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(54) **MANAGING BUFFER STATUS REPORTING DURING SMALL DATA TRANSMISSION**

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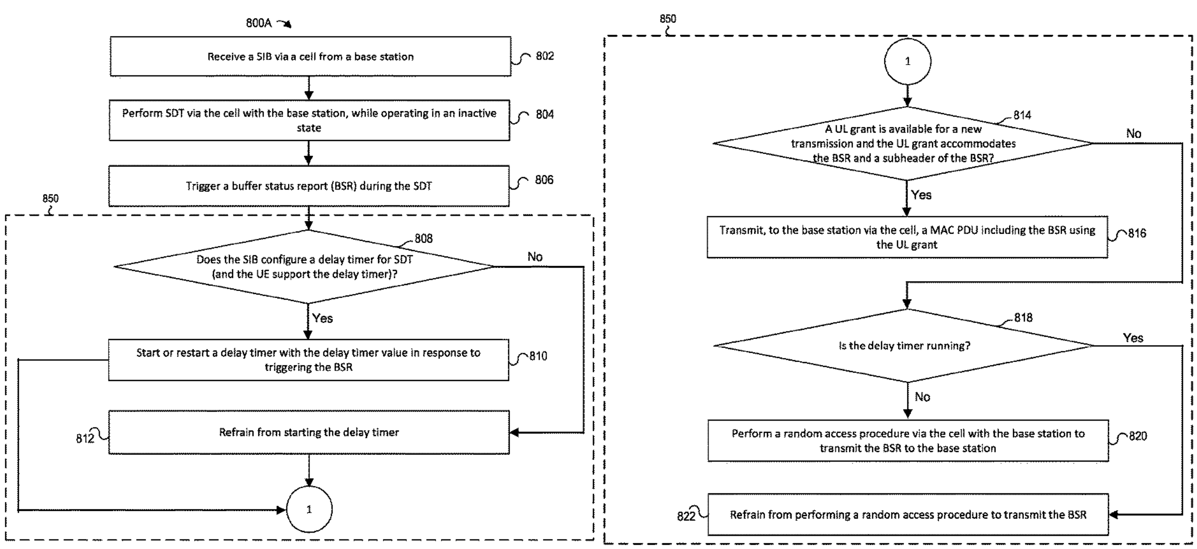
H04W 74/0833 (2024.01)

(52) **U.S. Cl.**
CPC ***H04W 28/0278*** (2013.01); ***H04W 72/21*** (2023.01); ***H04W 74/0833*** (2013.01)

(57) **ABSTRACT**

A user equipment (UE) receives, from a radio access network (RAN), a system information block (SIB). The UE triggers, when communicating data with the RAN in an inactive or idle state associated with a protocol for controlling radio resources, a buffer status report (BSR) to the RAN; and in response to the triggering and when the SIB includes a configuration of a delay timer for communicating data in the inactive or idle state, the UE starts or restarts the delay timer according to the configuration.



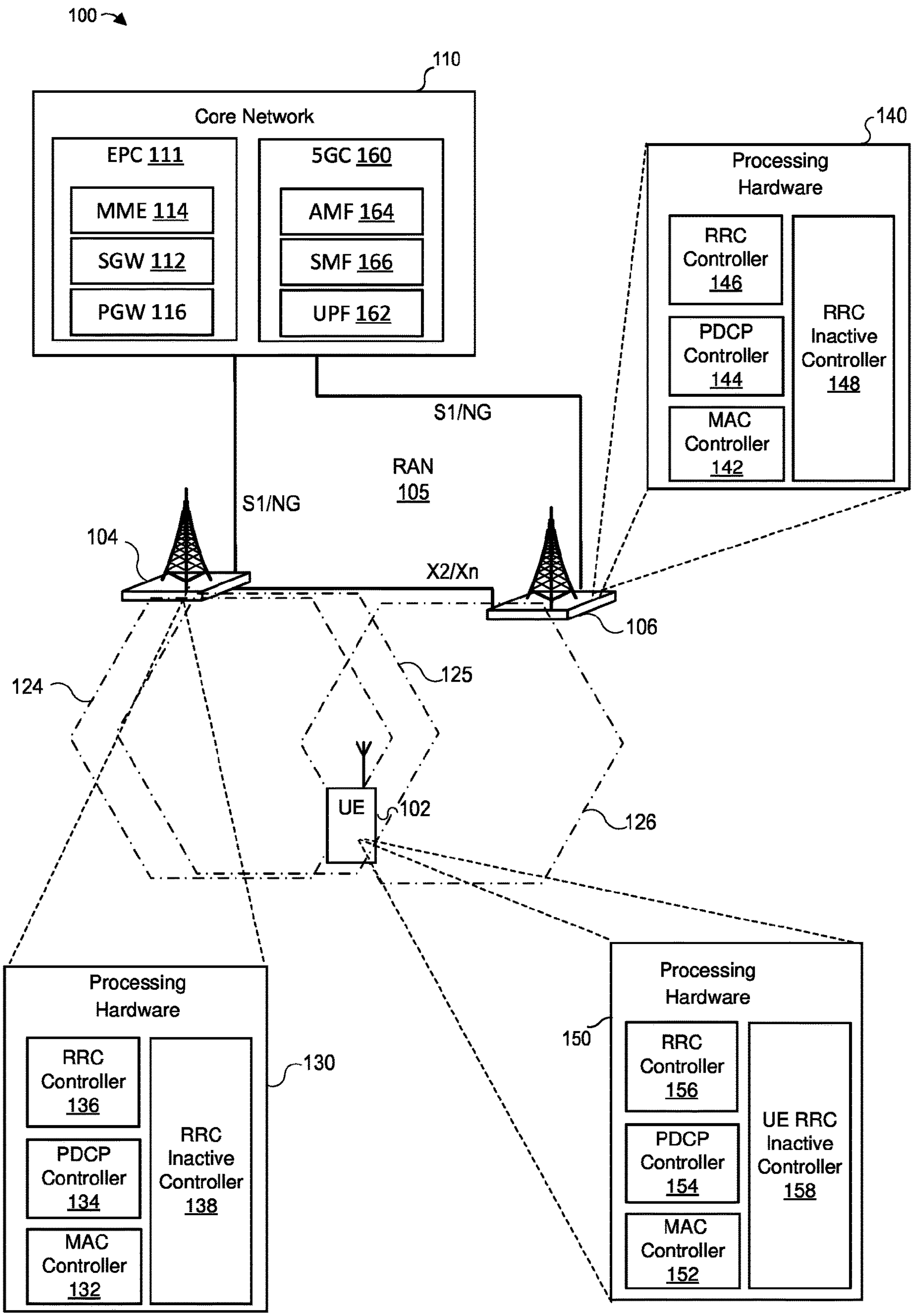

100
110
Core Network
EPC 111
MME 114
SGW 112
PGW 116
5GC 160
AMF 164
SMF 166
UPF 162
140
Processing Hardware
RRC Controller 146
PDCP Controller 144
MAC Controller 142
RRC Inactive Controller 148
S1/NG
RAN 105
S1/NG
104
X2/Xn
106
124
125
UE
102
126
Processing Hardware
RRC Controller 136
PDCP Controller 134
MAC Controller 132
RRC Inactive Controller 138
130
Processing Hardware
150
RRC Controller 156
PDCP Controller 154
MAC Controller 152
UE RRC Inactive Controller 158

Figure 1A

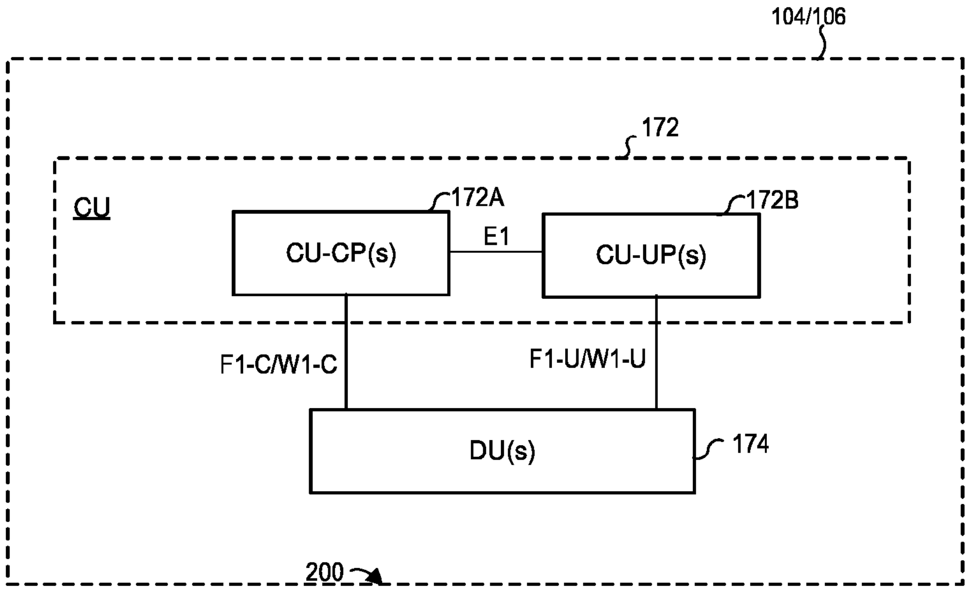


Figure 1B

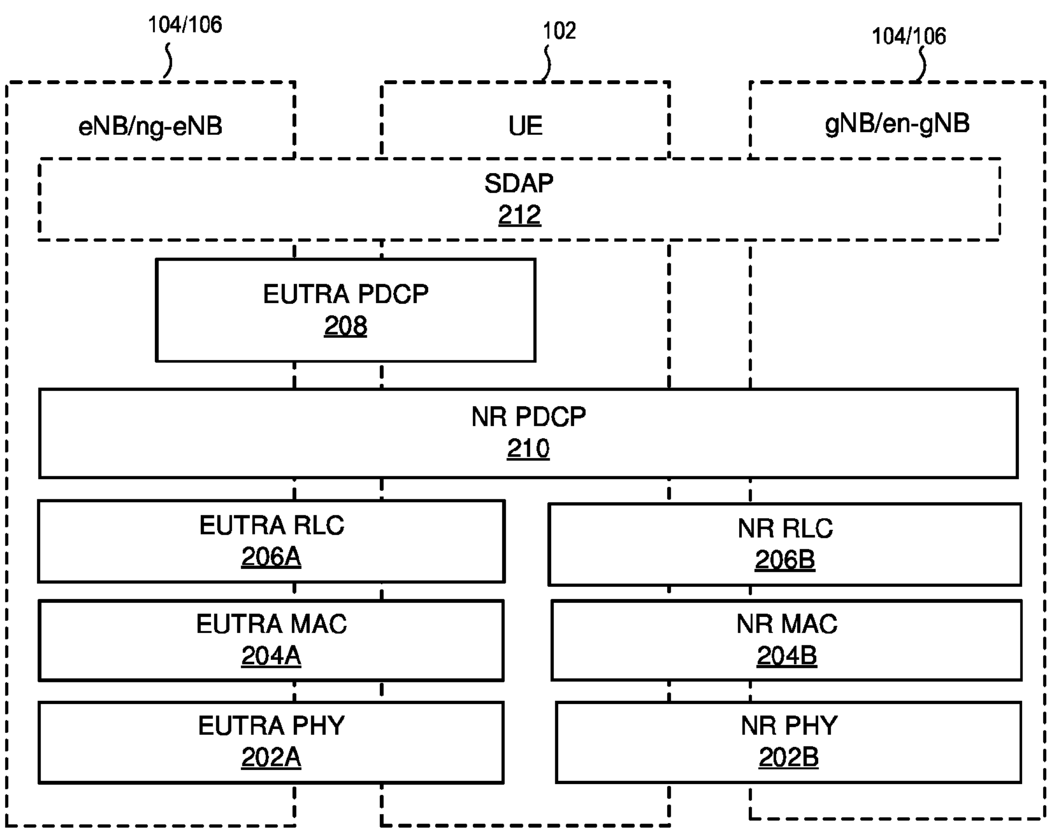


Figure 2A

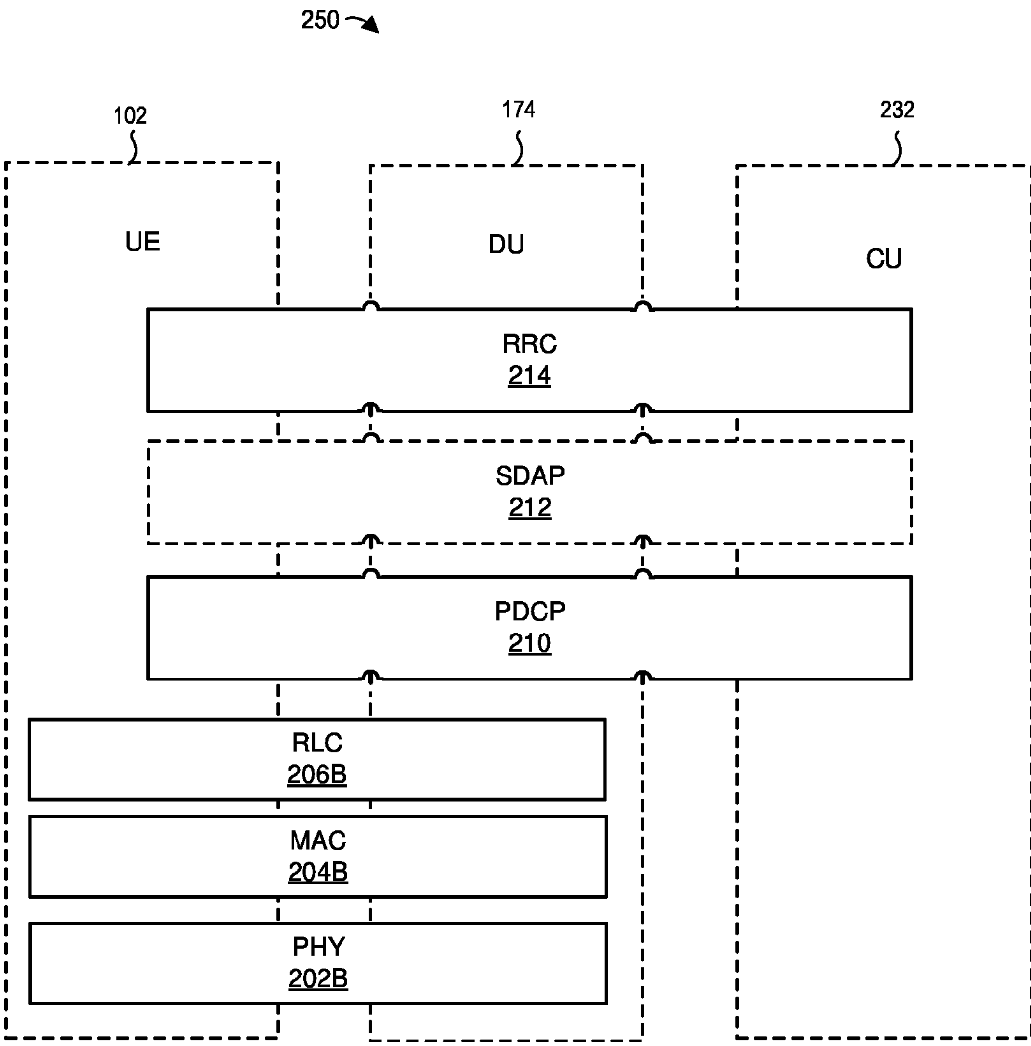

250
102
174
232
UE
DU
CU
RRC
214
SDAP
212
PDCP
210
RLC
206B
MAC
204B
PHY
202B

Figure 2B

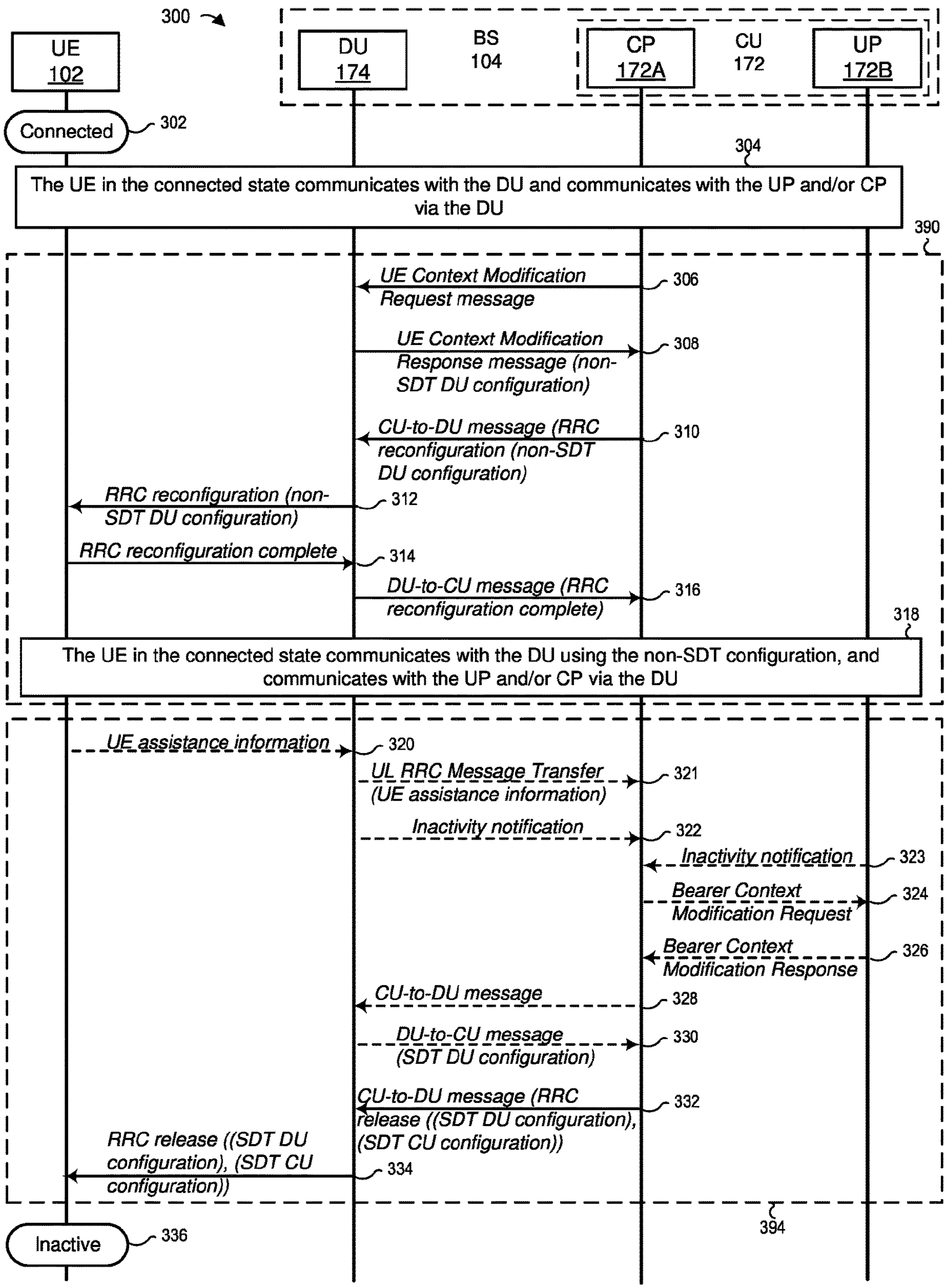

300
UE
102
DU
174
BS
104
CP
172A
CU
172
UP
172B
Connected
302
304
The UE in the connected state communicates with the DU and communicates with the UP and/or CP via the DU
390
UE Context Modification Request message
306
UE Context Modification Response message (non-SDT DU configuration)
308
CU-to-DU message (RRC reconfiguration (non-SDT DU configuration)
310
RRC reconfiguration (non-SDT DU configuration)
312
RRC reconfiguration complete
314
DU-to-CU message (RRC reconfiguration complete)
316
318
The UE in the connected state communicates with the DU using the non-SDT configuration, and communicates with the UP and/or CP via the DU
UE assistance information
320
UL RRC Message Transfer (UE assistance information)
321
Inactivity notification
322
Inactivity notification
323
Bearer Context Modification Request
324
Bearer Context Modification Response
326
CU-to-DU message
328
DU-to-CU message (SDT DU configuration)
330
CU-to-DU message (RRC release ((SDT DU configuration), (SDT CU configuration))
332
RRC release ((SDT DU configuration), (SDT CU configuration))
334
394
Inactive
336

Figure 3

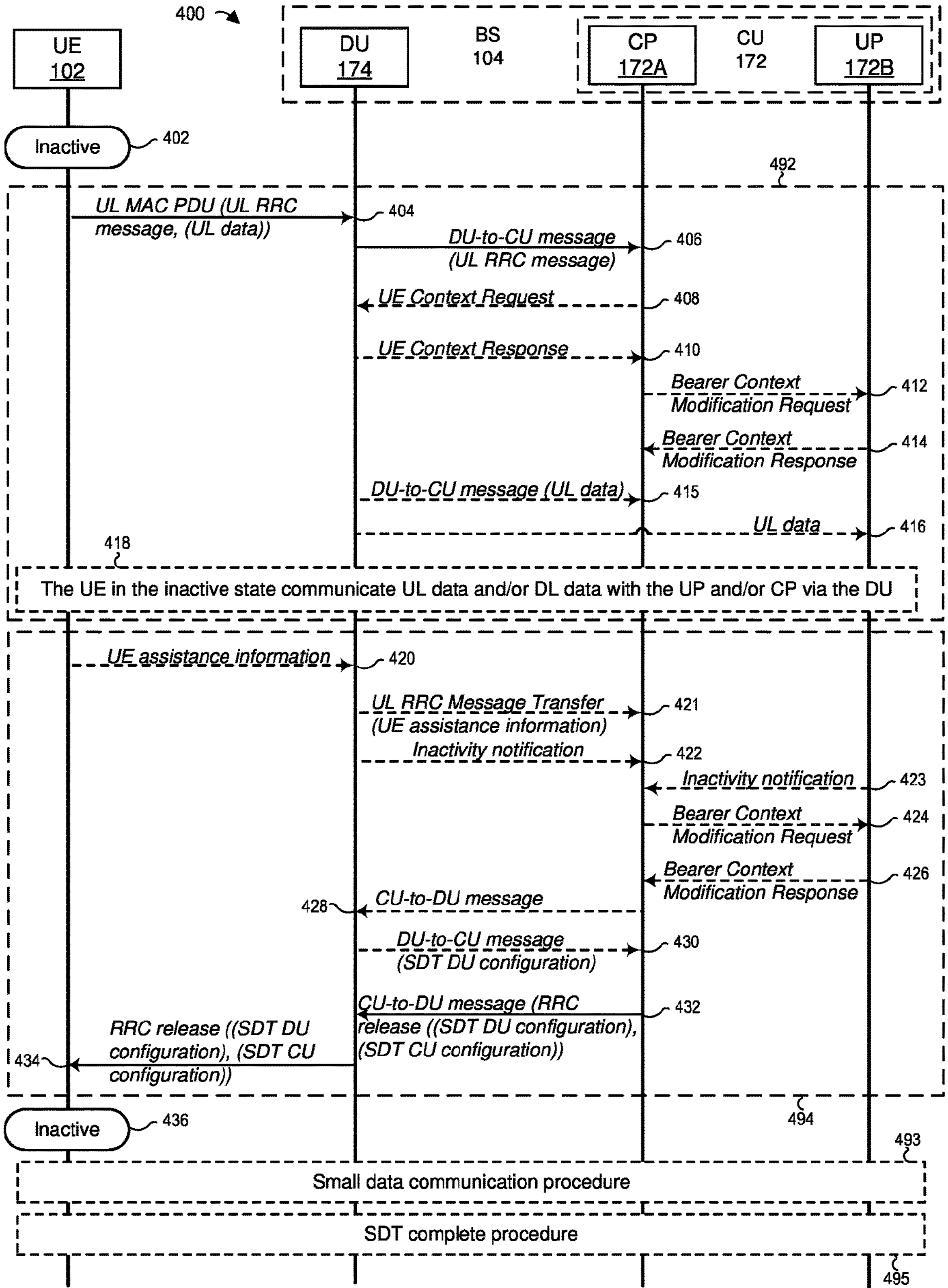

400
UE 102
DU 174
BS 104
CP 172A
CU 172
UP 172B
Inactive
402
492
UL MAC PDU (UL RRC message, (UL data))
404
DU-to-CU message (UL RRC message)
406
UE Context Request
408
UE Context Response
410
Bearer Context Modification Request
412
Bearer Context Modification Response
414
DU-to-CU message (UL data)
415
UL data
416
418
The UE in the inactive state communicate UL data and/or DL data with the UP and/or CP via the DU
UE assistance information
420
UL RRC Message Transfer (UE assistance information)
421
Inactivity notification
422
Inactivity notification
423
Bearer Context Modification Request
424
Bearer Context Modification Response
426
CU-to-DU message
428
DU-to-CU message (SDT DU configuration)
430
CU-to-DU message (RRC release ((SDT DU configuration), (SDT CU configuration))
432
RRC release ((SDT DU configuration), (SDT CU configuration))
434
494
Inactive
436
493
Small data communication procedure
SDT complete procedure
495

Figure 4

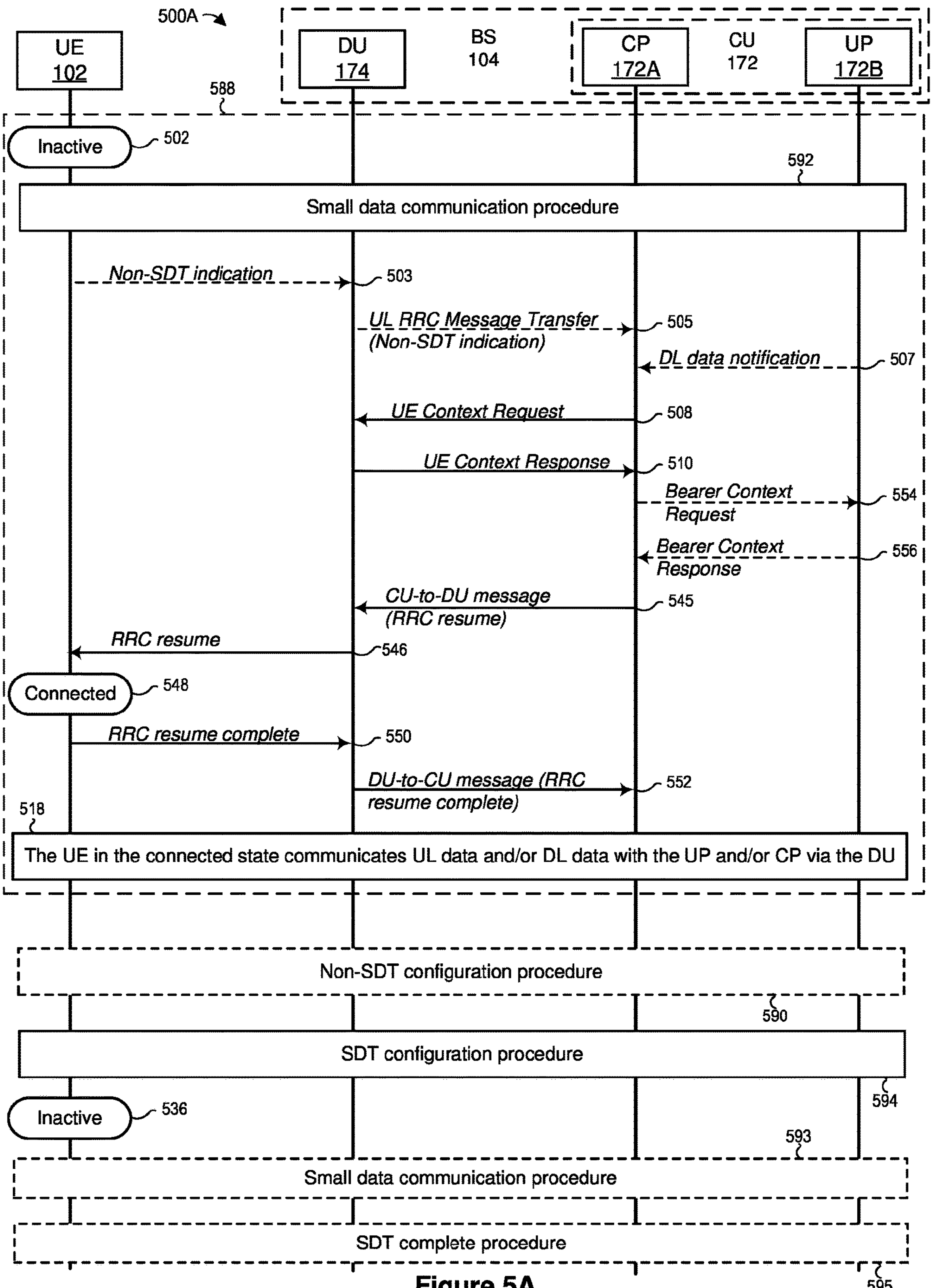

500A
UE
102
DU
174
BS
104
CP
172A
CU
172
UP
172B
588
Inactive
502
592
Small data communication procedure
Non-SDT indication
503
UL RRC Message Transfer
(Non-SDT indication)
505
DL data notification
507
UE Context Request
508
UE Context Response
510
Bearer Context
Request
554
Bearer Context
Response
556
CU-to-DU message
(RRC resume)
545
RRC resume
546
Connected
548
RRC resume complete
550
DU-to-CU message (RRC
resume complete)
552
518
The UE in the connected state communicates UL data and/or DL data with the UP and/or CP via the DU
Non-SDT configuration procedure
590
SDT configuration procedure
594
Inactive
536
593
Small data communication procedure
SDT complete procedure
595

Figure 5A

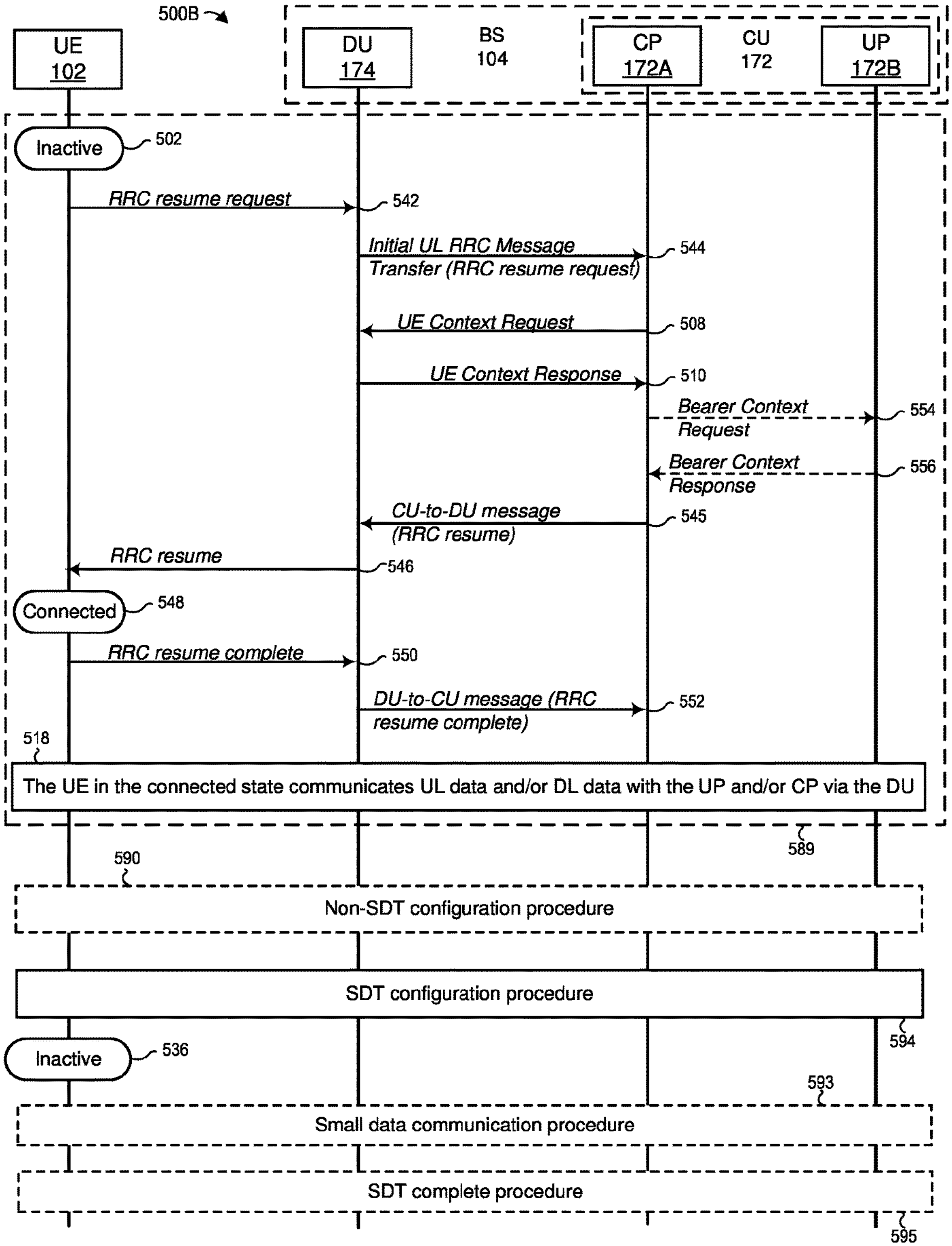

500B
UE
102
DU
174
BS
104
CP
172A
CU
172
UP
172B
Inactive
502
RRC resume request
542
Initial UL RRC Message Transfer (RRC resume request)
544
UE Context Request
508
UE Context Response
510
Bearer Context Request
554
Bearer Context Response
556
CU-to-DU message (RRC resume)
545
RRC resume
546
Connected
548
RRC resume complete
550
DU-to-CU message (RRC resume complete)
552
518
The UE in the connected state communicates UL data and/or DL data with the UP and/or CP via the DU
589
590
Non-SDT configuration procedure
SDT configuration procedure
594
Inactive
536
593
Small data communication procedure
SDT complete procedure
595

Figure 5B

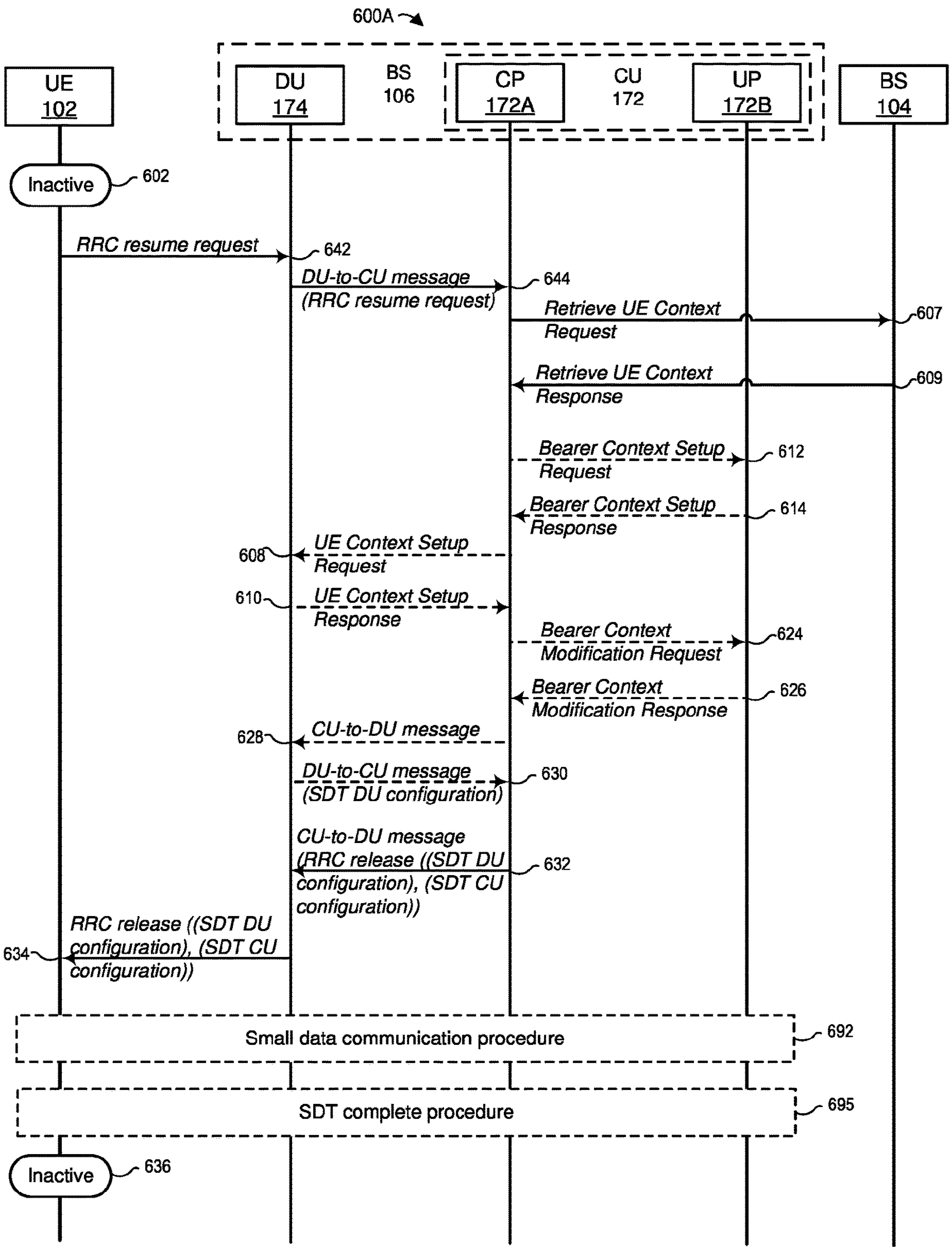

600A
BS 106
CU 172
UE 102
DU 174
CP 172A
UP 172B
BS 104
Inactive
602
RRC resume request
642
DU-to-CU message (RRC resume request)
644
Retrieve UE Context Request
607
Retrieve UE Context Response
609
Bearer Context Setup Request
612
Bearer Context Setup Response
614
UE Context Setup Request
608
UE Context Setup Response
610
Bearer Context Modification Request
624
Bearer Context Modification Response
626
CU-to-DU message
628
DU-to-CU message (SDT DU configuration)
630
CU-to-DU message (RRC release ((SDT DU configuration), (SDT CU configuration))
632
RRC release ((SDT DU configuration), (SDT CU configuration))
634
Small data communication procedure
692
SDT complete procedure
695
Inactive
636

Figure 6A

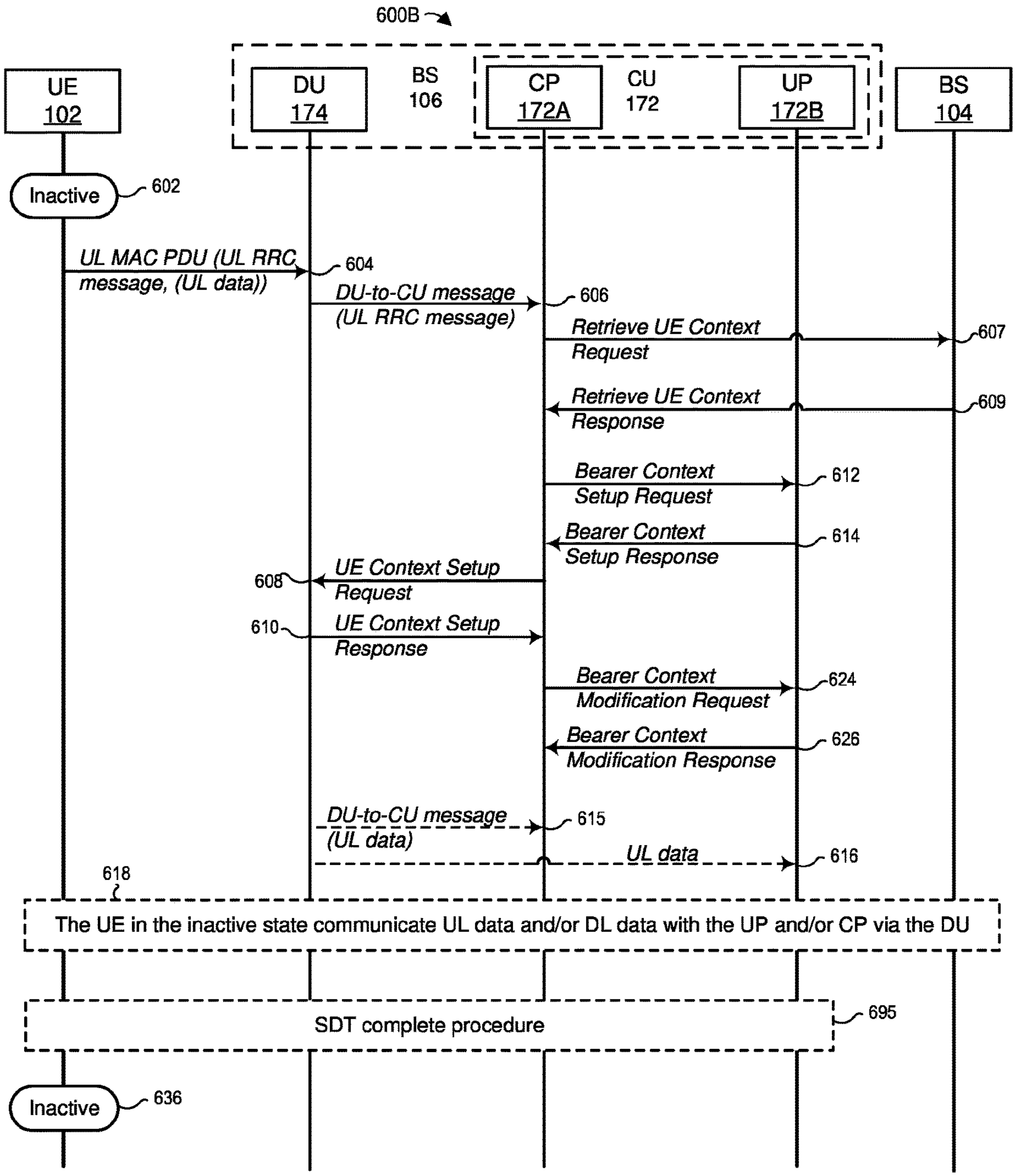

600B
BS
106
DU
174
CU
172
CP
172A
UP
172B
UE
102
BS
104
Inactive
602
UL MAC PDU (UL RRC message, (UL data))
604
DU-to-CU message
(UL RRC message)
606
Retrieve UE Context
Request
607
Retrieve UE Context
Response
609
Bearer Context
Setup Request
612
Bearer Context
Setup Response
614
UE Context Setup
Request
608
UE Context Setup
Response
610
Bearer Context
Modification Request
624
Bearer Context
Modification Response
626
DU-to-CU message
(UL data)
615
UL data
616
618
The UE in the inactive state communicate UL data and/or DL data with the UP and/or CP via the DU
SDT complete procedure
695
Inactive
636

Figure 6B

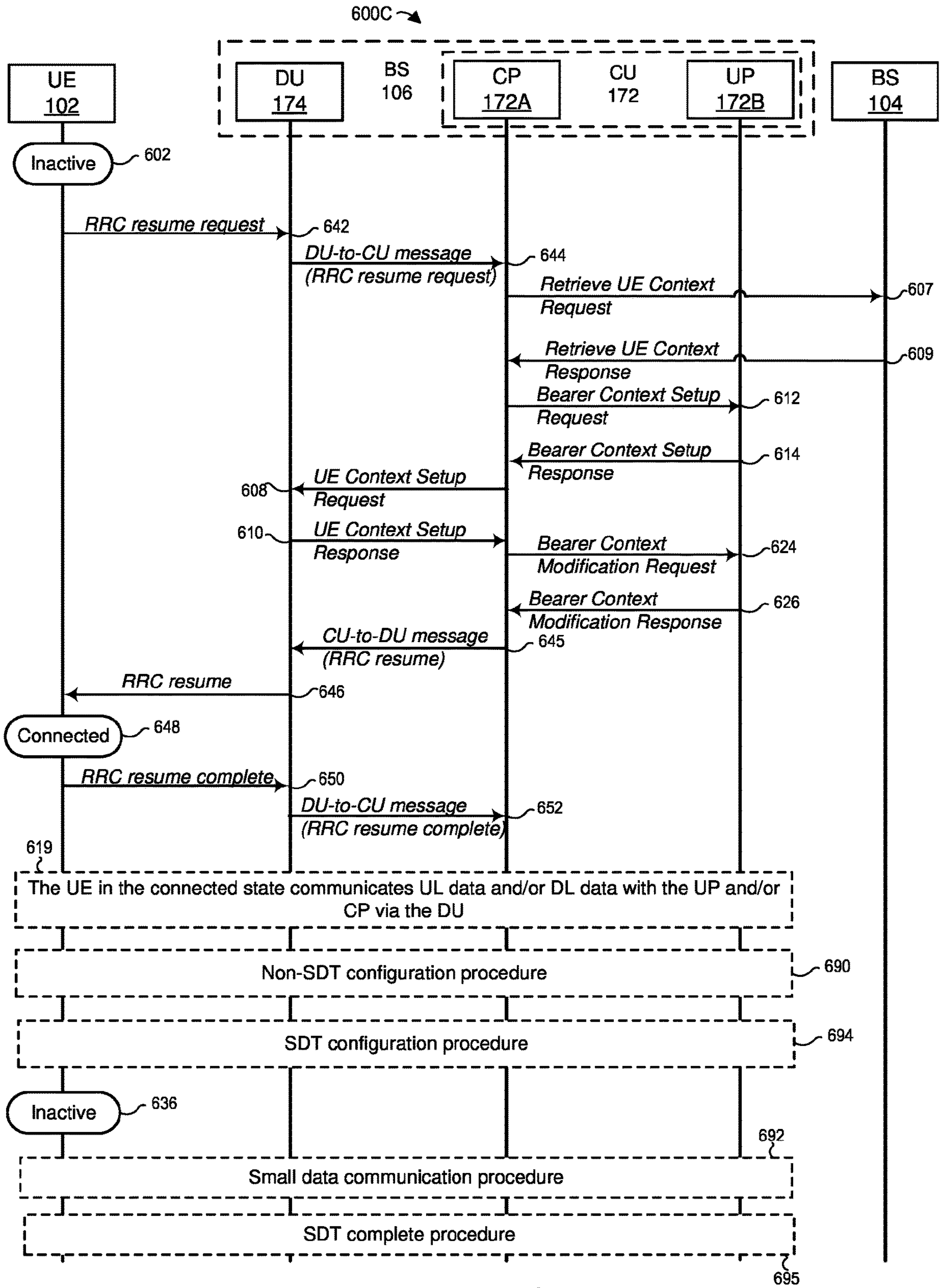

600C
UE
102
BS
106
DU
174
CP
172A
CU
172
UP
172B
BS
104
Inactive
602
RRC resume request
642
DU-to-CU message
(RRC resume request)
644
Retrieve UE Context
Request
607
Retrieve UE Context
Response
609
Bearer Context Setup
Request
612
Bearer Context Setup
Response
614
UE Context Setup
Request
608
UE Context Setup
Response
610
Bearer Context
Modification Request
624
Bearer Context
Modification Response
626
CU-to-DU message
(RRC resume)
645
RRC resume
646
Connected
648
RRC resume complete
650
DU-to-CU message
(RRC resume complete)
652
619
The UE in the connected state communicates UL data and/or DL data with the UP and/or CP via the DU
Non-SDT configuration procedure
690
SDT configuration procedure
694
Inactive
636
692
Small data communication procedure
SDT complete procedure
695

Figure 6C

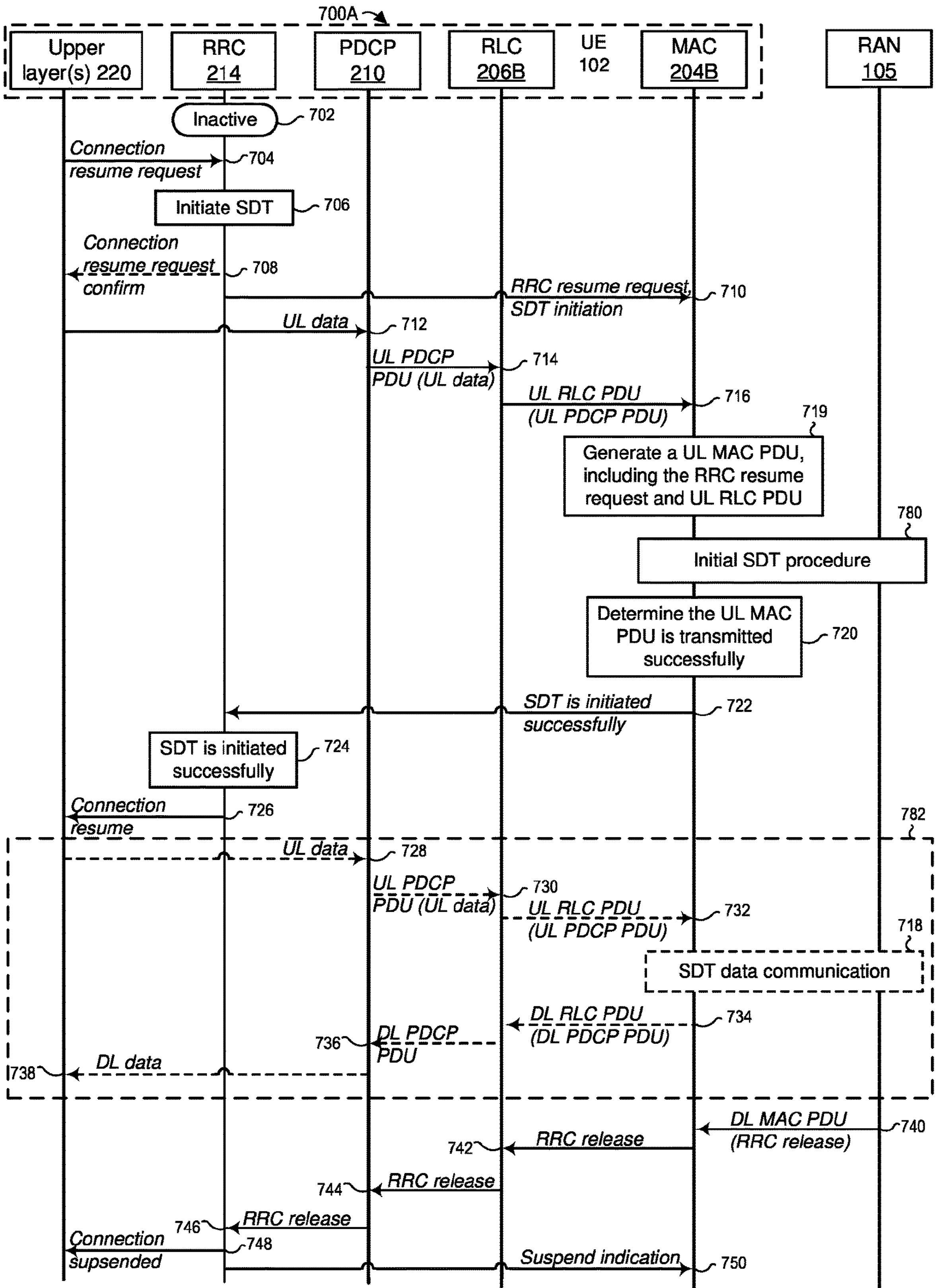

700A
Upper layer(s) 220
RRC 214
PDCP 210
RLC 206B
UE 102
MAC 204B
RAN 105
Inactive
702
Connection resume request
704
Initiate SDT
706
Connection resume request confirm
708
RRC resume request, SDT initiation
710
UL data
712
UL PDCP PDU (UL data)
714
UL RLC PDU (UL PDCP PDU)
716
719
Generate a UL MAC PDU, including the RRC resume request and UL RLC PDU
780
Initial SDT procedure
Determine the UL MAC PDU is transmitted successfully
720
SDT is initiated successfully
722
SDT is initiated successfully
724
Connection resume
726
782
UL data
728
UL PDCP PDU (UL data)
730
UL RLC PDU (UL PDCP PDU)
732
718
SDT data communication
DL RLC PDU (DL PDCP PDU)
734
736
DL PDCP PDU
738
DL data
DL MAC PDU (RRC release)
740
742
RRC release
744
RRC release
746
RRC release
Connection suspended
748
Suspend indication
750

Figure 7A

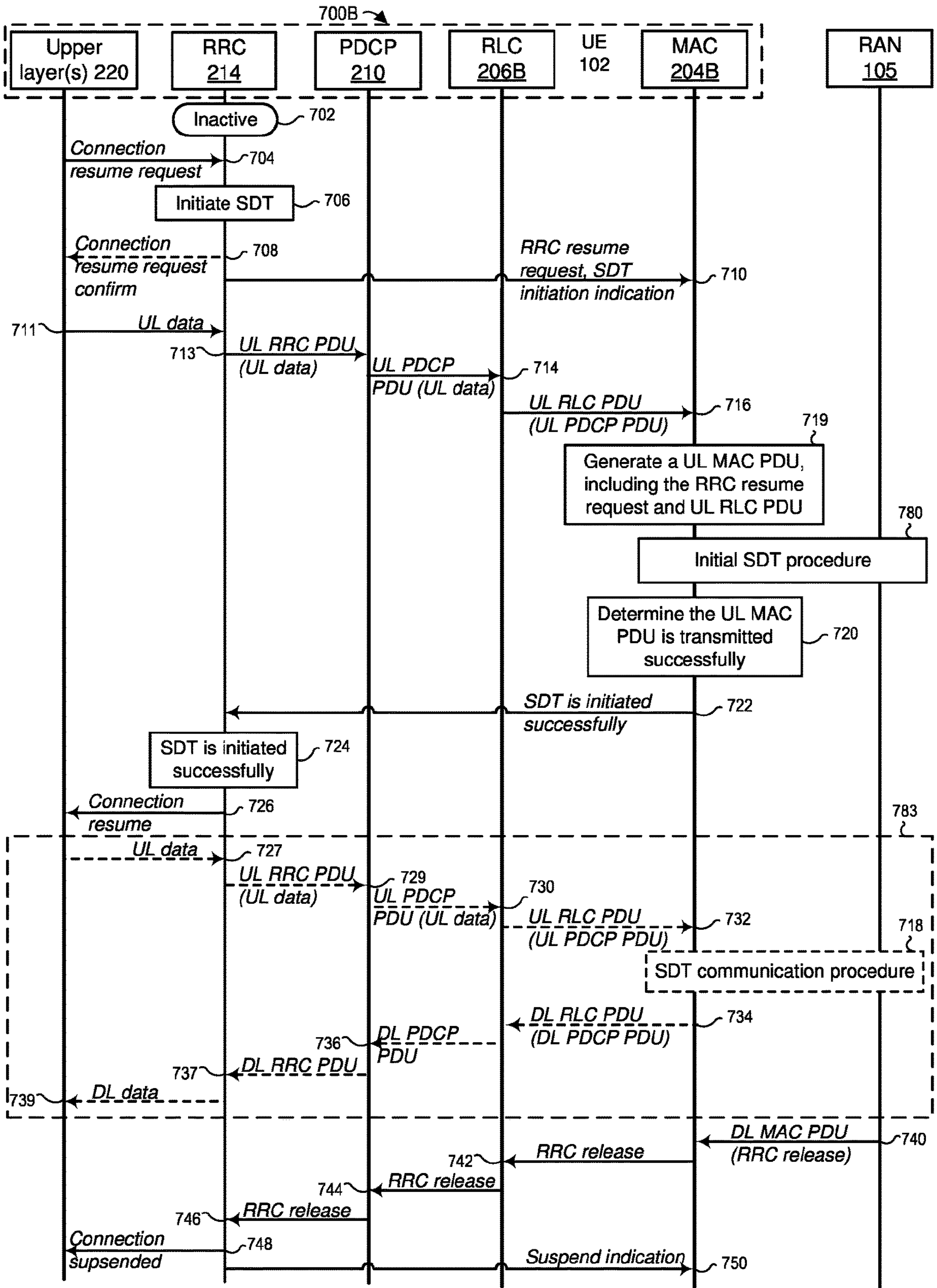

700B
Upper layer(s) 220
RRC 214
PDCP 210
RLC 206B
UE 102
MAC 204B
RAN 105
Inactive
702
Connection resume request
704
Initiate SDT
706
Connection resume request confirm
708
RRC resume request, SDT initiation indication
710
711
UL data
713
UL RRC PDU (UL data)
UL PDCP PDU (UL data)
714
UL RLC PDU (UL PDCP PDU)
716
719
Generate a UL MAC PDU, including the RRC resume request and UL RLC PDU
780
Initial SDT procedure
Determine the UL MAC PDU is transmitted successfully
720
SDT is initiated successfully
722
SDT is initiated successfully
724
Connection resume
726
783
UL data
727
UL RRC PDU (UL data)
729
UL PDCP PDU (UL data)
730
UL RLC PDU (UL PDCP PDU)
732
718
SDT communication procedure
DL RLC PDU (DL PDCP PDU)
734
736
DL PDCP PDU
737
DL RRC PDU
739
DL data
DL MAC PDU (RRC release)
740
742
RRC release
744
RRC release
746
RRC release
Connection suspended
748
Suspend indication
750

Figure 7B

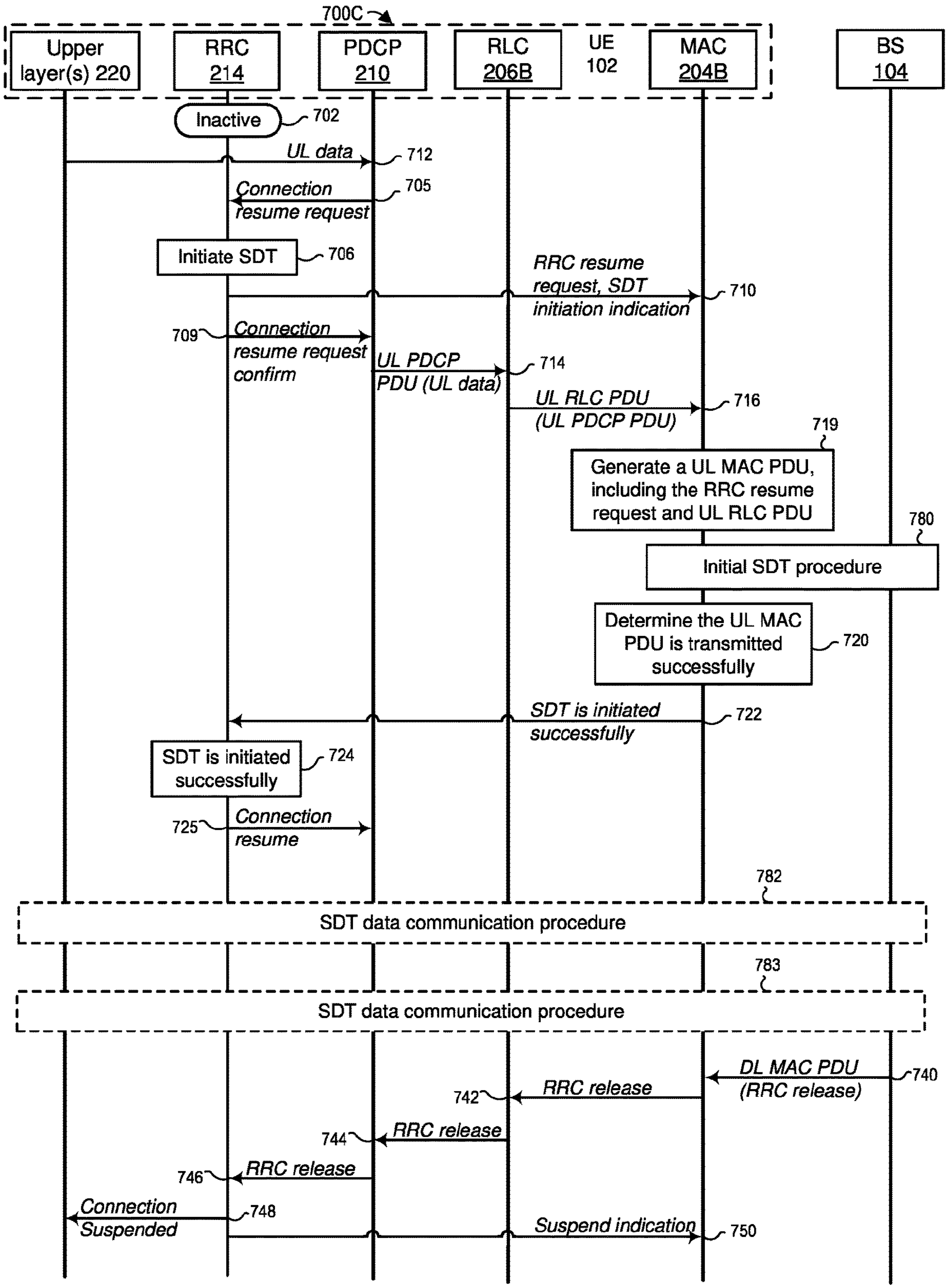
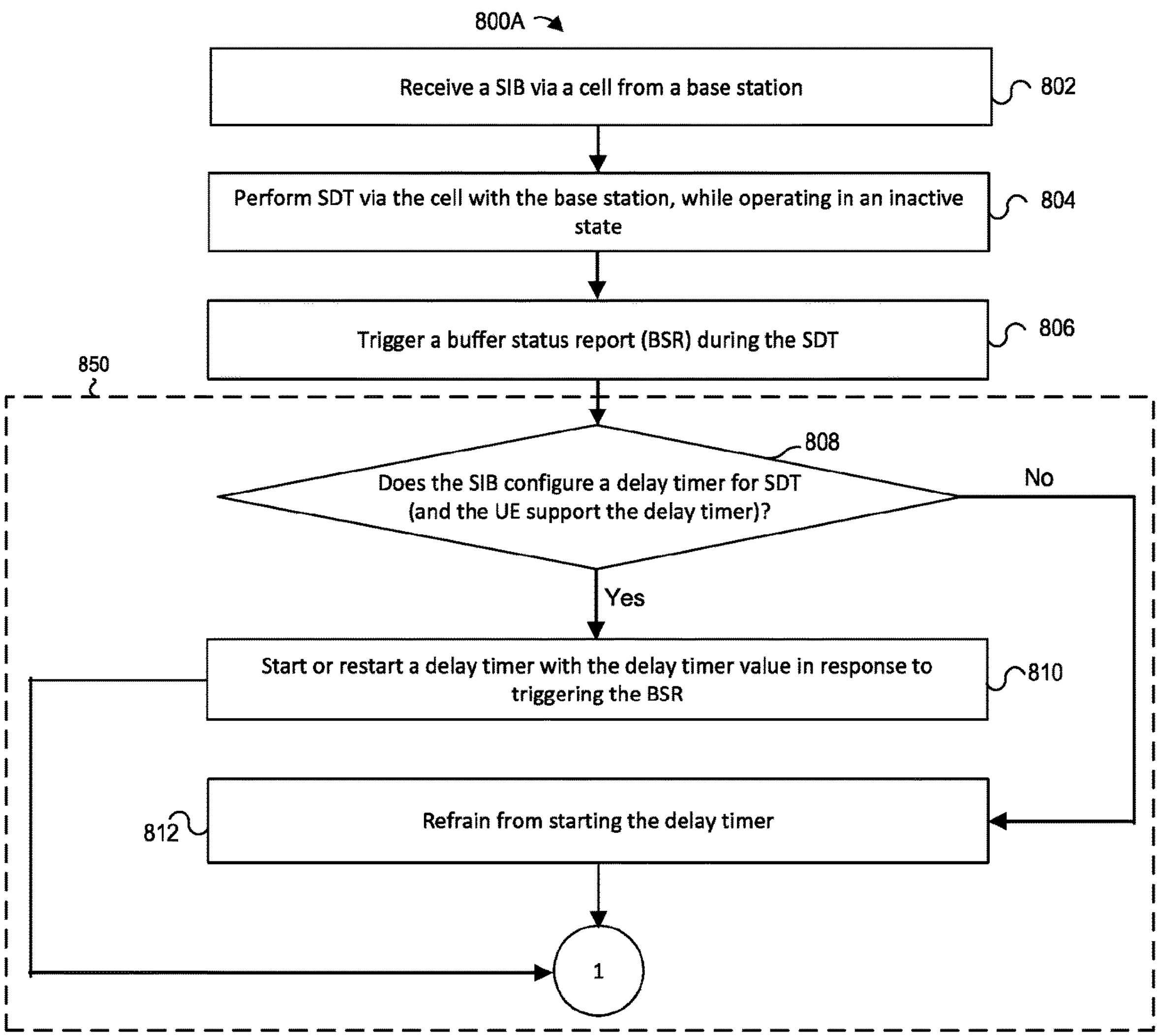

700C
Upper layer(s) 220
RRC 214
PDCP 210
RLC 206B
UE 102
MAC 204B
BS 104
Inactive
702
UL data
712
Connection resume request
705
Initiate SDT
706
RRC resume request, SDT initiation indication
710
709
Connection resume request confirm
UL PDCP PDU (UL data)
714
UL RLC PDU (UL PDCP PDU)
716
719
Generate a UL MAC PDU, including the RRC resume request and UL RLC PDU
780
Initial SDT procedure
Determine the UL MAC PDU is transmitted successfully
720
SDT is initiated successfully
722
SDT is initiated successfully
724
725
Connection resume
782
SDT data communication procedure
783
SDT data communication procedure
DL MAC PDU (RRC release)
740
742
RRC release
744
RRC release
746
RRC release
Connection Suspended
748
Suspend indication
750

Figure 7C



800A
Receive a SIB via a cell from a base station
802
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) during the SDT
806
850
Does the SIB configure a delay timer for SDT (and the UE support the delay timer)?
808
No
Yes
Start or restart a delay timer with the delay timer value in response to triggering the BSR
810
Refrain from starting the delay timer
812
1

Figure 8A-1

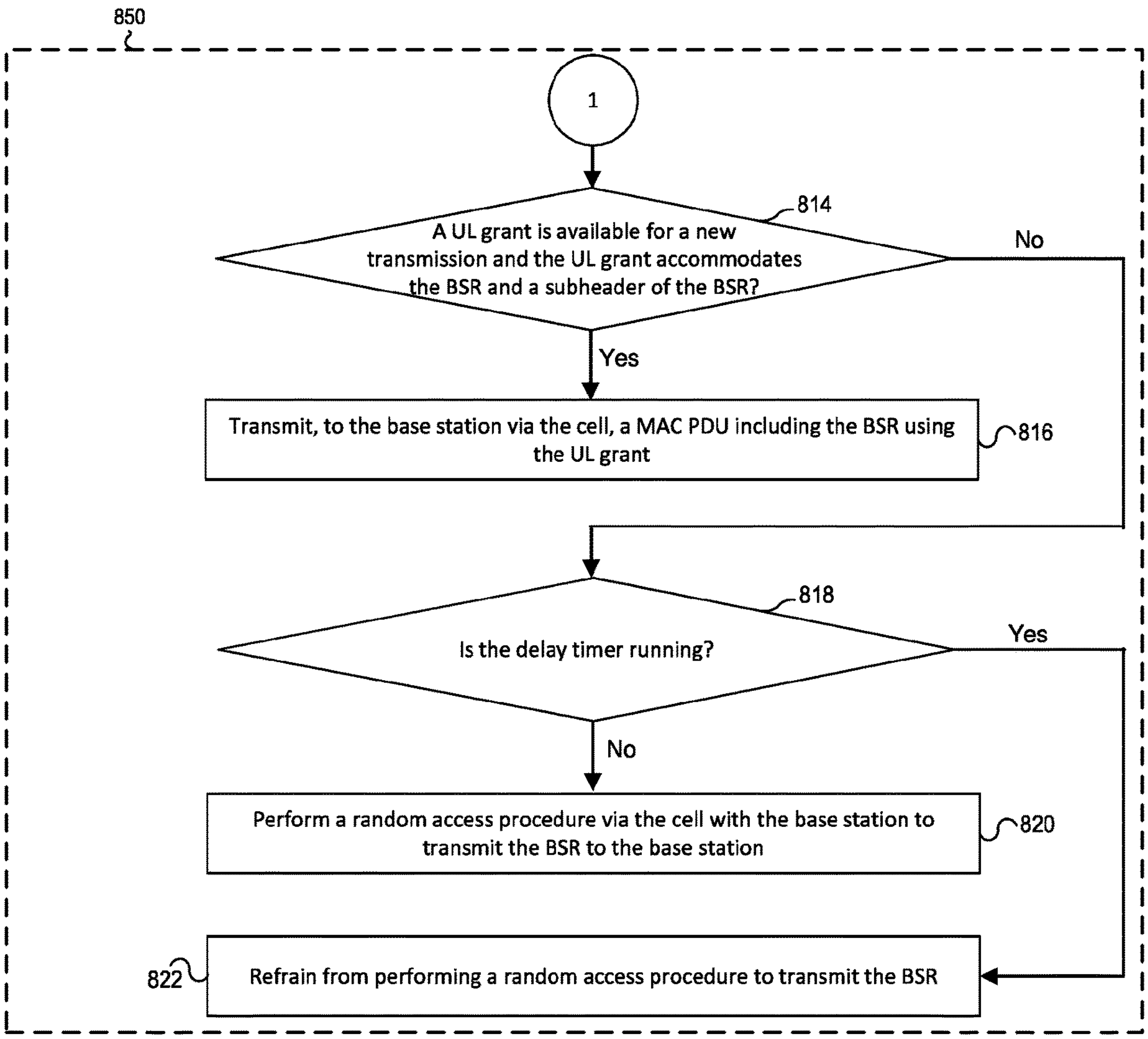

850
1
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
814
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
816
Is the delay timer running?
818
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
820
822
Refrain from performing a random access procedure to transmit the BSR

Figure 8A-2

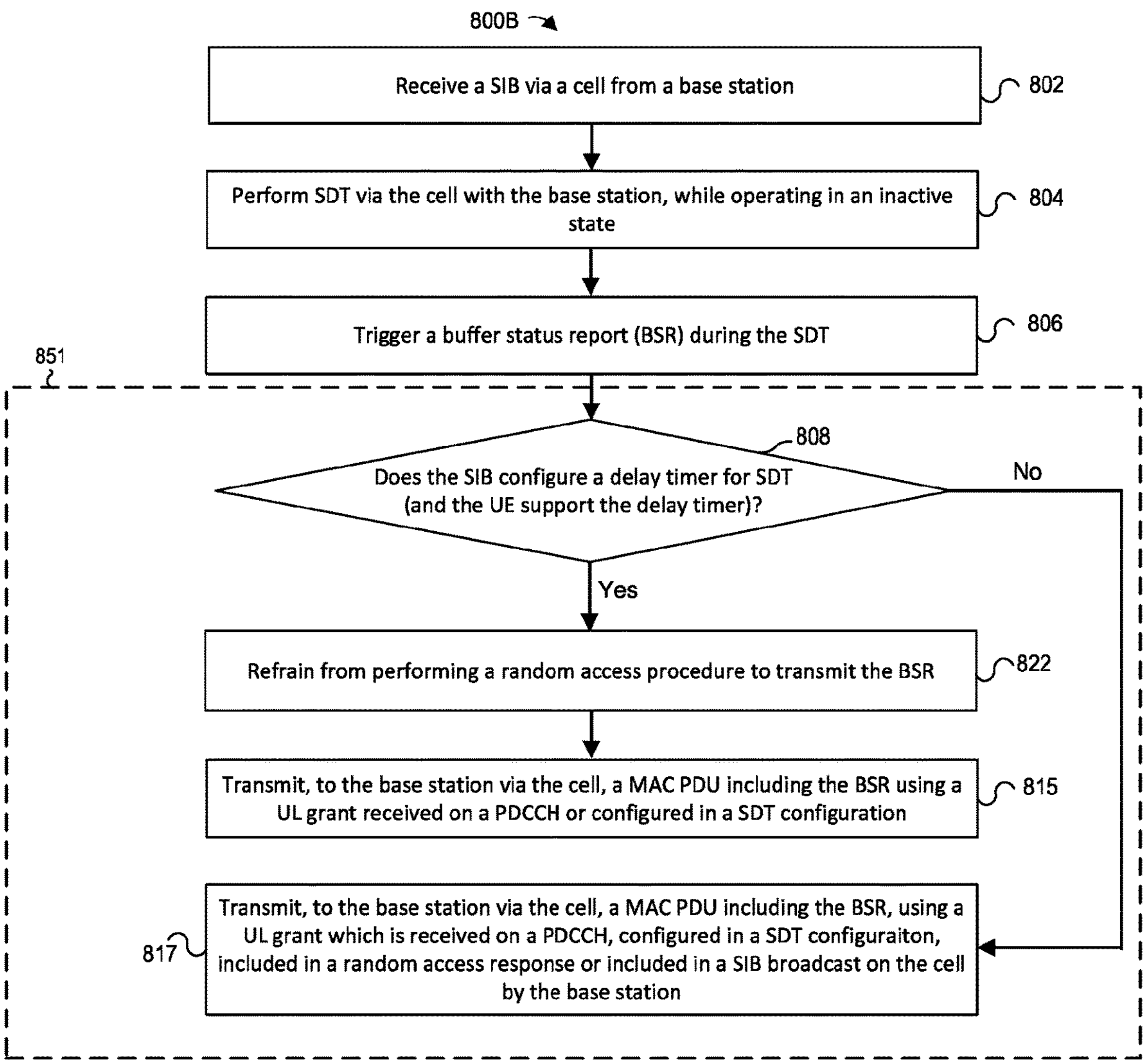

800B
Receive a SIB via a cell from a base station
802
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) during the SDT
806
851
Does the SIB configure a delay timer for SDT (and the UE support the delay timer)?
808
No
Yes
Refrain from performing a random access procedure to transmit the BSR
822
Transmit, to the base station via the cell, a MAC PDU including the BSR using a UL grant received on a PDCCH or configured in a SDT configuration
815
Transmit, to the base station via the cell, a MAC PDU including the BSR, using a UL grant which is received on a PDCCH, configured in a SDT configuraiton, included in a random access response or included in a SIB broadcast on the cell by the base station
817

Figure 8B

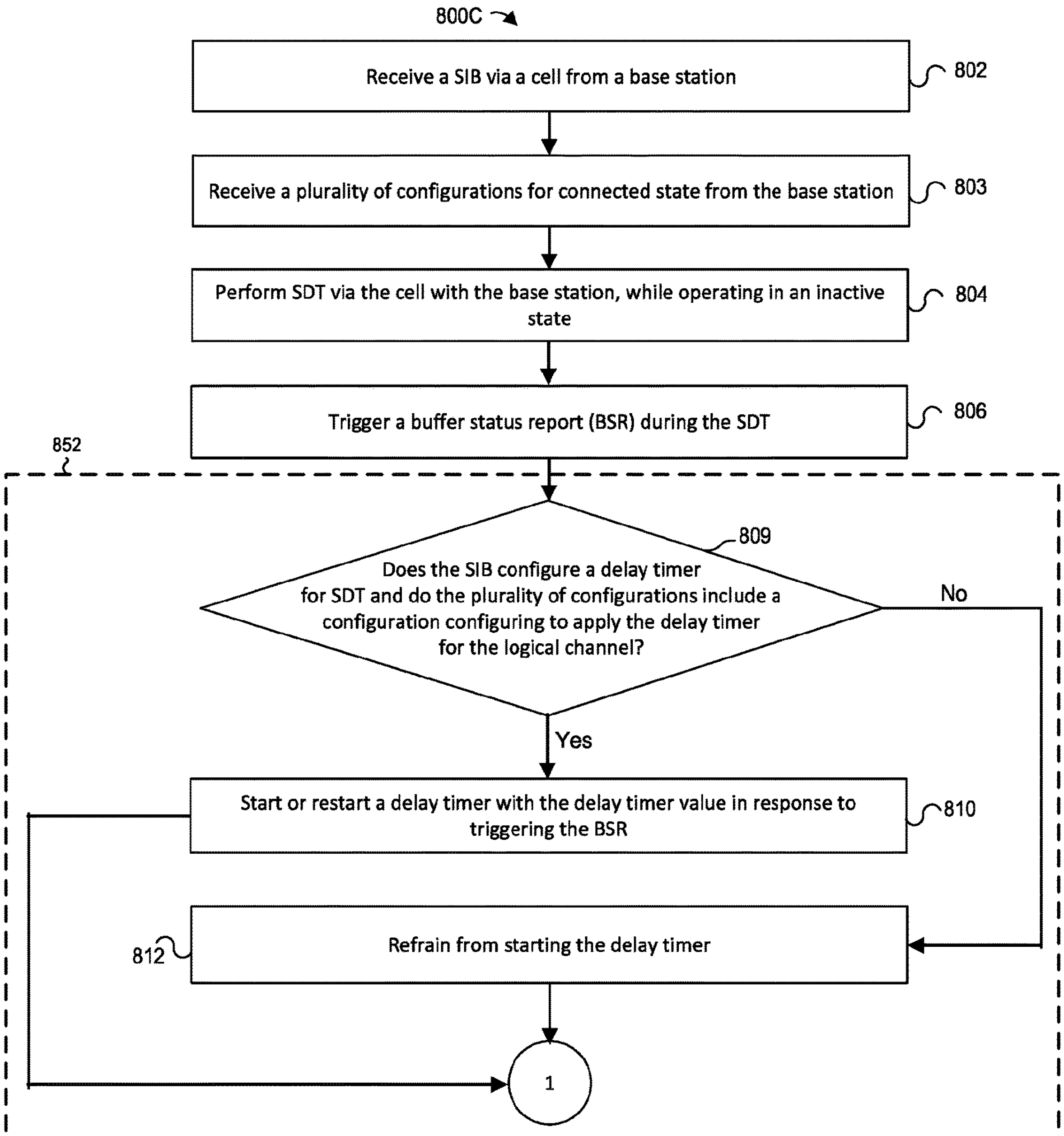

800C
Receive a SIB via a cell from a base station
802
Receive a plurality of configurations for connected state from the base station
803
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) during the SDT
806
852
Does the SIB configure a delay timer for SDT and do the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel?
809
No
Yes
Start or restart a delay timer with the delay timer value in response to triggering the BSR
810
Refrain from starting the delay timer
812
1

Figure 8C-1

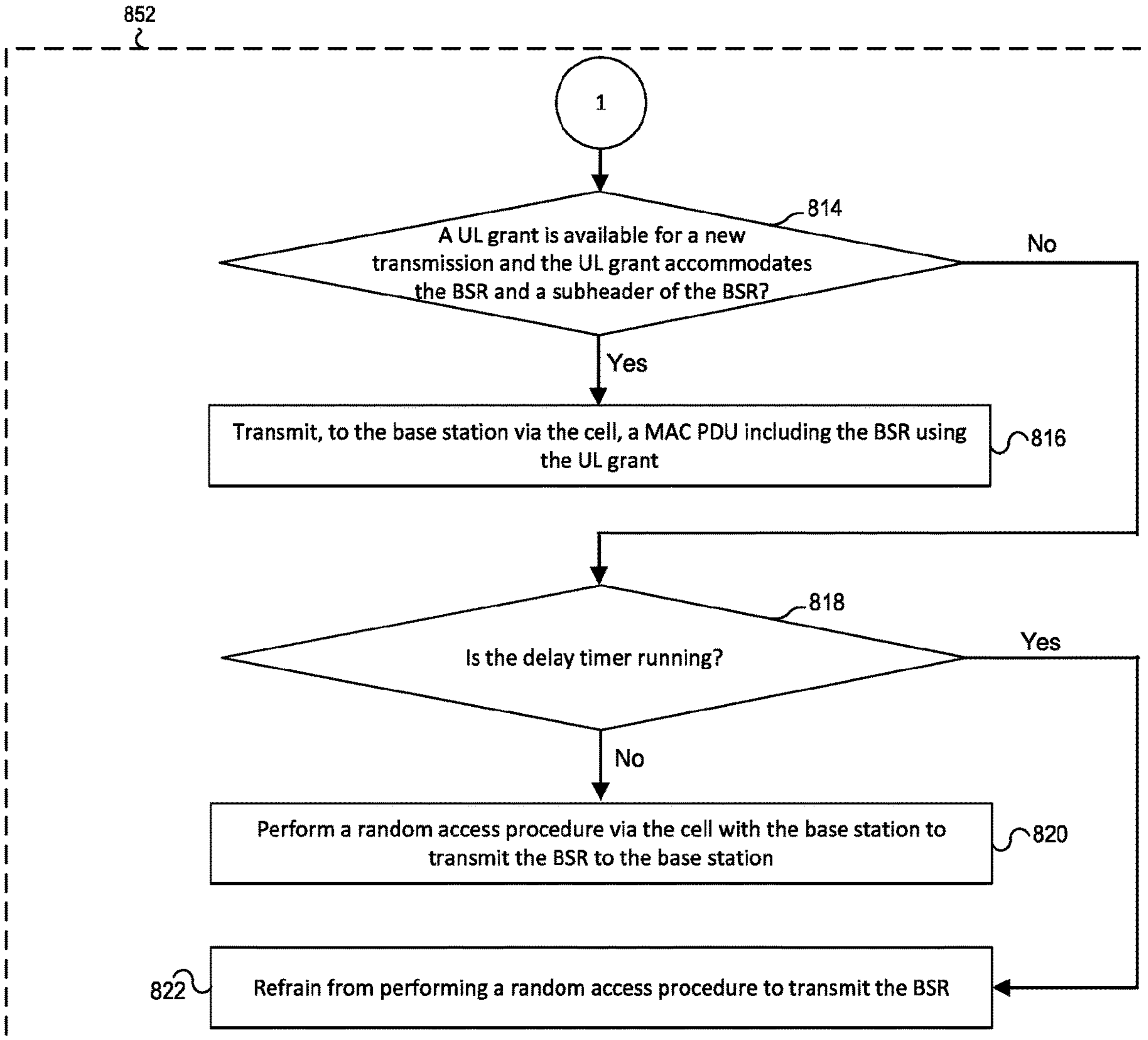

852
1
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
814
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
816
Is the delay timer running?
818
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
820
822
Refrain from performing a random access procedure to transmit the BSR

Figure 8C-2

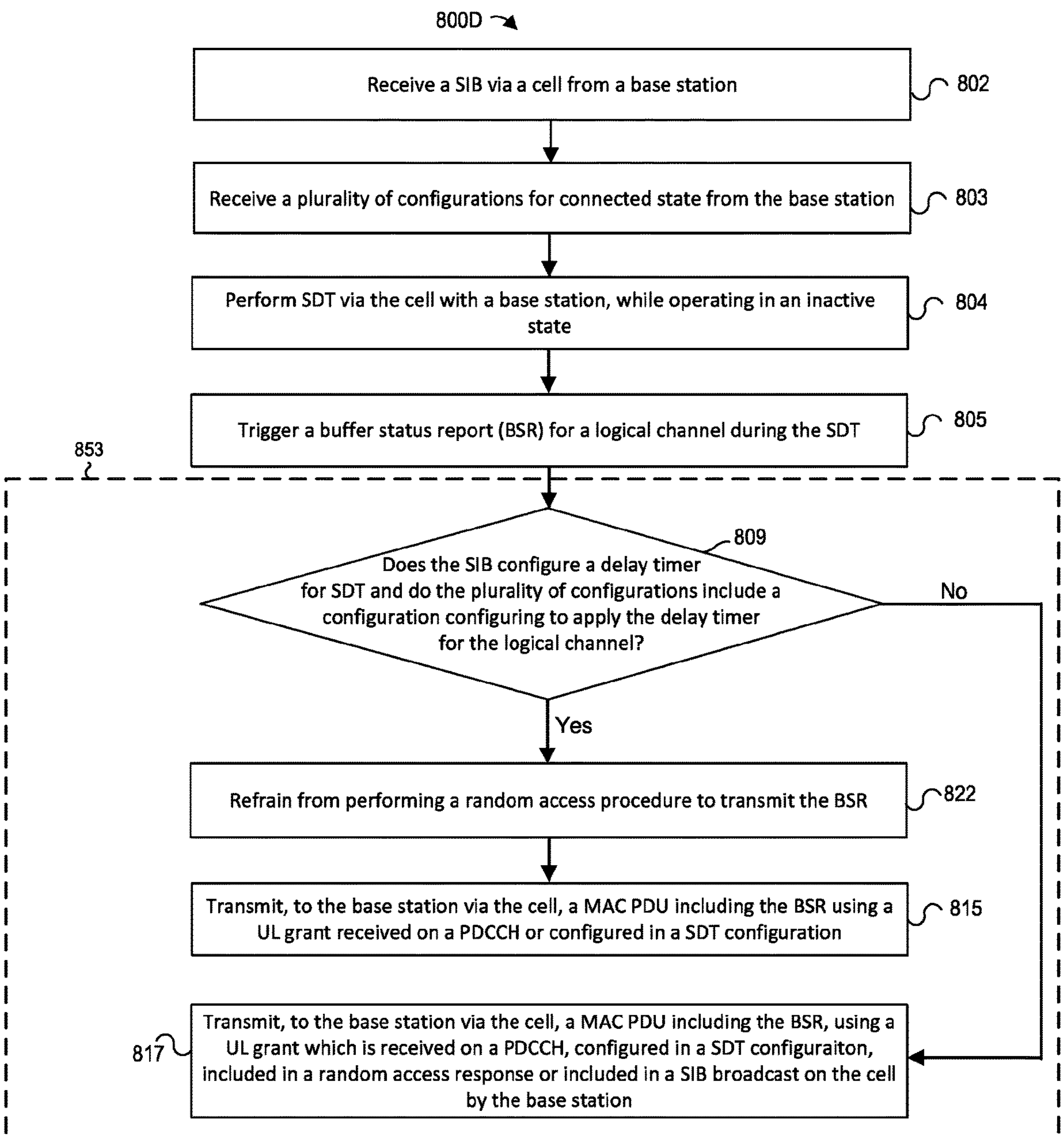

800D
Receive a SIB via a cell from a base station
802
Receive a plurality of configurations for connected state from the base station
803
Perform SDT via the cell with a base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) for a logical channel during the SDT
805
853
Does the SIB configure a delay timer for SDT and do the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel?
809
No
Yes
Refrain from performing a random access procedure to transmit the BSR
822
Transmit, to the base station via the cell, a MAC PDU including the BSR using a UL grant received on a PDCCH or configured in a SDT configuration
815
Transmit, to the base station via the cell, a MAC PDU including the BSR, using a UL grant which is received on a PDCCH, configured in a SDT configuraiton, included in a random access response or included in a SIB broadcast on the cell by the base station
817

Figure 8D

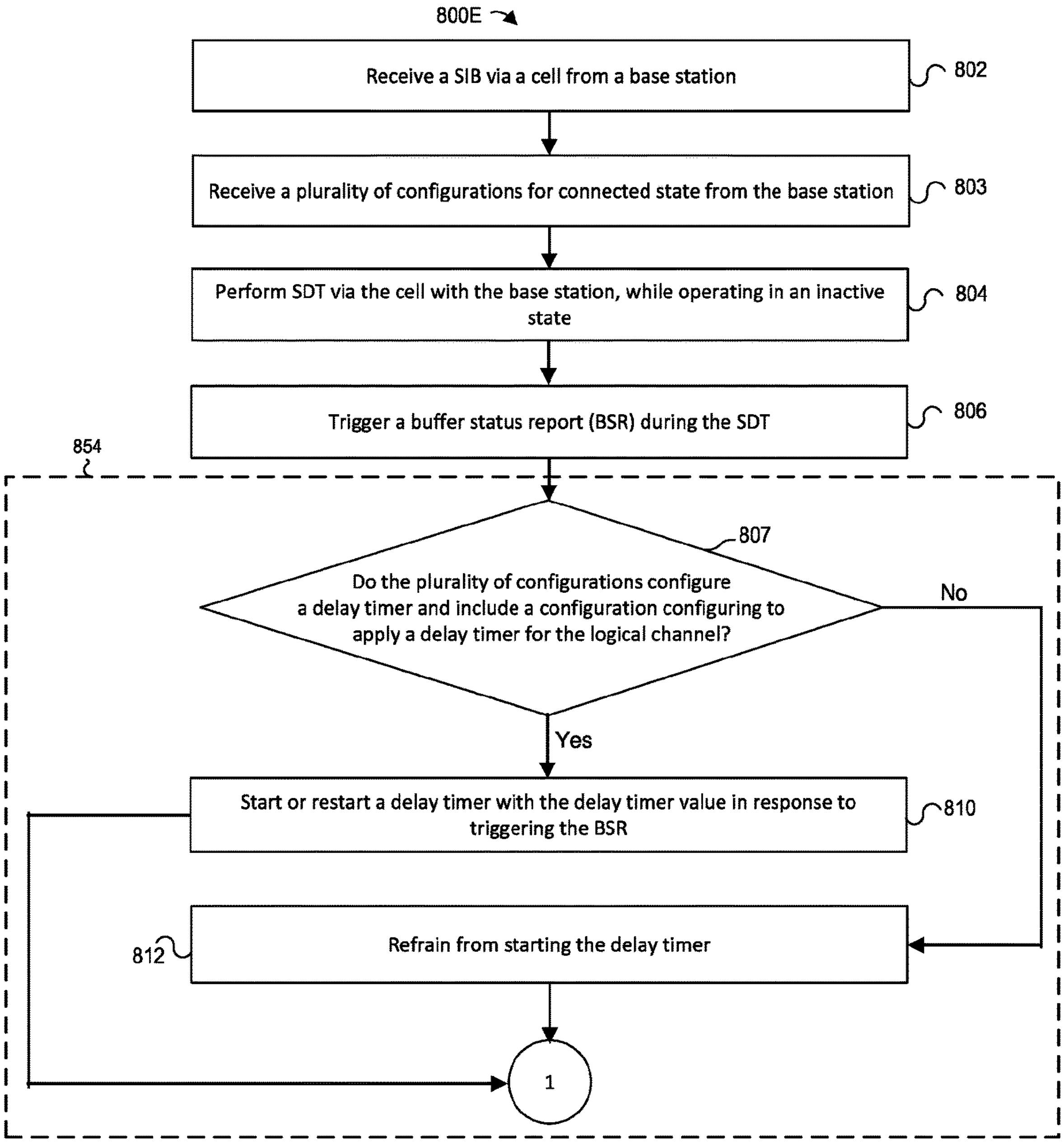

800E
Receive a SIB via a cell from a base station
802
Receive a plurality of configurations for connected state from the base station
803
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) during the SDT
806
854
807
Do the plurality of configurations configure a delay timer and include a configuration configuring to apply a delay timer for the logical channel?
No
Yes
Start or restart a delay timer with the delay timer value in response to triggering the BSR
810
812
Refrain from starting the delay timer
1

Figure 8E-1

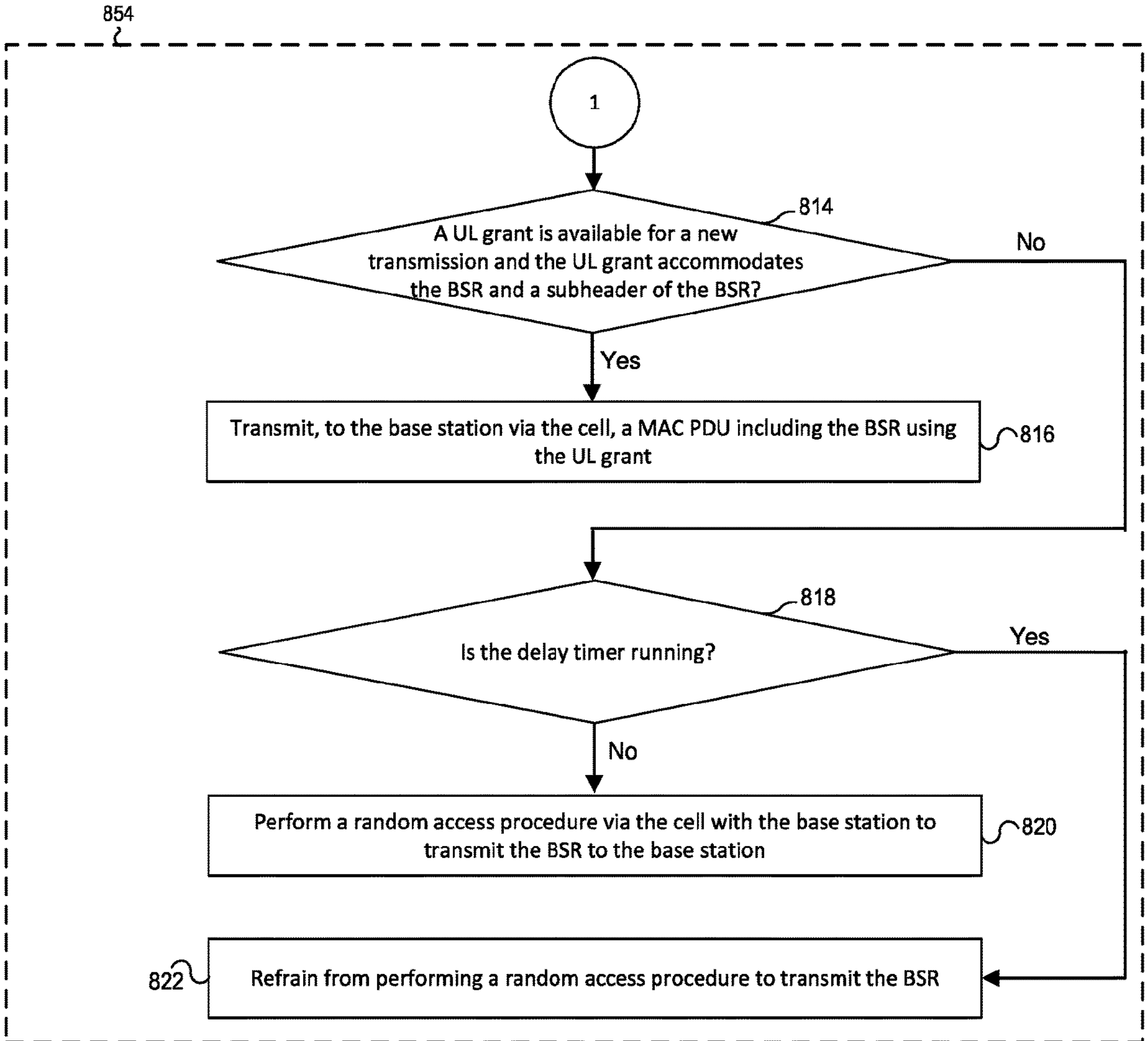

854
1
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
814
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
816
Is the delay timer running?
818
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
820
822
Refrain from performing a random access procedure to transmit the BSR

Figure 8E-2

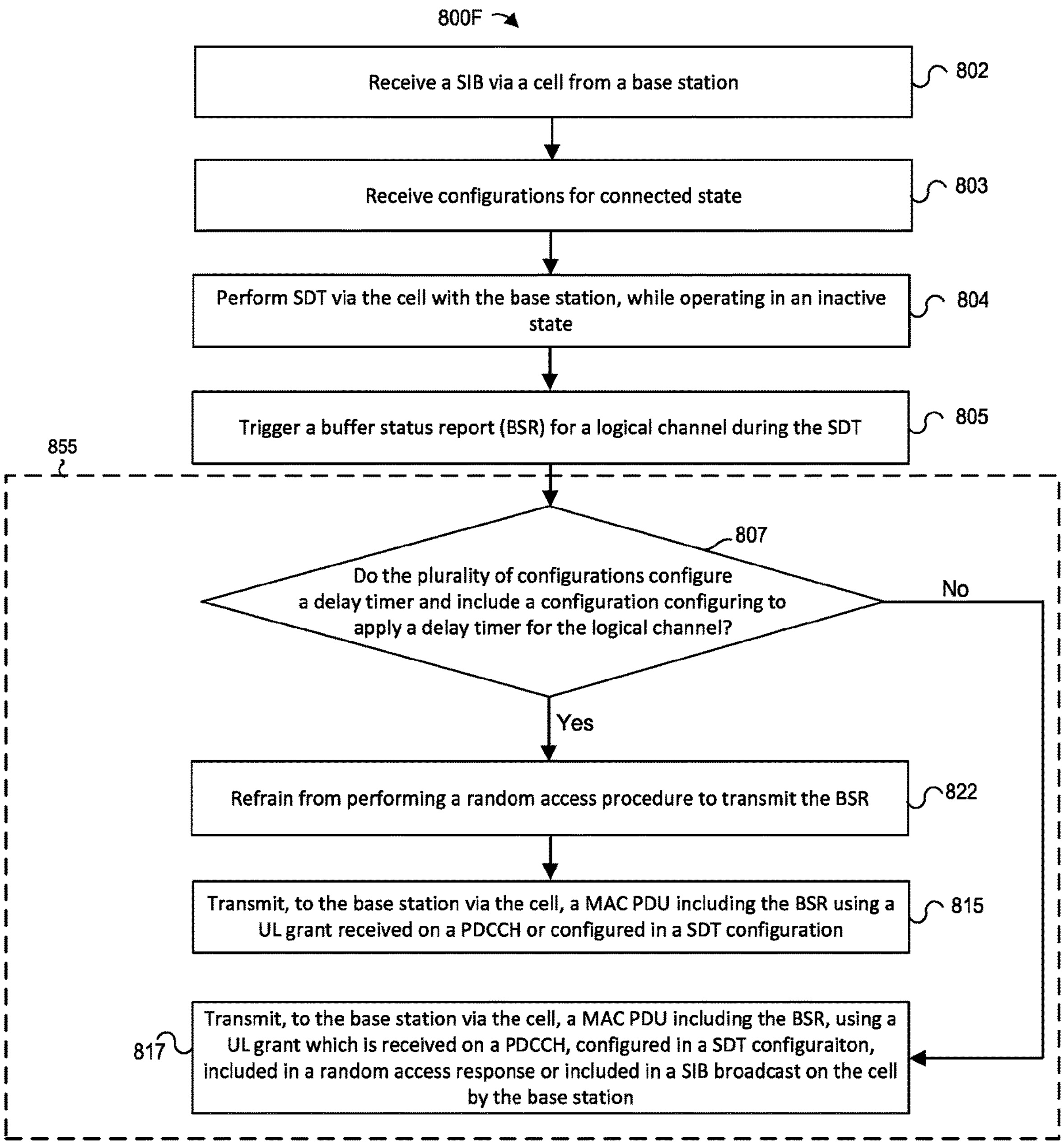

800F
Receive a SIB via a cell from a base station
802
Receive configurations for connected state
803
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) for a logical channel during the SDT
805
855
Do the plurality of configurations configure a delay timer and include a configuration configuring to apply a delay timer for the logical channel?
807
No
Yes
Refrain from performing a random access procedure to transmit the BSR
822
Transmit, to the base station via the cell, a MAC PDU including the BSR using a UL grant received on a PDCCH or configured in a SDT configuration
815
Transmit, to the base station via the cell, a MAC PDU including the BSR, using a UL grant which is received on a PDCCH, configured in a SDT configuraiton, included in a random access response or included in a SIB broadcast on the cell by the base station
817

Figure 8F

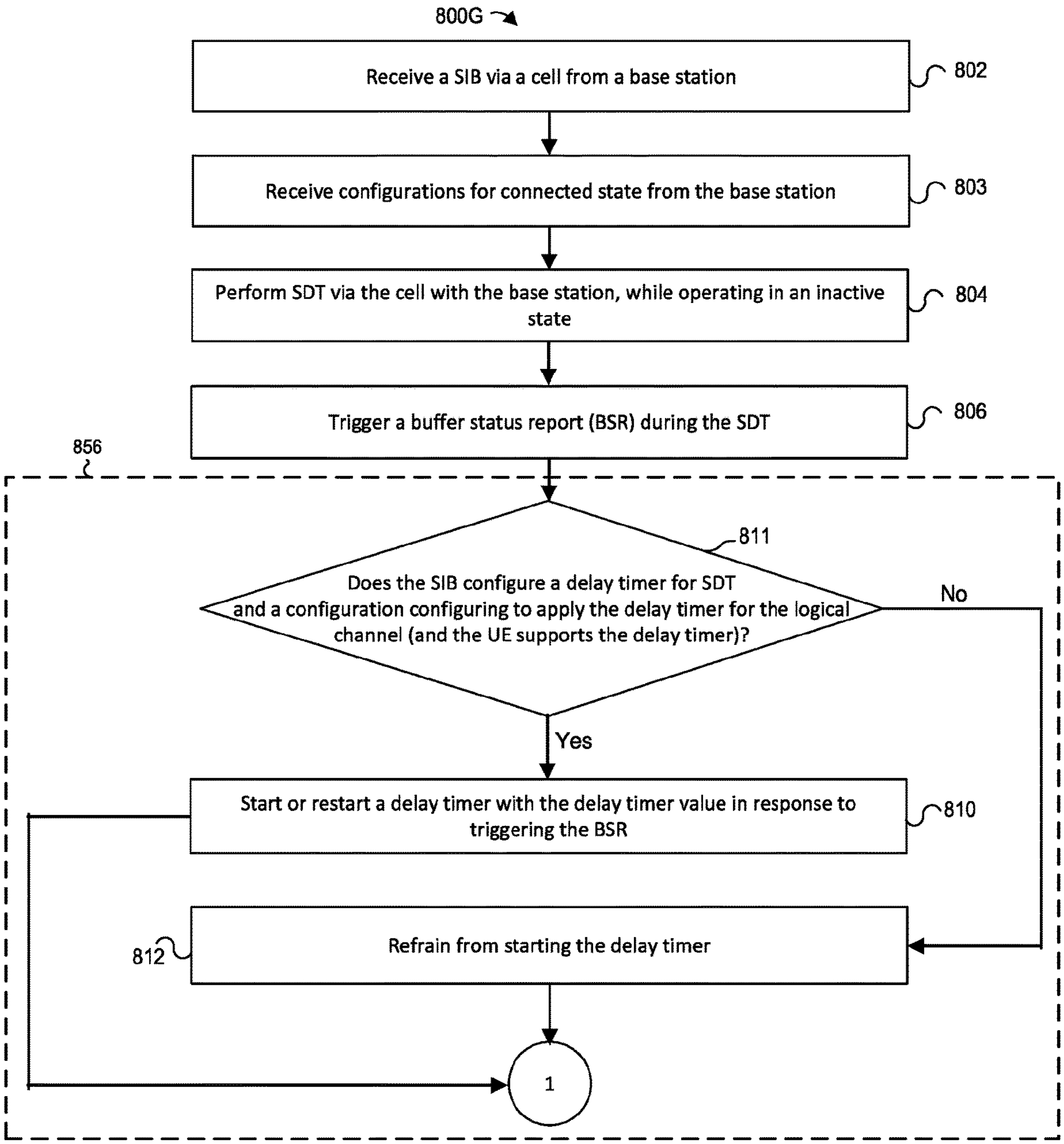

800G
Receive a SIB via a cell from a base station
802
Receive configurations for connected state from the base station
803
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) during the SDT
806
856
Does the SIB configure a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer)?
811
No
Yes
Start or restart a delay timer with the delay timer value in response to triggering the BSR
810
Refrain from starting the delay timer
812
1

Figure 8G-1

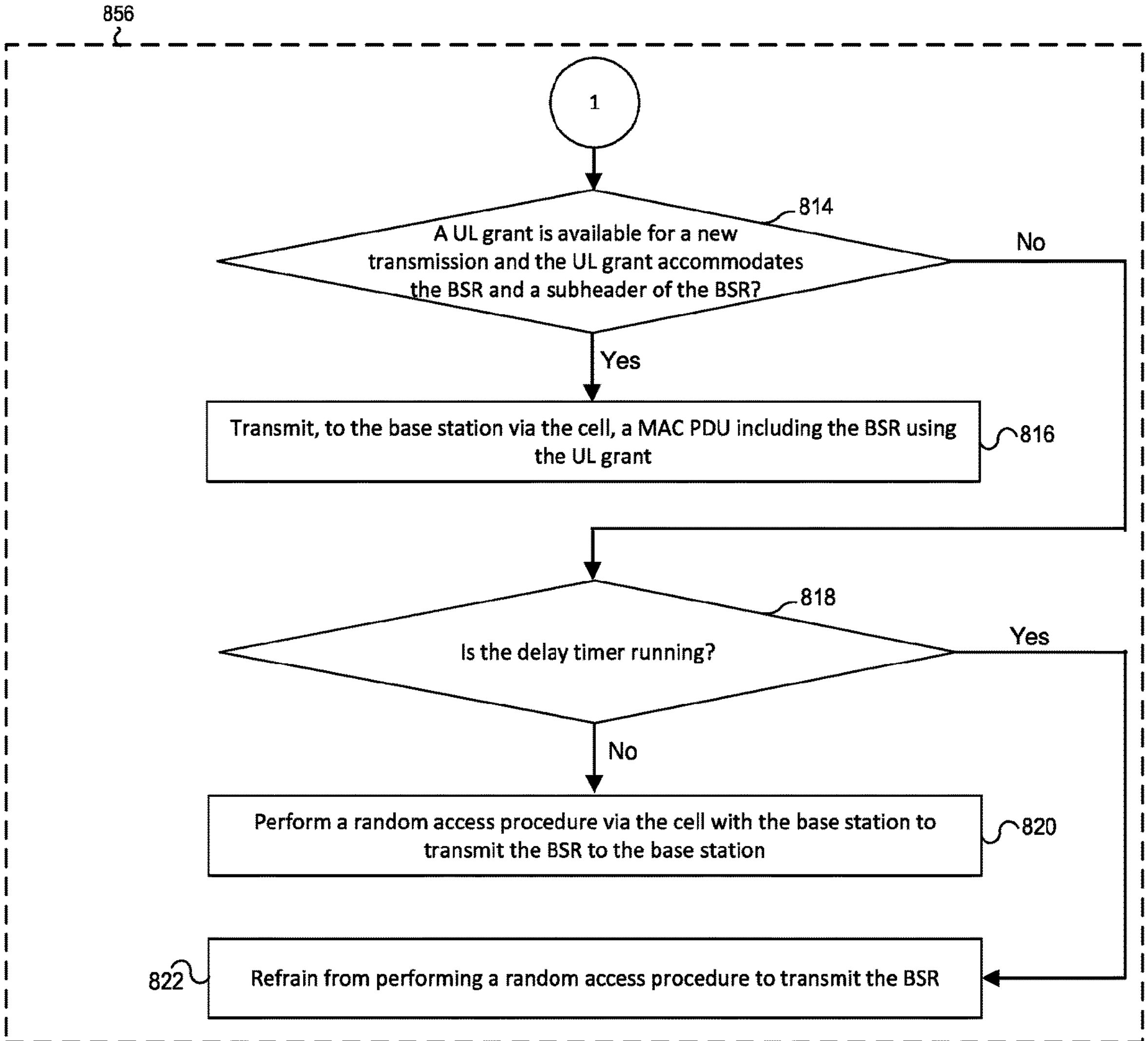

856
1
814
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
816
818
Is the delay timer running?
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
820
822
Refrain from performing a random access procedure to transmit the BSR

Figure 8G-2

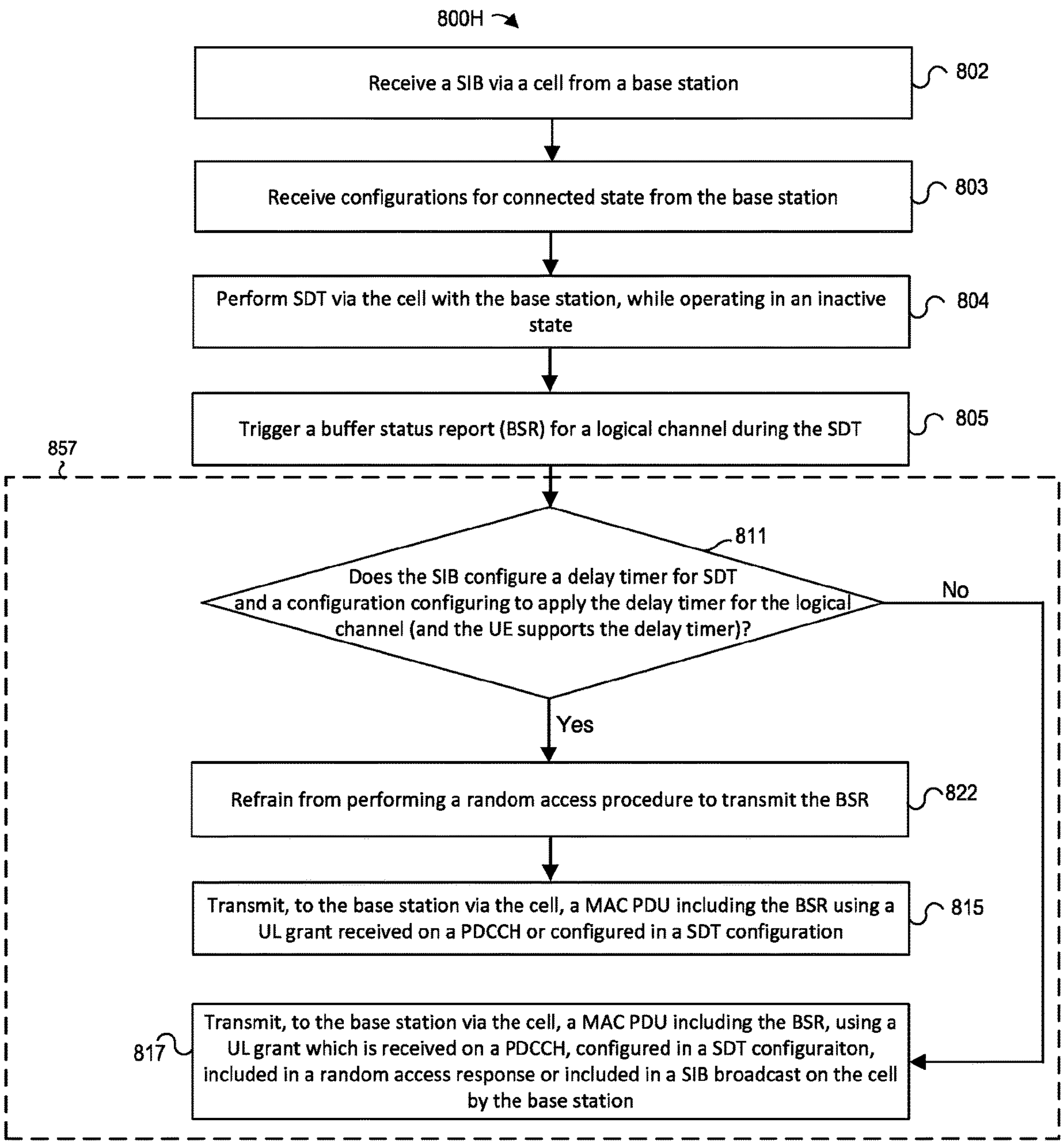

800H
Receive a SIB via a cell from a base station
802
Receive configurations for connected state from the base station
803
Perform SDT via the cell with the base station, while operating in an inactive state
804
Trigger a buffer status report (BSR) for a logical channel during the SDT
805
857
811
Does the SIB configure a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer)?
No
Yes
Refrain from performing a random access procedure to transmit the BSR
822
Transmit, to the base station via the cell, a MAC PDU including the BSR using a UL grant received on a PDCCH or configured in a SDT configuration
815
817
Transmit, to the base station via the cell, a MAC PDU including the BSR, using a UL grant which is received on a PDCCH, configured in a SDT configuraiton, included in a random access response or included in a SIB broadcast on the cell by the base station

Figure 8H

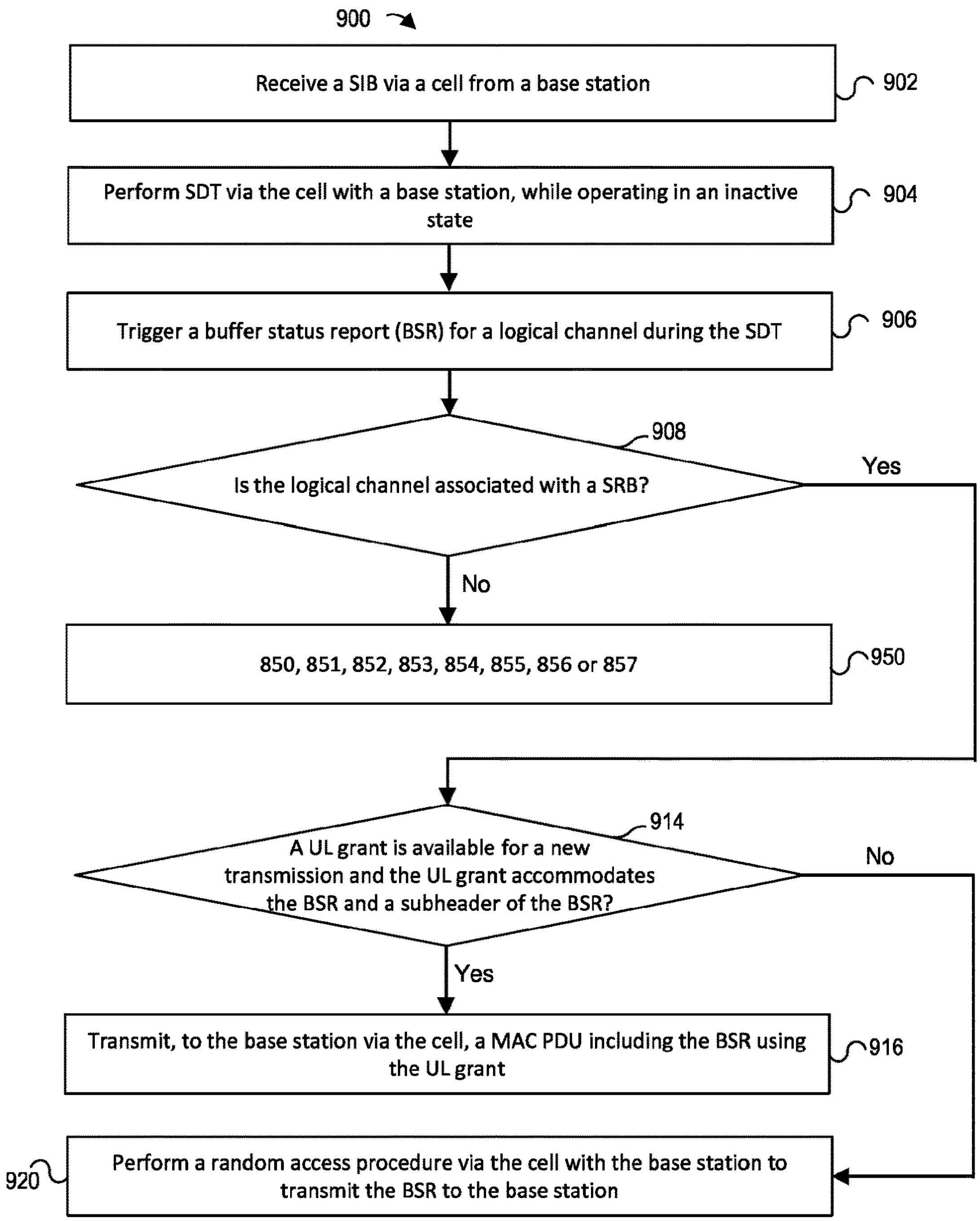

900
Receive a SIB via a cell from a base station
902
Perform SDT via the cell with a base station, while operating in an inactive state
904
Trigger a buffer status report (BSR) for a logical channel during the SDT
906
908
Is the logical channel associated with a SRB?
Yes
No
850, 851, 852, 853, 854, 855, 856 or 857
950
914
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
916
920
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station

Figure 9

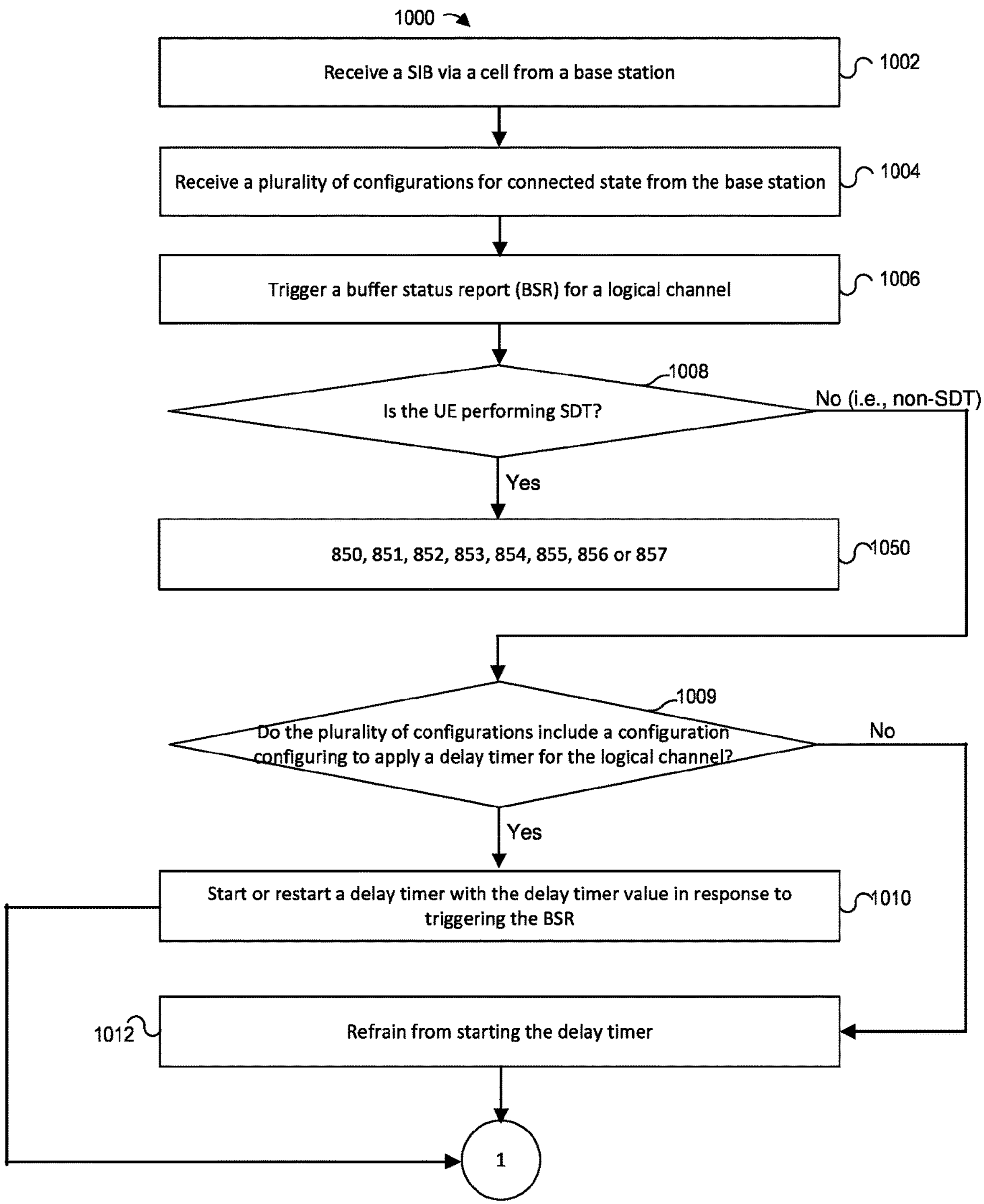

1000
Receive a SIB via a cell from a base station
1002
Receive a plurality of configurations for connected state from the base station
1004
Trigger a buffer status report (BSR) for a logical channel
1006
Is the UE performing SDT?
1008
No (i.e., non-SDT)
Yes
850, 851, 852, 853, 854, 855, 856 or 857
1050
Do the plurality of configurations include a configuration configuring to apply a delay timer for the logical channel?
1009
No
Yes
Start or restart a delay timer with the delay timer value in response to triggering the BSR
1010
1012
Refrain from starting the delay timer
1

Figure 10-1

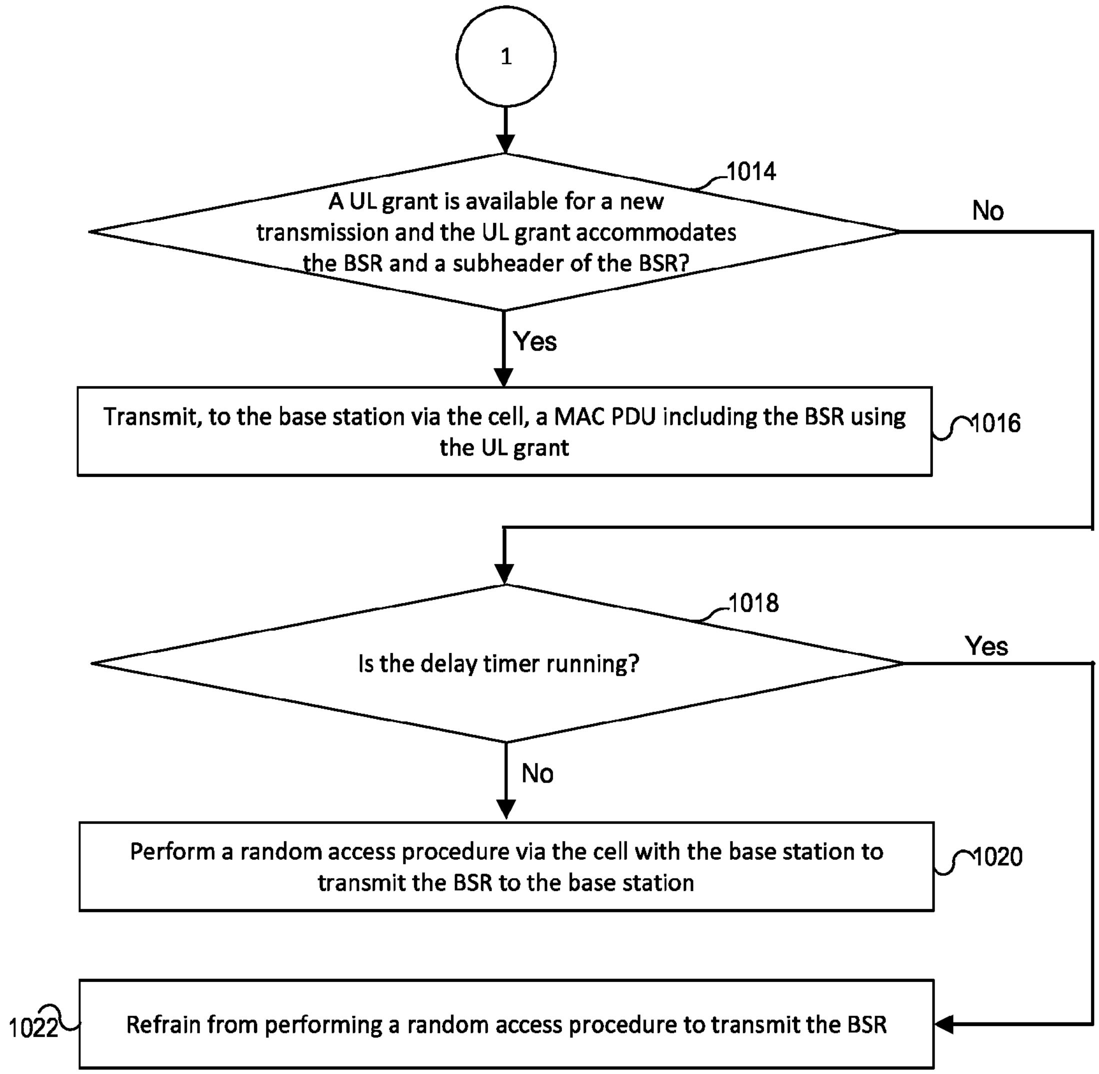

1
A UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
1014
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
1016
Is the delay timer running?
1018
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
1020
1022
Refrain from performing a random access procedure to transmit the BSR

Figure 10-2

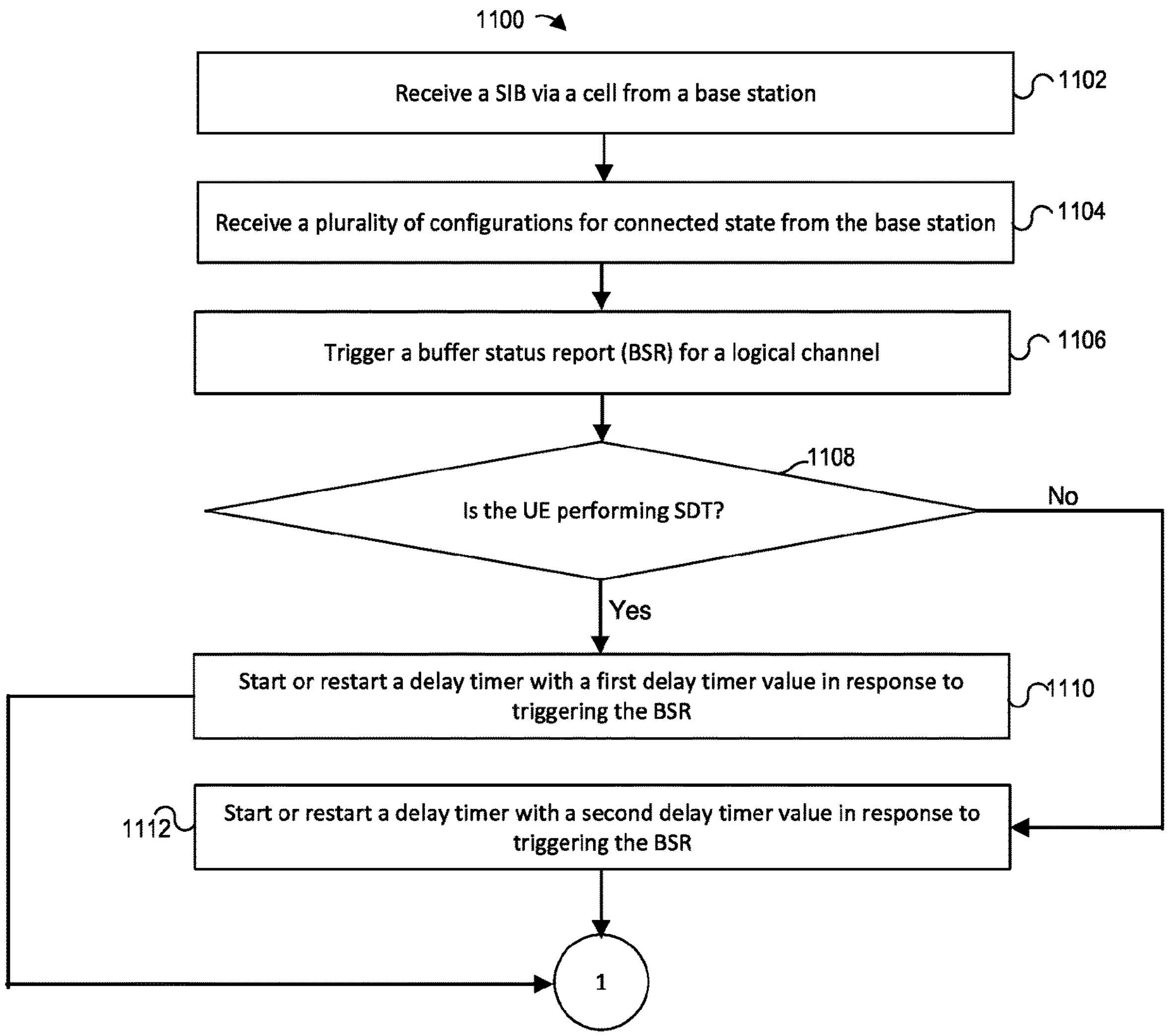

1100
Receive a SIB via a cell from a base station
1102
Receive a plurality of configurations for connected state from the base station
1104
Trigger a buffer status report (BSR) for a logical channel
1106
Is the UE performing SDT?
1108
No
Yes
Start or restart a delay timer with a first delay timer value in response to triggering the BSR
1110
Start or restart a delay timer with a second delay timer value in response to triggering the BSR
1112
1

Figure 11-1

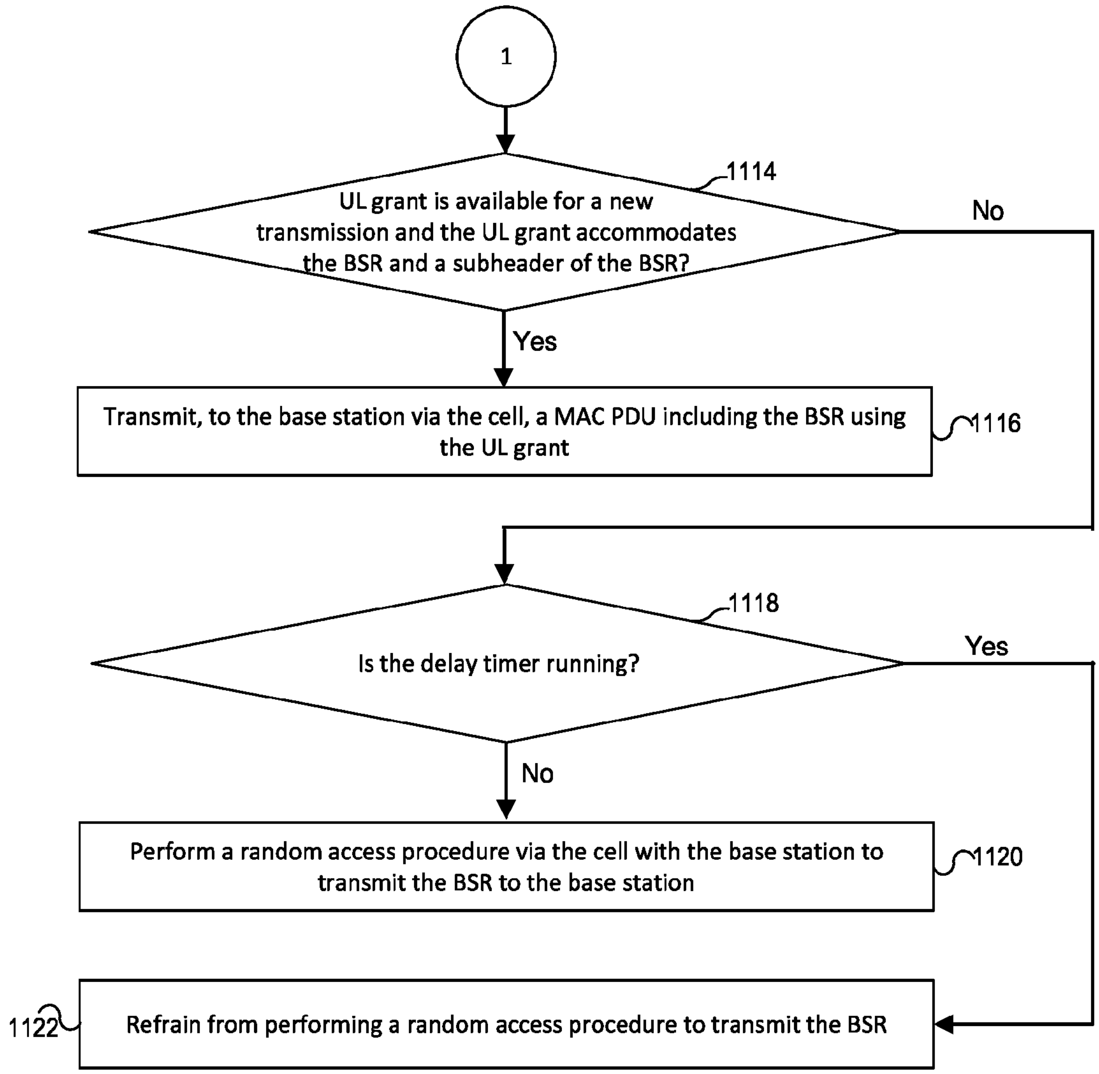

1
UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR?
1114
No
Yes
Transmit, to the base station via the cell, a MAC PDU including the BSR using the UL grant
1116
Is the delay timer running?
1118
Yes
No
Perform a random access procedure via the cell with the base station to transmit the BSR to the base station
1120
1122
Refrain from performing a random access procedure to transmit the BSR

Figure 11-2

MANAGING BUFFER STATUS REPORTING DURING SMALL DATA TRANSMISSION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of the filing date of provisional U.S. Patent Application No. 63/334,078, titled "MANAGING BUFFER STATUS REPORTING DURING SMALL DATA TRANSMISSION," filed on Apr. 22, 2022. The entire contents of the provisional application are hereby expressly incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] This disclosure relates generally to wireless communications and, more particularly, to managing configurations of small data communication of uplink and/or downlink data at a user equipment (UE) and a radio access network (RAN) when the UE operates in an inactive or idle state associated with a protocol for controlling radio resources.

BACKGROUND

[0003] This background description is provided for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] Generally speaking, a base station operating a cellular radio access network (RAN) communicates with a user equipment (UE) using a certain radio access technology (RAT) and multiple layers of a protocol stack. For example, the physical layer (PHY) of a RAT provides transport channels to the Medium Access Control (MAC) sublayer, which in turn provides logical channels to the Radio Link Control (RLC) sublayer, and the RLC sublayer in turn provides data transfer services to the Packet Data Convergence Protocol (PDCP) sublayer. The Radio Resource Control (RRC) sublayer is disposed above the PDCP sublayer.

[0005] The RRC sublayer specifies the RRC_IDLE state, in which a UE does not have an active radio connection with a base station; the RRC_CONNECTED state, in which the UE has an active radio connection with the base station; and the RRC_INACTIVE to allow a UE to more quickly transition back to the RRC_CONNECTED state due to Radio Access Network (RAN)-level base station coordination and RAN-paging procedures. In some cases, the UE in the RRC_INACTIVE state has only one, relatively small packet to transmit. In some such cases, a Small Data Transmission (SDT) procedure would support data transmission for the UE operating the RRC_INACTIVE (i.e., without transitioning to RRC_CONNECTED state).

[0006] SDT is enabled on a radio bearer basis and is initiated by the UE only if less than a configured amount of uplink data awaits transmission across all radio bearers for which SDT is enabled, the downlink RSRP is above a configured threshold, and a valid SDT resource is available. SDT procedure can be initiated by the UE with either a transmission over a random access channel (RACH) (i.e., called random access SDT (RA-SDT)) or over Type 1 configured grant (CG) resources (i.e., called CG-SDT). For RA-SDT, the network configures 2-step and/or 4-step random access resources for SDT. In RA-SDT, the UE transmits an initial transmission including data in a message 3 (Msg3) of a 4-step random access procedure or in a payload of a message A (MsgA) of a 2-step random access procedure. The network can then schedule subsequent uplink and/or downlink transmissions using dynamic uplink grants and downlink assignments, respectively, after the completion of the random access procedure.

[0007] During an SDT session with a base station (e.g., gNB), the UE obtains an uplink grant (e.g., a dynamic grant or a configured grant) for data transmission. In such cases, the UE may not have data available for transmission with the uplink grant. It is not clear whether the UE skips an uplink transmission configured by the uplink grant. It is also unknown how the base station manages small data communication for the UE.

SUMMARY

[0008] An example embodiment of the techniques of this disclosure is a method for wireless communication at a user equipment (UE). The method comprises receiving, from a radio access network (RAN), a system information block (SIB); triggering, when communicating data with the RAN in an inactive or idle state associated with a protocol for controlling radio resources, a buffer status report (BSR) to the RAN; and in response to the triggering and when the SIB includes a configuration of a delay timer for communicating data in the inactive or idle state, starting or restarting the delay timer according to the configuration.

[0009] Another example embodiment of these techniques is a user equipment comprising a transceiver, and a processing hardware configured to implement the method above.

[0010] Yet another example embodiment of these techniques is a method for wireless communications at a radio access network (RAN). The method comprises transmitting, to the UE, a system information block (SIB) that includes a configuration of a delay timer for communicating data while the RAN and UE have an inactive radio connection; and receiving a buffer status report (BSR) from the UE according to the configuration while the RAN and UE do not have an active radio connection.

[0011] Another example embodiment of these techniques is a base station comprising a processing hardware configured to implement the method above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1A is a block diagram of an example wireless communication system in which a user device and a base station of this disclosure can implement the techniques of this disclosure for reducing latency in data communication;

[0013] FIG. 1B is a block diagram of an example base station in which a centralized unit (CU) and a distributed unit (DU) that can operate in the system of FIG. 1A;

[0014] FIG. 2A is a block diagram of an example protocol stack according to which the UE of FIG. 1A communicates with base stations;

[0015] FIG. 2B is a block diagram of an example protocol stack according to which the UE of FIG. 1A communicates with a CU and a DU;

[0016] FIG. 3 is a messaging diagram of an example scenario in which a RAN node configures a UE for SDT communication;

[0017] FIG. **4** is a messaging diagram of an example scenario generally similar to the scenario of FIG. **3**, but in which the UE initially operates in an inactive state;

[0018] FIG. **5**A is a messaging diagram of an example scenario in which a UE transitions from communicating small in the inactive state to communicating non-SDT data in the connected state;

[0019] FIG. **5**B is a messaging diagram of a scenario generally similar to that of FIG. **5**A, but in which the UE initiates a resume procedure instead of an SDT procedure;

[0020] FIG. **6**A is a messaging diagram of an example scenario in which the RAN, in response to a request from a UE to resume a suspended radio connection, releases the connection with an SDT configuration;

[0021] FIG. **6**B is a messaging diagram of an example scenario in which a UE transmits uplink data in an active state;

[0022] FIG. **6**C is a messaging diagram of an example scenario in which a UE resumes a suspended radio connection with a distributed base station;

[0023] FIG. **7**A is a messaging diagram of an example scenario in which an upper layer of a communication stack of a UE requests that the RRC layer resume the radio connection and sends uplink data to the PDCP layer;

[0024] FIG. **7**B is a messaging diagram of an example scenario in which an upper layer of a communication stack of a UE requests that the RRC layer resume the radio connection and sends uplink data to the RRC layer;

[0025] FIG. **7**C is a messaging diagram of an example scenario in which an upper layer of a communication stack of a UE sends uplink data to the PDCP layer, which then requests that the RRC resume a suspended radio connection;

[0026] FIG. **8**A-H are flow diagrams of an example methods for applying an SDT delay timer for buffer status reporting, in accordance with various configurations and UE capability, and availability of an uplink grant, which can be implemented in the UE of FIG. **1**A; and

[0027] FIGS. **9-11** are a flow diagram of an example method for generating a buffer status report during SDT, which can be implemented in the UE of FIG. **1**A.

DETAILED DESCRIPTION OF THE DRAWINGS

[0028] As discussed in more detail below, a user equipment (UE) and/or a network node of a radio access network (RAN) can use the techniques of this disclosure for managing early data communication and transitioning a UE between states of a protocol for controlling radio resources between the UE and the RAN. As used in this disclosure, early data communication can refer to early data transmission (EDT) from the perspective of the network (i.e., EDT in the downlink direction), or EDT from the perspective of the UE (i.e., EDT in the uplink direction).

[0029] Referring first to FIG. **1**A, an example wireless communication system **100** includes a UE **102**, a base station (BS) **104**, a base station **106**, and a core network (CN) **110**. The base stations **104** and **106** can operate in a RAN **105** connected to the core network (CN) **110**. The CN **110** can be implemented as an evolved packet core (EPC) **111** or a fifth generation (5G) core (5GC) **160**, for example. The CN **110** can also be implemented as a sixth generation (6G) core in another example.

[0030] The base station **104** covers a cell **124**, and the base station **106** covers a cell **126**. If the base station **104** is a gNB, the cell **124** is an NR cell. If the base station **104** is an ng-eNB, the cell **124** is an evolved universal terrestrial radio access (E-UTRA) cell. Similarly, if the base station **106** is a gNB, the cell **126** is an NR cell, and if the base station **106** is an ng-eNB, the cell **126** is an E-UTRA cell. The cells **124** and **126** can be in the same Radio Access Network Notification Areas (RNA) or different RNAs. In general, the RAN **105** can include any number of base stations, and each of the base stations can cover one, two, three, or any other suitable number of cells. The UE **102** can support at least a 5G NR (or simply, "NR") or E-UTRA air interface to communicate with the base stations **104** and **106**. Each of the base stations **104**, **106** can connect to the CN **110** via an interface (e.g., S1 or NG interface). The base stations **104** and **106** also can be interconnected via an interface (e.g., X2 or Xn interface) for interconnecting NG RAN nodes.

[0031] Among other components, the EPC **111** can include a Serving Gateway (SGW) **112**, a Mobility Management Entity (MME) **114**, and a Packet Data Network Gateway (PGW) **116**. The SGW **112** in general is configured to transfer user-plane packets related to audio calls, video calls, Internet traffic, etc., and the MME **114** is configured to manage authentication, registration, paging, and other related functions. The PGW **116** provides connectivity from the UE to one or more external packet data networks, e.g., an Internet network and/or an Internet Protocol (IP) Multimedia Subsystem (IMS) network. The 5GC **160** includes a User Plane Function (UPF) **162** and an Access and Mobility Management Function (AMF) **164**, and/or Session Management Function (SMF) **166**. Generally speaking, the UPF **162** is configured to transfer user-plane packets related to audio calls, video calls, Internet traffic, etc., the AMF **164** is configured to manage authentication, registration, paging, and other related functions, and the SMF **166** is configured to manage PDU sessions.

[0032] As illustrated in FIG. **1**A, the base station **104** supports a cell **124**, and the base station **106** supports a cell **126**. The cells **124** and **126** can partially overlap, so that the UE **102** can select, reselect, or hand over from one of the cells **124** and **126** to the other. To directly exchange messages or information, the base station **104** and base station **106** can support an X2 or Xn interface. In general, the CN **110** can connect to any suitable number of base stations supporting NR cells and/or EUTRA cells.

[0033] As discussed in detail below, the UE **102** and/or the RAN **105** may utilize the techniques of this disclosure when the radio connection between the UE **102** and the RAN **105** is suspended, e.g., when the UE **102** operates in an inactive or idle state of the protocol for controlling radio resources between the UE **102** and the RAN **105**. For clarity, the examples below refer to the RRC_INACTIVE or RRC_IDLE state of the RRC protocol.

[0034] As used in this disclosure, the term "data" or "data packet" refers to signaling, control-plane information at a protocol layer of controlling radio resources (e.g., RRC); controlling mobility management (MM); controlling session management (SM); or non-signaling, non-control-plane information at protocol layers above the layer of the protocol for controlling radio resources (e.g., RRC), above the layer of the protocol for controlling mobility management (MM), above the layer of the protocol for controlling session management (SM), or above the layer of the protocol for controlling quality of service (QoS) flows (e.g., service data adaptation protocol (SDAP)). The data to which the UE and/or the RAN applies the techniques of this disclosure can include, for example, Internet of Things (IoT) data, ethernet traffic data, internet traffic data, or a short message service (SMS) message. Further, as discussed below, the UE **102** in some implementations applies these techniques only if the size of the data is below a certain threshold value.

[0035] In the example scenarios discussed below, the UE **102** transitions to the RRC_INACTIVE or RRC_IDLE state, selects a cell of the base station **104**, and exchanges data with the base station **104**, either via the base station **106** or with the base station **104** directly, without transitioning to RRC_CONNECTED state. As a more specific example, after the UE **102** determines that data is available for uplink transmission in the RRC_INACTIVE or RRC_IDLE state, the UE **102** can apply one or more security functions to an uplink (UL) data packet, generate a first uplink (UL) protocol data unit (PDU) including the security-protected packet, include a UL RRC message along with the first UL PDU in a second UL PDU, and transmit the second UL PDU to the RAN **105**. The UE **102** includes a UE identity/identifier (ID) for the UE **102** in the UL RRC message. The RAN **105** can identify the UE **102** based on the UE ID. In some implementations, the UE ID can be an inactive Radio Network Temporary Identifier (I-RNTI), a resume ID, or a non-access stratum (NAS) ID. The NAS ID can be an S-Temporary Mobile Subscriber Identity (S-TMSI) or a Global Unique Temporary Identifier (GUTI).

[0036] The security function can include an integrity protection and/or encryption function. When integrity protection is enabled, the UE **102** can generate a message authentication code for integrity (MAC-I) to protect integrity of the data. Thus, the UE **102** in this case generates a security-protected packet including the data and the MAC-I. When encryption is enabled, the UE **102** can encrypt the data to obtain an encrypted packet, so that the security-protected packet includes encrypted data. When both integrity protection and encryption are enabled, the UE **102** can generate a MAC-I for protecting integrity of the data and encrypt the data along with the MAC-I to generate an encrypted packet and an encrypted MAC-I. The UE **102** then can transmit the security-protected packet to the RAN **105** while in the RRC_INACTIVE or RRC_IDLE state.

[0037] In some implementations, the data is an uplink (UL) service data unit (SDU) of the packet data convergence protocol (PDCP) or SDAP. The UE **102** applies the security function to the SDU and includes the secured SDU in a first UL PDU (e.g., a UL PDCP PDU). The UE **102** then includes the UL PDCP PDU in a second UL PDU such as a UL MAC PDU, which can be associated with the medium access control (MAC) layer. Thus, the UE **102** in these cases transmits the secured UL PDCP PDU in the UL MAC PDU. In some implementations, the UE **102** can include, in the UL MAC PDU, a UL RRC message. In further implementations, the UE **102** may not include a UL RRC message in the UL MAC PDU. In this case, the UE **102** may not include a UE ID of the UE **102** in the UL MAC PDU not including a UL RRC message. In yet further implementations, the UE **102** can include the UL PDCP PDU in a UL radio link control (RLC) PDU and then include the UL RLC PDU in the UL MAC PDU. In the case of including the UL RRC message in the UL MAC PDU, the UE **102** in some implementations generates an RRC MAC-I and includes the RRC MAC-I in the UL RRC message. For example, the RRC MAC-I is a resumeMAC-I field, as specified in 3GPP specification 38.331. In further implementations, the UE can obtain the RRC MAC-I from the UL RRC message with an integrity key (e.g., K_{RRCint} key), an integrity protection algorithm, and other parameters COUNT (e.g., 32-bit, 64-bit or 128-bit value), BEARER (e.g., 5-bit value) and DIRECTION (e.g., 1-bit value).

[0038] In further implementations, the data is a UL service data unit (SDU) of the NAS. The UE **102** applies the security function to the SDU and includes the secured SDU in a first UL PDU such as a NAS PDU, which can be associated with the NAS layer. For example, the NAS layer can be an MM sublayer or SM sublayer of 5G, Evolved Packet System (EPS), or 6G. Then the UE **102** can include the UL NAS PDU in a second UL PDU such as a UL RRC message. Thus, the UE **102** in these cases transmits the (first) secured UL NAS PDU in the UL RRC message. In some implementations, the UE **102** can include the UL RRC message in a UL MAC PDU and transmits the UL MAC PDU to a base station (e.g., base station **104** or **106**) via a cell (e.g., cell **124** or **126**). In this case, the UE **102** may not include an RRC MAC-I in the UL RRC message. Alternatively, the UE **102** may include an RRC MAC-I as described above.

[0039] In some implementations, the UL RRC message described above can be a common control channel (CCCH) message, an RRC resume request message, or an RRC early data request message. The UL RRC message can include a UE ID of the UE **102** as described above.

[0040] More generally, the UE **102** can secure the data using at least one of encryption and integrity protection, include the secured data as a security-protected packet in the first UL PDU, and transmit the first UL PDU to the RAN **105** in the second UL PDU.

[0041] In some scenarios and implementations, the base station **106** can retrieve the UE ID of the UE **102** from the UL RRC message and identify the base station **104** as the destination of the data in the first UL PDU, based on the determined UE ID. In one example implementation, the base station **106** retrieves the first UL PDU from the second UL PDU and transmits the first UL PDU to the base station **104**. The base station **104** then retrieves the security-protected packet from the first UL PDU, applies one or two security functions to decrypt the data and/or check the integrity protection, and transmits the data to the CN **110** (e.g., SGW **112**, UPF **162**, MME **114** or AMF **164**) or an edge server. In some implementations, the edge server can operate within the RAN **105**. More specifically, the base station **104** derives at least one security key from UE context information of the UE **102**. Then the base station **104** retrieves the data from the security-protected packet by using the at least one security key and transmits the data to the CN **110** or edge server. When the security-protected packet is an encrypted packet, the base station **104** decrypts the encrypted packet to obtain the data by using the at least one security key (e.g., an encryption and/or decryption key). If the security-protected packet is an integrity-protected packet, the integrity-protected packet may include the data and the MAC-I. The base station **104** can verify whether the MAC-I is valid for the security-protected packet by using the at least one security key (e.g., an integrity key). When the base station **104** confirms that the MAC-I is valid, the base station **104** sends the data to the CN **110** or edge server. However, when the base station **104** determines that the MAC-I is invalid, the base station **104** discards the security-protected packet. Further, if the security-protected packet is both encrypted and integrity-protected, the encrypted and integrity-protected packet may include the encrypted packet along with the encrypted MAC-I. The base station **104** in this case decrypts the encrypted packet and the encrypted MAC-I to obtain the data and the MAC-I. The base station **104** then determines whether the MAC-I is valid for the data. If the base station **104** determines that the MAC-I is valid, the base station **104** retrieves the data and forwards the data to the CN **110** or edge server. However, if the base station **104** determines that the MAC-I is invalid, the base station **104** discards the packet.

[0042] In another implementation, the base station **106** retrieves the security-protected packet from the first UL PDU. The base station **106** performs a retrieve UE context procedure with the base station **104** to obtain UE context information of the UE **102** from the base station **104**. The base station **106** derives at least one security key from the UE context information. Then the base station **106** retrieves the data from the security-protected packet by using the at least one security key and transmits the data to the CN **110** (e.g., UPF **162**) or an edge server. When the security-protected packet is an encrypted packet, the base station **106** decrypts the encrypted packet to obtain the data by using the at least one security key (e.g., an encryption and/or decryption key). If the security-protected packet is an integrity-protected packet, the integrity protected packet may include the data and the MAC-I. The base station **106** can verify whether the MAC-I is valid for the security-protected packet by using the at least one security key (e.g., an integrity key). When the base station **106** confirms that the MAC-I is valid, the base station **106** sends the data to the CN **110**. On the other hand, when the base station **106** determines that the MAC-I is invalid, the base station **106** discards the security-protected packet. Further, if the security-protected packet is both encrypted and integrity-protected, the encrypted and integrity-protected packet may include the encrypted packet along with the encrypted MAC-I. The base station **106** in this case decrypts the encrypted packet and the encrypted MAC-I to obtain the data and the MAC-I. The base station **106** then determines whether the MAC-I is valid for the data. If the base station **106** determines that the MAC-I is valid, the base station **106** retrieves the data and forwards the data to the CN **110**. However, if the base station **106** determines that the MAC-I is invalid, the base station **106** discards the packet.

[0043] In other scenarios and implementations, the base station **104** can retrieve the UE ID of the UE **102** from the UL RRC message and identify that the base station **104** stores UE context information of the UE **102**. Thus, the base station **104** retrieves the security-protected packet from the first UL PDU, retrieves the data from the security-protected packet, and sends the data to the CN **110** or edge server as described above.

[0044] Further, the RAN **105** in some cases transmits data in the downlink (DL) direction to the UE **102** operating in the RRC_INACTIVE or RRC_IDLE state.

[0045] For example, when the base station **104** determines that data is available for downlink transmission to the UE **102** currently operating in the RRC_INACTIVE or RRC_IDLE state, the base station **104** can apply at least one security function to the data to generate a security-protected packet, generate a first DL PDU including the security-protected packet, and the first DL PDU in a second DL PDU. To secure the data, the base station **104** can apply the security function (e.g., integrity protection and/or encryption) to the data. More particularly, when integrity protection is enabled, the base station **104** generates a MAC-I for protecting integrity of the data, so that the security-protected packet includes the data and the MAC-I. When encryption is enabled, the base station **104** encrypts the data to generate an encrypted packet, so that the security-protected packet is an encrypted packet. Further, when both integrity protection and encryption are enabled, the base station **104** can generate a MAC-I for protecting the integrity of the data and encrypt the data along with the MAC-I to generate an encrypted packet and an encrypted MAC-I. The base station **104** in some implementations generates a first DL PDU, such as a DL PDCP PDU, using the security-protected packet, includes the first DL PDU in a second DL PDU associated with the MAC layer for example (e.g., a DL MAC PDU), and transmits the second DL PDU to the UE **102** without first causing the UE **102** to transition from the RRC_INACTIVE or RRC_IDLE state to the RRC_CONNECTED state. In some implementations, the base station **104** includes the DL PDCP PDU in a DL RLC PDU, includes the DL RLC PDU in the DL MAC PDU and transmits the DL MAC PDU to the UE **102** without first causing the UE **102** to transition from the RRC_INACTIVE or RRC_IDLE state to the RRC_CONNECTED state.

[0046] In another implementation, the base station **104** transmits the first DL PDU to the base station **106**, which then generates a second PDU (e.g., a DL MAC PDU) including the first DL PDU and transmits the second DL PDU to the UE **102** without first causing the UE **102** to transition from the RRC_INACTIVE or RRC_IDLE state to the RRC_CONNECTED state. In some implementations, the base station **106** generates a DL RLC PDU including the first DL PDU and includes the DL RLC PDU in the second DL PDU. In yet another implementation, the base station **104** includes the first DL PDU in a DL RLC PDU and transmits the DL RLC PDU to the base station **106**, which then generates a second DL PDU (e.g., a DL MAC PDU), including the DL RLC PDU, and transmits the second DL PDU to the UE **102**.

[0047] In some implementations, the base station (i.e., the base station **104** or **106**) generates a downlink control information (DCI) and a cyclic redundancy check (CRC) scrambled with an ID of the UE **102** to transmit the second DL PDU generated by the base station. In some implementations, the ID of the UE **102** can be a Radio Network Temporary Identifier (RNTI). For example, the RNTI can be a cell RNTI (C-RNTI), a temporary C-RNTI or an inactive C-RNTI. The base station transmits the DCI and scrambled CRC on a physical downlink control channel (PDCCH) to the UE **102** operating in the RRC_INACTIVE or RRC_IDLE state. The base station scrambles the CRC with the ID of the UE **102**. In some implementations, the base station may assign the ID of the UE **102** to the UE **102** in a random access response or a message B (MsgB) that the base station transmits in a random access procedure with the UE **102** before transmitting the DCI and scrambled CRC. In further implementations, the base station may assign the ID of the UE **102** to the UE **102** in an RRC message (e.g., RRC release message or an RRC reconfiguration message) that the base station transmits to the UE **102** before transmitting the DCI and scrambled CRC, e.g., while the UE **102** was in the RRC_CONNECTED state.

[0048] The UE **102** operating in the RRC_INACTIVE or RRC_IDLE state can receive the DCI and scrambled CRC on the PDCCH. Then the UE **102** confirms that a physical downlink shared channel (PDSCH), including the second DL PDU, is addressed to the UE **102** according to the ID of the UE **102**, DCI, and scrambled CRC. The UE **102** then can retrieve the data from the security-protected packet. If the security-protected packet is an encrypted packet, the UE **102** can decrypt the encrypted packet using the appropriate decryption function and the security key to obtain the data. If the security-protected packet is the integrity-protected packet including the data and the MAC-I, the UE **102** can determine whether the MAC-I is valid. If the UE **102** confirms that the MAC-I is valid, the UE **102** retrieves the data. If, however, the UE **102** determines that the MAC-I is invalid, the UE **102** discards the packet. Finally, when the security-protected packet is both encrypted and integrity-protected, with encrypted data and an encrypted MAC-I, the UE **102** can decrypt the encrypted packet and encrypted MAC-I to obtain the data and the MAC-I. The UE **102** can then verify that the MAC-I is valid for the data. If the UE **102** confirms that the MAC-I is valid, the UE **102** retrieves and processes the data. Otherwise, when the UE **102** determines that the MAC-I is invalid, the UE **102** discards the data.

[0049] The base station **104** is equipped with processing hardware **130** that can include one or more general-purpose processors (e.g., CPUs) and a non-transitory computer-readable memory storing instructions that the one or more general-purpose processors execute. Additionally or alternatively, the processing hardware **130** can include special-purpose processing units. The processing hardware **130** in an example implementation includes a Medium Access Control (MAC) controller **132** configured to perform a random access procedure with one or more user devices, receive uplink MAC protocol data units (PDUs) to one or more user devices, and transmit downlink MAC PDUs to one or more user devices. The processing hardware **130** can also include a Packet Data Convergence Protocol (PDCP) controller **134** configured to transmit DL PDCP PDUs in accordance with which the base station **104** can transmit data in the downlink direction, in some scenarios, and receive UL PDCP PDUs in accordance with which the base station **104** can receive data in the uplink direction, in other scenarios. The processing hardware further can include an RRC controller **136** to implement procedures and messaging at the RRC sublayer of the protocol communication stack. The processing hardware **130** in an example implementation includes an RRC inactive controller **138** configured to manage uplink and/or downlink communications with one or more UEs operating in the RRC_INACTIVE or RRC_IDLE state. The base station **106** can include generally similar components. In particular, components **140**, **142**, **144**, **146**, and **148** of the base station **106** can be similar to the components **130**, **132**, **134**, **136**, and **138**, respectively.

[0050] The UE **102** is equipped with processing hardware **150** that can include one or more general-purpose processors such as CPUs and non-transitory computer-readable memory storing machine-readable instructions executable on the one or more general-purpose processors, and/or special-purpose processing units. The processing hardware **150** in an example implementation includes an RRC inactive controller **158** configured to manage uplink and/or downlink communications when the UE **102** operates in the RRC_INACTIVE state. The processing hardware **150** in an example implementation includes a Medium Access Control (MAC) controller **152** configured to perform a random access procedure with a base station, transmit uplink MAC protocol data units (PDUs) to the base station, and receive downlink MAC PDUs from the base station. The processing hardware **150** can also include a PDCP controller **154** configured to, in some scenarios, transmit DL PDCP PDUs in accordance with which the base station **106** can transmit data in the downlink direction, and, in further scenarios, receive UL PDCP PDUs in accordance with which the base station **106** can receive data in the uplink direction. The processing hardware further can include an RRC controller **156** to implement procedures and messaging at the RRC sublayer of the protocol communication stack.

[0051] FIG. **1**B depicts an example distributed or disaggregated implementation of any one or more of the base stations **104**, **106**. In this implementation, the base station **104**, **106** includes a central unit (CU) **172** and one or more distributed units (DUs) **174**. The CU **172** includes processing hardware, such as one or more general-purpose processors (e.g., CPUs) and a computer-readable memory storing machine-readable instructions executable on the general-purpose processor(s), and/or special-purpose processing units. For example, the CU **172** can include a PDCP controller, an RRC controller and/or an RRC inactive controller such as PDCP controller **134**, **144**, RRC controller **136**, **146** and/or RRC inactive controller **138**, **148**. In some implementations, the CU **172** can include a radio link control (RLC) controller configured to manage or control one or more RLC operations or procedures. In further implementations, the CU **172** does not include an RLC controller.

[0052] Each of the DUs **174** also includes processing hardware that can include one or more general-purpose processors (e.g., CPUs) and computer-readable memory storing machine-readable instructions executable on the one or more general-purpose processors, and/or special-purpose processing units. For example, the processing hardware can include a MAC controller (e.g., MAC controller **132**, **142**) configured to manage or control one or more MAC operations or procedures (e.g., a random access procedure), and/or an RLC controller configured to manage or control one or more RLC operations or procedures. The process hardware can also include a physical layer controller configured to manage or control one or more physical layer operations or procedures.

[0053] In some embodiments, the RAN **105** supports Integrated Access and Backhaul (IAB) functionality. In some implementations, the DU **174** operates as an (IAB)-node, and the CU **172** operates as an IAB-donor.

[0054] In some implementations, the CU **172** can include a logical node CU-CP **172**A that hosts the control plane part of the PDCP protocol of the CU **172**. The CU **172** can also include logical node(s) CU-UP **172**B that hosts the user plane part of the PDCP protocol and/or Service Data Adaptation Protocol (SDAP) protocol of the CU **172**. The CU-CP **172**A can transmit control information (e.g., RRC messages, F1 application protocol messages), and the CU-UP **172**B can transmit the data packets (e.g., SDAP PDUs or Internet Protocol packets).

[0055] The CU-CP **172**A can be connected to multiple CU-UP **172**B through the E1 interface. The CU-CP **172**A selects the appropriate CU-UP **172**B for the requested services for the UE **102**. In some implementations, a single CU-UP **172**B can connect to multiple CU-CP **172**A through the E1 interface. The CU-CP **172**A can connect to one or more DU **174**s through an F1-C interface. The CU-UP **172**B can connect to one or more DU **174** through the F1-U interface under the control of the same CU-CP **172**A. In some implementations, one DU **174** can connect to multiple CU-UP **172**B under the control of the same CU-CP **172**A. In such implementations, the connectivity between a CU-UP **172**B and a DU **174** is established by the CU-CP **172**A using Bearer Context Management functions.

[0056] FIG. **2**A illustrates, in a simplified manner, an example protocol stack **200** according to which the UE **102** can communicate with an eNB/ng-eNB or a gNB (e.g., one or more of the base stations **104**, **106**).

[0057] In the example stack **200**, a physical layer (PHY) **202**A of EUTRA provides transport channels to the EUTRA MAC sublayer **204**A, which in turn provides logical channels to the EUTRA RLC sublayer **206**A. The EUTRA RLC sublayer **206**A in turn provides RLC channels to an EUTRA PDCP sublayer **208** and, in some cases, to an NR PDCP sublayer **210**. Similarly, the NR PHY **202**B provides transport channels to the NR MAC sublayer **204**B, which in turn provides logical channels to the NR RLC sublayer **206**B. The NR RLC sublayer **206**B in turn provides data transfer services to the NR PDCP sublayer **210**. The NR PDCP sublayer **210** in turn can provide data transfer services to Service Data Adaptation Protocol (SDAP) **212** or a radio resource control (RRC) sublayer (not shown in FIG. **2**A). The UE **102**, in some implementations, supports both the EUTRA and the NR stack as shown in FIG. **2**A, to support handover between EUTRA and NR base stations and/or to support DC over EUTRA and NR interfaces. Further, as illustrated in FIG. **2**A, the UE **102** can support layering of NR PDCP **210** over EUTRA RLC **206**A, and SDAP sublayer **212** over the NR PDCP sublayer **210**.

[0058] The EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** receive packets (e.g., from an Internet Protocol (IP) layer, layered directly or indirectly over the PDCP layer **208** or **210**) that can be referred to as service data units (SDUs), and output packets (e.g., to the RLC layer **206**A or **206**B) that can be referred to as protocol data units (PDUs). Except where the difference between SDUs and PDUs is relevant, this disclosure for simplicity refers to both SDUs and PDUs as "packets."

[0059] On a control plane, the EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** can provide signaling radio bearers (SRBs) or RRC sublayer (not shown in FIG. **2**A) to exchange RRC messages or non-access-stratum (NAS) messages, for example. On a user plane, the EUTRA PDCP sublayer **208** and the NR PDCP sublayer **210** can provide Data Radio Bearers (DRBs) to support data exchange. Data exchanged on the NR PDCP sublayer **210** can be SDAP PDUs, Internet Protocol (IP) packets or Ethernet packets.

[0060] FIG. **2**B illustrates, in a simplified manner, an example protocol stack **250**, which the UE **102** can communicate with a DU (e.g., DU **174**) and a CU (e.g., CU **172**). The radio protocol stack **200** is functionally split as shown by the radio protocol stack **250** in FIG. **2**B. The CU at any of the base stations **104** or **106** can hold all the control and upper layer functionalities (e.g., RRC **214**, SDAP **212**, NR PDCP **210**), while the lower layer operations (e.g., NR RLC **206**B, NR MAC **204**B, and NR PHY **202**B) are delegated to the DU. To support connection to a 5GC, NR PDCP **210** provides SRBs to RRC **214**, and NR PDCP **210** provides DRBs to SDAP **212** and SRBs to RRC **214**.

[0061] Next, several example scenarios that involve several components of FIG. **1**A and relate to transmitting data in an inactive or idle state are discussed next with reference to FIGS. **3** and **4**. To simplify the following description, the "inactive state" is used and can represent the RRC_INACTIVE or RRC_IDLE state, and the "connected state" is used and can represent the RRC_CONNECTED state.

[0062] Referring first to FIG. **3**, which illustrates a scenario **300**, in which the base station **104** includes a central unit (CU) **172** and a distributed unit (DU) **174**, and the CU **172** includes a CU-CP **172**A and a CU-UP **172**B. In the scenario **300**, the UE **102** initially operates in a connected state **302** and communicates **304** with the DU **174** by using a DU configuration (i.e., a first non-SDT configuration), and further communicates **304** with the CU-CP **172**A and/or CU-UP **172**B via the DU **174** by using a CU configuration (i.e., a first non-SDT CU configuration). While the UE communicates **304** with the base station **104**, the CU-CP **172**A sends **306** a UE Context Modification Request message. In response, the DU **174** sends **308** a UE Context Modification Response message to including a non-SDT configuration (i.e., a second non-SDT configuration) for the UE **102** to the CU-CP **172**A. The CU-CP **172**A generates an RRC reconfiguration message including the non-SDT DU configuration and transmits **310** a first CU-to-DU message (e.g., DL RRC Message Transfer message), including the RRC reconfiguration message, to the DU **174**. In turn, the DU **174** transmits **312** the RRC reconfiguration message to the UE **102**. In response, the UE **102** transmits **314** an RRC reconfiguration complete message to the DU **174**, which in turn transmits **316** a first DU-to-CU message (e.g., UL RRC Message Transfer message), including the RRC reconfiguration complete message, to the CU-CP **172**A.

[0063] After receiving **312** the RRC reconfiguration message, the UE **102** in the connected state communicates **318** with the DU **174** using the second non-SDT DU configuration. The UE **102** further communicates with the CU-CP **172**A and/or CU-UP **172**B via the DU **174**. In cases where the RRC reconfiguration message does not include a CU configuration, the UE **102** communicates **318** with the CU-CP **172**A and/or CU-UP **172**B via the DU **174** using the first non-SDT CU configuration. In cases where the RRC reconfiguration message includes a non-SDT CU configuration (i.e., a second non-SDT CU configuration), the UE **102** communicates **318** with the CU-CP **172**A and/or CU-UP **172**B via the DU **174**, using the second non-SDT CU configuration.

[0064] In some implementations, the second non-SDT CU configuration augments the first non-SDT CU configuration and/or includes at least one new configuration parameter not included in the first non-SDT CU configuration. In some such cases, the UE **102** and at least one of the CU-CP **172**A and/or the CU-UP **172**B communicate **318** with one another using the second non-SDU CU configuration as well as configuration parameters in the first non-SDT CU configuration that the second non-SDU CU configuration does not augment. In some implementations, the first non-SDT CU configuration includes configuration parameters related to operations of RRC and/or PDCP protocol layers (e.g., RRC **214** and/or NR PDCP **210**), that the UE **102** and CU **172** use to communicate with one another while the UE **102** operates in the connected state. Similarly, in further implementations, the second non-SDT CU configuration includes configuration parameters related to operations for the RRC and/or

PDCP protocol layers, that the UE **102** and CU **172** use to communicate with one another while the UE **102** operates in the connected state.

[0065] In some implementations, the first non-SDT CU configuration includes configuration parameters in a RadioBearerConfig information element (IE) and/or MeasConfig IE (e.g., as defined in 3GPP specification 38.331 v 16.7.0 or later). Similarly, the second non-SDT CU configuration includes configuration parameters in the RadioBearerConfig IE and/or MeasConfig IE (e.g., as defined in 3GPP specification 38.331 v 16.7.0 or later). In some implementations, the first non-SDT CU configuration is or includes a RadioBearerConfig IE and/or a MeasConfig IE, and the second non-SDT CU configuration is or includes a RadioBearerConfig IE and/or MeasConfig IE.

[0066] In some implementations, the first non-SDT DU configuration includes configuration parameters related to operations of RRC, RLC, MAC, and/or PHY protocol layers (e.g., RLC **206**B, MAC **204**B and/or PHY **202**B) that the UE **102** and DU **174** use to communicate with one another while the UE **102** operates in the connected state. Similarly, in further implementations, the second non-SDT DU configuration includes configuration parameters related to operations of the RRC, RLC, MAC, and/or PHY protocol layers that the UE **102** and DU **174** use to communicate with one another while the UE **102** operates in the connected state.

[0067] In some implementations, the first non-SDT DU configuration includes configuration parameters in a CellGroupConfig IE (e.g., as defined in 3GPP specification 38.331 v 16.7.0). Similarly, the second non-SDT DU configuration includes configuration parameters in the CellGroupConfig IE (e.g., defined in 3GPP specification 38.331 v 16.7.0). In some implementations, the first non-SDT DU configuration and the second non-SDT DU configuration are CellGroupConfig IEs.

[0068] The events **306**, **308**, **310**, **312**, **314**, **316** and **318** are collectively referred to in FIG. **3** as a non-SDT resource configuration/reconfiguration procedure **390**.

[0069] Depending on the implementation, while the UE **102** communicates with the base station **104** or after the non-SDT resource configuration/reconfiguration procedure **390**, the CU-CP **172**A determines to cause the UE **102** to transition to an inactive state from the connected state, based on data inactivity of the UE **102** (i.e., the UE **102** in the connected state has no data activity with the base station **104**). In some implementations, either while the UE **102** communicates with the base station **104** or after the non-SDT resource configuration/reconfiguration procedure **390**, the UE **102** determines or detects data inactivity and transmits **320**, to the DU **174**, UE assistance information (e.g., a UEAssistanceInformation message) indicating that the UE **102** prefers or requests to transition to the inactive state or leave the connected state. In some implementations, the UE **102** indicates, in the UE assistance information, that the UE **102** prefers or requests to transition to the inactive state with SDT configured. In turn, the DU **174** transmits **321** a UL RRC Message Transfer message including the UE assistance information to the CU-CP **172**A. Thus, the CU-CP **172**A can determine that the UE **102** has data inactivity based on the UE assistance information.

[0070] In other implementations, the DU **174** performs data inactivity monitoring for the UE **102**. Depending on the implementation, the CU-CP **172**A transmits a CU-to-DU message (e.g., a UE Context Setup Request message or a UE Context Modification Request message) to the DU **174** to request or command the DU **174** to perform the data inactivity monitoring. In some cases where the DU **174** detects or determines that the UE **102** has data inactivity during the monitoring, the DU **174** transmits **322** an inactivity notification (e.g., UE Inactivity Notification message) to the CU-CP **172**A. Thus, the CU-CP **172**A can determine that the UE **102** has data inactivity based on the inactivity notification received from the DU **174**.

[0071] In yet other implementations, the CU-UP **172**B performs data inactivity monitoring for the UE **102**. In some such implementations, the CU-CP **172**A transmits a CP-to-UP message (e.g., a Bearer Context Setup Request message or a Bearer Context Modification Request message) to the CU-UP **172**B to request or command the CU-UP **172**B to perform the data inactivity monitoring. In some cases where the CU-UP **172**B detects or determines that the UE **102** has data inactivity during the monitoring, the CU-UP **172**B transmits **323** an inactivity notification (e.g., Bearer Context Inactivity Notification message) to the CU-CP **172**A. Thus, the CU-CP **172**A can determine that the UE **102** has data inactivity based on the inactivity notification received from the CU-UP **172**B. In some implementations, the CU-CP **172**A determines that the UE **102** has data inactivity based on the UE assistance information, inactivity notification of the event **322**, and/or inactivity notification of the event **323**.

[0072] In some implementations, after a certain period of data inactivity, the CU-CP **172**A determines that neither the CU **172** (i.e., the CU-CP **172**A and/or the CU-UP **172**B) nor the UE **102** has transmitted any data in the downlink direction or the uplink direction, respectively, during the period. In some implementations, in response to the determination, the CU-CP **172**A determines to cause the UE **102** to transition to the inactive state with SDT configured. Alternatively, the CU-CP **172**A determines to cause the UE **102** to transition to the inactive state without SDT configured in response to determining that the UE **102** has data inactivity.

[0073] In response to or after determining that the UE **102** has data inactivity (e.g., for a certain period) or determining to cause the UE **102** to transition to the inactive state with SDT configured, the CU-CP **172**A sends **324**, to the CU-UP **172**B, a Bearer Context Modification Request message to suspend data transmission for the UE **102**. In response, the CU-UP **172**B suspends data transmission for the UE **102** and sends **326** a Bearer Context Modification Response message to the CU-CP **172**A. In some implementations, in response to or after determining that the UE **102** has data inactivity (e.g., for the certain period) or determining to cause the UE **102** to transition to the inactive state with SDT configured, the CU-CP **172**A sends **328** a second CU-to-DU message (e.g., a UE Context Modification Request message) to instruct the DU **174** to provide an SDT DU configuration for the UE **102**. In some implementations, the CU-CP **172**A includes an SDT request indication (e.g., an IE such as a CG-SDT Query Indication IE or SDT Query Indication IE) to request an SDT DU configuration in the second CU-to-DU message.

[0074] In further implementations, in response to the SDT request indication or the second CU-to-DU message, the DU **174** transmits **330** a second DU-to-CU message (e.g., UE Context Modification Response message) to the CU-CP **172**A. Alternatively, the DU **174** does not include the SDT DU configuration in the second DU-to-CU message. Instead, the DU **174** sends, to the CU-CP **172**A, an additional DU-to-CU message (e.g., UE Context Modification Required message), including the SDT DU configuration, after receiving the second CU-to-DU message or transmitting the second DU-to-CU message. In some implementations, the CU-CP **172**A transmits an additional CU-to-DU message (e.g., UE Context Modification Confirm message) to the DU **174** in response to the additional CU-to-DU message.

[0075] In other implementations, the CU-CP **172**A transmits the second CU-to-DU message and receives the second DU-to-CU message or the additional DU-to-CU message, before determining that the UE **102** has data inactivity. In yet other implementations, the CU-CP **172**A includes the SDT request indication in the first CU-to-DU message of the event **308** and the DU **174** includes the SDT DU configuration in the first DU-to-CU message of the event **310** in response to the SDT request indication.

[0076] Depending on the implementation, in response to determining to cause the UE **102** to transition to the inactive state with SDT configured, the CU-CP **172**A generates an RRC release message (e.g., RRCRelease message or RRCConnectionRelease message) to cause the UE **102** to transition to the inactive state. In some implementations, the CU-CP **172**A includes the SDT DU configuration (e.g., if obtained from the DU **174**) and/or an SDT CU configuration in the RRC release message. The CU-CP **172**A then sends **332** to the DU **174** a third CU-to-DU message (e.g., a UE Context Release Command message, a UE Context Modification Request message, or a DL RRC Message Transfer message) which includes the RRC release message. In turn, the DU **174** transmits **334** the RRC release message to the UE **102**. In some implementations, the DU **174** generates a MAC PDU including the RRC release message and transmits **334** the MAC PDU to the UE **102**. The RRC release message instructs the UE **102** to transition to the inactive state. The UE **102** transitions **336** to the inactive state from the connected state upon receiving the RRC release message. Depending on the implementation, in response to the third CU-to-DU message, the DU **174** retains the SDT DU configuration (e.g., if generated by the DU **174** during the procedure **328**, **330**) and releases or retains at least a portion of the first non-SDT DU configuration and/or at least a portion of the second non-SDT DU configuration. The DU **174** can send a third DU-to-CU message (e.g., a UE Context Release Complete message or a UE Context Modification Response message) to the CU-CP **172**A in response to the third CU-to-DU message.

[0077] In some implementations, the UE **102** monitors a PDCCH using a C-RNTI to receive a DCI while operating **302** in the connected state. In response to or after receiving **334** the RRC release message, the UE **102** stops using the C-RNTI to monitor a PDCCH. In some implementations, the UE **102** retains the C-RNTI in response to or after receiving **334** the RRC release message or transitioning **336** to the inactive state from the connected state. In further implementations, the UE **102** performs a two-step or a four-step random access procedure with the base station **104** (e.g., the CU-CP **172**A and/or DU **174**) and receives, from the DU **174**, a random access response message, including the C-RNTI, in the random access procedure. In other implementations, the UE **102** receives an RRC message (e.g., RRC reconfiguration message), including the C-RNTI from the CU-CP **172**A via the DU **174** or another base station (e.g., base station **106**) not shown in FIG. **3**.

[0078] The events **320**, **321**, **322**, **323**, **324**, **326**, **328**, **330**, **332**, and **334** are collectively referred to in FIG. **3** as an SDT configuration procedure **394**.

[0079] In some implementations, the UE **102** releases the first non-SDT DU configuration and/or second non-SDT DU configuration in response to the RRC release message. In further implementations, the UE **102** releases at least a portion of the first non-SDT DU configuration and at least a portion of the second non-SDT DU configuration in response to the RRC release message. In other implementations, if the RRC release message instructs the UE **102** to transition to the inactive state (i.e., RRC_IDLE), the UE **102** releases the first non-SDT DU configuration and/or second non-SDT configuration. In yet other implementations, if the RRC release message instructs the UE **102** to transition to the inactive state (i.e., RRC_INACTIVE), the UE **102** releases a first portion of the first and/or second non-SDT DU configurations and retains a second portion of the first and/or second non-SDT DU configurations. In yet other implementations, if the RRC release message instructs the UE **102** to transition to the inactive state (i.e., RRC_INACTIVE), the UE **102** retains the first non-SDT DU configuration (not augmented by the second non-SDT DU configuration if received) and/or second non-SDT DU configuration.

[0080] In some implementations, the CU-CP **172**A does not include an indication in the third CU-to-DU message to instruct the DU **174** to retain the SDT DU configuration. The DU **174** retains the SDT DU configuration as described above. In other implementations, the CU-CP **172**A includes an indication in the third CU-to-DU message (e.g., a UE Context Release Command message) to instruct the DU **174** to retain the SDT DU configuration, and the DU **174** retains the SDT DU configuration in response to the indication. If the UE Context Release Command message excludes the indication, the DU **174** releases the SDT DU configuration. In yet other implementations, the CU-CP **172**A does not include an indication in the third CU-to-DU message (e.g., a UE Context Modification Request message or a DL RRC Message Transfer message) for the UE **102** to instruct the DU **174** to release the SDT DU configuration. Thus, the DU **174** retains the SDT DU configuration in response to the third CU-to-DU message excluding the indication. If the third CU-to-DU message includes the indication, the DU **174** releases the SDT DU configuration.

[0081] In some implementations, the SDT CU configuration (e.g., SDT-Config IE) includes a DRB list (e.g., a std-DRB-List) including a list of DRB ID(s) that indicate ID(s) of DRB(s) configured for SDT. In some implementations, the SDT CU configuration includes an SRB2 indication (e.g., sdt-SRB2-Indication) that indicates an SRB2 configured for SDT. In some implementations, the SDT CU configuration includes a compression protocol continuation indication (e.g., sdt-DRB-ContinueROHC) that indicates whether a PDCP entity for the DRB(s) configured for SDT, during SDT operation (i.e., initial and/or subsequent SDT described for FIG. **4**), continues. For example, the compression protocol can be a Robust Header Compression (ROHC). In some implementations, the SDT CU configuration includes a data volume threshold (e.g., sdt-DataVolume Threshold) for the UE **102** to determine whether the UE **102** can initiate SDT. In some implementations, the CU-CP

172A includes the SDT DU configuration in the SDT CU configuration. In some implementations, "SDT CU configuration" is simplified to "SDT configuration".

[0082] In some implementations, the SDT DU configuration includes at least one of a buffer status reporting (BSR) configuration, a power headroom reporting (PHR) configuration, configured grant (CG) configuration(s) for CG-SDT, a UL bandwidth part (BWP) configuration, a DL BWP configuration for CG-SDT, a time alignment timer value for CG-SDT (e.g., CG-SDT time alignment timer (CG-SDT-TAT) value), and/or a timing advance validity threshold for CG-SDT. In some implementations, the UL BWP configuration configures a dedicated UL BWP for the UE **102** to perform CG-SDT. Depending on the implementation, the UL BWP configuration includes the CG configuration(s), a PUCCH configuration, a PUSCH configuration, and/or a sounding reference signal (SRS) configuration. In some implementations, the DL BWP configuration configures a dedicated DL BWP for the UE **102** during CG-SDT. In some implementations, the DL BWP configuration includes a PDCCH configuration and/or a PDSCH configuration for the UE to receive DL control signals on PDCCH(s) and data on PDSCH(s) from the DU **174** while the UE **102** performs CG-SDT with the DU **174**. In some implementations, each of the CG configuration(s) configures periodic radio resources (i.e., CG resources) that the UE **102** uses to transmit data without receiving a dynamic grant for data transmission. Each of the CG configuration(s) configures or includes a periodicity indicating that CG resources periodically occur. In some implementations, the periodicity is a fixed number of symbols, slots, or subframes. Depending on the implementation, some or all of the CG configuration(s) have the same periodicity or different periodicities.

[0083] In some implementations, each of the CG configuration(s) configures or includes an offset indicating a time domain offset (e.g., timeDomainOffset), related to a reference time (e.g., system frame number (SFN)), for the CG resources. In some implementations, the CG configuration configures or includes the reference time (e.g., timeReferenceSFN). In some implementations, the CG configuration is or is similar to a ConfiguredGrantConfig IE (e.g., as specified in 3GPP specification 38.331). The DU **174** configures the timing advance validity threshold (e.g., including an RSRP range) for the UE **102** to determine whether the UE **102** can initiate SDT using the configured grant configuration for CG-SDT as described for FIG. **4**. In accordance with the timing advance validity threshold, the UE **102** evaluates whether a stored timing advance value is still valid. In implementations where the UE **102** determines that the stored timing advanced value is invalid, the UE **102** initiates an RA-SDT with the CU **172** via the DU **174** as described for FIG. **4**. In some implementations, the SDT DU configuration is an SDT-MAC-PHY-CG-Config IE or SDT-MAC-PHY-Config IE.

[0084] In some implementations, the "SDT DU configuration" is replaced by "CG-SDT configuration(s)". In such implementations, the configurations in the SDT DU configuration are specific for CG-SDT. In other implementations, some of the configuration(s) in the SDT DU configuration described above are part of the CG-SDT configuration (s) and the other configuration(s) (e.g., the BSR configuration and/or PHR configuration) in the SDT DU configuration are not part of the CG-SDT configuration(s). The SDT DU configuration includes the CG-SDT configuration(s). In such cases, the UE **102** configures the other configuration(s) for CG-SDT or RA-SDT. In other implementations, the "SDT DU configuration" is simplified to "SDT configuration".

[0085] In some implementations, the DU **174** starts or restarts a DU CG-SDT timer in response to or after: receiving the SDT request indication, generating the CG-SDT configuration(s), receiving **328** the second CU-to-DU message, transmitting **330** the CG-SDT configuration(s) to the CU **172**, receiving **332** the third CU-to-DU message, or transmitting **334** the CG-SDT configuration(s) to the UE **102**. In further implementations, the DU **174** starts or restarts the DU CG-SDT timer with a timer value to manage the CG-SDT configuration(s).

[0086] In some implementations, the timer value is the same as the CG-SDT time alignment timer value. In other implementations, the timer value is close to the CG-SDT time alignment timer value. In one example, the timer value is larger than and close to the CG-SDT time alignment timer value. In another example, the timer value is smaller than and close to the CG-SDT time alignment timer value. In cases where the DU CG-SDT timer expires, the DU **174** releases the CG-SDT configuration(s) or the CG resources configured in the CG-SDT configuration(s). When or after releasing the CG-SDT configuration(s), the DU **174** refrains from receiving PUSCH transmissions from the UE **102** on the radio resources that the RAN **105** reserved or configured for the CG-SDT configuration(s). In some implementations, when or after releasing the CG-SDT configuration(s), the DU **174** schedules transmissions for other UE(s) on the radio resources that were reserved or configured for the CG-SDT configuration(s).

[0087] As described above, the RRC release message **334**, in some implementations, includes the CG-SDT configuration(s). The UE **102** starts or restarts a UE CG-SDT timer (e.g., CG-SDT-TAT) in response to or after receiving the CG-SDT configuration(s). In some implementations, the UE **102** starts or restarts the UE CG-SDT timer (i.e., a first UE CG-SDT timer) with the CG-SDT time alignment timer value, in response to or after receiving the CG-SDT configuration(s). In some cases where the UE CG-SDT timer expires, the UE **102** releases the CG-SDT configuration(s). In other cases where the UE CG-SDT timer expires, the UE **102** retains the CG-SDT configuration(s) and refrains from transmitting UL transmissions (e.g., MAC PDUs) on the CG resources. In some such instances, the UE **102** releases the CG resources or determines that the CG resources are not valid. Depending on the implementation, when the UE CG-SDT timer expires, the UE **102** releases the SRS configuration or SRS resources configured in the SRS configuration. Alternatively, when the UE CG-SDT timer expires, the UE **102** retains the SRS configuration and refrains from transmitting one or more SRSs to the DU **174** on the SRS resources.

[0088] While the UE CG-SDT timer is running, the UE **102** in the inactive state communicates (e.g., performs CG-SDT, transmits SRS(s), and/or receives DL control signals (e.g., DCI) and/or data) with the DU **174** via the dedicated DL BWP and dedicated UL BWP. In some implementations, when the UE CG-SDT timer expires, the UE **102** in the inactive state switches to an initial DL BWP and an initial UL BWP from the dedicated DL BWP and dedicated UL BWP, respectively. In some such cases, the UE **102** retunes transceivers of the UE **102** to switch to the initial DL

BWP and initial UL BWP. In some implementations, the UE **102** in the inactive state switches to the initial DL BWP and initial UL BWP to perform a random access procedure, while the RAN **105** configures the UE **102** with the CG-SDT configuration. Depending on the implementation, the UE **102** performs the random access procedure for different cases as described below. In some implementations, the UE **102** in the inactive state switches to the initial DL BWP and initial UL BWP to perform measurements on SSBs that the DU **174** transmits on the initial DL BWP.

[0089] In some implementations, the DU **174** or CU-CP **172**A configures the dedicated DL BWP and dedicated UL BWP to be the same as or to include the initial DL BWP and initial UL BWP, respectively. In some such implementations, when the UE CG-SDT timer expires, the UE **102** does not switch to the initial DL BWP and initial UL BWP from the dedicated DL BWP and dedicated UL BWP, respectively. In further such cases, the UE **102** does not retune transceivers of the UE **102** due to switching BWPs. In yet further such cases, when the UE **102** in the inactive state performs a random access procedure with the DU **174**, the UE **102** performs the random access procedure without switching to the initial DL BWP and initial UL BWP. In such cases, the UE **102** performs measurements on SSBs that the DU **174** transmits within the initial DL BWP, while performing CG-SDT with the DU **174**.

[0090] In some implementations, in response to or after the UE CG-SDT timer expires, the UE **102** performs RA-SDT with the CU **172** via the DU **174** on the initial UL BWP and initial DL BWP, as described for FIG. **4**. That is, the UE **102** determines that RA-SDT is valid in response to or after the UE CG-SDT timer expires.

[0091] In some implementations, the DU **174** reserves CG resources configured according to the CG configuration(s). In further implementations, the DU **174** releases the CG resources when releasing either the SDT DU configuration or the CG-SDT configuration(s), or when the DU CG-SDT timer expires. In some implementations, the DU **174** releases the SRS resources configured in the SRS configuration when releasing either the SDT DU configuration or the CG-SDT configuration(s), or when the DU CG-SDT timer expires.

[0092] In cases where the DU **174** does not provide the CG-SDT configuration(s) or the SDT DU configuration to the CU-CP **172**A, the DU **174** releases all signaling and user data transport resources for the UE **102** in response to the third CU-to-DU message. In cases where the DU **174** provides the SDT DU configuration or the CG-SDT configuration(s) to the CU-CP **172**A, the DU **174** retains signaling and user data transport resources for the UE **102** in response to or after receiving the third CU-to-DU message.

[0093] In some cases where the SDT DU configuration does not include a configuration for CG-SDT, the CU-CP **172**A and/or the DU **174** configures RA-SDT for the UE **102**. In some such cases, the UE **102** performs RA-SDT with the CU **172** via the DU **174** as described for FIG. **4**.

[0094] In some implementations, the CU-CP **172**A does not request the DU **174** to provide an SDT DU configuration when determining to cause the UE **102** to transition to the inactive state with SDT configured. In some such cases, the events **328** and **330** are omitted, and the CU-CP **172**A does not include the SDT DU configuration in the RRC release message. Alternatively, the CU-CP **172**A generates the SDT DU configuration by itself, without requesting the DU **174** to provide an SDT DU configuration, and includes the SDT DU configuration in the RRC release message.

[0095] In some implementations, the DU **174** does not include an SDT DU configuration in the second DU-to-CU message. In some such implementations, the DU **174** does not include the SDT DU configuration in the second DU-to-CU message because the UE **102** does not support CG-SDT, and the DU **174** therefore does not support CG-SDT. In other implementations, the DU **174** does not include the SDT DU configuration in the second DU-to-CU message because the DU **174** does not have available radio resources for CG-SDT. In such cases, the RRC release message does not include an SDT DU configuration. Otherwise, the DU **174** transmits an SDT DU configuration to the CU-CP **172**A as described above. In some implementations, the DU **174** does not include a configuration for CG-SDT in the SDT DU configuration in the second DU-to-CU message, similar to the SDT DU configuration above.

[0096] In some implementations, the CU-CP **172**A requests the DU **174** to provide an SDT DU configuration as described above, such as in cases where the UE **102** supports CG-SDT and/or the DU **174** supports CG-SDT. In cases where the UE **102** does not support CG-SDT or the DU **174** does not support CG-SDT, the CU-CP **172**A does not request the DU **174** to provide an SDT DU configuration. Depending on the implementation, the CU-CP **172**A receives a UE capability (e.g., UE-ETURA-Capability IE, UE-NR-Capability IE, UE-6G-Capability IE) for the UE **102** from the UE **102**, the CN **110** (e.g., MME **114** or AMF **164**), or the base station **106** while the UE **102** operates **302** in the connected state. The UE capability indicates whether the UE **102** supports CG-SDT. Thus, the CU-CP **172**A can determine whether the UE **102** supports CG-SDT in accordance with the UE capability. In some implementations, the CU-CP **172**A receives, from the DU **174**, a DU-to-CU message indicating whether the DU **174** supports CG-SDT. Depending on the implementation, the DU-to-CU message is the second DU-to-CU message, the message of the event **308** or **316**, or a non-UE associated message (e.g., a non-UE associated F1AP message defined in 3GPP specification 38.473).

[0097] In some implementations, the DU **174** determines whether to provide an SDT DU configuration for the UE **102** to the CU-CP **172**A, depending on whether the UE **102** supports CG-SDT or not. In further implementations, the DU **174** additionally determines whether to provide an SDT DU configuration for the UE **102** to the CU-CP **172**A, depending on whether the DU **174** supports CG-SDT or not. In cases where the UE **102** supports CG-SDT and/or the DU **174** supports CG-SDT, the DU **174** provides an SDT DU configuration for the UE **102** to the CU-CP **172**A as described above. In cases where the UE **102** does not support CG-SDT or the DU **174** does not support CG-SDT, the DU **174** does not provide an SDT DU configuration for the UE **102** (e.g., the DU **174** does not include the SDT DU configuration in the second DU-to-CU message). In some implementations, the DU **174** receives the UE capability from the CU-CP **172**A while the UE **102** operates **302** in the connected state or in the inactive state before the event **302**. Thus, the DU **174** can determine whether the UE supports CG-SDT in accordance with the UE capability. In some implementations, the DU **174** sends a DU-to-CU message to the CU-CP **172**A to indicate whether the DU **174** does support CG-SDT or not, as described above.

[0098] Referring now to FIG. **4**, a scenario **400** depicts small data transmission similar to the scenario **300**, but in which the UE **102** is in an inactive state. In the scenario **400**, the base station **104** includes a CU **172** and a DU **174**. The CU **172** includes a CU-CP **172**A and a CU-UP **172**B. In the scenario **400**, the UE **102** initially operates **402** in an inactive state with SDT configured. In some implementations or scenarios, the UE **102** transitions to the inactive state with SDT configured from the connected state as described for FIG. **3**. In some such implementations, the UE receives from the CU-CP **172**A an RRC release message including a first SDT CU configuration and/or a first SDT DU configuration (e.g., events **332**, **334**).

[0099] In other implementations or scenarios, the UE **102** transitions to the inactive state with SDT configured from the inactive state without SDT configured. For example, the UE **102** receives, from a base station (e.g., the base station **104** or base station **106**), an RRC release message causing the UE **102** to transition to the inactive state and not configuring SDT (e.g., indicating releasing SDT or not including an SDT configuration in the RRC release message). In such a case, the UE **102** transitions to the inactive state without SDT configured in response to the RRC release message. In some implementations, the UE **102** in the inactive state with or without SDT configured performs a RAN notification area (RNA) update with the base station without state transitions. During the RNA update, the UE **102** receives another RRC release message including a first SDT CU configuration and/or a first SDT DU configuration from the base station, similar to the RRC release message of the events **332**, **334**. The components (e.g., UE **102**, CU **172**, DU **174**, etc.) in FIG. **4** can be the same as or different from the equivalently numbered components in FIG. **3**.

[0100] At a later time, the UE **102** operating in the inactive state with SDT configured initiates SDT. In response to or after initiating SDT, the UE **102** generates an initial UL MAC PDU, which includes a UL RRC message and transmits **404** the initial UL MAC PDU to the DU **174** on a cell (e.g., the cell **124** or another cell of the base station **104** not shown in FIG. **1**A). The following events between the UE **102** and the DU **174** occur on the cell. In some implementations, the UE **102** starts an SDT session timer in response to initiating the SDT. In some implementations, the SDT session timer is a new timer (e.g., as defined in an RRC specification (e.g., v 17.0.0)). The DU **174** retrieves the UL RRC message from the initial UL MAC PDU, generates a first DU-to-CU message including the UL RRC message, and sends **406** the first DU-to-CU message to the CU-CP **172**A. In some implementations, the first DU-to-CU message is an Initial UL RRC Message Transfer message. In other implementations, the first DU-to-CU message is a UL RRC Message Transfer message.

[0101] In scenarios in which the UE **102** initiates SDT to transmit UL data qualifying for SDT, the UE **102** includes the UL data in the initial UL MAC PDU that the UE **102** transmits **404**. In some implementations, the UL data includes a PDU (e.g., PDCP PDU) or a data packet (e.g., IP packet or Ethernet packet). In scenarios in which the UE **102** initiates SDT to receive DL data, the UE **102** does not include a UL data packet in the initial UL MAC PDU that the UE **102** transmits **404**. In some implementations, the UE **102** initiates SDT to receive DL data in response to receiving a paging from the DU **174**. In some such scenarios, the UE **102** includes an SDT indication in the initial UL MAC PDU or the UL RRC message to indicate, to the base station **104**, that the UE **102** is initiating SDT to receive DL data. In some implementations, the DL data includes a PDU (e.g., PDCP PDU) or a data packet (e.g., IP packet or Ethernet packet).

[0102] In some implementations, the UE **102** in the inactive state performs a random access procedure with the DU **174** to transmit **404** the UL MAC PDU. In some such cases, the SDT is an RA-SDT. For example, the random access procedure can be a four-step random access procedure or a two-step random access procedure. In the case of the four-step random access procedure, the UE **102** transmits a random access preamble to the DU **174** and, in response, the DU **174** transmits to the UE **102** a random access response (RAR) including an uplink grant, a temporary C-RNTI, and a timing advance command, and the UE **102** transmits **404** the UL MAC PDU to the DU **174** in accordance with the uplink grant. The DU **174** receives **404** the UL MAC PDU in accordance with the uplink grant in the RAR and transmits a DL MAC PDU including a contention resolution MAC control element to the UE **102** in response. In the case of the two-step random access procedure, the UE **102** transmits **404**, to the DU **174**, a message A (MsgA) including a random access preamble and the UL MAC PDU in accordance with two-step random access configuration parameters. In some implementations, the UE **102** receives a message B (MsgB) including a temporary C-RNTI and a timing advance command from the DU **174** in response to the MsgA. In further implementations, the DU **174** includes a contention resolution MAC control element in the MsgB. The UE **102** receives the two-step random access configuration parameters in a system information broadcast by the DU **174** on the cell **124** before transmitting **404** the UL MAC PDU. The DU **174** receives **404** the UL MAC PDU in accordance with the two-step random access configuration parameters.

[0103] When the UE **102** succeeds in a contention resolution in the random access procedure (i.e., receives the contention resolution MAC control element), the UE **102** discards a previously retained C-RNTI (e.g., described for FIG. **3**) and determines the temporary C-RNTI to be a new C-RNTI. The UE **102** monitors a PDCCH from the DU **174** using the C-RNTI to communicate **418** data (e.g., UL data and/or DL data) with the base station **104**. In details, the UE **102** receives a DCI and a cyclic redundancy check (CRC) of the DCI on a PDCCH from the DU **174** and verifies the CRC using the C-RNTI. Depending on the implementation, the DCI includes an uplink grant or a downlink assignment. If the UE **102** verifies the CRC is correct and the DCI includes an uplink grant, the UE **102** uses the uplink grant to transmit **418** UL data to the DU **174**. If the UE **102** verifies the CRC is correct and the DCI includes a downlink assignment, the UE **102** uses the downlink assignment to receive **418** DL data from the DU **174**.

[0104] In other implementations, the UE **102** transmits **404** the UL MAC PDU on CG resources, such as in cases where the UE **102** receives or is configured with CG configuration(s) (e.g., as described for FIG. **3**). In such cases, the UE **102** performs CG-SDT. The UE **102** does not perform a random access procedure for transmitting **404** the UL MAC PDU. Thus, the DU **174** receives **404** the UL MAC PDU on the CG resources. In some such implementations, in response to or after generating or transmitting **404** the UL MAC PDU, the UE **102** starts a UE timer (e.g., a second UE CG-SDT timer) if the CU-CP **172**A or the DU **174** configures the UE **102** to apply the UE timer during SDT. In some implementations, the UE **102** starts the UE timer with a UE timer value (e.g., cg-SDT-RetransmissionTimer value). In some implementations, the UE **102** receives an RRC release message including the UE timer value from the base station **104**, similar to the events **332**, **334**, **432**, and **434**. In some implementations, the CP-CP **172**A includes the UE timer value in a CG-SDT configuration and transmits the RRC release message including the CG-SDT configuration to the UE **102** via the DU **174**. In other implementations, the UE **102** receives the UE timer value in a system information block broadcast by the DU **174** via the cell **124**. While the UE timer is running, the UE **102** in the inactive state or SDT session refrains from retransmitting the UL MAC PDU on the CG resources. In some implementations, in response to or after receiving **404** the UL MAC PDU on the CG resources, the DU **174** starts a DU timer (e.g., a second DU CG-SDT timer) with a DU timer value. In some implementations, the DU timer value is the same as or larger than the UE timer value. While the DU timer is running, the DU **174** processes UL transmissions received from the UE **102** on the CG resources as new transmissions.

[0105] In some implementations, the UE **102** transmits **418** subsequent UL MAC PDU(s), including one or more UL data packets, on the CG radio resources. In some implementations, the UE **102** transmits **418** the subsequent UL MAC PDU(s) on radio resources configured in uplink grant(s) received on PDCCH(s) from the DU **174**. In some implementations, the UE **102** transmits **418** some of the subsequent UL MAC PDU(s) on radio resources configured in the CG configuration and transmits **418** the other of the subsequent UL MAC PDU(s) on radio resources configured in the uplink grant(s).

[0106] In some cases where the UE **102** transmits **418** subsequent UL MAC PDU(s) on the CG resources, the UE **102** starts or restarts the timer (e.g., the second UE CG-SDT timer) in response to or after generating or transmitting **418** each of the subsequent UL MAC PDU(s). The UE **102** can start or restart the timer with the timer value as described above. While the UE timer is running, the UE **102** in the inactive state or SDT session refrains from retransmitting the UL MAC PDU. In some implementations, in response to or after receiving **418** each of subsequent UL MAC PDU(s) on the CG resources, the DU **174** starts or restarts the DU timer (e.g., the second DU CG-SDT timer) with the DU timer value. While the DU timer is running, the DU **174** processes UL transmissions received from the UE **102** on the CG resources as new transmissions.

[0107] If the UE **102** includes UL data in the initial UL MAC PDU **404**, the DU **174** retrieves the UL data from the initial UL MAC PDU. In some such cases, the DU **174** includes the UL data in the DU-to-CU message of the event **406**. Alternatively, the DU **174** sends **415** a DU-to-CU message including the UL data to the CU-CP **172**A. In some such alternatives, the UL data includes or is a PDCP PDU, an RRC PDU, NAS PDU, or an LTE positioning protocol (LPP) PDU. The PDCP PDU can include an RRC PDU. The UL data can be associated with an SRB (e.g., SRB1 or SRB2). In some implementations, the UE **102** applies one or more security functions (e.g., encryption and/or integrity protection) to the UL data as described above. The CU-CP **172**A applies one or more security functions (e.g., decryption and/or integrity protection check) to the UL data as described above. Alternatively, the DU **174** sends **416** the UL data to the CU-UP **172**B separately via a user-plane (UP) connection (e.g., a GTP tunnel) as described below. In some such alternatives, the UL data includes or is a PDCP PDU, a SDAP PDU, an IP packet, or an Ethernet packet. In some implementations, the UL data is associated with an SDT DRB. In some implementations, the UE **102** applies one or more security functions (e.g., encryption and/or integrity protection) to the UL data as described above. The CU-UP **172**B applies one or more security functions (e.g., decryption and/or integrity protection check) to the UL data as described above.

[0108] After receiving **406** the first DU-to-CU message, the CU-CP **172**A in some implementations sends **408** a UE Context Request message to the DU **174** to request the DU **174** to establish a UE context for the UE **102**. In some implementations, in the UE Context Request message, the CU-CP **172**A includes transport layer information for one or more GTP-U tunnels between the CU-UP **172**B and DU **174** so that the DU **174** can transmit the UL data and/or subsequent UL data (e.g., in small data communication **418**) via the one or more GTP-U tunnels to the CU-UP **172**B. In response, depending on the implementation, the DU **174** sends **410** a UE Context Response message to the CU-CP **172**A.

[0109] In some implementations, the UE Context Request message and UE Context Response message are a UE Context Setup Request message and a UE Context Setup Response message, respectively. In some such implementations, the events **408** and **410** are grouped as a UE Context Setup procedure. In other implementations, the UE Context Request message and UE Context Response message are a UE Context Modification Request message and a UE Context Modification Response message, respectively. In some implementations, the CU-CP **172**A does not transmit a UE Context Request message to the DU **174**, such as in cases where the DU **174** already has a UE context of the UE **102**. In some such implementations, the events **408** and **410** can be omitted or skipped.

[0110] After receiving **406** the first DU-to-CU message, transmitting **408** the UE Context Request message, or receiving **410** the UE Context Response message, the CU-CP **172**A transmits **412**, to the CU-UP **172**B, a Bearer Context Modification Request message to resume SDT DRB(s) of the UE **102**. In response, the CU-UP **172**B resumes the SDT DRB(s) and transmits **414** a Bearer Context Modification Response message to the CU-CP **172**A. The events **412** and **414** can be grouped as a Bearer Context Modification procedure. In some implementations, the CU-CP **172**A includes a resume indication (e.g., Bearer Context Status Change IE with a "ResumeforSDT" value) in the Bearer Context Modification Request message **424** to indicate the CU-UP **172**B resume the SDT DRB(s). In response to the resume indication, the CU-UP **172**B resumes the SDT DRB(s) and maintains the non-SDT DRB(s) as suspended or suspends the non-SDT DRB(s).

[0111] In some implementations, after receiving **406** the UL RRC message, receiving **408** the UE Context Request message, or transmitting **410** the UE Context Response message, the DU **174** transmits **415** the DU-to-CU message, including the UL data, to the CU-CP **172**A, such as in cases where the UL data of the event **404** includes an RRC message or is associated with an SRB (e.g., SRB1 or SRB2). In some cases where the UL data is associated with a DRB, the DU **174** transmits **416** the UL data to the CU-UP **172**B, after receiving **406** the UL RRC message, receiving **408** the UE Context Request message or transmitting **410** the UE Context Response message.

[0112] In some implementations, the CU-CP **172**A includes transport layer information of the CU-UP **172**B in the UE Context Request message. The transport layer information of the CU-UP **172**B can include an IP address and/or an uplink tunnel endpoint ID (e.g., TEID). In some implementations, the DU **174** transmits **416** the UL data to the CU-UP **172**B using the transport layer information of the CU-UP **172**B. In some cases where the UE **102** has subsequent UL data (e.g., one or more UL data packets) to transmit, the UE **102** transmits **418** one or more subsequent UL MAC PDUs, including the subsequent UL data, to the DU **174**. In turn, the DU **174** retrieves the subsequent UL data from the subsequent UL MAC PDU(s). In cases where the subsequent UL data is associated with one or more SRB (e.g., SRB1 and/or SRB2), the DU **174** transmits **418** the one or more DU-to-CU messages (e.g., UL RRC Message Transfer message(s)) including the subsequent UL data to the CU-CP **172**A. Each DU-to-CU message can include a particular UL data packet of the subsequent UL data. In some cases where the CU-CP **172**A receives DL data from the CN **110** or edge server, the CU-CP **172**A transmits **418** one or more CU-to-DU messages (e.g., DL RRC Message Transfer message(s)) including the DL data (e.g., one or more DL data packets) to the DU **174**. In turn, the DU **174** transmits **418** one or more DL MAC PDUs including the DL data to the UE **102** operating in the inactive state. In some implementations, the DL data include or are NAS PDU(s) and/or LPP PDU(s).

[0113] In cases where the subsequent UL data is associated with one or more DRBs, the DU **174** transmits **418** the subsequent UL data to the CU-UP **172**B, similar to the event **416**. In some implementations, the DU **174** includes DU transport layer information of the DU **174** in the UE Context Setup Response message. In turn, the CU-CP **172**A includes the transport layer information of the DU **174** in the Bearer Context Modification Request message. In some implementations, the transport layer information of the DU **174** includes an IP address and/or a downlink TEID. In some cases where the CU-UP **172**B receives DL data from the CN **110** or edge server, the CU-UP **172**B transmits **418** the DL data (e.g., one or more DL data packets) to the DU **174** using the transport layer information of the DU **174**. In turn, the DU **174** transmits **418** one or more DL MAC PDUs including the DL data to the UE **102** operating in the inactive state.

[0114] In some implementations, the UE **102** includes a buffer status report or a power headroom report in the initial and/or subsequent UL MAC PDU(s) (e.g., in accordance with the BSR configuration and/or PHR configuration, respectively). In the buffer status report, the UE **102** can include or indicate its buffer status for one or more logical channels or logical channel groups. In the power headroom report, the UE **102** can include or indicate power headroom status or value.

[0115] In some example scenarios, the subsequent UL data and/or DL data described above include Internet Protocol (IP) packet(s), an Ethernet packet(s), or an application packet(s). In other scenarios, the UL data include or are PDU(s) (e.g., RRC PDU(s), PDCP PDU(s) or RLC PDU(s)) that includes RRC message(s), NAS message(s), IP packet (s), Ethernet packet(s), or application packet(s).

[0116] The events **404**, **406**, **408**, **410**, **412**, **414**, **415**, **416**, and **418** are collectively referred to in FIG. **4** as a small data communication procedure **492**. The events **404**, **406**, **408**, **410**, **412**, **414**, **415** and **416** are collectively referred to in FIG. **4** as an initial small data transmission (SDT) procedure **480**.

[0117] In some implementations, the UL RRC message is an existing RRC resume request message (e.g., an RRCResumeRequest message, an RRCResumeRequest1 message, an RRCConnectionResumeRequest message, or an RRCConnectionResumeRequest1 message). In other implementations, the UL RRC message is a new RRC resume request message, similar to the existing RRC resume request message. For example, the new RRC resume request message may be defined in future 3GPP standards documentation. The new RRC resume request message may be a format of an existing RRC resume request message. In some implementations, for downlink SDT, the UL RRC message includes an SDT indication, which can be a field or information element (IE) (e.g., resumeCause or ResumeCause). In some implementations, the UL RRC message is a common control channel (CCCH) message.

[0118] After the UE **102** transmits **404** the UL MAC PDU or communicates **418** the subsequent UL data and/or DL data with the DU **174**, the CU-CP **172**A, CU-UP **172**B, or DU **174** can determine that the UE **102** is in data inactivity based on the UE assistance information, inactivity notification of the event **422** and/or inactivity notification of the event **423**, as described above with regard to FIG. **3**.

[0119] In some implementations, after a certain period of data inactivity, the CU-CP **172**A determines that neither the CU **172** nor the UE **102** has transmitted any data in the downlink direction or the uplink direction, respectively, during the period. In response to the determination, the CU-CP **172**A can determine to stop the SDT. Alternatively, the CU-CP **172**A determines to immediately stop the SDT for the UE **102** in response to determining that the UE **102** is in data inactivity.

[0120] In response to or after determining that the UE **102** is in data inactivity (for the certain period) or determining to cause the UE **102** to transition to the inactive state with SDT configured, the CU-CP **172**A configures an SDT DU configuration by performing events **424**, **426**, and/or **428** similar to events **324**, **326**, and/or **328**, respectively.

[0121] Similarly, in response to an SDT request indication or a second CU-to-DU message, the DU **174** transmits **430** a second DU-to-CU message (e.g., UE Context Modification Response message) to the CU-CP **172**A. In some implementations, the DU **174** includes a second SDT DU configuration in the second DU-to-CU message. In some cases where the DU **174** obtained the first SDT DU configuration, the DU **174** generates the second SDT DU configuration to augment (e.g., replace or update) the first SDT DU configuration. In some implementations, the DU **174** generates the second SDT DU configuration as a complete and self-contained configuration (i.e., a full configuration) (e.g., because the DU **174** does not support delta configuration or none of configuration parameters in the first SDT DU configuration are valid). In some such implementations, the DU **174** includes, in the second DU-to-CU message, a first indication indicating that the second SDT DU configuration is a complete and self-contained configuration (i.e., a full configuration). For example, the first indication can be a setup indication or a full configuration indication.

[0122] In other implementations, the DU **174** generates the second SDT DU configuration to update a portion of the first SDT DU configuration (e.g., because the DU **174** supports delta configuration). In some scenarios or implementations, the DU **174** receives the first SDT DU configuration from the CU-CP **172**A (e.g., in the second CU-to-DU message). In other scenarios or implementations, the second CU-to-DU message does not include the first SDT DU configuration. In some such cases, the DU **174** still generates the second SDT DU configuration to augment the first SDT DU configuration because the DU **174** generated and retained the first SDT DU configuration. In such implementations, the DU **174** refrains from including the first indication in the second DU-to-CU message in order to indicate that the second SDT DU configuration is a delta configuration (i.e., the second SDT DU configuration includes configuration parameter(s) augmenting the first SDT DU configuration). In some implementations, the DU **174** includes, in the second DU-to-CU message, a second indication indicating that the second SDT DU configuration is a delta configuration. Alternatively, the DU **174** neither includes the second indication nor the first indication in order to indicate that the second SDT DU configuration is a delta configuration.

[0123] Alternatively, the DU **174** does not include the second SDT DU configuration in the second DU-to-CU message. Instead, the DU **174** sends, to the CU-CP **172**A, another DU-to-CU message (e.g., UE Context Modification Required message) including the second SDT DU configuration (e.g., after receiving the second CU-to-DU message or transmitting the second DU-to-CU message). In some alternative implementations, the CU-CP **172**A transmits the second CU-to-DU message and receives the second DU-to-CU message or another DU-to-CU message before or after determining that the UE **102** is in data inactivity.

[0124] In yet other implementations, the DU **174** determines to continue to configure the first SDT DU configuration for the UE **102**. In some such cases, the DU **174** does not include the first SDT DU configuration in the second DU-to-CU message. After the CU-CP **172**A receives the second DU-to-CU message not including an SDT DU configuration, the CU-CP **172**A determines that the DU **174** continues to reuse the first SDT DU configuration for the UE **102**. In some implementations, the DU **174** includes, in the second DU-to-CU message an indication indicating that the first SDT DU configuration continues to be used for the UE **102**. In other implementations, in the second DU-to-CU message, the DU **174** indicates that the first SDT DU configuration reused for the UE **102** by not including an SDT DU configuration in the second DU-to-CU message.

[0125] In yet other implementations, the CU-CP **172**A refrains from transmitting the first SDT DU configuration to the DU **174**. For example, the CU-CP **172**A refrains from including the first SDT DU configuration in the second CU-to-DU message. In some cases where the DU **174** does not have the first SDT DU configuration, the DU **174** generates the second SDT DU configuration as a complete and self-contained configuration (e.g., a full SDT DU configuration).

[0126] In yet other implementations, the CU-CP **172**A includes, in the second CU-to-DU message, an indication to the DU **174** to generate an SDT DU configuration as a complete and self-contained configuration (e.g., a full SDT DU configuration). In response to the indication, the DU **174** generates the second SDT DU configuration as a complete and self-contained configuration (e.g., a full SDT DU configuration).

[0127] In yet other implementations, the DU **174** determines to release the first SDT DU configuration and does not configure an SDT DU configuration for the UE **102**. In some such cases, the DU **174** includes, in the second DU-to-CU message, an indication indicating that no SDT DU configuration is configured for the UE **102**. For example, the indication can be a cause indicating a reason why the DU **174** is unable to configure an SDT DU configuration for the UE **102**.

[0128] In some implementations, in response to determining to cause the UE **102** to transition to the inactive state with SDT configured, the CU-CP **172**A generates an RRC release message (e.g., RRCRelease message RRCConnectionRelease message) to cause the UE **102** to transition to the inactive state. In some implementations, the CU-CP **172**A includes the second SDT DU configuration (if obtained from the DU **174**) and a second SDT CU configuration in the RRC release message. Alternatively, the CU-CP **172**A does not include an SDT configuration in the RRC release message. In some such alternatives, the CU-CP **172**A indicates to the UE to release or retain the first SDT CU configuration and/or the first SDT DU configuration in the RRC release message. For example, the CU-CP **172**A can include a release indication indicating releasing the first SDT CU configuration or the first SDT DU configuration in the RRC release message. If the CU-CP **172**A or the DU **174** determines to reuse the first SDT DU configuration, the RRC release message does not include the release indication and the UE retains the first SDT CU configuration and/or the first SDT DU configuration. In some implementations, the CU-CP **172**A includes or does not include the first SDT DU configuration in the RRC release message.

[0129] The CU-CP **172**A then sends **432** to the DU **174** a third CU-to-DU message including the RRC release message. In turn, the DU **174** transmits **434** the RRC release message to the UE **102**. In some implementations, the DU **174** generates a MAC PDU including the RRC release message and transmits **434** the MAC PDU to the UE **102**. The RRC release message instructs the UE **102** to transition to the inactive state. The UE **102** stops the SDT and remains **436** in the inactive state upon receiving **434** the RRC release message.

[0130] The events **420**, **421**, **422**, **423**, **424**, **426**, **428**, **430**, **432**, and **434** are collectively referred to in FIG. **4** as an SDT complete procedure **494**.

[0131] During an SDT session (i.e., events **492** and **494**), the UE **102** monitors a PDCCH using a C-RNTI to receive a DCI. In some implementations, the UE **102** receives the C-RNTI in the random access procedure described for the event **404**. In other implementations, the UE **102** receives and retains the C-RNTI as described for FIG. **3**. In response to or after receiving **434** the RRC release message, the UE **102** ends the SDT session and stops using the C-RNTI to monitor a PDCCH. In some implementations, the UE **102** retains the C-RNTI in response to or after receiving **434** the RRC release message or transitioning **436** to the inactive state from the connected state. In cases where the RRC release message **434** configures CG-SDT, the UE **102** in some implementations retains the C-RNTI. In some cases where the RRC release message **434** does not configure or releases CG-SDT, the UE **102** releases the C-RNTI.

[0132] After the UE **102** ends the SDT session, the UE **102** in the inactive state monitors a PDCCH using a paging RNTI (P-RNTI). In some scenarios or implementations, the CU-CP **172**A determines to page the UE **102** to receive a mobile-terminated call or data. In some implementations, in response to the determination, the CU-CP **172**A sends a CU-to-DU message (e.g., Paging message) to the DU **174** to request the DU **174** to page the UE **102**. In response to the CU-to-DU message, the DU **174** generates a paging message, a DCI to schedule a PDSCH transmission including the paging message, a CRC of the DCI, scrambles the CRC with the P-RNTI to obtain a scrambled C-RNTI, and transmits the DCI and scrambled CRC on a PDCCH that the UE **102** monitors. The UE **102** receives the DCI and the scrambled CRC on the PDCCH and verifies the scrambled CRC with the P-RNTI. In cases where the UE **102** verifies that the scrambled CRC is valid, the UE **102** receives and decodes the PDSCH transmission in accordance with the DCI and retrieves the paging message from the PDSCH transmission.

[0133] In some implementations, the second SDT CU configuration is the same as the first SDT CU configuration. In other implementations, the second SDT CU configuration is different from the first SDT CU configuration. Depending on the implementation, the UE **102** updates (e.g., replaces or modifies) the first SDT CU configuration with the second SDT CU configuration. In some implementations, the CU-CP **172**A includes an indication in the RRC release message to indicate to the UE **102** to update the first SDT CU configuration with the second SDT CU configuration. In some such implementations, the UE **102** updates the first SDT CU configuration with the second SDT CU configuration in response to the indication. In other implementations, the CU-CP **172**A includes a modification indication in the RRC release message to indicate to the UE **102** to modify the first SDT CU configuration with the second SDT CU configuration. In some such implementations, the UE **102** modifies the first SDT CU configuration with the second SDT CU configuration in response to the modification indication. In yet other implementations, the CU-CP **172**A includes a setup indication in the RRC release message to indicate the UE **102** to replace the first SDT CU configuration with the second SDT CU configuration. In some such implementations, the UE **102** replaces the first SDT CU configuration with the second SDT CU configuration in response to the setup indication.

[0134] In some implementations, the CU-CP **172**A does not include an SDT CU configuration for the UE **102** in the RRC release message **432**, **434**, in order to configure the UE **102** to retain the first SDT CU configuration and keep using the first SDT CU configuration. When the UE **102** receives **434** the RRC release message, the UE **102** retains the first SDT CU configuration.

[0135] In some implementations, the second SDT DU configuration is the same as the first SDT DU configuration. In other implementations, the second SDT DU configuration is different from the first SDT DU configuration. Depending on the implementation, the UE **102** updates (e.g., replaces or modifies) the first SDT DU configuration with the second SDT DU configuration similar to the SDT CU configurations as described above.

[0136] In some implementations, the CU-CP **172**A does not include an SDT DU configuration for the UE **102** in the RRC release message, in order to configure the UE **102** to retain the first SDT DU configuration and keep using the first SDT DU configuration.

[0137] In some cases where the CU-CP **172**A and/or the DU **174** support delta configuration, the CU-CP **172**A does not send **428** the CU-to-DU message to obtain the second SDT DU configuration from the DU **174**. Unless a condition for releasing the first SDT configuration is satisfied, the DU **174** retains the first SDT DU configuration. Alternatively, the CU-CP **172**A includes the first SDT DU configuration in the second CU-to-DU message to cause the DU **174** to retain the first SDT DU configuration. In some such cases, the CU-CP **172**A does not include an SDT DU configuration and/or an SDT CU configuration in the RRC release message to cause the UE **102** to continue using the first SDT CU configuration and/or the first SDU DU configuration. In some implementations, the CU-CP **172**A does not include a release indication in the RRC release message in order to configure the UE to continue using the first SDT DU configuration and/or the first SDT CU configuration. The release indication indicates releasing the previously received SDT DU configuration and/or the SDT CU configuration. In some cases where the CU-CP **172**A includes the release indication in the RRC release message, the UE **102** releases the first SDT CU configuration and/or the first SDT DU configuration in response to the release indication.

[0138] In some cases where the CU-CP **172**A and/or DU **174** do not support delta configuration, the CU-CP **172**A does include the SDT DU configuration and/or the SDT CU configuration in the RRC release message as described above.

[0139] In some implementations, in response to the third CU-to-DU message, the DU **174** retains the second SDT DU configuration and releases or does not release the first non-SDT DU configuration and/or second non-SDT DU configuration. In further implementations, the DU **174** sends a third DU-to-CU message (e.g., a UE Context Release Complete message or a UE Context Modification Response message) to the CU-CP **172**A in response to the third CU-to-DU message. In some implementations, if the RRC release message instructs the UE **102** to transition to the inactive state (i.e., RRC_IDLE), the UE **102** releases a non-SDT configuration (e.g., the first non-SDT DU configuration, first non-SDT CU configuration, second non-SDT DU configuration and/or second non-SDT CU configuration described for FIG. **3**) and at least one SDT configuration (e.g., the SDT DU configuration and SDT CU configuration described for FIG. **3**).

[0140] Examples and implementations for events **320**, **321**, **322**, **323**, **324**, **326**, **328**, **330**, **332**, and **334** can apply to events **420**, **421**, **422**, **423**, **424**, **426**, **428**, **430**, **432**, and **434**, respectively. After stopping the SDT, the UE **102** can perform **493** another small data communication procedure with the base station **104**, similar to the procedure **492**. After completing the procedure **493**, the base station **104** can perform **495** an SDT complete procedure with the UE **102**, similar to the procedure **494**.

[0141] In some implementations, the CU-CP **172**A does not request the DU **174** to provide an SDT DU configuration for causing the UE **102** to transition the inactive state with SDT configured. In some such cases, the events **428** and **430** are omitted. In such cases, the CU-CP **172**A does not include an SDT DU configuration in the RRC release message. Alternatively, the CU-CP **172**A generates the SDT DU configuration by itself and includes the SDT DU configuration in the RRC release message.

[0142] In some implementations, the DU **174** does not include an SDT DU configuration in the second DU-to-CU message (e.g., if or because the UE **102** does not support CG-SDT, the DU **174** does not support CG-SDT, or the DU **174** does not have available radio resources for CG-SDT). In such cases, the RRC release message does not include an SDT DU configuration. Otherwise, depending on the implementation, the DU **174** includes an SDT DU configuration as described above. In some implementations, the DU **174** does not include a CG-SDT configuration in the SDT DU configuration in the second DU-to-CU message (e.g., if or because the UE **102** does not support CG-SDT, the DU **174** does not support CG-SDT, or the DU **174** does not have available radio resources for CG-SDT). In such cases, the SDT DU configuration does not include a CG-SDT configuration. Otherwise, depending on the implementation, the DU **174** includes the CG-SDT configuration in the SDT DU configuration as described above.

[0143] In some implementations, the CU-CP **172**A requests the DU **174** to provide an SDT DU configuration as described above, such as in cases where the UE **102** supports CG-SDT and/or the DU **174** supports CG-SDT. In cases where the UE **102** does not support CG-SDT or the DU **174** does not support CG-SDT, the CU-CP **172**A does not request the DU **174** to provide an SDT DU configuration. In some implementations, the CU-CP **172**A receives a UE capability (e.g., UE-NR-Capability IE) of the UE **102** from the UE **102**, the CN **110** (e.g., MME **114** or AMF **164**) or the base station **106**, before the UE **102** initiates the SDT, while the UE operates **402** in the inactive state, while the UE performs the SDT (e.g., in the UE Context Setup Request message of the event **408** or the CU-to-DU message of the event **428**), or while the UE operates in the connected state as described for FIG. **3**. The UE capability indicates whether the UE **102** supports CG-SDT. Thus, the CU-CP **172**A can determine whether the UE supports CG-SDT in accordance with the UE capability. In some implementations, the CU-CP **172**A receives from the DU **174** a DU-to-CU message indicating whether the DU **174** supports CG-SDT. The DU-to-CU message can be the second DU-to-CU message, the message of the event **308** or **316**, or a non-UE associated message (e.g., a non-UE associated F1AP message defined in 3GPP specification 38.473).

[0144] In some implementations, the DU **174** determines whether to provide an SDT DU configuration for the UE **102** to the CU-CP **172**A, depending on whether the UE **102** supports CG-SDT or not. In addition to whether the UE **102** supports CG-SDT or not, the DU **174** may additionally determine whether to provide an SDT DU configuration for the UE **102** to the CU-CP **172**A, depending on whether the DU **174** supports CG-SDT or not. In cases where the UE **102** supports CG-SDT and/or the DU **174** supports or enables CG-SDT, the DU **174** provides an SDT DU configuration for the UE **102** to the CU-CP **172**A as described above. In cases where the UE **102** does not support CG-SDT or the DU **174** does not support CG-SDT, the DU **174** does not provide an SDT DU configuration for the UE **102** (e.g., the DU **174** does not include the SDT DU configuration in the second DU-to-CU message). In some implementations, the DU **174** receives the UE capability from the CU-CP **172**A (e.g., while the UE **102** operates in the connected state or in the inactive state). Thus, the DU **174** can determine whether the UE supports CG-SDT in accordance with the UE capability. In some implementations, the DU **174** sends a DU-to-CU message to the CU-CP **172**A to indicate whether the DU **174** does support CG-SDT or not, as described above.

[0145] Referring now to FIG. **5**A, a scenario **500**A depicts small data transmission and transitioning from the inactive state with SDT to the connected state with non-SDT. In the scenario **500**A, the base station **104** includes a CU **172** and a DU **174**. The CU **172** includes a CU-CP **172**A and a CU-UP **172**B. In the scenario **500**A, the UE **102** initially operates **502** in an inactive state with SDT configured, similar to the event **402**. The UE **102** then performs **592** a small data communication procedure with the base station **104**, similar to the event **492**.

[0146] In some implementations, during the small data communication procedure **592**, the CU-CP **172**A determines whether to cause the UE **102** to transition to a connected state (e.g., based on UL or DL data activity of the UE **102**). In some implementations, the UE **102** transmits **503** to the DU **174** a non-SDT indication message to indicate that UL data is available or request to transition to the connected state. In some implementations, the UE **102** transmits **503** to the DU **174** the non-SDT indication message on radio resources configured in a CG configuration for SDT (or CG-SDT configuration). In other implementations, the UE **102** receives an uplink grant on a PDCCH from the DU **174** using a C-RNTI and transmit **503** to the DU **174** the non-SDT indication message on radio resources configured in the uplink grant. In turn, the DU **174** transmits **505** a UL RRC Message Transfer message including the non-SDT indication message to the CU-CP **172**A. The CU-CP **172**A determines to cause the UE **102** to transition the connected state in response to or based on the non-SDT indication message. In other implementations, the CU-UP **172**B receives DL data from the CN **110** and transmits **507** a DL data notification (e.g., DL Data Notification message) to the CU-CP **172**A to indicate that DL data is available for transmission in response to receiving the DL data. In some implementations, the CU-CP **172**A determines to cause the UE **102** to transition to the connected state in response to or based on the DL data notification. In other implementations, the CU-CP **172**A determines to cause the UE **102** to transition to the connected state based on measurement results received from the UE **102**. In yet other implementations, the CU-CP **172**A receives DL data (e.g., NAS message(s)) from the CN **110** and determines to cause the UE **102** to transition to the connected state in response to receiving the DL data.

[0147] In some implementations, the UL data and DL data are associated with radio bearer(s) (e.g., SRB(s) and/or DRB(s)) of the UE **102**. For example, the UL data includes RRC message(s) or NAS message(s) associated with SRB(s) of the UE **102**. In another example, the UL data includes IP packet(s) associated with DRB(s) of the UE **102**. In some implementations, the DRB(s) are SDT DRB(s). In other implementations, the DRB(s) are non-SDT DRB(s). In some implementations, the UE **102** includes ID(s) of the radio bearer(s) in the non-SDT indication message. Thus, the CU-CP **172**A determines whether to cause the UE **102** to transition to the connected state based on the ID(s). For example, if the radio bearer(s) identified by the ID(s) do not qualify for SDT, the CU-CP **172**A can determine to cause the UE **102** to transition to the connected state. Otherwise, the CU-CP **172**A can determine not to cause the UE **102** to transition to the connected state. In some implementations, the UE **102** includes data volume information of the UL data in the non-SDT indication message. Thus, the CU-CP **172**A determines whether to cause the UE **102** to transition to the connected state based on the data volume information. In some implementations, the data volume information includes a total data volume of the UL data, which can be quantized or rounded to a value that can be indicated in the data volume information. In further implementations, the data volume information includes a data volume for each of the radio bearer(s), which can be quantized or rounded to a value that can be indicated in the data volume information. For example, if the total data volume is above a predetermined threshold, the CU-CP **172**A can determine to cause the UE **102** to transition to the connected state. Otherwise, the CU-CP **172**A can determine not to cause the UE **102** to transition to the connected state. In another example, if the data volume for a particular radio bearer is above a predetermined threshold, the CU-CP **172**A determines to cause the UE **102** to transition to the connected state. Otherwise, the CU-CP **172**A determines not to cause the UE **102** to transition to the connected state. In yet another example, if the total data volume is above a predetermined threshold and the data volume for a particular radio bearer is above another predetermined threshold, the CU-CP **172**A determines to cause the UE **102** to transition to the connected state. Otherwise, the CU-CP **172**A determines not to cause the UE **102** to transition to the connected state.

[0148] In response to or after determining to cause the UE **102** to transition to the connected state, the CU-CP **172**A transmits **508** a UE Context Request message (e.g., a UE Context Setup Request message or a UE Context Modification Request message) to the DU **174**. In response, the DU **174** transmits **510** a UE Context Response message (e.g., a UE Context Setup Response message or a UE Context Modification Response message) to the CU-CP **172**A. In some implementations, the DU **174** includes a non-SDT DU configuration (i.e., a first non-SDT DU configuration) in the UE Context Response message. After receiving **510** the UE Context Response message, the CU-CP **172**A transmits **545** a CU-to-DU message including an RRC resume message (e.g., an RRCResume message or an RRCConnectionResume message) to the DU **174**. In turn, the DU **174** transmits **546** the RRC resume message to the UE **102**. In some implementations, the DU **174** transmits **546** one or more PDUs including the RRC resume message to the UE **102**. Depending on the implementation, the PDU(s) are MAC PDU(s) or RLC PDU(s). In some implementations, the CU-to-DU message is a DL RRC Message Transfer message or a UE Context Modification Request message. In some cases regarding the UE Context Modification Request message, the DU **174** transmits a UE Context Modification Response message to the CU-CP **172**A in response. In response to the RRC resume message, the UE **102** transitions **548** to the connected state and transmits **550** an RRC resume complete message (e.g., an RRCResumeComplete message or an RRCConnectionResumeComplete message) to the DU **174**. In cases where the UE Context Response message includes the non-SDT DU configuration, the CU-CP **172**A includes the non-SDT DU configuration in the RRC resume message. The DU **174** transmits **552** a DU-to-CU message including the RRC resume complete message to the CU-CP **172**A. In some implementations, the DU-to-CU message is a UL RRC Message Transfer message, a UE Context Modification Required message, or a UE Context Modification Response message.

[0149] In some implementations, after determining to cause the UE **102** to transition to the connected state, the CU-CP **172**A transmits a **554** Bearer Context Request message (e.g., a Bearer Context Setup Request message or a Bearer Context Modification Request message) to the CU-UP **172**B to indicate the CU-UP **172**B to resume radio bearer(s) (e.g., SDT DRB(s) and/or non-SDT DRB(s)) of the UE **102**, if suspended. In response, the CU-UP **172**B resumes the radio bearer(s) for the UE **102** and transmits **556** a Bearer Context Response message (e.g., a Bearer Context Setup Response message or a Bearer Context Modification Response message) to the CU CP-**172**A. The events **554** and **556** can be grouped as a Bearer Context procedure (e.g., a Bearer Context Setup procedure or a Bearer Context Modification procedure).

[0150] In some implementations, the CU-CP **172**A transmits **554** the Bearer Context Request message after transmitting **508** the UE Context Request message, receiving **510** the UE Context Response message, transmitting **545** the CU-to-DU message, or receiving **552** the DU-to-CU message. In cases where the CU-CP **172**A determines no radio bearer(s) of the UE **102** are suspended when determining to cause the UE **102** to transition to the connected state, the CU-CP **172**A does not transmit the Bearer Context Request message **554** to the CU-UP **172**B. In some implementations, the CU-CP **172**A transmits **545** the CU-to-DU message before or after transmitting **554** the Bearer Context Request message or receiving **556** the Bearer Context Response message.

[0151] In some implementations, the CU-CP **172**A includes an indication indicating the DU **174** to generate a non-SDT configuration in the UE Context Request message, and the DU **174** includes the first non-SDT DU configuration in the UE Context Response message in response to the indication. In yet other implementations, the CU-CP **172**A stores a non-SDT DU configuration (i.e., a second non-SDT DU configuration) that a DU (e.g., the DU **174** or another DU or base station) used to communicate with the UE **102**. Depending on the implementation, the UE **102** also stores the second non-SDT DU configuration. In some such cases, the CU-CP **172**A includes the second non-SDT DU configuration in the UE Context Request message, and the DU **174** includes the first non-SDT DU configuration in the UE Context Response message in response to receiving the second non-SDT DU configuration. In some implementations, the first non-SDT DU configuration augments or replaces the second non-SDT DU configuration. Examples and implementations for the first and second non-SDT DU configurations are as the non-SDT DU configurations described above. In some implementations, the DU **174** transmits an additional DU-to-CU message (e.g., a UE Context Modification Required message) including the first non-SDT DU configuration to the CU-CP **172**A instead of including the first non-SDT DU configuration in the UE Context Response message.

[0152] After transitioning to the connected state, the UE **102** communicates **518** UL data and/or DL data with the CU-CP **172**A and/or CU-UP **172**B via the DU **174**. In some implementations, the UL data includes the UL data triggering the UE to transmit the non-SDT indication message. In further implementations, the UL data also includes new UL data available for transmission. In some implementations, the UL data includes PDCP PDU(s), RRC PDU(s), NAS PDU(s), or an LTE positioning protocol (LPP) PDU(s). Depending on the implementation, the UL data is associated with an SRB (e.g., SRB1 or SRB2). In some implementations, the UE **102** applies one or more security functions (e.g., encryption and/or integrity protection) to the UL data as described above. The CU-CP **172**A applies one or more security functions (e.g., decryption and/or integrity protection check) to the UL data as described above. Depending on the implementation, the UL data includes PDCP PDU(s), SDAP PDU(s), IP packet(s), or Ethernet packet(s). In some implementations, the UL data is associated with DRB(s) (e.g., SDT DRB(s) and/or non-SDT DRB(s)). In some implementations, the UE **102** applies one or more security functions (e.g., encryption and/or integrity protection) to the UL data as described above. The CU-UP **172**B applies one or more security functions (e.g., decryption and/or integrity protection check) to the UL data as described above.

[0153] In some implementations, the DL data includes the DL data received from the CN **110** as described above. In further implementations, the DL data includes new DL data that the CU-CP **172**A and/or CU-UP **172**B receive from the CN **110**. Depending on the implementation, the DL data includes DL data packet(s) such as NAS PDU(s), IP packet (s), or Ethernet packet(s). In the case of the NAS PDU(s), the CU-CP **172**A receives the NAS PDU(s) from the CN **110** (e.g., AMF **164**) and generates RRC PDU(s) each including a particular NAS PDU of the NAS PDU(s). In some implementations, the CU-CP **172**A applies one or more security functions (e.g., encryption and/or integrity protection) to the RRC PDU(s) as described above. The UE **102** applies one or more security functions (e.g., decryption and/or integrity protection check) to the RRC PDU(s) as described above. In the case of the NAS PDU(s), the CU-CP **172**A receives the NAS PDU(s) from the CN **110** (e.g., AMF **164**) and generates RRC PDU(s) each including a particular NAS PDU of the NAS PDU(s). In some implementations, the CU-CP **172**A applies one or more security functions (e.g., encryption and/or integrity protection) to the RRC PDU(s) as described above. The UE **102** applies one or more security functions (e.g., decryption and/or integrity protection check) to the RRC PDU(s) as described above. In the case of the IP packet(s) or Ethernet packet(s), the CU-UP **172**B receives the DL data packet(s) from the CN **110** (e.g., UPF **162**) or an edge server and generates PDCP PDU(s) each including a particular DL data packet of the DL data packet(s). In some implementations, the CU-UP **172**B applies one or more security functions (e.g., encryption and/or integrity protection) to the DL data packet(s) as described above. The UE **102** applies one or more security functions (e.g., decryption and/or integrity protection check) to the DL data packet(s) as described above.

[0154] In cases where the RRC resume message includes the first non-SDT DU configuration, the UE **102** communicates **518** with the DU **174** using the first non-SDT DU configuration. In some cases where the second non-SDT DU configuration is not completely replaced by the first non-SDT DU configuration (i.e., the UE **102** does not release the second non-SDT DU configuration in response to the RRC resume message), the UE **102** communicates **518** with the DU **174** using the configuration parameters in the second non-SDT DU configuration, which are not augmented by the first non-SDT DU configuration.

[0155] In some implementations, the DU **174** does not provide the first non-SDT DU configuration to the CU-CP **172**A in the UE Context Response message and the additional DU-to-CU message. In such cases, the RRC resume message does not include the first non-SDT configuration, and the UE **102** and the DU **174** communicate **518** with one another using the second non-SDT DU configuration.

[0156] In some implementations, the UE **102** releases the SDT configuration(s) (e.g., the SDT CU configuration, the SDT DU configuration and/or the CG-SDT configuration(s) in response to the RRC resume message or transitioning to the connected state. In some implementations, the base station **104** (e.g., the CU-CP **172**A and/or DU **174**) releases the SDT configuration(s) in response to or after causing the UE **102** to transition to the connected state, receiving **510** the CU-to-DU message, or transmitting **545**, **546** the RRC resume message. In other implementations, the base station **104** releases the SDT configuration(s) in response to or after receiving an acknowledgement (e.g., a RLC acknowledgement or a HARQ acknowledgement) for the PDU(s) including the RRC resume message. In yet other implementations, the base station **104** (e.g., the CU-CP **172**A and/or DU **174**) releases the SDT configuration(s) in response to or after communicating **508** the UE Context Request message or **510** the UE Context Response message.

[0157] In other implementations, the UE **102** retains the SDT configuration(s) (e.g., the SDT CU configuration, the SDT DU configuration and/or the CG-SDT configuration(s)) in response to or after receiving the RRC resume message or transitioning to the connected state. In some implementations, the UE **102** refrains from using the SDT configuration (s) to communicate (e.g., **550** the RRC resume complete message and/or **518** data) with the base station **104**, while operating in the connected state. In other implementations, the UE **102** uses the SDT configuration(s) to communicate (e.g., **550** the RRC resume complete message and/or **518** data) with the base station **104**, while operating in the connected state. In some implementations, the base station **104** retains the SDT configuration(s) in response to or after causing the UE **102** to transition to the connected state or transmitting the RRC resume message. In some implementations, the base station **104** refrains from using the SDT configuration(s) to communicate (e.g., **550** the RRC resume complete message and/or **518** data) with the UE **102** operating in the connected state. In other implementations, the base station **104** uses the SDT configuration(s) to communicate (e.g., **550** the RRC resume complete message and/or **518** data) with the UE **102** operating in the connected state.

[0158] In some implementations, the UE **102** discards a UE Inactive AS Context in response to or after causing the UE **102** to transition to the connected state or transmitting the RRC resume message. In some implementations, the UE **102** releases one or more configuration parameters in a suspend configuration (e.g., suspendConfig) except RAN notification area information (e.g., ran-Notification-AreaInfo). Depending on the implementation, the UE **102** receives the suspend configuration in an RRC release message from the base station **104**, similar to event **334** or **434**, before performing **592** the procedure.

[0159] In some implementations, the non-SDT indication message is or includes an RRC message (e.g., a UEAssistanceInformation message or a new RRC message). In some such implementations, the UE **102** continues to perform small data communication with the base station **104** after transmitting the non-SDT indication message. In some implementations, the UE **102** transmits a UL MAC PDU including the non-SDT indication message to the CU-CP **172**A via the DU **174**. In some implementations, the UE **102** includes data in the UL MAC PDU in addition to the non-SDT indication message. In other implementations, the UE refrains from including data in the UL MAC PDU. In some implementations, the UE **102** transmits the non-SDT indication message to the CU-CP **172**A via the DU **174** and SRB1. In such implementations, the UE **102** refrains from re-establishing a UE PDCP entity for the SRB1 in response to determining to transmit the non-SDT indication message. The UE **102** generates a UL PDCP PDU including the non-SDT indication message using the UE PDCP entity and transmits **503**, **505** the UL PDCP PDU to the CU-CP **172**A via the DU **174**. Then, the UE **102** uses the UE PDCP entity to receive **546** a DL PDCP PDU including the RRC resume message without re-establishing the UE PDCP entity. The CU-CP **172**A uses a CU-CP PDCP entity to receive the **505** the UL PDCP PDU. The CU-CP **172**A refrains from re-establishing the CU-CP PDCP entity for the SRB1 in response to the receiving the non-SDT indication message. The CU-CP **172**A generates the DL PDCP PDU using the CU-CP PDCP entity and transmits **545**, **546** the DL PDCP PDU to the UE **102** via the DU **174** and SRB1. The UE **102** generates a UL PDCP PDU including the RRC resume complete message using the UE PDCP entity and transmits **550**, **552** the UL PDCP PDU to the CU-CP **172**A via the DU **174** and SRB1. The CU-CP **172**A receives **550**, **552** the UL PDCP PDU from the UE **102** via the DU **174**, using the CU-CP PDCP entity. In these implementations, the UE **102** and the CU-CP **172**A communicates the PDCP PDUs via the SRB1 without re-establishing the UE PDCP entity and CU-CP PDCP entity.

[0160] In other implementations, the non-SDT indication message is an RRC resume request message (e.g., RRCResumeRequest message or RRCResumeConnectionRequest message). In some such implementations, the UE **102** stops **592** small data communication with the base station **104** to transmit the non-SDT indication message. In some implementations, the UE **102** transmits the non-SDT indication message to the CU-CP **172**A via the DU **174** and SRB0. In some implementations, the UE **102** re-establishes the UE PDCP entity in response to determining to transmit the non-SDT indication. After re-establishing the UE PDCP entity, the UE **102** receives **546** the DL PDCP PDU using the UE PDCP entity from the DU **174**. Similarly, the CU-CP **172**A re-establishes the CU-CP PDCP entity upon receiving the non-SDT indication message. After re-establishing the CU-CP PDCP entity, the CU-CP **172**A generates the DL PDCP PDU using the CU-CP PDCP entity and transmits **545**, **546** the DL PDCP PDU to the UE **102** via the DU **174** and SRB1. After re-establishing the UE PDCP entity, the UE **102** generates a UL PDCP PDU including the RRC resume complete message using the UE PDCP entity and transmits **550**, **552** the UL PDCP PDU to the CU-CP **172**A via the DU **174** and SRB1. After re-establishing the CU-CP PDCP entity, the CU-CP **172**A receives **550**, **552** the UL PDCP PDU from the UE **102** via the DU **174**, using the CU-CP PDCP entity.

[0161] Before performing **592** the small data communication procedure, the UE **102** operating **502** in the inactive state starts or restarts a first UE CG-SDT timer (e.g., CG-SDT-TAT), as described for FIGS. **3** and **4**. In some implementations, the UE **102** starts or restarts the first UE CG-SDT timer in response to receiving a timing advance command from the DU **174** during **592** the small data communication procedure. In some implementations, the UE **102** maintains (e.g., keeps or does not stop, start or restart) the first UE CG-SDT timer (e.g., CG-SDT-TAT) running in response to or after receiving the RRC resume message. In other implementations, the UE **102** stops the first UE CG-SDT timer in response to or after receiving the RRC resume message.

[0162] Similarly, depending on the implementation, the DU **174** runs a first DU CG-SDT timer for the UE **102** operating **502** in the inactive state, as described for FIGS. **3** and **4**. In some implementations, the DU **174** starts or restarts the first DU CG-SDT timer in response to transmitting a timing advance command to the UE **102**. In some implementations, the DU **174** maintains (e.g., keeps or does not stop, start or restart) the first DU CG-SDT timer running in response to or after receiving **508** the UE Context Request message, transmitting **510** the UE Context Response message, or transmitting **512** the resume message. In other implementations, the DU **174** stops the first DU CG-SDT timer in response to or after receiving **508** the UE Context Request message, transmitting **510** the UE Context Response message or transmitting **545** the RRC resume message. In some cases where the first DU CG-SDT timer expires, the DU **174** releases the CG-SDT configuration(s). In some cases where the first DU CG-SDT timer expires, the DU **174** alternatively retains the CG-SDT configuration(s) and refrains from receiving or attempting to receive UL transmissions (e.g., MAC PDUs) on the CG resources. In some such cases, the DU **174** releases the CG resources or determines the CG resources not valid.

[0163] In some implementations, the UE **102** in the inactive state runs a second UE CG-SDT timer during **592** the small data communication procedure, as described for the procedure **492**. In cases where the second UE CG-SDT timer is running, the UE **102** stops the second UE CG-SDT timer in response to or after receiving **546** the RRC resume message or transitioning **548** to the connected state, in some implementations. Alternatively, the UE **102** maintains the second UE CG-SDT timer running in response to or after receiving **546** the RRC resume message or transitioning **548** to the connected state. In some implementations, the UE **102** receives an RRC setup message (e.g., RRCSetup message) instead of the RRC resume message. In response to or after receiving the RRC setup message, the UE **102** stops the second UE CG-SDT timer and transmits an RRC setup complete message to the CU-CP **172**A via the DU **174**.

[0164] Similarly, in some implementations, the DU **174** runs a second DU CG-SDT timer during **592** the small data communication procedure. In some implementations, the DU **174** starts or restarts the second DU CG-SDT timer when or after receiving from the UE **102** a PUSCH transmission on radio resources configured in the CG-SDT configuration. While the second DU CG-SDT timer is running, the DU **174** transmits a PDCCH using the C-RNTI. In cases where the second DU CG-SDT timer is running, the DU **174** stops the second DU CG-SDT timer in response to or after receiving **508** the UE Context Request message, transmitting **510** the UE Context Response message, or transmitting **546** the RRC resume message, in some implementations. In other implementations, the DU **174** maintains the second DU CG-SDT timer in response to or after receiving **508** the UE Context Request message, transmitting **510** the UE Context Response message or transmitting **546** the RRC resume message. The DU **174** transmits, to the UE **102** operating in the connected state, a DCI on a PDCCH using the C-RNTI irrespective of the second DU CG-SDT timer (e.g., running, expiring or stopping).

[0165] The events **502**, **592**, **503**, **505**, **507**, **508**, **510**, **545**, **546**, **548**, **550**, **552**, **554**, **556** and **518** are collectively referred to in FIG. **5**A as a state transition procedure **588**.

[0166] At a later time, the base station **104** performs **590** a non-SDT configuration procedure and **594** an SDT configuration procedure with the UE **102**, similar to the procedure **390** and the procedure **394**, respectively. The UE **102** transitions **536** to the inactive state in response to receiving an RRC release message in the procedure **594**. In some implementations, after transitioning to the inactive state, the UE **102** in the inactive state performs **593** a small data communication procedure and **595** an SDT complete procedure with the base station **104**, similar to the procedure **492** and **494**, respectively.

[0167] Referring next to FIG. **5**B, a scenario **500**B is generally similar to the scenario **500**A, except that the UE **102** initiates an RRC resume procedure instead of **592** the small data communication procedure. The differences between the scenarios **500**B and **500**A are discussed below.

[0168] In response to initiating the RRC resume procedure, the UE **102** in the inactive state transmits **542** an RRC resume request message to the DU **174**, which in turn transmits **544** an Initial UL RRC Message Transfer message including the RRC resume request message (e.g., an RRCResumeRequest message or an RRCConnectionResumeRequest message) to the CU-CP **172**A. In response to receiving the RRC resume request message, the CU-CP **172**A determines to cause the UE **102** to transition to the connected state. In response to or after determining to cause the UE **102** to transition to the connected state, the CU-CP **172**A transitions the UE to the connected state as described for the scenario **500**A.

[0169] In some implementations, the UE **102** generates a UL MAC PDU including the RRC resume request message and transmits **542** UL MAC PDU to the DU **174**. In some implementations, the UE **102** transmits **542** to the DU **174** the UL MAC PDU on radio resources configured in a CG configuration for SDT. In other implementations, the UE **102** performs a random access procedure to transmit the UL MAC PDU, similar to the event **404**.

[0170] In some implementations, the UE **102** initiates the RRC resume procedure to transmit non-SDT data (i.e., data not qualifying for SDT). More specifically, an upper protocol layer (e.g., NAS layer) of the UE **102** requests an RRC layer (e.g., RRC **214**) of the UE **102** to initiate the RRC resume procedure. In other implementations, the UE **102** receives a paging message from the DU **174** and initiates the RRC resume procedure to respond the paging message. In some implementations, the RRC layer (e.g., RRC **214**) initiates the RRC resume procedure in response to the paging message. In yet other implementations, the UE **102** detects a periodic RAN notification area update (RNAU) timer expires and initiates the RRC resume procedure in response to the periodic RNAU timer expiring. In some implementations, the RRC layer (e.g., RRC **214**) starts or restarts the RNAU timer, maintains the RNAU timer running, and initiates the RRC resume procedure in response to the RNAU timer expiring.

[0171] The events **502**, **508**, **510**, **518**, **542**, **544**, **545**, **546**, **548**, **550**, **552**, **554**, and **556** are collectively referred to in FIG. **5**B as a state transition procedure **589**.

[0172] Referring next to FIG. **6**A, a scenario **600**A depicts an RRC resume request and a response with an RRC release message. In the example scenario **600**A, the base station **106** includes a CU **172** and a DU **174**. The CU **172** includes a CU-CP **172**A and a CU-UP **172**B. The UE **102** initially operates **602** in an inactive state. In some implementations, the UE **102** operates in the connected state with the base station **104** before operating **602** in the inactive state and later transitions to the inactive state **602**, as described for FIG. **3**. In other implementations, the UE **102** operates in the inactive state, performs small data transmission with the base station **104**, stops the small data transmission with the base station **104**, and stays in the inactive state **602**, as described for FIG. **4**. In some such implementations, the UE **102** is configured with SDT configuration parameters (e.g., SDT CU configuration and/or SDT DU configuration) by the base station **104**, as described for FIG. **3** or FIG. **4**. "SDT configuration" is used to represent the SDT configuration parameters to simplify the following description. In some implementations, the SDU configuration includes CG-SDT configuration(s). In some such cases, the UE **102** discards the CG-SDT configuration(s) because the base station **106** does not configure the CG-SDT configuration(s) for the UE **102** (i.e., the CG-SDT configuration(s) is not valid).

[0173] At a later time, the UE **102** in the inactive state initiates an RRC resume procedure with the base station **106**. In some implementations, the UE **102** initiates the RRC resume procedure for an RNA update because the base station **106** belongs to another RNA different from an RNA of a cell where the UE **102** receives an RRC release message configuring the UE **102** to transition to the inactive state **602**. In other implementations, the UE **102** performs the RRC resume procedure for a periodic RNA update. In response to the initiation, the UE **102** in the inactive state transmits **642** an RRC resume request message to the DU **174**, which in turn transmits **644** an Initial UL RRC Message Transfer message including the RRC resume request message (e.g., an RRCResumeRequest message or an RRCConnectionResumeRequest message) to the CU-CP **172**A. In some implementations, the RRC resume request message includes a UE ID of the UE **102**. For example, the UE ID can be an I-RNTI (e.g., a fullI-RNTI or shortI-RNTI value or field). In some implementations, the RRC resume request message includes an RRC MAC-I. In further implementations, the RRC MAC-I is a resumeMAC-I field and the UE **102** obtains the resumeMAC-I (e.g., as specified in 3GPP specification 38.331). In other implementations, the UE **102** obtains the RRC MAC-I (e.g., a resumeMAC-I field) from the RRC resume request with an integrity key (e.g., K_{RRCint} key), an integrity protection algorithm, and other parameters COUNT (e.g., 32-bit, 64-bit or 128-bit value), BEARER (e.g., 5-bit value), and DIRECTION (e.g., 1-bit value). In some implementations, the UE **102** sets bits for COUNT, BEARER, and DIRECTION set to binary ones to generate the RRC MAC-I.

[0174] After receiving the RRC resume request message, the CU-CP **172**A transmits **607** a Retrieve UE Context Request message to a base station **104** to retrieve a UE context of the UE **102**. In response, the base station **104** transmits **609** a Retrieve UE Context Response message including UE context information of the UE **102** to the

CU-CP **172**A. In some implementations, the CU-CP **172**A includes the RRC MAC-I in the Retrieve UE Context Request message. In some implementations, the CU-CP **172**A determines a first IP address of the base station **104**, a CU-CP of the base station **104**, or a CU of the base station **104** in accordance with the UE ID. The CU-CP **172**A generates a first IP packet, including a source address (i.e., an IP address of the CU-CP **172**A), a destination address (i.e., the first IP address), and the Retrieve UE Context Request message. The CU-CP **172**A transmits the first IP packet to the base station **104**. The base station **104** generates a second IP packet including a source address (i.e., the first IP address or another IP address of the base station **104**), a destination address (i.e., the IP address of the CU-CP **172**A), and the Retrieve UE Context Response message. The base station transmits the second IP packet to the CU-CP **172**A.

[0175] In some implementations, the UE context information includes security capabilities, security information, a maximum bit rate, a PDU session resources to be setup list, an RRC context, a UE radio capability ID, and/or the SDT configuration. In some implementations, the RRC context includes configuration parameters that the base station **104** configures for the UE **102** operating in the connected state to communicate with the base station **104**. For example, the configuration parameters include a cell group configuration (e.g., CellGroupConfig IE), a radio bearer configuration (e.g., RadioBearerConfig IE), and/or measurement configuration(s) (e.g., MeasConfig IE(s)). In some implementations, the base station **104** includes the SDT configuration in the RRC context. In other implementations, the base station **104** refrains from including the SDT configuration in the RRC context or in the Retrieve UE Context Response message.

[0176] In some cases where the SDT configuration includes CG-SDT configuration(s), the base station **104** excludes the CG-SDT configuration(s) from the SDT configuration. Alternatively, the base station **104** still includes the CG-SDT configuration(s) from the SDT configuration. In some implementations, when the CU-CP **172**A receives the CG-SDT configuration(s), the CU-CP **172**A discards the CG-SDT configuration(s). In some implementations, the CU-CP **172**A discards the SDT configuration, (e.g., in cases where the CU-CP **172**A does not support delta configuration). In other implementations, the base station **104** refrains from including the SDT configuration in the Retrieve UE Context Response message.

[0177] In some implementations, after receiving **609** the Retrieve UE Context Response message, the CU-CP **172**A transmits **612** a Bearer Context Setup Request message to the CU-UP **172**B to request the CU-UP **172**B to establish bearer context(s) for SDT DRB(s) configured in the SDT configuration for the UE **102**. In response, the CU-UP **172**B establishes (i.e., sets up) bearer context(s) for the SDT DRB(s) and transmits **614** a Bearer Context Setup Response message to the CU-CP **172**A to confirm that that bearer context(s) for the SDT DRB(s) are established. In some implementations, if non-SDT DRB(s) of the UE **102** exist, the CU-CP **172**A requests the CU-UP **172**B to establish bearer context(s) for the non-SDT DRB(s) in the Bearer Context Setup Request message. In such a case, the CU-UP **172**B establishes bearer context(s) for the non-SDT DRB(s) in response to the Bearer Context Setup Request message **612**. In some implementations, the CU-UP **172**B includes transport layer information of the CU-UP **172**B in the Bearer Context Setup Response message. The transport layer information of the CU-UP **172**B configures and/or includes IP address(es) and/or uplink TEID(s) associated with the SDT DRB(s) and/or non-SDT DRB(s). In some implementations, each of the SDT DRB(s) and non-SDT DRB(s) is associated with a particular IP address and/or a particular uplink TEID, which can identify a GTP tunnel. The Bearer Context Setup Request message and Bearer Context Setup Response message can be grouped as a Bearer Context Setup procedure.

[0178] In further implementations, after receiving **609** the Retrieve UE Context Response message or receiving **614** the Bearer Context Setup Response message, the CU-CP **172**A transmits **608** a UE Context Setup Request message to the DU **174** to request the DU **174** to establish a UE context for the UE **102**. In response, the DU **174** establishes a UE context for the UE **102** and transmits **610** a UE Context Setup Response message to the CU-CP **172**A. In some implementations, the CU-CP **172**A includes the transport layer information of the CU-UP **172**B in the UE Context Setup Request message. In some implementations, the DU **174** includes transport layer information of the DU **174** in the UE Context Setup Response message. The UE Context Setup Request message and UE Context Setup Response message can be grouped as a UE Context Setup procedure. The transport layer information of the DU **174** configures and/or includes IP address(es) and/or downlink TEID(s) associated with the SDT DRB(s) and/or non-SDT DRB(s). In some implementations, each of the SDT DRB(s) and non-SDT DRB(s) is associated with a particular IP address and/or a particular downlink TEID, which can identify a GTP tunnel.

[0179] After receiving **614** Bearer Context Setup Response message or receiving **610** the UE Context Setup Response message, the CU-CP **172**A transmits **624** a Bearer Context Modification Request message to the CU-UP **172**B. In response, the CU-UP **172**B transmits **626** a Bearer Context Modification Response message to the CU-CP **172**A. In some implementations, the CU-CP **172**A includes the transport layer information of the DU **174** in the Bearer Context Modification Request message. The Bearer Context Modification Request message and Bearer Context Modification Response message can be grouped as a Bearer Context Modification procedure.

[0180] In some implementations, the CU-CP **172**A includes a suspend indication (e.g. Bearer Context Status Change IE with a "Suspend" value) in the Bearer Context Setup Request message to indicate to suspend the one or more bearer contexts. Alternatively, the CU-CP **172**A includes the suspend indication in the Bearer Context Modification Request message instead of including the suspend indication in the Bearer Context Setup Request message. In response to the suspend indication, the CU-UP **172**B suspends all of the DRB(s) (i.e., the SDT DRB(s) and/or the non-SDT DRB(s)) of the UE **102**. In some implementations, when the CU-UP **172**B suspends the DRB(s), the CU-UP **172**B suspends the bearer contexts of the DRB(s) and/or data communication for the DRB(s).

[0181] In some implementations, after receiving **609** the Retrieve UE Context Response message, **610** the UE Context Setup Response message, **614** the Bearer Context Setup Response message or **626** the Bearer Context Modification Response message, the CU-CP **172**A determines to obtain an SDT DU configuration from the DU **174**. In response to the determination, the CU-CP **172**A transmits **628** a CU-to-DU message to the DU **174** to obtain an SDT DU configuration, similar to the events **328**, **428**. In response, the DU **174** transmits **630** a DU-to-CU message including an SDT DU configuration to the CU-CP **172**A, similar to the events **330**, **430**. After receiving **609** the Retrieve UE Context Response message, **610** the UE Context Setup Response message, **614** the Bearer Context Setup Response message, **626** the Bearer Context Modification Response message, or **630** the DU-to-CU message, the CU-CP **172**A transmits **632**, **634** an RRC release message to the UE **102** via the DU **174**, similar to the events **332**, **334**, **432**, and **434**. The UE **102** determines that the RRC resume procedure successfully completes upon receiving **634** the RRC release message and stays in the inactive state.

[0182] In some implementations, after receiving **634** the RRC release message, the UE **102** performs **692** a small data communication procedure and perform **695** an SDT complete procedure with the base station **106**, similar to the events **492** and **494** respectively. In some implementations, the events **608**, **610**, **612**, **614**, **624** and/or **626** are omitted. In some such implementations, the events occur during the small data communication procedure **692**.

[0183] In some scenarios or implementations, the CU-UP **172**B receives a DL data packet for the UE **102** from a CN **110** (e.g., UPF **162**) or an edge server, and the DL data packet is associated with one of the SDT DRB(s). Because the CU-UP **172**B suspends the SDT DRB, the CU-UP **172**B suspends transmitting the DL data packet to the DU **174** and transmits to the CU-CP **172**A a UP-to-CP message (e.g., DL Data Notification message) to notify the CU-CP **172**A that the SDT DRB has data arrival. In some implementations, the CU-UP **172**B includes, in the UP-to-CP message, a PDU session ID and/or a QoS flow ID with which the SDT DRB is associated. In further implementations, in response to or after receiving the UP-to-CP message, the CU-CP **172**A transmits a CU-to-DU message (e.g., a F1AP Paging message) to the DU **174** to cause or command the DU **174** to transmit to a paging message (e.g., an RRC Paging message) to the UE **102**. In response to the CU-to-DU message, the DU **174** transmits a paging message to the UE **102**.

[0184] In some scenarios or implementations, the CU-UP **172**B receives a DL data packet for the UE **102** from a CN **110** (e.g., UPF **162**) or an edge server, and the DL data packet is associated with one of the non-SDT DRB(s). Because the CU-UP **172**B suspends the non-SDT DRB, the CU-UP **172**B suspends transmitting the DL data packet to the DU **174** and transmits to the CU-CP **172**A a UP-to-CP message (e.g., DL Data Notification message) to notify the CU-CP **172**A that the non-SDT DRB has data arrival. In some implementations, the CU-UP **172**B includes, in the UP-to-CP message, a PDU session ID and/or a QoS flow ID with which the non-SDT DRB is associated. In further implementations, in response to or after receiving the UP-to-CP message, the CU-CP **172**A transmits a CU-to-DU message (e.g., a F1AP Paging message) to the DU **174** to cause or command the DU **174** to transmit to a paging message (e.g., an RRC Paging message) to the UE **102**. In response to the CU-to-DU message, the DU **174** transmits a paging message to the UE **102**.

[0185] Referring next to FIG. **6**B, a scenario **600**B depicts small data transmission, similar to the scenarios **400** and **600**A. Except events **607** and **609**, events **602**, **604**, **606**, **608**, **610**, **612**, **614**, **615**, **616**, **618**, **695**, **636** are similar to events **402**, **404**, **406**, **408**, **410**, **412**, **414**, **415**, **416**, **418**, **494**, **436**, respectively. Examples and implementations for FIG. **4** and FIG. **6**A can apply to FIG. **6**B. The differences among FIGS. **4** and **6**A and FIG. **6**B are described below.

[0186] In the scenario **600**B, the UE **102** initially operates **602** in an inactive state and is configured with an SDT configuration. In some implementations, the UE **102** receives the SDT configuration as described for FIGS. **3**, **4**, **5**A, and/or **5**B. The UE **102** operating **602** in the inactive state initiates SDT. In response to the initiation, the UE **102** transmits **604** a UL MAC PDU including a UL RRC message to the DU **174**. In turn, the DU **174** transmits **606** a DU-to-CU message including the UL RRC message to the CU-CP **172**A. In response to or after receiving **606** the UL RRC message, the CU-CP **172**A transmits **607** the Retrieve UE Context Request message to the base station **104**. In response, the base station **104** transmits **609** the Retrieve UE Context Response message to the CU-CP **172**A.

[0187] In cases where the UE **102** includes UL data in the initial UL MAC PDU **604**, the DU **174** can transmit **615** a DU-to-CU message including the UL data to the CU-CP **172**A or **616** the UL data, similar to the events **415** or **416**, respectively.

[0188] In some implementations, after transmitting **604** the initial UL MAC PDU, the UE **102** in the inactive state transmits **618** subsequent UL data to CU-CP **172**A and/or CU-U **172**B via the DU **174**, similar to the event **418**. In further implementations, after transmitting **604** the initial UL MAC PDU, the UE **102** in the inactive state receives **618** DL data from CU-CP **172**A and/or CU-U **172**B via the DU **174**, similar to the event **418**. In some implementations, after the events **604** and/or **618**, the UE **102** and base station **106** perform **694** an SDT complete procedure, similar to the event **494**. The UE **102** remains **636** in the inactive state in response to or after performing **694** the SDT complete procedure.

[0189] In some implementations, the CU-CP **172**A refrains from including a suspend indication (e.g., Bearer Context Status Change IE with a "Suspend" value) in the Bearer Context Setup Request message **612**. In some implementations, the CU-CP **172**A includes, in the Bearer Context Setup Request message **612**, a resume indication (e.g., Bearer Context Status Change IE with a "ResumeforSDT" value) indicating to the CU-UP **172**B to suspend the non-SDT DRB(s). In response to the resume indication, the CU-UP **172**B suspends the non-SDT DRB(s). In other implementations, the CU-CP **172**A refrains from including the resume indication in the Bearer Context Setup Request message **612**. In some such implementations, the CU-CP **172**A includes a resume indication (e.g., Bearer Context Status Change IE with a "ResumeforSDT" value) in the Bearer Context Modification Request message **624** to indicate to the CU-UP **172**B to suspend the non-SDT DRB(s). In response to the resume indication, the CU-UP **172**B suspends the non-SDT DRB(s). In some implementations, if the UE **102** is not configured with a non-SDT DRB, the CU-CP **172**A excludes the resume indication in the Bearer Context Setup Request message **612** and/or the Bearer Context Modification Request message **624**.

[0190] In some implementations, when the CU-UP **172**B suspends the non-SDT DRB(s), the CU-UP **172**B suspends the bearer context(s) of the non-SDT DRB(s) and/or data communication for the non-SDT DRB(s).

[0191] In further implementations, after establishing the bearer context(s) for the SDT DRB(s), the CU-UP **172**B receives **616**, **618** the UL data from the DU **174** and processes the UL data, because the SDT DRB(s) where the UL data is associated is not suspended by the CU-UP **172**B. In some scenarios or implementations, the CU-UP **172**B receives a DL data packet for the UE **102** from a CN **110** (e.g., UPF **162**) or an edge server. If the DL data packet is associated with one of the SDT DRB(s), the CU-UP **172**B transmits **618** the DL data packet to the DU **174**, which in turn transmits **618** the DL data packet(s) to the UE **102**. If the DL data packet is associated with one of the non-SDT DRB(s), the CU-UP **172**B suspends transmitting the DL data packet(s) to the DU **174**. In response to receiving the DL data packet associated with the non-SDT DRB(s), the CU-UP **172**B transmits, to the CU-CP **172**A, a UP-to-CP message (e.g., DL Data Notification message) to notify the CU-CP **172**A that a DL data packet for the non-SDT DRB arrives. In some implementations, the CU-UP **172**B can include, in the UP-to-CP message, a PDU session ID and/or a QoS flow ID where the non-SDT DRB is associated.

[0192] Referring next to FIG. **6**C, a scenario **600**C depicts small data transmission, similar to the scenario **500**A/**500**B and **600**A. Except events **607** and **609**, events **602**, **604**, **606**, **608**, **610**, **645**, **646**, **648**, **650**, **652**, **612**, **614**, **619**, **690**, **694**, **636**, **692**, and **695** are similar to events **502**, **542**, **554**, **506**, **508**, **510**, **545**, **546**, **548**, **550**, **552**, **512**, **514**, **518**, **590**, **594**, **536**, **592**, and **595**, respectively. Examples and implementations for FIGS. **5**A, **5**B and **6**A can apply to FIG. **6**C. The differences among FIGS. **5**A, **5**B, and **6**A and FIG. **6**C are described below.

[0193] In the scenario **600**C, the CU-CP **172**A refrains from including a suspend indication (e.g. Bearer Context Status Change IE with a "Suspend" value) in the Bearer Context Setup Request message **612** and the Bearer Context Modification Request message **624**. Thus, the CU-UP **172**B does not suspend a DRB of the UE **102** in response to or after receiving the Bearer Context Setup Request message **612** and the Bearer Context Modification Request message **624**.

[0194] In some implementations, after establishing the bearer context(s) for the DRB(s) of the UE **102** (e.g., the SDT DRB(s) and/or the non-SDT DRB(s) of the UE **102**), the CU-UP **172**B receives **616**, **619** the UL data packet(s) from the DU **174** and processes the UL data packet(s), because the DRB(s) with which the UL data is associated are not suspended by CU-UP **172**B. The UL data packet(s) can be PDCP PDU(s), SDAP PDU(s), IP packet(s) or Ethernet packet(s). The UL data packet(s) are associated with DRB(s) (e.g., SDT DRB(s) and/or non-SDT DRB(s)). In some implementations, the UE **102** applies one or more security functions (e.g., encryption and/or integrity protection) to the UL data packet(s) as described above. The CU-UP **172**B applies one or more security functions (e.g., decryption and/or integrity protection check) to the UL data packet(s) as described above. In some scenarios or implementations, the CU-UP **172**B receives DL data packet(s) for the UE **102** from a CN (e.g., UPF **162**) or an edge server. The DL data packet(s) can be IP packet(s) or Ethernet packet(s) and associated with the DRB(s). In some implementations, the CU-UP **172**B applies one or more security functions (e.g., encryption and/or integrity protection) to the DL data packet (s) as described above. The UE **102** applies one or more security functions (e.g., decryption and/or integrity protection check) to the DL data packet(s) as described above.

[0195] Referring first to FIG. **7**A, a scenario **700**A depicts data communication between the UE **102** and RAN **105** (e.g., base station **104** or **106**) while the UE **102** operates in an inactive state (i.e., small data transmission). In the scenario **700**A, the UE **102** includes the MAC sublayer **204**B, the RLC sublayer **206**B, the PDCP sublayer **210**, the RRC sublayer **214**, and upper layer(s) **220**. Depending on the implementation, the upper layer(s) **220** include a mobility management (MM) sublayer, a session management (SM) sublayer, the SDAP sublayer **212**, a data transport layer, a data connection manager, and/or a packet handler. For example, the MM sublayer and the SM sublayer can be a 5GMM sublayer and a 5GSM sublayer, respectively. In some implementations, the data transport sublayer is an IP layer or an Ethernet layer. In some implementations, the data connection manager manages to establish, release, suspend, or resume a data connection. The packet handler is a module to dispatch IP packets or Ethernet packets to a data connection. In some implementations, a data connection includes a packet data network (PDN) connection, a PDU session, an EPS bearer, a QoS flow, and/or a data path among the data transport layer, the packet handler, the SDAP sublayer **212**, and/or the PDCP sublayer **210**. In some implementations, the data connection manager is further divided into different modules (e.g., PDN (connection) management module, PDU (session) manage module, network service module, or data service module) each responsible for particular function (s).

[0196] To simplify the following description, "RRC **214**, "PDCP **210**", "RLC **206**B", "MAC **204**B", and "PHY **202**B" are used to represent "RRC sublayer **214**", "PDCP sublayer **210**", "RLC sublayer **206**B", "MAC sublayer **204**B", and "PHY sublayer **202**B", respectively.

[0197] Initially, the UE **102** operates **702** in the inactive state with SDT configured (e.g., as described for FIG. **3** or **4**). Later, the upper layer(s) **220** determine to initiate data transmission or resume a (suspended) connection to transmit data. In response to the determination, the upper layer(s) **220** send **704** a connection resume request message to the RRC **214**. In response to or after receiving the connection resume request message, the RRC **214** initiates **706** an SDT procedure (i.e., the UE **102** starts an SDT session). In some implementations, the RRC **214** can send **708** a connection resume request confirm message to the upper layer(s) **220**, confirming that the RRC **214** receives or is processing the connection resume request message.

[0198] In some implementations, the upper layer(s) **220** include data volume information in the connection resume request message. The data volume information includes or indicates a data volume of data available for transmission. Based on the data volume information, the RRC **214** determines to initiate **706** the SDT procedure. For example, if the data volume in the data volume information is below a threshold, the RRC **214** determines to initiate **706** the SDT procedure. In some implementations, the UE **102** receives the threshold in a system information block (SIB) broadcast by the RAN **105**. In other implementations, the RRC **214** receives the threshold in an RRC release message transmitted by the RAN **105** (e.g., similar to events **334** or **434**). In cases where the RRC **214** receives a connection resume request message including data volume information and a data volume in the data volume information is above the threshold, the RRC **214** initiates an RRC connection resume procedure to transition to a connected state instead of the SDT procedure.

[0199] In other implementations, the upper layer(s) **220** includes an SDT indication in the connection resume request message, and the SDT indication indicates to the RRC **214** to initiate an SDT procedure. In response to the SDT indication, the RRC **214** initiates **706** SDT. In such implementations, the RRC **214** sends the threshold to the upper layer(s) **220**. The upper layer(s) **220** determine to include the SDT indication if the data volume is below the threshold. If the data volume is above the threshold, the upper layer(s) **220** refrain from including the SDT indication in the connection resume request message.

[0200] In response to initiating **706** the SDT procedure, the RRC **214** generates an RRC resume request message and sends **710** the RRC resume request message to the MAC **204**B. In some implementations, the RRC **214** sends **710** to the MAC **204**B a UL SDT initiation indication indicating that the RRC resume request message is for UL SDT initiation. In some implementations, the RRC **214** sends an interface message including the RRC resume request message and the UL SDT initiation to the MAC **204**B. In other implementations, the RRC **214** sends, to the MAC **204**B, separate interface messages including the RRC resume request message and the SDT initiation indication, respectively. In some implementations, the MAC **204**B sends a confirmation interface message to the RRC **214** to confirm that the MAC **204**B receives the interface message(s) and will transmit the RRC resume request message. When the MAC **204**B receives the SDT initiation indication and/or the RRC resume request message, the MAC **204**B waits to receive UL data from the RLC **204**B to generate an initial UL MAC PDU like event **719**.

[0201] In some implementations, in response to determining to initiate **706** the SDT procedure, the RRC **214** sends, to the PDCP **210**, a resume indication message. In further implementations, the PDCP **210** resumes SRB2 and/or DRB (s) configured for SDT in response to the resume indication message. In some implementations, the RRC **214** indicates that the SRB2 and/or DRB(s) are to be resumed in the resume indication message. For example, the RRC **214** can include an ID of the SRB2 and ID(s) of DRB(s) in the resume indication message. In other implementations, the RRC **214** indicates that the resume indication message is for SDT. For example, the RRC **214** can include an SDT indication in the resume indication message.

[0202] After determining to initiate data transmission or resume a connection, transmitting **704** the connection resume request message, or receiving **708** the connection resume request confirm message, the upper layer(s) **220** send **712** UL data to the PDCP **210**. In some implementations, the UL data includes data packet(s) such as IP packet (s) or Ethernet packet(s) and are generated by an application or operating system (e.g., Android, Windows, iOS, Mac OS, and Chrome OS). In other implementations, the UL data includes SDAP PDU(s). The PDCP **210** generates UL PDCP PDU(s), including the UL data, and sends **714** the UL PDCP PDU(s) to the RLC **206**B. In some implementations, the PDCP **210** sends **714** the UL PDCP PDU(s) to the RLC **206**B in response to after receiving the resume indication. The RLC **206**B generates UL RLC PDU(s), including the UL PDCP PDU(s), and sends **716** the UL RLC PDU(s) to the MAC **204**B. In some implementations, each of the UL RLC PDU(s) includes a particular UL PDCP PDU of the UL PDCP PDU(s). The MAC **204**B then generates **719** an initial UL MAC PDU, which includes the RRC resume request message and the UL RLC PDU(s). Alternatively, the RLC **206**B generates a UL RLC PDU segment, including a first portion of the UL PDCP PDU, and sends **716** the UL RLC PDU segment to the MAC **204**B. The MAC **204**B then generates **719** an initial UL MAC PDU, which includes the RRC resume request message and the UL RLC PDU segment. In some implementations, the MAC **204**B includes at least one MAC control element (e.g., a buffer status report (BSR)) in the initial UL MAC PDU. In some implementations, the MAC **204**B includes a data volume in the BSR, and the data volume indicates data available for transmission.

[0203] The MAC **204**B performs **780** an initial SDT procedure to transmit the initial UL MAC PDU to the RAN **105** via a cell, similar to the event **404**, procedure **480**, or event **604**. In the initial SDT procedure, the MAC **204**B transmits the initial UL MAC PDU to the RAN **105**, similar to the event **404**. In some implementations, after transmitting **780** the initial UL MAC PDU, the MAC **204**B determines **720** that the initial UL MAC PDU is transmitted successfully (i.e., the UL MAC PDU is received by the RAN **105**). In some implementations, the MAC **204**B performs a random access procedure with the RAN **105** via the cell to transmit the initial UL MAC PDU to the RAN **105** (i.e., RA-SDT). In such implementations, the MAC **204**B determines that the initial UL MAC PDU is transmitted successfully upon receiving a contention resolution MAC control element in the random access procedure. In cases where the random access procedure is a two-step random access procedure, the MAC **204**B receives, from the RAN **105**, the contention resolution MAC CE in a Message B (MsgB) of the random access procedure. In cases where the random access procedure is a four-step random access procedure, the MAC **204**B receives, from the RAN **105**, the contention resolution MAC control element in a Message 4 (Msg4) (i.e., a DL MAC PDU) of the random access procedure. In some implementations, the MAC **204**B generates the initial UL MAC PDU before performing the random access procedure. For example, in some cases where the random access procedure is a two-step random access procedure, the MAC **204**B generates **719** the initial UL MAC PDU in accordance with a UL grant configured in a system information block (SIB).

[0204] In other implementations, the MAC **204**B generates the initial UL MAC PDU during the random access procedure. For example, in some cases where the random access procedure is a four-step random access procedure, the MAC **204**B performs the four-step random access procedure upon receiving **710** the RRC resume request message or the SDT initiation indication from the RRC **214**. In further such cases, the MAC **204**B generates **719** the initial UL MAC PDU upon receiving a UL grant in a random access response in the random access procedure. Alternatively, the MAC **204**B generates **719** the initial UL MAC PDU in accordance with a MAC PDU size before initiating the random acc. In some implementations, the MAC PDU size is a preconfigured size. In other implementations, the UE **102** determines the MAC PDU size based on a UL grant in a random access response in a random access procedure that the UE **102** previously performed.

[0205] In some cases where the MAC 204B transmits 780, to the RAN 105 via the cell, the UL MAC PDU on CG resources using a configured UL grant, the MAC 204B determines 720 that the initial UL MAC PDU is transmitted successfully upon receiving from PHY 202B (not shown in FIG. 7A) a successful delivery indication indicating that the initial UL MAC PDU is transmitted successfully. In some implementations, the PHY 202B receives, on a PDCCH, a DCI and a CRC (of the DCI) scrambled with an ID of the UE 102 after transmitting 780 the initial UL MAC PDU. In response to or after receiving the DCI and CRC, the PHY 202B sends the indication to the MAC 204B. In some implementations, the ID of the UE 102 is a C-RNTI. In other implementations, the ID of the UE 102 is a configured scheduling RNTI (CS-RNTI). In some implementations, the DCI includes a dynamic UL grant. In other implementations, the DCI includes a downlink assignment.

[0206] In some implementations, the MAC 204B indicates a maximum RLC data size to the RLC 206B. The RLC 206B ensures a total size of the UL RLC PDU(s) or UL RLC PDU segment of the event 716 not larger than the maximum size. In some implementations, the MAC 204B determines a MAC PDU size of the initial UL MAC PDU based on the UL grant in the SIB, the UL grant in the random access response, or the configured UL grant. The MAC 204B determines the maximum RLC data size as (the MAC PDU size−a size of the RRC resume request message−a size of a subheader for the RRC resume request message). In cases where the MAC 204B determines to transmit at least one MAC control element (e.g., a BSR), the MAC 204B determines the maximum RLC data size as (the MAC PDU size−a size of the RRC resume request message−a size of a subheader for the RRC resume request message−a size of the at least one MAC control element−a size of a subheader for each of the at least one MAC control element).

[0207] In some cases where the initial UL MAC PDU includes the first portion of the UL PDCP PDU, the MAC 204B transmits, to the RAN 105, other UL MAC PDU(s) including other UL RLC PDU segment(s). In further implementations, the segment(s) include the rest of the portion(s) of the UL PDCP PDU. Each of the RLC PDU segment(s) include a particular portion of the UL PDCP PDU. Depending on the implementation, each of the other UL MAC PDU(s) includes a particular RLC PDU segment of the other UL RLC PDU segment(s). In some implementations, the MAC 204B transmits the other UL MAC PDU(s) using dynamic UL grant(s). The UE 102 (e.g., PHY 202B) receives the dynamic UL grants on PDCCH(s) from the RAN 105. In other implementations, the MAC 204B transmits the other UL MAC PDU(s) using configured UL grant(s) configured in CG configuration(s) that the UE 102 receives in an RRC release message (e.g., events 334 or 434). The RAN 105 receives the other UL MAC PDU(s), retrieves the other UL RLC PDU segment(s) from the other UL MAC PDU(s), and assembles the other UL RLC PDU segment(s) to obtain the UL PDCP PDU.

[0208] In response to the determination 720, the MAC 204B sends 722 to the RRC 214 an indication indicating that the SDT procedure is initiated successfully (i.e., the initial UL MAC PDU, RRC resume request message, or UL data has been transmitted successfully). In response to receiving 722 the indication, the RRC 214 determines 724 that the SDT procedure is initiated successfully. In response to the determination 724 or the indication 722, the RRC 214 transmits 726 a connection resume message to the upper layer(s) 220 to indicate that the connection is resumed. In some implementations, after receiving 726 the connection resume message, the upper layer(s) 220 send 728 subsequent UL data packet(s) to the PDCP 210. For each of the subsequent UL data packet(s), the PDCP 210 generates a UL PDCP PDU, including the subsequent UL data packet, and sends 730 the UL PDCP PDU to the RLC 206B. In some implementations, the RLC 206B generates subsequent UL RLC PDU(s), including the UL PDCP PDU(s), and/or generates UL RLC PDU segments, including the UL PDCP PDU. The RLC 206 sends 732 the subsequent UL RLC PDU(s) and/or UL RLC PDU segments to the MAC 204B. The MAC 204B generates subsequent UL MAC PDU(s), including the subsequent UL RLC PDU(s) and/or UL RLC PDU segments. The MAC 204B performs 718 SDT data communication to transmit the subsequent UL MAC PDU(s) to the RAN 105, similar to the event 418. In some implementations, the MAC 204B transmits the subsequent UL MAC PDU(s) using dynamic UL grant(s). The UE 102 receives the dynamic UL grants on PDCCH(s) from the RAN 105. In other implementations, the MAC 204B transmits the other UL MAC PDU(s) using configured UL grant(s) configured in CG configuration(s) that the UE 102 receives in an RRC release message (e.g., events 334 or 434).

[0209] In some implementations, during the SDT session, the RAN 105 performs 718 SDT communication to transmit the DL MAC PDU(s) to the UE 102, similar to the event 418. The DL MAC PDU(s) include MAC SDU(s). Each of the DL MAC PDU(s) includes at least one MAC SDU. Depending on the implementation, the MAC SDU(s) are or include DL RLC PDU(s) and/or DL RLC PDU segments. Each of the MAC SDU(s) includes at least one DL RLC PDU and/or at least one DL RLC PDU segment. The MAC 204B retrieves the MAC SDU(s) from the DL MAC PDU(s). The MAC 204B sends 734 the MAC SDU(s) to the RLC 206B. The RLC 206B retrieves DL PDCP PDU(s) from the DL RLC PDU(s) and/or DL RLC PDU segments, and sends 736 the DL PDCP PDU(s) to the PDCP 210. The PDCP 210 retrieves DL data packet(s) from the DL PDCP PDU(s) and sends 738 the DL data packets to the upper layer(s) 220. In some implementations, the DL data packet(s) are IP packet (s), Ethernet packet(s), or SDAP PDU(s).

[0210] The events 728, 730, 732 and events 734, 736, 738 can overlapped or non-overlapped. The events 728, 730, 732, 718, 734, 736, and 738 are collectively referred to in FIG. 7A as SDT data communication 782.

[0211] In some implementations, during the SDT session, the upper layer(s) 220 (e.g., the MM sublayer) communicate the UL data and/or DL data with the RAN 105 via the RRC 214, PDCP 210, RLC 206B, and MAC 204B (see e.g., SDT data communication 783 in FIG. 7B).

[0212] In further implementations, the RAN 105 later determines to stop the SDT session (e.g., as described for FIG. 4). In response to the determination, the RAN 105 generates an RRC release message to stop the SDT session and configure the UE 102 to remain in the inactive state, and transmits the RRC release message to the UE 102, similar to the events 332, 334, 432, 434. The RAN 105 transmits 740 DL MAC PDU(s) including the RRC release message to the UE 102. In some implementations, the RAN 105 generates an RRC PDU (e.g., DL-DCCH-Message), including the RRC release message, and generates a DL PDCP PDU including the RRC PDU message. In one implementation, the RAN **105** generates a DL RLC PDU including the DL PDCP PDU, generates a DL MAC PDU including the DL RLC PDU, and transmits **740** the DL MAC PDU to the UE **102**. The MAC **204**B retrieves the DL RLC PDU from the DL MAC PDU and sends **742** the DL RLC PDU to the RLC **206**B. The RLC **206**B retrieves the DL PDCP PDU from the DL RLC PDU and sends **744** the DL PDCP PDU to the PDCP **210**. The RRC **214** retrieves the RRC release message from the RRC PDU. In other implementations, the RAN **105** generates DL RLC PDU segments including the DL PDCP PDU. Each of the DL RLC PDU segments includes a particular portion of the DL PDCP PDU. The RAN **105** generates DL MAC PDUs, each including a particular DL RLC PDU segment of the DL RLC PDU segments, and transmits **740** the DL MAC PDUs to the UE **102**. The MAC **204**B retrieves the DL RLC PDU segments from the DL MAC PDUs and sends **742** the DL RLC PDU segments to the RLC **206**B. The RLC **206**B retrieves the DL PDCP PDU from the DL RLC PDU segments and sends **744** the DL PDCP PDU to the PDCP **210**.

[0213] After receiving the DL PDCP PDU, the PDCP **210** retrieves the RRC PDU from the DL PDCP PDU and sends **746** the RRC PDU message to the RRC **214**. The RRC **214** retrieves the RRC release message from the RRC PDU. The RRC **214** stops the SDT session and remains in the inactive state in response to the RRC release message. In some implementations, after or in response to receiving the RRC release message, the RRC **214** sends **748**, to the upper layer(s) **220**, a connection suspended indication indicating the connection is suspended. Thus, the upper layer(s) **220** determine that the connection is suspended in accordance with the connection suspended indication.

[0214] In further implementations, after or in response to receiving the RRC release message, the RRC **214** sends **750**, to the MAC **204**B, an indication (e.g., a suspend indication, stop (SDT) indication, or release indication) indicating to stop communication with the RAN **105**. In response to the indication **750**, the MAC **204**B stops communication with the RAN **105**. Depending on the implementation, in response to receiving the indication **750**, the MAC **204**B commands the PHY **202**B to stop communication with the RAN **105**. Alternatively, the RRC **214** sends, to the PHY **202**B, an indication indicating to the PHY **202**B to stop communication with the RAN **105** (not shown in FIG. **7**A). In response to the indication from the MAC **202**B or RRC **214**, the PHY **202**B stops communication with the RAN **105**. For example, stopping communication includes stopping monitoring a PDCCH with the ID(s) of the UE **102**. The ID(s) includes a C-RNTI and/or a CS-RNTI. When stopping monitoring a PDCCH with the ID(s) of the UE **102**, the UE **102** monitors a PDCCH with one or more common RNTIs for receiving paging or system information. For example, the common RNTIs include paging RNTI (P-RNTI) and/or system information RNTI (SI-RNTI).

[0215] Referring next to FIG. **7**B, a scenario **700**B depicts small data transmission, similar to the scenario **700**A. The differences between FIGS. **7**A and **7**B are described below.

[0216] In the scenario **700**B, the upper layer(s) **220** send **711** UL data to the RRC **214** instead of the PDCP **212**. In some implementations, the UL data can include NAS PDU (s). The RRC **214** generates a UL RRC PDU, including the UL data, and sends **713** the UL RRC PDU to the PDCP **212**. The PDCP **212** generates a UL PDCP PDU, including the UL RRC PDU, and sends **714** the UL PDCP PDU to the RLC **206**B.

[0217] In some implementations, after receiving **726** the connection resume message, the upper layer(s) **220** send **727** subsequent UL data packet(s) (e.g., NAS PDU(s) or LPP PDU(s)) to the RRC **214**. For each of the subsequent UL data packet(s), the RRC **214** generates a UL RRC PDU, including the subsequent UL data packet, and sends **729** the UL RRC PDU to the PDCP **210**. When the PDCP **210** receives **736** DL PDCP PDU(s) from the RLC **206**B, the PDCP **210** retrieves DL RRC PDU(s) from the DL PDCP PDU(s) and sends **737** the DL RRC PDU(s) to the RRC **214**. The RRC **214** retrieves DL data packet(s) (e.g., NAS PDU(s) or LPP PDU(s)) from the DL RRC PDU(s) and sends **739** DL data packet(s) to the upper layer(s) **220**.

[0218] The events **727**, **729**, **730**, **732**, **718**, **734**, **736**, **737** and **739** are collectively referred to in FIG. **7**B as SDT data communication **783**.

[0219] In some implementations, during the SDT session, the upper layer(s) **220** (e.g., the data connection manager, packet handler, the SDAP sublayer **212**, etc.) communicate UL data packet(s) and/or DL data packet(s) with the RAN **105** via the RRC **214**, PDCP **210**, RLC **206**B and MAC **204**B (see e.g., SDT data communication **782** in FIG. **7**A). In some implementations, the communication of the UL data packet(s) and/or DL data packet(s) overlap with the SDT communication **783**. In other implementations, the communication of the UL data packet(s) and/or DL data packet(s) occur before or after the SDT communication **783**.

[0220] Referring next to FIG. **7**C, a scenario **700**C depicts small data transmission, similar to the scenarios **700**A and **700**B. The differences among FIGS. **7**A, **7**B, and **7**C are described below.

[0221] In the scenario **700**C, when the upper layer(s) **220** has UL data available for transmission, the upper layer(s) **220** send **712** UL data to the PDCP **210**. Depending on the implementation, the UL data includes NAS PDU(s) or data packet(s) (e.g., IP packet(s), Ethernet packet(s), or SDAP PDU(s)), as described above. As the connection is suspended, the PDCP **210** buffers the UL data and sends **705** a connection resume request message to the RRC **214**. In response to or after receiving the connection resume request message, the RRC **214** initiates **706** an SDT procedure (i.e., the UE **102** starts an SDT session). In some implementations, the RRC **214** sends **709** a connection resume request confirm message to the PDCP **210**, confirming that the RRC **214** receives or is processing the connection resume request message. After receiving **709** the connection resume request confirm message, the PDCP **210** sends **714** the UL PDCP PDU(s) to the RLC **206**B. In some implementations, the SDT data communication **782** and SDT data communication **783** overlap. In other implementations, the SDT data communication **782** occur before or after the SDT data communication **783**.

[0222] Next, several example methods that can be implemented in a UE (e.g., the UE **102**) to support small data transmissions in the inactive state with a base station, DU, CU, or otherwise in a RAN, are discussed with reference to FIGS. **3**-**7**C.

[0223] FIG. **8**A illustrates a method **800**A for handling small data communication, which can be implemented by a UE. The method **800**A begins at block **802**, where the UE receives a SIB via a cell from a base station. At block **804**, the UE performs SDT via the cell with the base station, while operating in an inactive state (e.g., events **404**, **418**, **492**, **493**, **420**, **494**, **495**, **592**, **593**, **594**, **595**, **692**, **694**, **695**, **706**, **710**, **711**, **712**, **713**, **714**, **716**, **719**, **720**, **722**, **724**, **780**). At block **806**, the UE triggers a buffer status report (BSR) during the SDT. That is, the UE determines to transmit a BSR during the SDT. At block **808**, the UE determines whether the SIB configures a delay timer for SDT (and the UE supports the delay timer). In some implementations, the delay timer value is used to delay transmitting a scheduling request for a logical channel where UL data is available. If the SIB configures the delay timer for SDT (and the UE supports the delay timer), the flow proceeds to block **810**. At block **810**, the UE starts or restarts a delay timer with the delay timer in response to triggering the BSR. Otherwise, if the SIB does not configure the delay timer for SDT (and/or the UE does not support the delay timer), the flow proceeds to block **812**. At block **812**, the UE refrains from starting the delay timer. The flow proceeds to block **814** from block **812** as well as from block **810**. At block **814**, the UE determines whether a UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR. If a UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR, the flow proceeds to block **816**. At block **816**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR using the UL grant (e.g., events **418**, **492**, **493**, **592**, **692**, **693**, **727**, **729**, **730**, **732**, **718**). Otherwise, if a UL grant is not available for a new transmission or a UL grant does not accommodate the BSR and a subheader of the BSR, the flow proceeds to block **818**. At block **818**, the UE determines whether the delay timer is running. If the delay timer is not running, the flow proceeds to block **820**. At block **820**, the UE performs a random access procedure via the cell with the base station to transmit the BSR to the base station. Otherwise, if the delay timer is running, the flow proceeds to block **822**. At block **822**, the UE refrains from performing a random access procedure to transmit the BSR. Blocks **808**, **810**, **812**, **814**, **816**, **818**, **820** and **822** are grouped as block **850**.

[0224] In some implementations, the SIB can include a delay timer value to configure the UE and other UEs to apply the delay timer when the UE and other UEs perform SDT via the cell with the base station. In such implementations, the delay timer value can be an sdt-LogicalChannelSR-DelayTimer-r17. In some implementations, the UL grant can be a dynamic grant that the UE receives on a PDCCH. In other implementations, the UL grant can be a configured grant configured in a SDT configuration that the UE receives in a RRC release message from the base station.

[0225] FIG. **8**B illustrates a method **800**B for handling small data communication, similar to the method **800**A. The method **800**B begins at block **802**, where the UE receives a SIB via a cell from a base station. At block **804**, the UE performs SDT via the cell with a base station, while operating in an inactive state (e.g., events **404**, **418**, **492**, **493**, **420**, **494**, **495**, **592**, **593**, **594**, **595**, **692**, **694**, **695**, **706**, **710**, **711**, **712**, **713**, **714**, **716**, **719**, **720**, **722**, **724**, **780**). At block **806**, the UE triggers a buffer status report (BSR) during the SDT. At block **808**, the UE determines whether the SIB configures a delay timer for SDT (and the UE supports the delay timer). If the SIB configures a delay timer for SDT (and the UE supports the delay timer), the flow proceeds to block **822**. At block **822**, the UE refrains from performing a random access procedure to transmit the BSR. At block **815**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR using a UL grant received on a PDCCH or a configured in a SDT configuration. Otherwise, if the SIB does not configure a delay timer for SDT (and/or the UE does not support the delay timer), the flow proceeds to block **817**. At block **817**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR, using a UL grant which is received on a PDCCH, configured in a SDT configuration, included in a random access response or included in a SIB broadcast on the cell by the base station (e.g., events **418**, **492**, **493**, **592**, **692**, **693**, **727**, **729**, **730**, **732**, **718**). Blocks **808**, **822**, **815**, and **817** are grouped as block **851**.

[0226] FIG. **8**C is a flow diagram of an example method **800**C, similar to the methods **800**A-B, except that the method **800**C includes blocks **803** and **809**, instead of block **808**. At block **803**, the UE receives a plurality of configurations for connected state from the base station (e.g., events **312**, **390**, **590**, **690**). Alternatively, the UE receives the plurality of configurations for connected state from another base station. At block **809**, the UE determines whether the SIB configures a delay timer for SDT and the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel. If the SIB configures a delay timer for SDT and the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel, the flow proceeds to block **810**. Otherwise, if the SIB does not configure a delay timer for SDT and/or the plurality of configurations do not include a configuration configuring to apply the delay timer for the logical channel, the flow proceeds to block **812**. Blocks **809**, **810**, **812**, **814**, **816**, **818**, **820** and **822** are grouped as block **852**.

[0227] In some implementations, the UE at block **803** receives at least one non-SDT configuration (e.g., CellGroupConfig) including the plurality of configurations. In some implementations, the configuration configuring to apply the delay timer for the logical channel can be a logicalChannelSR-DelayTimerApplied.

[0228] FIG. **8**D is a flow diagram of an example method **800**D, similar to the methods **800**A-C, except that the method **800**D includes block **805**. At block **805**, the UE triggers a buffer status report (BSR) for a logical channel during the SDT. At block **809**, the UE determines whether the SIB configures a delay timer for SDT and the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel. If the SIB configures a delay timer for SDT and the plurality of configurations include a configuration configuring to apply the delay timer for the logical channel, the flow proceeds to block **822**. Otherwise, if the SIB does not configure a delay timer for SDT and/or the plurality of configurations do not include a configuration configuring to apply the delay timer for the logical channel, the flow proceeds to block **817**. Blocks **809**, **822**, **815**, and **817** are grouped as block **853**.

[0229] FIG. **8**E is a flow diagram of an example method **800**E, similar to the methods **800**A-D, except that the method **800**E includes block **807**, instead of blocks **808** and **809**. At block **807**, the UE determines whether the plurality of configurations configures a delay timer and include a configuration configuring to apply a delay timer for the logical channel. If the plurality of configurations configure a delay timer and include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **810**. Otherwise, if the plurality of configurations do not configure a delay timer and/or include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **812**. Blocks **807**, **810**, **812**, **814**, **816**, **818**, **820** and **822** are grouped as block **854**.

[0230] FIG. **8**F is a flow diagram of an example method **800**F, similar to the methods **800**A-E. At block **807**, the UE determines whether the plurality of configurations configure a delay timer and include a configuration configuring to apply a delay timer for the logical channel. If the plurality of configurations configures a delay timer and include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **822**. Otherwise, if the plurality of configurations do not configure a delay timer and/or include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **817**. Blocks **807**, **822**, **815**, and **817** are grouped as block **855**.

[0231] FIG. **8**G is a flow diagram of an example method **800**G, similar to the methods **800**A-F, except that the method **800**G includes block **811** instead of blocks **807**, **808**, and **809**. At block **811**, the UE determines whether the SIB configures a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer). If the SIB configures a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer), the flow proceeds to block **810**. Otherwise, if the SIB does not configure a delay timer for SDT and/or a configuration configuring to apply the delay timer for the logical channel (and/or the UE does not support the delay timer), the flow proceeds to block **812**. Blocks **811**, **810**, **812**, **814**, **816**, **818**, **820** and **822** are grouped as block **856**.

[0232] FIG. **8**H is a flow diagram of an example method **800**H, similar to the methods **800**A-G. At block **811**, the UE determines whether the SIB configures a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer). If the SIB configures a delay timer for SDT and a configuration configuring to apply the delay timer for the logical channel (and the UE supports the delay timer), the flow proceeds to block **822**. Otherwise, if the SIB does not configure a delay timer for SDT and/or a configuration configuring to apply the delay timer for the logical channel (and/or the UE supports the delay timer), the flow proceeds to block **817**. Blocks **811**, **822**, **815**, and **817** are grouped as block **857**.

[0233] FIG. **9** illustrates an example method **900** for handling small data communication, which can be implemented by a UE. Blocks **902**, **904**, **906**, **914**, **916** and **920** are similar blocks **802**, **804**, **805**, **814**, **816** and **820**, respectively. Examples and implementations described for FIGS. **8**A-**8**H can apply to FIG. **9**.

[0234] The method **900** begins at block **902**, where the UE receives a SIB via a cell from a base station. At block **904**, the UE performs SDT via the cell with a base station, while operating in an inactive state (e.g., events **404**, **418**, **492**, **493**, **420**, **494**, **495**, **592**, **593**, **594**, **595**, **692**, **694**, **695**, **706**, **710**, **711**, **712**, **713**, **714**, **716**, **719**, **720**, **722**, **724**, **780**). At block **906**, the UE triggers a buffer status report (BSR) for a logical channel during the SDT. At block **908**, the UE determines whether the logical channel is associated with a SRB. In some implementations, the SRB can be SRB1 or SRB2. In other implementations, the SRB can be a particular SRB, i.e., SRB L. If the logical channel is not associated with a(the) SRB, the flow proceeds to block **950**. At block **950**, the flow proceeds to block **850**, block **851**, block **852**, block **853**, block **854**, block **855**, block **856**, or block **857**. Otherwise, if the logical channel is associated with a(the) SRB, the flow proceeds to block **914**. At block **914**, the UE determines whether a UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR. If a UL grant is available for a new transmission and the UL grant accommodates the BSR and the subheader of the BSR, the flow proceeds to block **916**. At block **916**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR using the UL grant (e.g., events **418**, **492**, **493**, **592**, **692**, **693**, **727**, **729**, **730**, **732**, **718**). Otherwise, if a UL grant is not available for a new transmission or a UL grant does not accommodates the BSR and the subheader of the BSR, the flow proceeds to block **920**. At block **920**, the UE performs a random access procedure with the base station via the cell to transmit the BSR to the base station.

[0235] In some implementations, if the logical channel is associated with a(the) SRB, the UE refrains from starting a delay timer described above. In other implementations, if the logical channel is associated with a(the) SRB and the UE has started a delay timer (as described above), the UE can stop the delay timer. In yet other implementations, if the logical channel is associated with a(the) SRB and the UE has started a delay timer (as described above), the UE remains (i.e., retains, keeps or maintains) the delay timer running. In some implementations, "SRB" can be replaced by "SRB1". In other implementations, "SRB" can be replaced by "SRB1 or SRB2".

[0236] In accordance with the method **900**, when the UE does not have a UL grant to transmit UL data with a(the) SRB and the delay timer for SDT is configured by the base station, the UE performs a random access procedure with the base station to transmit the UL data in order not to delay transmission of the UL data. When the UE does not have a UL grant to transmit UL data with a DRB and the delay timer for SDT is configured by the base station, the UE refrains from performing a random access procedure and waits for receiving a UL grant on a PDCCH from the base station or waits for an occasion of a configured grant coming.

[0237] FIG. **10** is a flow diagram of an example method **1000** for managing small data communication, which can be implemented by a UE. Blocks **1002**, **1004**, **1006**, **1010**, **1012**, **1014**, **1016**, **1018**, and **1020** are similar blocks **802**, **804**, **805**, **810**, **812**, **814**, **816**, **818** and **820**, respectively. Examples and implementations described for FIGS. **8**A-**8**H can apply to FIG. **10**.

[0238] The method **1000** begins at block **1002**, where the UE receives a SIB via a cell from a base station. At block **1004**, the UE receives a plurality of configurations for connected state. At block **1006**, the UE triggers a buffer status report (BSR) for a logical channel. At block **1008**, the UE determines whether the UE is performing SDT. If the UE is performing SDT, the flow proceeds to block **1050**. At block **1050**, the flow proceeds to block **850**, block **851**, block **852**, block **853**, block **854**, block **855**, block **856**, or block **857**. Otherwise, if the UE is not performing SDT (i.e., the UE operates in a connected state), the flow proceeds to block **1009**. At block **1009**, the UE determines whether the plurality of configurations include a configuration configuring to apply a delay timer for the logical channel. If the plurality of configurations include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **1010**. At block **1010**, the UE starts or restarts a delay timer with the delay timer value in response to triggering the BSR. Otherwise, if the plurality of configurations do not include a configuration configuring to apply a delay timer for the logical channel, the flow proceeds to block **1012**. At block **1012**, the UE refrains from starting the delay timer. The flow proceeds to block **1014** from block **1014** as well as from block **1016**.

[0239] At block **1014**, the UE determines whether a UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR. If a UL grant is available for a new transmission and the UL grant accommodates the BSR and the subheader of the BSR, the flow proceeds to block **1016**. At block **1016**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR using the UL grant. Otherwise, if a UL grant is not available for a new transmission or a UL grant does not accommodate the BSR and a subheader of the BSR, the flow proceeds to block **1018**. At block **1018**, the UE determines whether the delay timer is running. If the delay timer is not running, the flow proceeds to block **1020**. At block **1020**, the UE performs a random access procedure with the base station via the cell to transmit the BSR. Otherwise, if the delay timer is running, the flow proceeds to block **1022**. At block **1022**, the UE refrains from performing a random access procedure to transmit the BSR.

[0240] FIG. **11** is a flow diagram of an example method **1100** for managing small data communication, which can be implemented by a UE. Blocks **1102**, **1104**, **1106**, **1110**, **1114**, **1116**, **1118**, and **1120** are similar blocks **802**, **804**, **805**, **810**, **814**, **816**, **818** and **820**, respectively. Examples and implementations described for FIGS. **8**A-**8**H can apply to FIG. **11**.

[0241] The method **1100** begins at block **1102**, where the UE receives a SIB via a cell from a base station. At block **1104**, the UE receives a plurality of configurations for connected state from the base station. At block **1106**, the UE triggers a buffer status report (BSR) for a logical channel. At block **1108**, the UE determines whether the UE is performing SDT. If the UE is performing SDT, the flow proceeds to block **1110**. At block **1110**, the UE starts or restarts a delay timer with a first delay timer value in response to triggering the BSR. Otherwise, if the UE is not performing SDT (i.e., the UE operates in a connected state), the flow proceeds to block **1112**. At block **1112**, the UE starts or restarts a delay timer with a second delay timer value in response to triggering the BSR. At block **1114**, the UE determines whether the UL grant is available for a new transmission and the UL grant accommodates the BSR and a subheader of the BSR. If a UL grant is available for a new transmission and the UL grant accommodates the BSR and the subheader of the BSR, the flow proceeds to block **1116**. At block **1116**, the UE transmits, to the base station via the cell, a MAC PDU including the BSR using the UL grant. Otherwise, if a UL grant is not available for a new transmission and a UL grant does not accommodate the BSR and the subheader of the BSR, the flow proceeds to block **1118**. At block **1118**, the UE determines whether the delay timer is running. If the delay timer is not running, the flow proceeds to block **1120**. At block **1120**, the UE performs a random access procedure with the base station via the cell to transmit the BSR to the base station. Otherwise, if the delay timer is running, the flow proceeds to block **1122**. At block **1122**, the UE refrains from performing a random access procedure to transmit the BSR.

[0242] In some implementations, the base station can set the second delay timer value longer than the first delay timer value. For example, the base station does so, because DRB(s) configured for the UE and non-SDT can tolerate longer latency than DRB(s) configured for the UE and SDT. In another example, the base station does so, because the base station always provide UL grants to satisfy the UE operating in the connected state.

[0243] In other implementations, the base station can set the first delay timer value longer than the second delay timer value, e.g., because DRB(s) configured for the UE and SDT can tolerate longer latency than DRB(s) configured for the UE and non-SDT.

[0244] The following description may apply to the description above.

[0245] Generally speaking, description for one of the above figures can apply to another of the above figures. An event or block described above can be optional or omitted. For example, an event or block with dashed lines in the figures can be optional. In some implementations, "message" is used and can be replaced by "information element (IE)", and vice versa. In some implementations, "IE" is used and can be replaced by "field", and vice versa. In some implementations, "configuration" can be replaced by "configurations" or "configuration parameters", and vice versa. In some implementations, "small data transmission" can be replaced by "early data transmission (EDT)" and "SDT" can be replaced by "EDT", and vice versa. In some implementations, "small data transmission" can be replaced by "small data communication", and vice versa. In some implementations, "SDT", "SDT procedure", "SDT session" are interchangeable. In some implementations, "stop" can be replaced by "suspend" and vice versa. In some implementations, "configured grant" and "configured uplink grant" are interchangeable.

[0246] In some implementations, the "second UE CG-SDT timer" can be replaced by "CG-SDT retransmission timer (cg-SDT-RetransmissionTimer)". In some implementations, "CG-SDT", "CG", "SDT-CG" can be interchanged. In some implementations, "sublayer" can be replaced by the "entity". In some implementations, "sublayer" can be replaced by the "entity". In some implementations, the "SDT configuration", "SDT DU configuration" and "SDT CU configuration" are interchangeable.

[0247] A user device in which the techniques of this disclosure can be implemented (e.g., the UE **102**) can be any suitable device capable of wireless communications such as a smartphone, a tablet computer, a laptop computer, a mobile gaming console, a point-of-sale (POS) terminal, a health monitoring device, a drone, a camera, a media-streaming dongle or another personal media device, a wearable device such as a smartwatch, a wireless hotspot, a femtocell, or a broadband router. Further, the user device in some cases may be embedded in an electronic system such as the head unit of a vehicle or an advanced driver assistance system (ADAS). Still further, the user device can operate as an internet-of-things (IoT) device or a mobile-internet device (MID). Depending on the type, the user device can include one or more general-purpose processors, a computer-readable memory, a user interface, one or more network interfaces, one or more sensors, etc.

[0248] Certain embodiments are described in this disclosure as including logic or a number of components or modules. Modules may can be software modules (e.g., code, or machine-readable instructions stored on non-transitory machine-readable medium) or hardware modules. A hardware module is a tangible unit capable of performing certain operations and may be configured or arranged in a certain manner. A hardware module can comprise dedicated circuitry or logic that is permanently configured (e.g., as a special-purpose processor, such as a field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC), a digital signal processor (DSP), etc.) to perform certain operations. A hardware module may also comprise programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software to perform certain operations. The decision to implement a hardware module in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

[0249] When implemented in software, the techniques can be provided as part of the operating system, a library used by multiple applications, a particular software application, etc. The software can be executed by one or more general-purpose processors or one or more special-purpose processors.

1. A method for wireless communication at a user equipment (UE), the method comprising:
receiving, from a radio access network (RAN), a system information block (SIB);
triggering, when performing a small data transmission (SDT) procedure, a buffer status report (BSR) to the RAN; and
in response to the triggering and when the SIB includes a configuration of a delay timer for the SDT procedure, starting or restarting the delay timer according to the configuration.

2. The method of claim **1**, wherein the configuration is specific to a logical channel on which uplink (UL) data is available for transmission to the RAN.

3. The method of claim **1**, wherein the starting or restarting of the delay timer is further in response to the configuration including a logicalChannelSR-DelayTimerApplied field.

4. The method of claim **1**, wherein the configuration includes sdt-LogicalChannelSR-DelayTimer-r17 as a value for the delay timer.

5. The method of claim **1**, wherein the starting or restarting of the delay timer is further in response to the UE supporting the delay timer.

6. The method of claim **1**, wherein the starting or restarting of the delay timer occurs in a first instance; the method further comprising, in a second instance:
in response to the triggering and when the SIB does not include the configuration of the delay timer, refraining from starting or restarting the delay timer.

7. The method of claim **1**, further comprising:
in response to determining that an uplink grant is available for transmitting the BSR to the RAN, transmitting the BSR to the RAN.

8. The method of claim **1**, further comprising:
in response to determining that (i) an uplink grant is unavailable for transmitting the BSR to the RAN and (ii) the delay timer is not running, performing a random access procedure to transmit the BSR to the RAN.

9. The method of claim **1**, further comprising:
in response to determining that (i) an uplink grant is unavailable for transmitting the BSR to the RAN and (ii) the delay timer is running, refraining from performing a random access procedure to transmit the BSR to the RAN.

10. A user equipment (UE) comprising:
a transceiver; and
a processing hardware; wherein the UE is configured to:
receive, from a radio access network (RAN), a system information block (SIB),
trigger, when performing a small data transmission (SDT) procedure, a buffer status report (BSR) to the RAN, and
in response to the triggering and when the SIB includes a configuration of a delay timer for the SDT procedure, start or restart the delay timer according to the configuration.

11. A method for wireless communications at a radio access network (RAN), the method comprising:
transmitting, to a user equipment (UE), a system information block (SIB) that includes a configuration of a delay timer for performing a small data transmission (SDT) procedure; and
receiving a buffer status report (BSR) from the UE according to the configuration while the RAN and UE do not have an active radio connection.

12. The method of claim **11**, wherein the configuration is specific to a logical channel associated on which uplink (UL) data is available for transmission to the RAN.

13. The method of claim **11**, wherein the configuration includes sdt-LogicalChannelSR-DelayTimer-r17 as a value for the delay timer.

14-15. (canceled)

16. The method of claim **11**, wherein the logical channel is configured for the SDT.

17. The UE of claim **10**, wherein:
the configuration is specific to a logical channel on which uplink (UL) data is available for transmission to the RAN.

18. The UE of claim **10**, wherein:
wherein the starting or restarting of the delay timer is further in response to the configuration including a logicalChannelSR-DelayTimerApplied field.

19. The UE of claim **10**, wherein:
the configuration includes sdt-LogicalChannelSR-DelayTimer-r17 as a value for the delay timer.

20. The UE of claim **10**, wherein:
the starting or restarting of the delay timer is further in response to the UE supporting the delay timer.

21. The UE of claim **10**, wherein:
the starting or restarting of the delay timer occurs in a first instance; the UE further configured to, in a second instance:
in response to the triggering and when the SIB does not include the configuration of the delay timer, refrain from starting or restarting the delay timer.

22. The UE of claim **10**, further configured to:
in response to determining that an uplink grant is available for transmitting the BSR to the RAN, transmit the BSR to the RAN.

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