-RNTI; CS-RNTI; RA-RNTI; TC-RNTI; MCS-C-RNTI; TPC-PUCCH-RNTI; TPC-PUSCH-RNTI; TPC-SRS-RNTI; INT-RNTI; SFI-RNTI; and/or SP-CSI-RNTI, for example, based on or in response to switching to the full function mode. The wireless device **2710** may send (e.g., transmit) SRS; send (e.g., transmit) on RACH and/or UL-SCH; and/or receive DL-SCH, for example, based on or in response to switching to the full function mode (e.g., after time **2740**).

FIG. **28** shows an example of DCI for power saving enabling (e.g., activating). A base station **2805** may communicate with a wireless device **2810** via a cell and/or on a BWP via the cell. Those communications may include the base station **2805** sending (e.g., transmitting) one or more configuration parameters to the wireless device **2810**.

At time **2815**, the base station **2805** may send (e.g., transmit) one or more messages to the wireless device **2810**. At time **2820**, the wireless device **2810** may receive the one or more messages from the base station **2805**. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise one or more first configuration parameters for a power saving mode. The one or more first configuration parameters may indicate one or more PS parameters for a plurality of power saving modes (e.g. PS mode 1, PS mode 2, etc.). One or more first PS parameters for a first power saving mode (e.g., PS mode 1) may indicate at least one of: one or more first search spaces and/or one or more first control resource sets (e.g., SS1/CORESET1); one or more first DCI formats (e.g., DCI format 0-0, 1-0, etc.); and/or one or more first PS signal parameters (e.g., PS signal format; periodicity; time/frequency location, etc.). One or more second PS parameters for a second power saving mode (e.g., PS mode 2) may indicate at least one of: one or more second search spaces and/or one or more second control resource sets (e.g., SS1/CORESET1 and/or SS2/CORESET2); one or more second DCI formats; and/or one or more second PS signal parameters. The one or more messages (e.g., RRC messages) may comprise second configuration parameters indicating one or more third search spaces and one or more third control resource sets (e.g., SS1/CORESET1, SS2/CORSET2 . . . , and/or SSn/CORESETn); and/or one or more third DCI formats.

The wireless device **2810** may communicate with the base station **2805** in a full function mode, for example in an RRC connected state. The wireless device **2810** may monitor one or more control channels (e.g., PDCCHs) for the one or more third DCI formats, for example, in the full function mode. The wireless device **2810** may monitor the one or more third search spaces of the one or more third control resource sets for the one or more third DCI formats. The wireless device **2810** may be configured for DRX operation, for example, based on one or more DRX parameters. The wireless device **2810** may periodically (e.g., discontinuously) monitor the one or more control channels (e.g., PDCCHs) in the full function mode, for example, if the DRX operation is configured as described above with respect to FIGS. **24** and/or **25**. The wireless device **2810** may apply one or more DRX parameters to periodically (e.g., discontinuously) monitor the one or more control channels (e.g., PDCCHs). In the full function mode, The wireless device **2810** may: monitor PDCCHs; send (transmit) SRS; send (transmit) on RACH and/or UL-SCH; and/or receive DL-SCH in the full function mode. As shown in FIG. **28**, the wireless device may communicate with the base station in the full function mode.

At time **2825**, the base station **2805** may send (e.g., transmit) first DCI to the wireless device **2810**. The first DCI (e.g., 1^{st} DCI) may comprise an indication to enable (e.g., activate) a first power saving mode (e.g., PS mode 1). The first power saving mode may be enabled (e.g., activated), for example, if a data service accessed by the wireless device **2810** is suitable for the first PS mode. Additionally or alternatively, the wireless **2810** device may operate (work) in the first PS mode. The first DCI may be sent (e.g., transmitted) with a first DCI format (e.g., one of DCI formats 0-0/0-1, 1-0/1-1, and/or 2-0/2-1/2-2/2-3) and/or a second DCI format (e.g., which may be any DCI format different from the first DCI format).

At time **2830**, the wireless device **2810** may receive the first DCI from the base station **2805**. The wireless device **2810** may enable (e.g., activate) the first PS mode, for example, based on or in response to receiving the first DCI. Additionally or alternatively, the wireless device **2810** may switch to the first PS mode from the full function mode, for example, based on or in response to receiving the first DCI. The wireless device **2810** may monitor a first control channel (e.g., PDCCH) for at least one DCI in the first PS mode. The wireless device **2710** may monitor one or more first search spaces of the one or more first control resource sets (e.g., SS1/CORESET1). The at least one DCI may comprise one or more first DCI formats. In the first PS mode, the wireless device **2810** may monitor the PS signal, for example, according to the one or more first PS signal parameters. The wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more second search spaces of the one or more second control resource sets, for example, if the wireless device **2810** is in the first PS mode. Similarly, the wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more third search spaces of the one or more third control resource sets, for example, if the wireless device **2810** is in the first PS mode.

At time **2835**, the base station **2805** may send (e.g., transmit) second DCI (e.g., 2^{nd} DCI) to the wireless device **2810**. The second DCI may comprise an indication to enable (e.g., activate) a second PS mode. (e.g., PS mode 2). At time **2840**, the wireless device **2810** may receive the second DCI from the base station **2805**. The wireless device **2810** may enable (e.g., activate) the second PS mode, for example, based on or in response to receiving the second DCI. Additionally or alternatively, the wireless device **2810** may switch to the second PS mode from the first PS mode, for example, based on or in response to receiving the second DCI. The wireless device **2810** may monitor a second control channel (e.g., PDCCH) for at least one DCI in the second PS mode. The wireless device **2810** may monitor one or more second search spaces of the one or more second control resource sets (e.g., SS1/CORESET1, SS2/CORESET2). The at least one DCI may comprise one or more second DCI formats. In the second PS mode, the wireless device **2810** may monitor the PS signal, for example, according to the one or more second PS signal parameters. The wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more first search spaces of the one or more first control resource sets, for example, if the wireless device **2810** is in the second PS mode. Similarly, the wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more third search spaces of the one or more third control resource sets, for example, if the wireless device **2810** is in the second PS mode.

At time **2845**, the base station **2805** may send (e.g., transmit) third DCI (e.g., 3^{rd} DCI) to the wireless device **2810**. The third DCI may comprise an indication to enable (activate) full function mode. At time **2850**, the wireless device **2810** may disable (e.g., deactivate) the first PS mode and/or the second PS mode, for example, based on or in response to receiving the third DCI. The wireless device **2810** may monitor a third control channel (e.g., PDCCH) for at least one DCI in the full function mode. The wireless device **2810** may monitor one or more third search spaces of the one or more third control resource sets (e.g., SS1/CORESET1, SS2/CORESET2 . . . , SSn/CORESETn). The at least one DCI may comprise one or more third DCI formats. In the full function mode, the wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more first search spaces of the one or more first control resource sets. Similarly, the wireless device **2810** may not monitor one or more control channels (e.g., PDCCHs) on the one or more second search spaces of the one or more second control resource sets in the full function mode.

FIG. **29** shows an example of DCI for power saving disabling (e.g., deactivating). FIG. **29** shows a base station **2905** may communicate with a wireless device **2910** via a cell and/or using a BWP via the cell. At time **2915**, the base station **2905** may send (e.g., transmit) one or more messages to the wireless device **2910**. At time **2920**, the wireless device **2910** may receive the one or more messages from the base station **2905**. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise first configuration parameters for a plurality of DRX configurations. The first configuration parameters may comprise a first DRX configuration (e.g., 1^{st} DRX configuration, DRX configuration 1). The first DRX configuration may indicate: one or more first search spaces (e.g., 1^{st} SSs) and/or one or more first control resource sets (e.g., 1^{st} CORESETs); one or more first RNTIs (e.g., 1^{st} RNTIs9) of PDCCH candidates monitoring; one or more first DCI formats (e.g., 1^{st} DCI formats); one or more first DRX timers; and/or one or more first PS signal parameters. The first configuration parameters may comprise a second DRX configuration (e.g., 2^{nd} DRX configuration, DRX configuration 2). The second DRX configuration may indicate: one or more second search spaces (e.g., 2^{nd} SSs) and/or one or more second control resource sets (e.g., 2^{nd} CORESETs); one or more second RNTIs (e.g., 2^{nd} RNTIs) of PDCCH candidates monitoring; one or more second DCI formats (e.g., 2^{nd} DCI formats); one or more second DRX timers; and/or one or more second PS signal parameters. The one or more RRC messages may comprise second configuration parameters indicating: one or more third search spaces (e.g., 3^{rd} SSs) and one or more third control resource sets (e.g., 3^{rd} CORESETs); one or more third DCI formats (e.g., 3^{rd} DCI formats); one or more third RNTIs (e.g., 3^{rd} RNTIs) of PDCCH candidates monitoring.

The wireless device **2910** may communicate with the base station **2905** in the full function mode, for example, prior to time **2930**. At time **2925**, the base station **2905** may send (e.g., transmit) first DCI (e.g., 1^{st} DCI) to the wireless device **2910**. The first DCI may comprise an indication to enable (e.g., activate) the first DRX configuration (e.g., 1^{st} DRX configuration). At time **2930**, the wireless device **2910** may receive the first DCI from the base station **2905**. The wireless device **2910** may enable (e.g., activate) the first DRX configuration, for example, based on or in response to receiving the first DCI. The wireless device may monitor a first control channel (e.g., PDCCH) for at least one first DCI, for example, based on the first DRX configuration. The wireless device **2910** may monitor one or more first search spaces of the one or more first control resource sets, for example, based on one or more parameters of the first DRX configuration. The at least one first DCI may comprise one or more first DCI formats, for example, based on the one or more first RNTIs.

At time **2935**, the base station **2905** may send (e.g., transmit) second DCI (e.g., 2^{nd} DCI) to the wireless device **2910**. The second DCI may comprise an indication to enable (activate) the second DRX configuration (e.g., 2^{nd} DRX configuration, DRX configuration 2). At time **2940**, the wireless device **2910** may receive the second DCI from the base station **2905**. The wireless device **2910** may enable (e.g., activate) the second DRX configuration, for example, based on or in response to receiving the second DCI. The wireless device **2910** may monitor a second control channel (e.g., PDCCH) for at least one second DCI. The wireless device **2910** may monitor one or more second search spaces of the one or more second control resource sets, for example, based on one or more parameters of the second DRX configuration. The at least one second DCI may comprise one or more second DCI formats, for example, based on the one or more second RNTIs.

At time **2945**, the base station **2905** may send (e.g., transmit) third DCI (e.g., 3^{rd} DCI) to the wireless device **2910**. The third DCI may comprise an indication to enable (e.g., activate) full function mode. At time **2950**, the wireless device **2910** may receive the third DCI from the base station

2905. The wireless device may disable (e.g., deactivate) the first DRX configuration and/or the second DRX configuration, for example, based on or in response to receiving the third DCI. The wireless device 2910 may monitor a third control channel (e.g., PDCCH) for at least one third DCI, for example, in the full function mode. The wireless device 2910 may monitor one or more third search spaces of the one or more third control resource sets. The third DCI may comprise one or more third DCI formats, for example, based on the one or more third RNTIs.

As shown in FIG. 28 and FIG. 29, the search spaces, control resource sets, RNTIs, and/or DCI formats that a wireless device may use in a power saving mode (e.g., micro sleep mode) may be different from those used in full function mode (and/or not in power saving mode). For example, fewer search spaces, control resource sets, RNTIs, and/or DCI formats may be used in power saving mode than those used in full function mode (and/or not in power saving mode). Thus, a base station and/or a wireless device may control power consumption appropriately, for example, based on whether the wireless device is working in power saving mode and/or in full function mode. A wireless device may reduce power consumption by using a micro sleep (e.g., mini-sleep, light-sleep, etc.) mode. The wireless device may reduce power consumption in the micro sleep mode, for example, if the wireless device receives DCI indicating a same slot scheduling of channel resources (e.g., PDSCH). The PDCCH resources may occur a quantity (e.g., number) of symbols after a last symbol of a slot that the DCI was received.

FIG. 30A shows an example of a power saving (e.g., a micro sleep mode) in a same-slot scheduling. A wireless device 3010 may receive DCI for same-slot scheduling. The wireless device 3010 may receive DCI from a base station 3005. The DCI may be received at a first symbol (e.g., symbol 1) of a slot. The DCI may indicate downlink radio resource(s) of a PDSCH transmission. The downlink radio resource(s) may occur, for example, at symbol 4 of the slot (or at any other location). The wireless device 3010 may switch to the micro sleep mode, for example, based on the DCI and/or if the wireless device 3010 supports the micro sleep mode. The switch may occur, for example, during at least a portion of a time period between symbol 1 and symbol 4 (or any other time period). The wireless device may switch to the micro sleep mode by: switching a radio frequency module to power saving mode; switching at least portion of a front-end hardware to power saving mode; skipping receiving/measuring CSI-RS s; skipping monitoring PDCCH; and/or skipping receiving a PDSCH transmission. The wireless device 3010 may reduce power consumption on one or more symbols of a slot, for example, by implementing the micro sleep mode.

FIG. 30B shows an example of a power saving mode (e.g., micro sleep mode) in a cross-slot scheduling. A wireless device 3020 may receive DCI for cross-slot scheduling. The wireless device 3020 may receive DCI from a base station 3015. The DCI may be received in slot 1 (or during any other time period). The DCI may indicate a downlink radio resource of a PDSCH transmission. The downlink radio resource may occur, for example, in slot 3 (or at any other time period). The wireless device 3020 may switch to the micro sleep mode, for example, based on the DCI and/or if the wireless device 3020 supports the micro sleep mode. The switch may occur, for example, during at least a portion of a time period between slot 1 and slot 3 (or any other time period). The wireless device may switch to the micro sleep mode by: switching a radio frequency module to power saving mode; switching at least portion of a front-end hardware to power saving mode; skipping receiving CSI-RSs; skipping monitoring PDCCH; and/or skipping receiving PDSCH. The wireless device 3020 may reduce power consumption on one or more slots, for example, by implementing the micro sleep mode. The wireless device 3020 may apply the cross-slot scheduling for transport block receptions, for example, after receiving the DCI indicating that cross-slot scheduling is applied. The wireless device may determine (e.g., assume) transport blocks are occurring at a different slot than a slot in which the wireless device receives DCIs scheduling the transport blocks, for example, if applying the cross-slot scheduling. The wireless device may not expect transport block to occur at a same slot, for example, in which the wireless device receives a DCI scheduling the transport block if applying the cross-slot scheduling. Cross-slot scheduling based on the cross-slot scheduling indication may reduce the wireless device's power consumption.

FIG. 30C shows an example of a power saving mode (e.g., micro sleep mode) in a multi-slot scheduling. A wireless device 3030 may receive DCI for multi-slot scheduling. The wireless device 3030 may receive DCI from a base station 3025. The DCI may be received in slot 1. The DCI may indicate a plurality of downlink radio resources for PDSCH transmission(s). The plurality of downlink radio resources may occur in a plurality of slots (e.g., slot 2, slot 3, slot 4, etc.). The wireless device 3030 may switch to the micro sleep mode, for example, based on the DCI and/or if the wireless device 3030 supports the micro sleep mode. The switch may occur, for example, during at least a portion of a time period between slot 1 and slot 4 (or any other time period). The wireless device may switch to the sleep mode by: switching a radio frequency module to power saving mode; switching at least portion of a front-end hardware to power saving mode; skipping measuring CSI-RSs; skipping monitoring PDCCH; and/or skipping receiving PDSCH. The wireless device 3030 may reduce power consumption on one or more slots, for example, by implementing the micro sleep mode.

As described above, different power saving (PS) operations may be used in different cases. First PS operations, such as those shown in FIGS. 26-29, may be triggered, for example, if changing a service type and/or if there is no activity in a cell and/or in a BWP (and/or in cell per a BWP). Second PS operations, such as those shown in FIGS. 30A-30C, may be applied, for example, for scheduling a PDSCH transmission in a same slot, a different slot, and/or a plurality of slots. The first PS operations may reduce power consumption more than the second PS operations.

A base station may send (e.g., transmit) DCI to a wireless device. The DCI may comprise a DCI format. The DCI may indicate a downlink assignment, an uplink grant, a slot format indication, a pre-emption indication, and/or a power control command. The DCI may be a unicast transmission to the wireless device. Additionally or alternatively, the DCI may be a broadcast/groupcast transmission to a group of wireless devices. The DCI for the broadcast/groupcast transmission may be referred to as a group common DCI.

FIG. 31 shows an example of a plurality of group common DCI formats. A base station may send (e.g., transmit) DCI to a group of wireless devices. The DCI may be DCI format 2_0. The DCI may indicate (e.g., notify) a slot format to the group of wireless devices. The DCI may be CRC scrambled by an SFI-RNTI. The DCI (e.g., DCI format 2_0) may comprise a plurality of slot format indicators. Each slot format indicator may be associated with a cell. Additionally or alternatively, each slot format indicator may indicate a slot format (e.g., downlink symbols, uplink symbols, and/or flexible symbols in a slot) for a cell associated with the slot format indicator.

Additionally or alternatively, the base station may send (e.g., transmit) DCI with DCI format 2_1 to the group of wireless devices. DCI format 2_1 may notify the group of wireless devices of PRB(s) and OFDM symbol(s). A wireless device in the group of wireless devices may determine (e.g., assume) no transmission is intended for the wireless device. DCI format 2_1 may be CRC scrambled by an RNTI (e.g., interruption RNTI (INT_RNTI)). DCI format 2_1 may comprise a plurality of pre-emption indications. Each pre-emption indication may be associated with a cell. Additionally or alternatively, each pre-emption indication may indicate whether one or more downlink resources are pre-empted and/or whether one or more downlink resources are not on a cell associated with the pre-emption indication.

The base station may send (e.g., transmit) DCI with DCI format 2_2 to the group of wireless devices. DCI format 2_2 may indicate TPC commands of PUCCH/PUSCH. DCI format 2_2 may be CRC scrambled by a TPC-PUCCH-RNTI and/or TPC-PUSCH-RNTI. DCI format 2_2 may comprise a plurality of blocks (e.g., bit strings). Each block may be associated with a cell. Additionally or alternatively, each block may indicate a TPC command for a PUCCH transmission on a cell associated with the block, for example, if CRC scrambled by the TPC-PUCCH-RNTI). Each block may indicate a TPC command for a PUSCH transmission on a cell associated with the block, for example, if CRC scrambled by the TPC-PUSCH-RNTI.

The base station may send (e.g., transmit) DCI with DCI format 2_3 to the group of wireless devices. DCI format 2_3 may indicate a group of TPC commands for SRS transmission by one or more wireless devices of the group of wireless devices. DCI format 2_3 may be CRC scramble by a TPC-SRS-RNTI. DCI format 2_3 may comprise a plurality of blocks (e.g., bit strings). Each block may be associated with a wireless device and/or a cell. Each block may indicate a TPC command for SRS transmission by a wireless device associated with the block. Additionally or alternatively, each block may indicate a TPC command for RSR transmission on a cell associated with the block.

A base station may send (e.g., transmit) a group command DCI (e.g., DCI format 2_1) to the group of wireless devices, for example, if multiple types of data services are supported in a cell. The group command DCI may comprise preemption indications to pre-empt downlink radio resource allocated previously for a first type of data service (e.g., eMBB). The base station may send (e.g., transmit) a downlink TB of a second type of data service (e.g., URLLC) on the pre-empted downlink radio resource.

FIG. **32** shows an example of transmission of a downlink pre-emption indication DCI. A base station may send (e.g., transmit) a first DCI **3210** to a first wireless device. First DCI **3210** may indicate a downlink radio resource for a first PDSCH transmission. The base station may send (e.g, transmit) a downlink pre-emption indication in a second DCI **3220** to the first wireless device, for example, if a second PDSCH transmission for a second wireless device is more urgent than the first wireless device. Second DCI **3220** may be DCI format 2_1. Second DCI **3220** may be sent (e.g, transmitted) to a group of wireless devices that comprises the first wireless device. The downlink pre-emption indication may indicate whether a portion of the downlink radio resource allocated in the first DCI **3210** is pre-empted. The first wireless device may receive a downlink TB based on the downlink radio resource and/or the pre-emption indication, for example, based on or in response to receiving the second DCI **3220**. The first wireless device may puncture one or more first data symbols received on the portion of the downlink radio resource, for example, if the pre-emption indicates that the portion of the downlink radio resource is pre-empted. The first wireless device may decode the downlink TB, for example, based on one or more second data symbols received on the downlink radio resource that remain after the puncturing. The first wireless device may decode the downlink TB, for example, if the pre-emption indication indicates that the portion of the downlink radio resource is not pre-empted. Decoding the downlink TB may be based on one or more data symbols received on the downlink radio resource. The base station may send (e.g., transmit) a third DCI to the second wireless device for the second PDSCH transmission via a pre-empted radio resource.

The second DCI **3220** may be transmitted at a last symbol of a slot. Second DCI **3220** may be referred to as a pre-emption DCI. Second DCI may be DCI format 2_1. Additionally or alternatively, the second DCI **3220** (e.g., the pre-emption DCI) may be sent (transmitted) in the middle of the slot (e.g., symbols 6-8 of a 14-symbol slot), for example, if the second DCI **3220** (e.g., the pre-emption DCI) indicates an uplink pre-emption. In some instances, the second DCI **3220** (e.g., the pre-emption DCI) may be sent (transmitted) at the beginning of the slot (e.g., the first symbol of the slot). The base station may send (e.g, transmit) one or more group common DCIs (e.g., DCI format 2_0/2_1/2_2/2_3) in one or more symbols of a slot. The locations of the one or more symbols may be configured for a search space set by an RRC message. A wireless device may monitor the search space set(s) for the one or more group command DCI, for example, if the wireless device is configured with search space set(s) for receiving the one or more group common DCIs. Monitoring a search space set may comprise decoding each PDCCH candidate of a set of PDCCH candidates, for example, based on monitored DCI formats. A wireless device may attempt to decode DCI content in a PDCCH candidate. The PDCCH candidate may be in possible (and/or configured) PDCCH locations with possible (and/or configured) PDCCH formats. The PDCCH candidate may be in in common search space set(s) or in wireless device-specific search space set(s). The decoding may be referred to as blind decoding. A wireless device may determine DCI as valid for the wireless device based on CRC checking (e.g., scrambled bits for CRC parity bits of the DCI matching a RNTI value). After determining that the DCI is valid for the wireless device, the wireless device may process information (e.g., scheduling assignment, uplink grant, power control, slot format indication, or downlink preemption, etc.) contained in the DCI.

FIG. **33** shows an example of PDCCH monitoring in one or more symbols of a slot. A base station may send (e.g, transmit) one or more messages to a wireless device. The one or more messages may be RRC messages (e.g., ServingCellConfig, ServingCellConfigCommon, SIB1, and/or CellGroupConfig). The one or more RRC messages may comprise configuration parameters for a plurality of search space sets. The configuration parameters for a search space set of the plurality of search space sets may comprise: a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of consecutive slots; a 14-bit monitoring indicator (e.g., 14-bit monitoringSymbolsWithinSlot in FIG.

33) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH candidates in the search space set; a quantity (number) of PDCCH candidates per aggregation level; and/or a search space set type (e.g., common, or UE-specific). If the search space set is a common search space set, the configuration parameters may comprise: a first indication (e.g., dci-Format0-0-AndFormat1-0) to monitor PDCCH candidates for DCI format 0_0 and DCI format 1_0); a second indication (e.g., dci-Format2-0) to monitor one or more PDCCH candidates for DCI format 2_0 and a corresponding CCE aggregation level; a third indication (e.g., dci-Format2-1) to monitor PDCCH candidates for DCI format 2_1; a fourth indication (e.g., dci-Format2-2) to monitor PDCCH candidates for DCI format 2_2; and/or a fifth indication (e.g., dci-Format2-3) to monitor PDCCH candidates for DCI format 2_3.

The wireless device may monitor at least one search space set of the plurality of search space sets, for example, based on the configuration parameters in the one or more RRC messages. As shown in FIG. **33**, the wireless device may monitor PDCCH candidates of the at least one search space set on a plurality of symbols in a slot. The slot may be a slot in which the wireless device monitors the PDCCH candidates, for example, based on the monitoring periodicity and/or offset indicator of the configuration parameters. In the example shown in FIG. **33**, symbols 1, 2, 3, and 14 (or any other symbols) may indicate which slots to monitor for PDCCH candidates. The wireless device may monitor the PDCCH candidates on a symbol associated with a bit, for example, if the bit is a first value (e.g., 1). The wireless device may skip monitoring the PDCCH candidates on the symbol associated with the bit, for example, if the bit is a second value (e.g., 0). The wireless device may monitor PDCCH candidates in the search space set on symbols 1, 2, 3, and 14 (or any other symbols), for example, based on bits of the 14-bit monitoring indicator associated with symbols 1, 2, 3, and 14 having the first value. The wireless device may skip monitoring PDCCH candidates in the search space set on symbols 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 (or any other symbols), for example, based on those bits having the second value (e.g., 0).

A wireless device may switch to a micro sleep mode, for example, if the wireless device receives DCI indicating a same-slot/cross-slot/multi-slot scheduling at a first time (e.g., a symbol/slot/minislot). The wireless device may switch to the micro sleep mode, for example, after the last symbol during which the DCI on a PDCCH is received. The wireless device may skip monitoring PDCCH during the micro sleep mode. The wireless device may switch back to a normal function mode (e.g., non-micro sleep mode), for example, based on a time location of a PDSCH resource indicated by the DCI. The wireless device may fail to detect (e.g., misdetect) one or more DCI in the micro sleep mode, for example, if the wireless device skips PDCCH monitoring Failing to detect the one or more DCI may not impact the reception of the PDSCH, for example, if the one or more DCI is for an uplink grant and/or for SRS transmission. Failure to detect the one or more DCI may result in an incorrect reception of the PDSCH, for example, if the one or more DCI comprise a pre-emption indication that at least a portion of radio resources of the PDSCH is pre-empted. Failure to detect the one or more DCI may result in an incorrect reception of the PDSCH, for example, if the one or more DCI comprise a slot format indication changing (restricting) one or more symbols of the radio resource of the PDSCH to uplink symbols and/or downlink symbols.

Failure to detect the one or more DCI may result in an incorrect reception of the PDSCH, for example, if the one or more DCI comprise scheduling information for an out-of-order PDSCH transmission. A base station may send (e.g., transmit) first DCI to a wireless device. The first DCI may indicate a first downlink assignment on a BWP and/or on a cell. The base station may send (e.g., transmit) second DCI to the wireless device. The second DCI may indicate a second downlink assignment on the BWP and/or on the cell, for example, if out-of-order PDSCH reception is supported by the base station and/or by the wireless device. The second DCI may be sent (e.g., transmitted) after the first DCI and/or before the wireless device starts reception of a downlink TB transmitted via a radio resource of the first downlink assignment. The second DCI may be referred to as an out-of-order PDCCH scheduling. Reception of a downlink TB sent (e.g., transmitted) via a radio resource of the second downlink assignment may be more urgent than reception of a downlink TB transmitted via a radio resource of the first downlink assignment. A transmission occasion via the radio resource of the second downlink assignment may be earlier in the time domain than a transmission occasion via the radio resource of the first downlink assignment. Failure to detect the one or more DCI may result in an uplink transmission failure, for example, if the one or more DCI comprises a TPC command for a PUCCH/PUSCH transmission. At least some power saving modes (e.g., at least some micro sleep modes) may lead to transmission errors, for example, if receiving DCI for a same-slot/cross-slot/multi-slot scheduling. As described herein, power sleep modes (e.g., micro sleep modes) may be improved, for example, to reduce errors in PDSCH reception and/or uplink transmission. This may result in improved downlink spectrum efficiency and/or uplink spectrum efficiency. Additionally or alternatively, a wireless device's power consumption in a power saving mode (e.g., a micro sleep mode) may be improved.

A wireless device may deactivate (e.g., disable, switch off, etc.) one or more operations on one or more cells, for example, to conserve power. The one or more operations may be deactivated, for example, if switching to a DRX off mode, for example, based on or in response to receiving a DRX MAC CE. Additionally or alternatively, the wireless device may deactivate one or more operations on one or more cells, for example, if the wireless device receives a power saving indication (e.g., a wake-up indication) to skip PDCCH monitoring in a next DRX Active Time. At least some power saving operations may not work and/or may not be efficient in cross-slot scheduling situations. For example, a wireless device may receive an indication of cross-slot scheduling to enable (e.g., activate) DRX on all cells simultaneously. This simultaneous control of all cells (or a group of cells) may lead to misalignment and/or increased power consumption by the wireless device.

As described herein, a base station may send (e.g., transmit) one or more messages to a wireless device, for example, to provide power saving if cross-slot scheduling is enabled. The one or more messages may be one or more RRC messages that comprise a at least one cross-slot scheduling indication parameter for a corresponding cell of a plurality of cells. The cross-slot scheduling indication parameter may indicate receiving a PDSCH transmission (e.g., DCI, downlink assignment, uplink grant, etc.) by applying the cross-slot scheduling indication parameter on a corresponding cell of the plurality of cells. The cross-slot scheduling indication parameter may be independently configured for each cell. The wireless device may apply the cross-slot scheduling indication parameter separately and/or independent on different cells. By independently configuring the cross-slot scheduling parameter, a base station and/or a wireless device may flexibly manage power consumption for each cell. This per-cell (or per group of cells) configuration for cross-slot scheduling may improve data transmission latency, which may be particularly useful, for example, for URLLC service on a cell.

As described herein, a base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may be one or more RRC messages comprising a same/cross-slot scheduling indication parameter for a corresponding cell of a plurality of cells. The indication parameter may be independently configured for each cell. The wireless device may determine whether to apply the indication parameter to a cell, for example, in response to the scheduling DCI being received in a common search space. Additionally or alternatively, the wireless device may determine whether to apply the indication parameter to a cell, for example, based on or in response to the scheduling DCI being in a wireless device-specific search space. The indication parameter may indicate which cell of the plurality of cells to receive PDSCH. The wireless device may apply the same/cross-slot scheduling indication parameter, for example, based on or in response to the DCI being received in the wireless device-specific search space. The wireless device may not apply the indication parameter, for example, if the indication parameter is received in a common search space of the cell. By independently configuring the same/cross-slot scheduling indication parameter for different cells and/or restricting application of the parameter for DCIs received in different search space types, a base station and/or a wireless device may flexibly manage power consumption for each cell and/or improve data transmission latency, which may be particularly useful, for example, for URLLC service on a cell.

As described herein, a base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise a same/cross-slot indication parameter. The indication parameter may indicate which cell a same/cross-slot indication will be sent (e.g., transmitted). The wireless device may monitor one or more control channels (e.g., PDCCH) on the cell configured by the base station for receiving the same/cross-slot indication. The wireless device may switch to a same-slot scheduling for all cells, for example, based on or in response to receiving the same-slot indication parameter. Additionally or alternatively, the wireless device may switch to a cross-slot scheduling for all cells, for example, based on or in response to receiving the same-slot indication parameter. By transmitting the same/cross-slot indication on a single cell and/or applying the indication parameter to all cells, the wireless device may improve power consumption, for example, if all cells (or a plurality of cells) are configured with cross-carrier scheduled by a cell.

FIG. **34** shows an example of PDCCH monitoring. The PDCCH monitoring may occur in one or more symbols of a slot, for example, if a wireless device is in a non-power saving mode (e.g., a non-micro sleep mode) or if the wireless device is in a power saving mode (e.g., a micro sleep mode). A base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may be one or more RRC messages. The one or more RRC messages may comprise configuration parameters for a plurality of search space sets. Configuration parameters for a search space set may comprise: a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of slots (e.g., consecutive or non-consecutive); a first monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (and/or switches to) a non-power saving mode (e.g., a non-micro sleep mode); a second monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (and/or switches to) a power saving mode (e.g., a micro sleep mode); quantity (e.g., number) of PDCCH candidates per aggregation level; a search space set type (e.g., common, wireless device-specific, etc.). The configuration parameters may comprise (e.g., if the search space set is a common search space set): a first indication (e.g., dci-Format0-0-AndFormat1-0) to monitor PDCCH candidates for DCI format 0_0 and/or DCI format 1_0; a second indication (e.g., dci-Format2-0) to monitor one or two PDCCH candidates for DCI format 2_0 and/or a corresponding CCE aggregation level; a third indication (e.g., dci-Format2-1) to monitor PDCCH candidates for DCI format 2_1; a fourth indication (e.g., dci-Format2-2) to monitor PDCCH candidates for DCI format 2_2; and/or a fifth indication (e.g., dci-Format2-3) to monitor PDCCH candidates for DCI format 2_3.

A first monitoring indication **3410** may comprise 14 bits (or any other quantity of bits). Each of the 14-bits may be associated with a respective symbol in a slot. A bit set to a first value (e.g., 1) may indicate monitoring PDCCH candidates in the search space set on the symbol associated with the bit. A bit set to a second value (e.g., 0) may indicate not monitoring PDCCH candidates in the search space set on a symbol associated with the bit. The least significant bit in the first monitoring indication **3410** may indicate whether a wireless device may monitor PDCCH candidates in the search space set on a first symbol of a slot (e.g., comprising 14 symbols), for example, if the wireless device is in a non-power saving mode (e.g., a non-micro sleep mode). The first monitoring indication **3410** may indicate PDCCH monitoring on a plurality of symbols (e.g., symbol 1, 2, 3 and/or 14).

The second monitoring indication **3420** may comprise 14 bits (or any other quantity of bits). Each bit may be associated with a symbol in a slot. A bit set to a first value (e.g., 1) may indicate monitoring PDCCH candidates in the search space set on a symbol associated with the bit. A bit set to a second value (e.g., 0) may indicate not monitoring PDCCH candidates in the search space set on a symbol associated with the bit. The least significant bit in the second monitoring indication **3420** may indicate whether a wireless device may monitor PDCCH candidates in the search space set on a first symbol of a slot (e.g., comprising 14 symbols), for example, if the wireless device is in a power saving mode (e.g., a micro sleep mode). The second monitoring indication **3420** may indicate PDCCH monitoring on a plurality of symbols (e.g., symbol 1 and/or 14 as) in a slot in the micro sleep mode.

FIG. **35** shows an example of a power saving mode (e.g., micro sleep mode). A base station **3505** may communicate with a wireless device **3510** via a cell and/or on a BWP via the cell. At time **3515**, the base station **3505** may send (e.g., transmit) one or more messages to the wireless device **3510**. At time **3520**, the wireless device **3510** may receive the one or more messages from the base station **3505**. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise a first monitoring indication and/or a second monitoring indication. The first monitoring indication and/or the second monitoring indication may be one or more examples discussed above with respect to FIG. **34**.

Between time **3520** and time **3530**, the wireless device **3510** may monitor one or more search space sets for PDCCH candidates, for example, based on the one or more messages (e.g., RRC messages) received from the base station **3505**. The wireless device may monitor one or more search space sets on a first quantity (e.g., number) of symbols in a slot. The wireless device **3510** may monitor the PDCCH candidates in one or more search space sets in the one or more symbols, for example, if the first monitoring indication indicates monitoring PDCCH candidates on one or more symbols (e.g., symbol 1, 2, 3 and/or 14 as shown in FIG. **34**) in a slot.

At time **3525**, the base station **3505** may send (e.g., transmit) first DCI to the wireless device **3510**. At time **3530**, the wireless device **3510** may receive the first DCI from the base station **3505**. The first DCI may indicate a same-slot/cross-slot/multi-slot scheduling of PDSCH resource(s). The wireless device **3510** may switch to a power saving mode (e.g., a micro sleep mode) for a time period, for example, based on or in response to receiving the first DCI. The time period may be indicated and/or defined by the first DCI. Between time **3530** and time **3540**, the wireless device **3510** may monitor the PDCCH candidates in the one or more search space sets in the one or more symbols in the power saving mode (e.g., micro sleep mode). The wireless device **3510** may monitor the PDCCH candidates in the one or more search space sets on second quantity (e.g., number) of symbols in one or more slots, for example, based on the second monitoring indication. Monitoring the PDCCH candidates based on the second monitoring indication may occur, for example, during at least a portion of the time period in the micro sleep mode. For example, the wireless device **3510** may monitor the PDCCH candidates in the one or more search space sets in the second monitoring indication (e.g., symbol 1 and/or 14 as shown in FIG. **34**).

At time **3535**, the base station may send (e.g., transmit) second DCI to the wireless device **3510**. At time **3540**, the wireless device **3510** may receive the second DCI from the base station **3505**. The second DCI may be received, for example, while monitoring the PDCCH candidates in the one or more search space sets. The second DCI may indicate one or more parameters (e.g., a pre-emption indication). The pre-emption indication may indicate whether or not a portion of the PDSCH resource(s) is pre-empted. At time **3545**, the wireless device **3510** may receive downlink TB(s), for example, based on the first DCI and/or the second DCI. The wireless device **3510** may puncture first data symbols received on the portion of the PDSCH resource(s), for example, if the pre-emption indication in the second DCI indicates a portion of the PDSCH resource(s) is pre-empted. The wireless device **3510** may decode the downlink TB(s), for example, based on the puncturing and/or data symbols received on the PDSCH resources. The wireless device **3510** may decode the downlink TB(s), for example, based on one or more data symbols received on the PDSCH resource(s), if the pre-emption indication in the second DCI indicates the portion of the PDSCH resource(s) is not pre-empted.

A wireless device may receive DCI (e.g., DCI format 2_1) comprising a pre-emption indication, for example, if the wireless device is in a power saving mode (e.g., a micro sleep mode). The wireless device may correctly decode a downlink TB via a PDSCH resource same-slot/cross-slot/multi-slot scheduled by a downlink assignment DCI (e.g., DCI format 1_0/1_1), for example, based on the DCI. By monitoring the PDCCH candidates in the one or more search space sets in the one or more symbols defined by the monitoring indication and including a pre-emption indication that allows a downlink TB to be decoded, the downlink transmission spectrum efficiency and/or power consumption of the wireless device may be improved.

The monitoring indication and/or pre-emption indication described above may apply to one or more group common DCI format (e.g., DCI format 2_0, DCI format 2_2, and/or DCI format 2_3). A base station may configure a first monitoring indication and/or a second monitoring indication for receiving DCI format 2_0/2_2/2_3. The first monitoring indication may indicate which symbol(s) of a slot a wireless device may monitor PDCCH candidates for receiving DCI format 2_0/2_2/2_3 in a non-micro sleep mode. The second monitoring indication may indicate which symbol(s) of the slot a wireless device may monitor PDCCH candidates for receiving DCI format 2_0/2_2/2_3 in a power saving mode (e.g., micro sleep mode). The wireless device may switch to the power saving mode (e.g., micro sleep mode), for example, based on or in response to receiving first DCI (e.g., DCI format 1_0/1_1) indicating a same-slot/cross-slot/multi-slot scheduling. The wireless device may monitor PDCCH candidates in one or more symbols of a slot based on the second monitoring indication, for example, based on or in response to the wireless device switching to a power saving mode (e.g, a micro sleep mode). The wireless device may decode PDSCH and/or send (e.g., transmit) uplink channel/signal based on the first DCI and/or the second DCI, for example, based on or in response to receiving a second DCI with DCI format 2_0/2_2/2_3.

FIG. **36** shows an example of search spaces in a power saving mode (e.g., micro sleep mode). A base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise configuration parameters for first search space sets **3610** (e.g., search space set 1-N) mode and second search space sets **3620** (e.g., search space set L-M). The first search space sets **3610** may be for a non-power saving mode (e.g., a non-micro sleep mode). The second search space sets **3620** may be a power saving mode (e.g., a micro sleep mode). The configuration parameters for the first search space sets **3610** and the second search space sets **3620** may comprise a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of consecutive slots; a monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set; a quantity (number) of PDCCH candidates per aggregation level; a search space set type (e.g., common, wireless device-specific, etc.). If the search space set is a common search space set, the configuration parameters may comprise a first indication (e.g., dci-Format0-0-AndFormat1-0) to monitor PDCCH candidates for DCI format 0_0 and/or DCI format 1_0); a second indication (e.g., dci-Format2-0) to monitor one or two PDCCH candidates for DCI format 2_0 and/or a corresponding CCE aggregation level; a third indication (e.g., dci-Format2-1) to monitor PDCCH candidates for DCI format 2_1; a fourth indication (e.g., dci-Format2-2) to monitor PDCCH candidates for DCI format 2_2; and/or a fifth indication (e.g., dci-Format2-3) to monitor PDCCH candidates for DCI format 2_3. The wireless device may monitor at least one of the first search space sets according to the configuration parameters, for example, based on or in response to the wireless device being in (or switching to) a non-power saving mode (e.g., a non-micro sleep mode). The wireless device may monitor at least one of the second search space sets according to the configuration parameters, for example, based on or in response to the wireless device being in (or switching to) a power saving mode (e.g., a micro sleep mode).

FIG. **37** shows an example of a power saving mode (e.g., micro sleep mode). A base station **3705** may communicate with a wireless device **3710** via a cell and/or using a BWP via the cell. The wireless device **3710** may be configured with the first search space sets and/or the second search space sets. At time **3715**, the base station **3705** may send (e.g., transmit) one or more messages to the wireless device **3710**. At time **3720**, the wireless device **3710** may receive the one or more messages from the base station **3705**. The one or more messages may be one or more RRC messages that comprise configuration parameters for a first search space sets and a second search space set.

Between time **3720** and time **3730**, the wireless device **3710** may monitor PDCCH candidates in at least one of the first search space sets and/or in at least one of the second search space sets, for example based on the one or more RRC messages. At time **3725**, the base station **3705** may send (e.g., transmit) a first DCI to the wireless device **3710**. At time **3730**, the wireless device **3710** may receive the first DCI. The first DCI may indicate a same-slot/cross-slot/multi-slot scheduling of PDSCH resource(s). The wireless device **3710** may switch to a power saving mode (e.g., a micro sleep mode) for a time period, for example, based on or in response to receiving the first DCI. The time period for the micro sleep mode may be indicated by the first DCI. Between time **3730** and time **3740**, the wireless device **3710** may monitor the PDCCH candidates in the at least one of the second search space sets. Monitoring the PDCCH candidates in the at least one of the second search space may occur, for example, during at least a portion of the time period the wireless device **3710** is in the micro sleep mode. Between time **3730** and time **3740**, the wireless device **3710** may skip monitoring the PDCCH candidates in the at least one of the first search space sets. Skipping monitoring the PDCCH candidates in the at least one of the first search space sets may occur, for example, during at least a portion of the time period in the micro sleep mode.

At time **3735**, the wireless device **3710** may receive second DCI from the base station **3705**. The second DCI may be received in the at least one of the second search space sets, for example, during monitoring of the PDCCH candidates in the at least one of the second search space sets. The second DCI may indicate a pre-emption indication, a slot format indication, a power control command, and/or an out-of-order PDSCH scheduling (e.g., for an URLLC data TB). The pre-emption indication may indicate whether or not a portion of the PDSCH resource(s) is pre-empted.

At time **3745**, the wireless device **3710** may receive downlink TB(s). Receiving the downlink TB(s) may be based on the first DCI and/or the second DCI. The wireless device **3710** may puncture first data symbols received on the portion of the PDSCH resource(s), for example, if the pre-emption indication in the second DCI indicates a portion of the PDSCH resource(s) is pre-empted. The wireless device **3710** may decode the downlink TB(s), for example, based on the puncturing and/or the data symbols received on the PDSCH resources except for the portion of the PDSCH resource(s). The wireless device **3710** may decode the downlink TB(s), for example, based on one or more data symbols received on the PDSCH resource(s) and/or if the second DCI indicates that the portion of the PDSCH resource(s) is not pre-empted. If receiving a slot format indication in the second DCI, the wireless device **3710** may determine a reception on PDSCH resource(s), for example, based on the first DCI and/or the second DCI. The wireless device **3710** may receive a downlink TB based on the second DCI, for example, if the wireless device receives an out-of-order PDSCH scheduling in the second DCI.

A base station may send (e.g., transmit) one or more messages to a wireless device. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may indicate a plurality of search space sets. Each search space set may be configured with a skip indicator. A skip indicator for a search space set (e.g., 1 bit) may indicate whether the wireless device may skip monitoring the search space set in a power saving mode (e.g., a micro sleep mode). A skip indicator for a search space set (e.g., 1 bit) may indicate whether the wireless device may not skip monitoring on the search space set in a power saving mode (e.g., a micro sleep mode). The wireless device may switch to a power saving mode (e.g., a micro sleep mode) for a first time period in accordance with the one or more RRC messages, for example, if receiving DCI indicating a same-slot/cross-slot/multi-slot scheduling. The wireless device may skip monitoring a search space set during at least a portion of the first time period, for example, based on or in response to receiving a skip indicator for the search space set. The wireless device may monitor a search space set during at least a portion of the first time period, for example, base on or in response to receiving a skip indicator for the search space set.

A wireless device may receive DCI indicating a pre-emption indication, slot format indication, and/or an out-of-order PDSCH scheduling in a search space set configured by a base station for PDCCH monitoring in a power saving mode (e.g., a micro sleep mode), for example, if the wireless device is in the power saving mode (e.g., the micro sleep mode). The wireless device may correctly decode a downlink TB via a PDSCH resource same-slot/cross-slot/multi-slot scheduled by a downlink assignment DCI (e.g., DCI format 1_0/1_1), for example, based on the DCI. By configuring a search space set for PDCCH monitoring in a power saving mode (e.g., a micro sleep mode), downlink transmission spectrum efficiency and/or power consumption of the wireless device may be improved.

A base station may configure a plurality of search space sets. A wireless device may determine whether the wireless device may skip monitoring PDCCH candidates on the search space set, for example, if the wireless device switches to a power saving mode (e.g., a micro sleep mode). Determining whether the wireless device may skip monitoring PDCCH candidates on a search space set may be based on one or more configuration parameters provided by the base station. The one or more configuration parameters may comprise at least one of: a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (e.g., number) of consecutive slots; a monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set; a quantity (number) of PDCCH candidates per aggregation level; and/or a search space set type (e.g., common, wireless device-specific, etc.). The wireless device may skip monitoring PDCCH candidates in the search space set, for example, based on or in response to the search space set type of the search space set indicating a wireless device-specific search space set. If the search space set is a common search space set, the one or more configuration parameters may comprise a first indication (e.g., dci-Format0-0-AndFormat1-0) to monitor PDCCH candidates for DCI format 0_0 and/or DCI format 1_0); a second indication (e.g., dci-Format2-0) to monitor PDCCH candidates for DCI format 2_0 and/or a corresponding CCE aggregation level; a third indication (e.g., dci-Format2-1) to monitor PDCCH candidates for DCI format 2_1; a fourth indication (e.g., dci-Format2-2) to monitor PDCCH candidates for DCI format 2_2; and/or a fifth indication (e.g., dci-Format2-3) to monitor PDCCH candidates for DCI format 2_3. If the wireless device is in a power saving mode (e.g., a micro sleep mode), the wireless device may not skip monitoring PDCCH candidates for DCI format 2_1 in the common search space set, for example, based on or in response to the third indication of the one or more configuration parameters of a common search space set indicating monitoring PDCCH candidates for DCI format 2_1.

FIG. **38** shows an example of a power saving mode (e.g., micro sleep mode). A base station **3805** may communicate with a wireless device **3810** via a cell and/or using a BWP via the cell. At time **3815**, the base station **3805** may send (e.g., transmit) first DCI to the wireless device **3810**. At time T**1** **3820**, the wireless device **3810** may receive the first DCI from the base station **3805**. The first DCI may indicate a PDSCH resource for a same-slot/cross-slot/multi-slot downlink scheduling. The wireless device **3810** may switch to a power saving mode (e.g., a micro sleep mode) for a first time period (e.g., time **3820** T**1**-time **3835** Tn), for example, based on or in response to receiving the first DCI. The wireless device **3810** may skip monitoring first search space set(s), for example, during at least a portion of the first time period. The wireless device **3810** may monitor second search space set(s), for example, during at least a portion of the first time period. The second search space set(s) may comprise a common search space set for a group common DCI (e.g., DCI format 2_0/2_1/2_2/2_3). Additionally or alternatively, the second search space set(s) may comprise a wireless device-specific search space set (e.g., dedicated for URLLC data transmission), for example, if a quantity (e.g., number) of PDCCH monitoring occasions of the wireless device-specific search space set in a slot is greater than 1 (or other value). During the monitoring the second search space set(s), the wireless device **3810** may receive second DCI from the base station **3805**.

At time **3825**, the base station **3805** may send (e.g., transmit) second DCI to the wireless device **3810**. At time **3830**, the wireless device **3810** may receive the second DCI from the base station **3805**. The second DCI may indicate a slot format indication, a pre-emption, a power control command, and/or an out-of-order PDSCH scheduling (e.g., URLLC data transmission). At time **3835**, the wireless device **3810** may receive downlink transport block(s). The downlink transport block(s) may be received via a PDSCH resource, for example, based on the first DCI and/or the second DCI. At time **3840**, the wireless device **3810** may send (e.g., transmit) a PUCCH/SRS/PUSCH to the base station **3805**. The PUCCH/SRS/PUSHCH may be based on the first DCI and/or the second DCI. At time **3845**, the base station **3805** may receive the PUCCH/SRS/PUSCH from the wireless device **3810**.

A wireless device may determine whether the wireless device may skip monitoring a search space set, for example, based on one or more configuration parameters of the search space set, if the wireless device is in a power saving mode (e.g., a micro sleep mode). The wireless device may receive DCI from the base station, for example, based on the determination of whether the wireless device may skip monitoring the search space set and/or during the power saving mode (e.g., the micro sleep mode). The wireless device may decode a downlink TB via a PDSCH resource same-slot/cross-slot/multi-slot scheduled by a downlink assignment DCI (e.g., DCI format 1_0/1_1), for example, based on the DCI received from the base station. By allowing the wireless device to skip monitoring a search space set, downlink transmission spectrum efficiency and/or the wireless device's power consumption may be improved.

FIG. **39** shows an example of a power saving mode (e.g., micro sleep mode) such as in carrier aggregation and/or dual connectivity. A power saving mode (e.g., micro sleep mode) may be implemented based on one or more of the examples in FIGS. **30A-30C**. A base station (not shown) may send (e.g., transmit) one or more messages to a wireless device **3910**. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise configuration parameters for a first cell **3920** and at least a second cell **3930** (or any other quantity of cells). The first cell **3920** may comprise a first active bandwidth part (BWP) of a first plurality of BWPs. The second cell **3930** may comprise a second active BWP of a second plurality of BWPs. Configuration parameters of the first cell **3920** may indicate a first plurality of search space sets. Configuration parameters of the second cell **3930** may indicate a second plurality of search space sets. The second plurality of search space sets may comprise information for scheduling (e.g., self-scheduling, same-slot scheduling, cross-slot scheduling, multi-slot scheduling, etc.). The base station may indicate (e.g., configure) one or more configuration parameters for a power saving mode (e.g., a micro sleep mode) on the first cell **3920** and/the second cell **3930** according to at least one of the examples described herein with respect to FIGS. **34-38**, including but not limited to, for example the following parameters: a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of slots (e.g., consecutive or non-consecutive); a first monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set. For example, the one or more configuration parameters for a power saving mode (e.g., a micro sleep mode) may comprise at least one of: a first search space set; a second search space set; a first plurality of search space sets; a second plurality of search space sets; a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of slots (e.g., consecutive or non-consecutive); a first monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (or switches to) a non-power saving mode (e.g., a non-micro sleep mode); a second monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (or switches to) a power saving mode (e.g., a micro sleep mode); a quantity (e.g., number) of PDCCH candidates per aggregation level; a search space set type (e.g., common, wireless device-specific, etc.); a first monitoring indication; and/or a second monitoring indication.

The wireless device **3910** may monitor one or more PDCCH candidates, for example, if the wireless device **3910** is in a non-power saving mode (e.g., a non-micro sleep mode). The wireless device **3910** may monitor one or more PDCCH candidates in the first plurality of search space sets on the first cell **3920** in a quantity (e.g., number) of symbols in a slot. At time **3915**, the wireless device **3910** may receive DCI. The DCI may be received via a first cell. The DCI may indicate same-slot/cross-slot/multi-slot scheduling on the first cell. The wireless device **3910** may switch to a power saving mode (e.g., a micro sleep mode) for a first time period, for example, based on or in response to receiving the DCI. The wireless device **3910** may switch to a power saving mode (e.g., a micro sleep mode) on the first cell **3920** and/or on the second cell **3930** separately or independently. The wireless device may switch to the power saving mode (e.g., micro sleep mode) on the first cell, for example, by applying cross-slot scheduling parameters for PDSCH receptions on the first cell (or an active BWP of the first cell). The wireless device may apply the cross-slot scheduling parameters, for example, based on receiving the DCI on the first cell. The wireless device may maintain the non-power saving mode on the second cell (or an active BWP of the second cell), for example, by applying same-slot scheduling parameters for PDSCH receptions on the second cell. The same-slot scheduling parameters may be based on receiving the DCI on the first cell and/or not receiving the DCI on the second cell. The wireless device may stop monitoring PDCCH candidates in at least a first search space set of the first plurality of search space sets on the first cell **3920**, for example, during the first time period. The wireless device **3910** may monitor PDCCH candidates in at least a second search space set of the first plurality of search space sets on the first cell **3920**, for example, during the first time period. The wireless device **3910** may monitor PDCCH candidates in the first plurality of search space sets in a subset of the quantity (e.g., number) of symbols in a slot, for example, during the first time period. The wireless device **3910**, during a power saving mode (e.g., a micro sleep mode) on the first cell, may maintain (e.g., keep) the second cell **3930** in a non-power saving mode (e.g., non-micro sleep mode), for example, if the wireless device **3910** switches the first cell **3920** to power saving mode (e.g., micro sleep mode). The wireless device **3910** may maintain the second cell **3930** in the non-power saving mode (e.g., non-micro sleep mode), for example, if the second cell **3930** is configured to be self-scheduled. If the second cell **3930** is in the non-power saving mode (e.g., non-micro sleep mode), the wireless device **3910** may monitor PDCCH candidates on the second cell **3930** in the second plurality of search space sets on a quantity (e.g., number) of symbols in a slot.

FIG. **40** shows an example of a power saving mode (e.g., micro sleep mode) such as in in carrier aggregation and/or dual connectivity. A base station (not shown) may send (e.g., transmit) one or more messages to a wireless device **4010**. The one or more messages may comprise one or more RRC messages. The one or more RRC messages may comprise configuration parameters of a first cell **4020** and a second cell **4030**. Configuration parameters of the first cell **4020** may indicate a plurality of search space sets. Configuration parameters of the second cell **4030** may indicate that the second cell **4030** may be cross-carrier scheduled by one or more cells. For example, second cell **4030** may be cross-carrier scheduled by the first cell **4020**. The base station may indicate (e.g., configure) one or more configuration parameters for a power saving mode (e.g., a micro sleep mode) on the first cell **4020** and/or on the second cell **4030** according to one or more of the examples discussed above with respect to FIGS. **34-38**. As described herein, the one or more configuration parameters for a power saving mode (e.g., a micro sleep mode) may comprise at least one of: a first search space set; a second search space set; a first plurality of search space sets; a second plurality of search space sets; a search space set ID; a control resource ID associated with the search space set; a monitoring periodicity and/or offset indicator (e.g., in unit of slot); a duration field indicating a quantity (number) of slots (e.g., consecutive or non-consecutive); a first monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (or switches to) a non-power saving mode (e.g., a non-micro sleep mode); a second monitoring indicator (e.g., 14-bit) indicating on which symbol(s) in a slot the wireless device may monitor PDCCH in the search space set, for example, if the wireless device is in (or switches to) a power saving mode (e.g., a micro sleep mode); a quantity (e.g., number) of PDCCH candidates per aggregation level; a search space set type (e.g., common, wireless device-specific, etc.); a first monitoring indication; and/or a second monitoring indication.

The wireless device **4010** may monitor one or more PDCCH candidates, for example, if the wireless device **4010** is in a non-power saving mode (e.g., a non-micro sleep mode). The wireless device **4010** may monitor one or more PDCCH candidates in the plurality of search space sets for the first cell **4020** and/or the second cell **4030** on the first cell in a quantity (e.g., number) of symbols in a slot. At time **4015**, the wireless device **4010** may receive DCI from the base station via the first cell **4020**. The DCI may indicate a same-slot/cross-slot/multi-slot scheduling on the first cell **4020** and/or on the second cell **4030**. The wireless device **4010** may switch to a power saving mode (e.g., a micro sleep mode) on the first cell **4020** and/or on the second cell **4030** for a first time period, for example, based on or in response to receiving the DCI. The wireless device **4010** may switch to a power saving mode (e.g., a micro sleep mode) on the first cell **4020** and/or on the second cell **4030** jointly and/or simultaneously. The wireless device may stop monitoring PDCCH candidates in at least a first search space set of the plurality of search space sets on the first cell **4020**, for example, during the first time period. The first search space set may be for the first cell **4020** and/or the second cell **4030**. The wireless device **4010** may monitor PDCCH candidates in at least a second search space set of the plurality of search space sets on the first cell **4020**, for example, during the first time period. The second search space set may be for the first cell **4020** and/or the second cell **4030**. The wireless device **4010** may monitor PDCCH candidates in the plurality of search space sets in a subset of the quantity (e.g., number) of symbols in a slot, for example, during the first time period. The wireless device **4010** may switch to micro sleep mode on the second cell **4030**, for example, based on or in response to the wireless device **4010** switching to a power saving mode (e.g., a micro sleep mode) on the first cell **4020**. The wireless device **4010** may switch the second cell **4030** to a power saving mode (e.g., a micro sleep mode), for example, if the second cell **4030** is configured to be cross-carrier scheduled by the first cell **4020**.

A wireless device may receive DCI from a base station via a first cell. The DCI may indicate same-slot/cross-slot/multi-slot scheduling on a second cell. The wireless device may switch to a power saving mode (e.g., a micro sleep mode) on the second cell for a first time period, for example, based on or in response to receiving the DCI. The wireless device may maintain a non-power saving mode (e.g., a non-micro sleep mode) on the first cell, for example, based on or in response to receiving the DCI. The wireless device may stop monitoring PDCCH candidates in at least a first search space set of a plurality of search space sets for the second cell, for example, during the first time period. The first search space set may be on the first cell. The wireless device may monitor PDCCH candidates in at least a second search space set of the plurality of search space sets for the second cell, for example, during the first time period. The second search space set may be on the first cell. The wireless device may monitor PDCCH candidates in the plurality of search space sets for the first cell on the first cell, for example, during the first time period.

FIG. **41** shows an example of a power saving mode (e.g., micro sleep mode) such as in bandwidth part switching. FIG. **41** shows a base station **4105** communicating with a wireless device **4110** via a cell **4120**. The cell **4120** may comprise a first bandwidth part (BWP) **4122** and a second BWP **4124**. At time **4125**, the base station **4105** may send (e.g., transmit) DCI to the wireless device **4110** via/using the first BWP **4122** of the cell **4120**. At time **4130**, the wireless device **4110** may receive the DCI from the base station **4105**. The DCI may indicate a cross-slot scheduling on the second BWP **4124**. Additionally or alternatively, the DCI may indicate multi-slot scheduling on the second BWP **4124**. The wireless device **4110** may switch an active BWP from the first BWP **4122** to the second BWP **4124**, for example, based on or in response to receiving the DCI from the base station **4105**. The wireless device **4110** may switch to a power saving mode (e.g., a micro sleep mode), for example, after the wireless device **4110** switches to the second BWP **4124**. The wireless device **4110** may stay in the power saving mode (e.g., the micro sleep mode) on the second BWP **4124** for a first time period. The wireless device **4110** may stop monitoring PDCCH candidates in at least one of a plurality of search space sets configured on the second BWP **4124**, for example, during the first time period. The wireless device **4110** may skip receiving CSI-RSs/PDSCH/PDCCH on the second BWP **4124**, for example, during the first time period. The wireless device **4110** may not expect to receive a PDCCH/PDSCH/CSI-RS on the second BWP **4124**, during the first time period. The wireless device **4110** may switch from the power saving mode (e.g., micro sleep mode) to a normal function mode, for example, based on the DCI. The wireless device **4110** may receive PDCCH/PDSCH/CSI-RSs, for example, during the normal function mode. At time **4135**, the base station **4105** may send (e.g., transmit) a downlink TB, for example, based on the DCI. At time **4140**, the wireless device **4110** may receive the downlink TB on the second BWP **4124**.

FIG. **42** shows an example of a power saving mode (e.g., micro sleep mode) such as in bandwidth part switching. A process **4200** for determining a power saving mode (e.g., a micro sleep mode) with a BWP switching may be performed by a wireless device and/or a base station. At step **4210**, a wireless device may receive DCI from a base station. The DCI may be received via a first BWP. Additionally or alternatively, the DCI may be received at a first time (e.g., a first symbol or a first slot). The DCI may indicate a cross-slot downlink scheduling at a second time (e.g., a second symbol of a second slot). At step **4220**, the wireless device may determine whether the DCI indicates an active BWP switching from the first BWP to a second BWP.

The wireless device may switch the active BWP from the first BWP to the second BWP at step **4230**, for example, if the DCI indicates switching the active BWP from the first BWP to the second BWP. At step **4240**, the wireless device may determine whether to switch to a power saving mode (e.g., a micro sleep mode) on the second BWP. The determination of whether to switch to a power saving mode (e.g., a micro sleep mode) on the second BWP may be based on at least one of: a time gap between the first time and the second time (e.g., in units of slots of PDSCH transmission on the second BWP and/or in units of microseconds); a transition time for switching from the first BWP to the second BWP (e.g., in units of microseconds and/or slots); numerology parameters (e.g., subcarrier spacing, CP length, and/or symbol/slot length) of the first BWP and/or the second BWP; and/or a first time value. The first time value may be in units of slots of PDSCH transmissions on the second BWP. Additionally or alternatively, the first time value may be in units of microseconds (or any other time duration). The first time value may be configured by a base station and/or preconfigured to a fixed value (e.g., in units of slots of PDSCH transmissions on the second BWP and/or in units of microseconds or any other time duration). The wireless device may switch to the power saving mode (e.g., micro sleep mode) on the second BWP for a first time period in step **4250**, for example, based on or in response to a value of the time gap minus the transition time being greater than the first value. The first time period may be determined based on the time gap and/or the transition time. At step **4260**, the wireless device may receive a downlink transport block on the second BWP, for example, after the first time period. The downlink transport block may be scheduled based on the DCI. At step **4240**, the wireless device may not switch to the power saving mode (e.g., micro sleep mode) on the second BWP, for example, based on or in response to a value of the time gap minus the transition time being equal to or less than the first value. At step **4260**, the wireless device may receive a downlink transport block on the second BWP, for example, based on or in response to not switching to the power saving mode (e.g., micro sleep mode). The downlink transport block may be received on the second BWP, for example, based on the DCI.

The wireless device may switch to a power saving mode (e.g., micro sleep mode) on the first BWP in step **4250**, for example, if the DCI indicates that active BWP is the first BWP (e.g., no active BWP switching). The switch to a power saving mode (e.g., a micro sleep mode) may be based on the DCI. The switch to micro sleep mode may be for a time period, for example, if the DCI indicates a cross-slot scheduling on the first BWP. The time period may be determined based on one or more parameters of the DCI (e.g., K0 indicated in the DCI). In step **4260**, the wireless device may wake up to receive downlink TB, for example, after the time period. The wake up may be based on the DCI.

A wireless device may receive one or more radio resource control messages comprising configuration parameters of a search space set for a pre-emption indication. The wireless device may receive first DCI comprising a downlink resource assignment parameter. The wireless device may switch to a power saving mode (e.g., a micro sleep mode) for a first period, for example, based on or in response to the downlink resource assignment parameter indicating a cross-slot/multi-slot downlink scheduling. The wireless device may monitor the search space set for the pre-emption indication, for example, during at least a portion of the first period. The wireless device may receive second DCI comprising the pre-emption indication via a downlink control channel in the search space set. The wireless device may receive a downlink transport block, for example, based on the first downlink control information and/or the pre-emption indication. The wireless device may skip monitoring one or more of a plurality of search space sets, for example, during the first period. The wireless device may switch a radio frequency module to a power saving mode (e.g., micro sleep mode), for example, during the first period. during the first period, The wireless device may switch at least portion of a front-end hardware to power saving mode, for example during the first period. The wireless device may skip receiving CSI-RSs, for example during the first period. The wireless device may skip receiving PDSCH, for example, during the first period.

A wireless device may receive one or more RRC messages. The one or more RRC messages may comprise configuration parameters for a plurality of search space set of a cell. The plurality of search space sets may comprise at least a first search space set and/or at least a second search space set. The wireless device may monitor the at least first search space set for first DCI. The wireless device may receive the first DCI indicating a downlink resource assignment parameter. The wireless device may switch to a power saving mode (e.g., a micro sleep mode) for a first period, for example, based on or in response to the downlink resource assignment parameter indicating a cross-slot/multi-slot downlink scheduling. The wireless device may monitor the at least second search space set for a second DCI of a pre-emption indication, for example, during at least a portion of the first period. The wireless device may stop monitoring the at least first search space set, for example, during the at least a portion of the first period. The wireless device may receive second DCI via a PDCCH on the at least second search space. The wireless device may receive a downlink transport block, for example, based on the downlink resource assignment parameters and/or the second DCI. The at least first search space set may be a wireless device-specific search space set. The at least second search space set may be a common search space set. The at least second search space set may be a common search space set configured with a monitoring indication indicating PDCCH monitoring for DCI format 2_1. The wireless device may monitor the at least second search space set during at least a portion of the first period, for example, based on one or more configuration parameters of the at least second search space set. The one or more configuration parameters may comprise at least one of: a monitoring indication indicating on which symbol(s) of a slot the wireless device may monitor PDCCH candidates on the at least second search space set in a power saving mode (e.g., a micro sleep mode); a skip indicator indicating whether the wireless device may skip monitoring PDCCH candidates on the at least second search space set; and/or a search space set type (e.g., a wireless device-specific search space, a common search space set, etc.).

A wireless may receive at least one first parameter for a first cell and/or at least one second parameter for a second cell. The at least one first parameter may indicate a first power saving mode associated with cross-slot scheduling. The at least one second parameter may indicate a second power saving mode associated with cross-slot scheduling. The wireless device may receive downlink control information (DCI). The DCI may comprise an indication associated with first cross-slot scheduling for the first cell, for example, based on the first power saving mode. Based on determining that at least one physical downlink shared channel (PDSCH) resource associated with the first cross-slot scheduling is associated with the first cell, the wireless device may receive at least one downlink transport block via the at least one PDSCH resource and based on applying the first cross-slot scheduling to the first cell.

The wireless device may receive second DCI that comprises an indication associated with second cross-slot scheduling for the second cell. Based on determining that at least one PDSCH resource associated with the second cross-slot scheduling is associated with the second cell, the wireless device may receive at least one second downlink transport block via the at least one PDSCH resource associated with the second cross-slot scheduling and based on applying the second cross-slot scheduling to the second cell. The at least one first parameter may comprise a first time offset between a first downlink control channel associated with the DCI and the at least one PDSCH resource associated with the first cross-slot scheduling. The wireless device may apply the first time offset, for example, if applying the first cross-slot scheduling. The at least one second parameter may comprise a second time offset between a second downlink control channel associated with the second DCI and the at least one PDSCH resource associated with the second cross-slot scheduling. The wireless device may apply the second time offset, for example, if applying the second cross-slot scheduling. The first cross-slot scheduling may be on a first bandwidth part associated with the first cell, and the second cross-slot scheduling may be on a second bandwidth part associated with the second cell. The first power saving mode may be a same power saving mode as the second power saving mode. The same power saving mode may comprise a micro sleep mode. The indication may comprise at least one of: a one-bit indication of the first cross-slot scheduling of the first cell, a cross-slot scheduling configuration, or an offset indicator.

The wireless device may receive the at least one downlink transport block via the PDSCH at least one resource. Applying the first cross-slot scheduling to the first cell may comprise skipping monitoring, via the first cell, at least one first slot of the at least one PDSCH resource. Applying the first cross-slot scheduling to the first cell may also comprise monitoring, via the first cell, at least one second slot of the at least one PDSCH resource. The at least one first parameter may further indicate a first same slot scheduling and the at least one second parameter may further indicate a second same slot scheduling.

A wireless device may receive at least one first parameter and/or at least one second parameter. The at least one parameter may indicate a first time offset between a first downlink control channel and a first downlink shared channel for a first cell. The at least one second parameter may indicate a second time offset between a second downlink control channel and a second downlink shared channel for a second cell. The wireless device may receive downlink control information (DCI). The DCI may comprise an indication, based on the first time offset, associated with at least one physical downlink shared channel (PDSCH) resource for at least one downlink transport block. Based on determining that the at least one PDSCH resource is associated with the first cell, the wireless device may receive the at least one PDSCH resource via the at least one PDSCH resource and based on applying the first time offset to the first cell.

The wireless device may receive second DCI may comprise an indication, based on the second time offset, associated with at least one second PDSCH resource for at least one second downlink transport block. Based on determining that at least one second PDSCH resource is associated with the second cell, the wireless device may receive the at least one downlink transport block via the at least one second PDSCH resource and based on applying the second time offset to the second cell. The first time offset may be on a first bandwidth part associated with the first cell, and the second time offset may be on a second bandwidth part associated with the second cell. The indication may comprise at least one of: a one-bit indication of a cross-slot scheduling of the first cell, a cross-slot scheduling configuration, or an offset indicator. The wireless device may receive the at least one downlink transport block via the at least one PDSCH resource. Applying the first time offset to the first cell may comprise skipping monitoring, via the first cell, at least one first slot of the at least one PDSCH resource, and monitoring, via the first cell, at least one second slot of the at least one PDSCH resource.

A wireless device may receive at least one first parameter and/or at least one second parameter. The at least one first parameter may indicate a first time offset associated with a first cell, and the at least one second parameter may indicate a second time offset associated with a second cell. The wireless device may receive downlink control information (DCI) comprise an indication, based on the first time offset, associated with at least one physical downlink shared channel (PDSCH) resource for at least one downlink transport block. The wireless device may receive, via the at least one PDSCH resource and based on applying the first time offset to the first cell, the at least one downlink transport block. The wireless device may receive second DCI comprising an indication, based on the second time offset, associated with at least one second PDSCH resource for at least one second downlink transport block. The wireless device may receive, via the at least one second PDSCH resource and based on applying the second time offset to the second cell, the at least one second downlink transport block. The first time offset may be on a first bandwidth part associated with the first cell, and the second time offset may be on a second bandwidth part associated with the second cell. The indication may comprise a one-bit indication of a cross-slot scheduling of the first cell, a cross-slot scheduling configuration, or an offset indicator. Applying the first time offset to the first cell may comprise skipping monitoring, via the first cell, at least one first slot of the at least one PDSCH resource, and monitoring, via the first cell, at least one second slot of the at least one PDSCH resource.

FIG. **43** shows example elements of a computing device that may be used to implement any of the various devices described herein, including, e.g., the base station **120**A and/or **120**B, the wireless device **110** (e.g., **110**A and/or **110**B), or any other base station, wireless device, or computing device described herein. The computing device **4300** may include one or more processors **4301**, which may execute instructions stored in the random-access memory (RAM) **4303**, the removable media **4304** (such as a Universal Serial Bus (USB) drive, compact disk (CD) or digital versatile disk (DVD), or floppy disk drive), or any other desired storage medium. Instructions may also be stored in an attached (or internal) hard drive **4305**. The computing device **4300** may also include a security processor (not shown), which may execute instructions of one or more computer programs to monitor the processes executing on the processor **4301** and any process that requests access to any hardware and/or software components of the computing device **4300** (e.g., ROM **4302**, RAM **4303**, the removable media **4304**, the hard drive **4305**, the device controller **4307**, a network interface **4309**, a GPS **4311**, a Bluetooth interface **4312**, a WiFi interface **4313**, etc.). The computing device **4300** may include one or more output devices, such as the display **4306** (e.g., a screen, a display device, a monitor, a television, etc.), and may include one or more output device controllers **4307**, such as a video processor. There may also be one or more user input devices **4308**, such as a remote control, keyboard, mouse, touch screen, microphone, etc. The computing device **4300** may also include one or more network interfaces, such as a network interface **4309**, which may be a wired interface, a wireless interface, or a combination of the two. The network interface **4309** may provide an interface for the computing device **4300** to communicate with a network **4310** (e.g., a RAN, or any other network). The network interface **4309** may include a modem (e.g., a cable modem), and the external network **4310** may include communication links, an external network, an in-home network, a provider's wireless, coaxial, fiber, or hybrid fiber/coaxial distribution system (e.g., a DOCSIS network), or any other desired network. Additionally, the computing device **4300** may include a location-detecting device, such as a global positioning system (GPS) microprocessor **4311**, which may be configured to receive and process global positioning signals and determine, with possible assistance from an external server and antenna, a geographic position of the computing device **4300**.

The example in FIG. **43** may be a hardware configuration, although the components shown may be implemented as software as well. Modifications may be made to add, remove, combine, divide, etc. components of the computing device **4300** as desired. Additionally, the components may be implemented using basic computing devices and components, and the same components (e.g., processor **4301**, ROM storage **4302**, display **4306**, etc.) may be used to implement any of the other computing devices and components described herein. For example, the various components described herein may be implemented using computing devices having components such as a processor executing computer-executable instructions stored on a computer-readable medium, as shown in FIG. **43**. Some or all of the entities described herein may be software based, and may co-exist in a common physical platform (e.g., a requesting entity may be a separate software process and program from a dependent entity, both of which may be executed as software on a common computing device).

The disclosed mechanisms herein may be performed if certain criteria are met, for example, in a wireless device, a base station, a radio environment, a network, a combination of the above, and/or the like. Example criteria may be based on, for example, wireless device and/or network node configurations, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. If the one or more criteria are met, various examples may be used. It may be possible to implement examples that selectively implement disclosed protocols.

A base station may communicate with a mix of wireless devices. Wireless devices and/or base stations may support multiple technologies, and/or multiple releases of the same technology. Wireless devices may have some specific capability(ies) depending on wireless device category and/or capability(ies). A base station may comprise multiple sectors. A base station communicating with a plurality of wireless devices may refer to base station communicating with a subset of the total wireless devices in a coverage area. Wireless devices referred to herein may correspond to a plurality of wireless devices of a particular LTE or 5G release with a given capability and in a given sector of a base station. A plurality of wireless devices may refer to a selected plurality of wireless devices, and/or a subset of total wireless devices in a coverage area. Such devices may operate, function, and/or perform based on or according to drawings and/or descriptions herein, and/or the like. There may be a plurality of base stations or a plurality of wireless devices in a coverage area that may not comply with the disclosed methods, for example, because those wireless devices and/or base stations perform based on older releases of LTE or 5G technology.

One or more features described herein may be implemented in a computer-usable data and/or computer-executable instructions, such as in one or more program modules, executed by one or more computers or other devices. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types when executed by a processor in a computer or other data processing device. The computer executable instructions may be stored on one or more computer readable media such as a hard disk, optical disk, removable storage media, solid state memory, RAM, etc. The functionality of the program modules may be combined or distributed as desired. The functionality may be implemented in whole or in part in firmware or hardware equivalents such as integrated circuits, field programmable gate arrays (FPGA), and the like. Particular data structures may be used to more effectively implement one or more features described herein, and such data structures are contemplated within the scope of computer executable instructions and computer-usable data described herein.

Many of the elements in examples may be implemented as modules. A module may be an isolatable element that performs a defined function and has a defined interface to other elements. The modules may be implemented in hardware, software in combination with hardware, firmware, wetware (i.e., hardware with a biological element) or a combination thereof, all of which may be behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language configured to be executed by a hardware machine (such as C, C++, Fortran, Java, Basic, Matlab or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEWMathScript. Additionally or alternatively, it may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware may comprise: computers, microcontrollers, microprocessors, application-specific integrated circuits (ASICs); field programmable gate arrays (FPGAs); and complex programmable logic devices (CPLDs). Computers, microcontrollers, and microprocessors may be programmed using languages such as assembly, C, C++ or the like. FPGAs, ASICs, and CPLDs may be programmed using hardware description languages (HDL), such as VHSIC hardware description language (VHDL) or Verilog, which may configure connections between internal hardware modules with lesser functionality on a programmable device. The above-mentioned technologies may be used in combination to achieve the result of a functional module.

A non-transitory tangible computer readable media may comprise instructions executable by one or more processors configured to cause operations of multi-carrier communications described herein. An article of manufacture may comprise a non-transitory tangible computer readable machine-accessible medium having instructions encoded thereon for enabling programmable hardware to cause a device (e.g., a wireless device, wireless communicator, a wireless device, a base station, and the like) to allow operation of multi-carrier communications described herein. The device, or one or more devices such as in a system, may include one or more processors, memory, interfaces, and/or the like. Other examples may comprise communication networks comprising devices such as base stations, wireless devices or user equipment (wireless device), servers, switches, antennas, and/or the like. A network may comprise any wireless technology, including but not limited to, cellular, wireless, WiFi, 4G, 5G, any generation of 3GPP or other cellular standard or recommendation, wireless local area networks, wireless personal area networks, wireless ad hoc networks, wireless metropolitan area networks, wireless wide area networks, global area networks, space networks, and any other network using wireless communications. Any device (e.g., a wireless device, a base station, or any other device) or combination of devices may be used to perform any combination of one or more of steps described herein, including, for example, any complementary step or steps of one or more of the above steps.

Although examples are described above, features and/or steps of those examples may be combined, divided, omitted, rearranged, revised, and/or augmented in any desired manner Various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this description, though not expressly stated herein, and are intended to be within the spirit and scope of the descriptions herein. Accordingly, the foregoing description is by way of example only, and is not limiting.

The invention claimed is:

1. A method comprising:

receiving, by a wireless device, one or more radio resource control (RRC) messages comprising one or more parameters indicating a plurality of time offsets for downlink scheduling of a plurality of cells, wherein each time offset, of the plurality of time offsets, is for a cell of the plurality of cells;

receiving downlink control information (DCI) comprising an indication of a first time offset, of the plurality of time offsets, for reception of at least one downlink transport block via at least one physical downlink shared channel (PDSCH) resource of a first cell of the plurality of cells; and

receiving, via the at least one PDSCH resource and after the first time offset, the at least one downlink transport block.

2. The method of claim **1**, further comprising:

receiving second DCI comprising an indication of a second time offset for reception of at least one second downlink transport block via at least one second PDSCH resource of a second cell; and

receiving, via the at least one second PDSCH resource and after the second time offset, the at least one second downlink transport block.

3. The method of claim **1**, wherein the plurality of time offsets is associated with a plurality of power saving modes.

4. The method of claim **1**, wherein the receiving the at least one downlink transport block occurs during a time in which the wireless device is:

skipping monitoring at least one first slot of the at least one PDSCH resource; and

monitoring at least one second slot of the at least one PDSCH resource.

5. The method of claim **1**, wherein the receiving the at least one downlink transport block comprises applying the first time offset to the first cell.

6. The method of claim **1**, wherein:

the first time offset is associated with cross-slot scheduling for the first cell; and

a second time offset is associated with cross-slot scheduling for a second cell.

7. The method of claim **1**, wherein the one or more parameters comprise:
at least one first parameter indicating a first same slot scheduling; and
at least one second parameter indicating a second same slot scheduling.

8. A method comprising:
sending, by a base station to a wireless device, one or more radio resource control (RRC) messages comprising one or more parameters indicating a plurality of time offsets for downlink scheduling of a plurality of cells, wherein each time offset, of the plurality of time offsets, is for a cell of the plurality of cells;
sending downlink control information (DCI) comprising an indication of a first time offset, of the plurality of time offsets, for reception of at least one downlink transport block via at least one physical downlink shared channel (PDSCH) resource of a first cell of the plurality of cells; and
sending, via the at least one PDSCH resource and after the first time offset, the at least one downlink transport block.

9. The method of claim **8**, further comprising:
sending second DCI comprising an indication of a second time offset for reception of at least one second downlink transport block via at least one second PDSCH resource of a second cell; and
sending, via the at least one second PDSCH resource and after the second time offset, the at least one second downlink transport block.

10. The method of claim **8**, wherein the plurality of time offsets is associated with a plurality of power saving modes.

11. The method of claim **8**, wherein:
the first time offset is associated with cross-slot scheduling for the first cell; and
a second time offset is associated with cross-slot scheduling for a second cell.

12. The method of claim **8**, wherein the one or more parameters comprise:
at least one first parameter indicating a first same slot scheduling; and
at least one second parameter indicating a second same slot scheduling.

13. A wireless device, comprising:
one or more processors; and
memory storing instructions that, when executed by the one or more processors, cause the wireless device to:
receive one or more radio resource control (RRC) messages comprising one or more parameters indicating a plurality of time offsets for downlink scheduling of a plurality of cells, wherein each time offset, of the plurality of time offsets, is for a cell of the plurality of cells;
receive downlink control information (DCI) comprising an indication of a first time offset, of the plurality of time offsets, for reception of at least one downlink transport block via at least one physical downlink shared channel (PDSCH) resource of a first cell of the plurality of cells; and
receive, via the at least one PDSCH resource and after the first time offset, the at least one downlink transport block.

14. The wireless device of claim **13**, wherein the instructions, when executed by the one or more processors, cause the wireless device to:
receive second DCI comprising an indication of a second time offset for reception of at least one second downlink transport block via at least one second PDSCH resource of a second cell; and
receive, via the at least one second PDSCH resource and after the second time offset, the at least one second downlink transport block.

15. The wireless device of claim **13**, wherein the plurality of time offsets is associated with a plurality of power saving modes.

16. The wireless device of claim **13**, wherein the instructions, when executed by the one or more processors, cause the wireless device to receive the at least one downlink transport block during a time in which the wireless device is:
skipping monitoring at least one first slot of the at least one PDSCH resource; and
monitoring at least one second slot of the at least one PDSCH resource.

17. The wireless device of claim **13**, wherein the instructions, when executed by the one or more processors, cause the wireless device to receive the at least one downlink transport block by applying the first time offset to the first cell.

18. The wireless device of claim **13**, wherein:
the first time offset is associated with cross-slot scheduling for the first cell; and
a second time offset is associated with cross-slot scheduling for a second cell.

19. The wireless device of claim **13**, wherein the one or more parameters comprise:
at least one first parameter indicating a first same slot scheduling; and
at least one second parameter indicating a second same slot scheduling.

20. A base station, comprising:
one or more processors; and
memory storing instructions that, when executed by the one or more processors, cause the base station to:
send, to a wireless device, one or more radio resource control (RRC) messages comprising one or more parameters indicating a plurality of time offsets for downlink scheduling of a plurality of cells, wherein each time offset, of the plurality of time offsets, is for a cell of the plurality of cells;
send downlink control information (DCI) comprising an indication of a first time offset, of the plurality of time offsets, for reception of at least one downlink transport block via at least one physical downlink shared channel (PDSCH) resource of a first cell of the plurality of cells; and
send, via the at least one PDSCH resource and after the first time offset, the at least one downlink transport block.

21. The base station of claim **20**, wherein the instructions, when executed by the one or more processors, cause the base station to:
send second DCI comprising an indication of a second time offset for reception of at least one second downlink transport block via at least one second PDSCH resource of a second cell; and
send, via the at least one second PDSCH resource and after the second time offset, the at least one second downlink transport block.

22. The base station of claim **20**, wherein the plurality of time offsets is associated with a plurality of power saving modes.

23. The base station of claim **20**, wherein:
the first time offset is associated with cross-slot scheduling for the first cell; and

a second time offset is associated with cross-slot scheduling for a second cell.

24. The base station of claim **20**, wherein the one or more parameters comprise:

at least one first parameter indicating a first same slot scheduling; and

at least one second parameter indicating a second same slot scheduling.

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