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(54) **CONFIGURING AND ACTIVATING ON DEMAND SSB IN SCELL**

(71) Applicant: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

(72) Inventors: **Anil Agiwal**, McKinney, TX (US); **Kyeongin Jeong**, Frisco, TX (US); **Shiyang Leng**, Little Elm, TX (US); **Hongbo Si**, Allen, TX (US)

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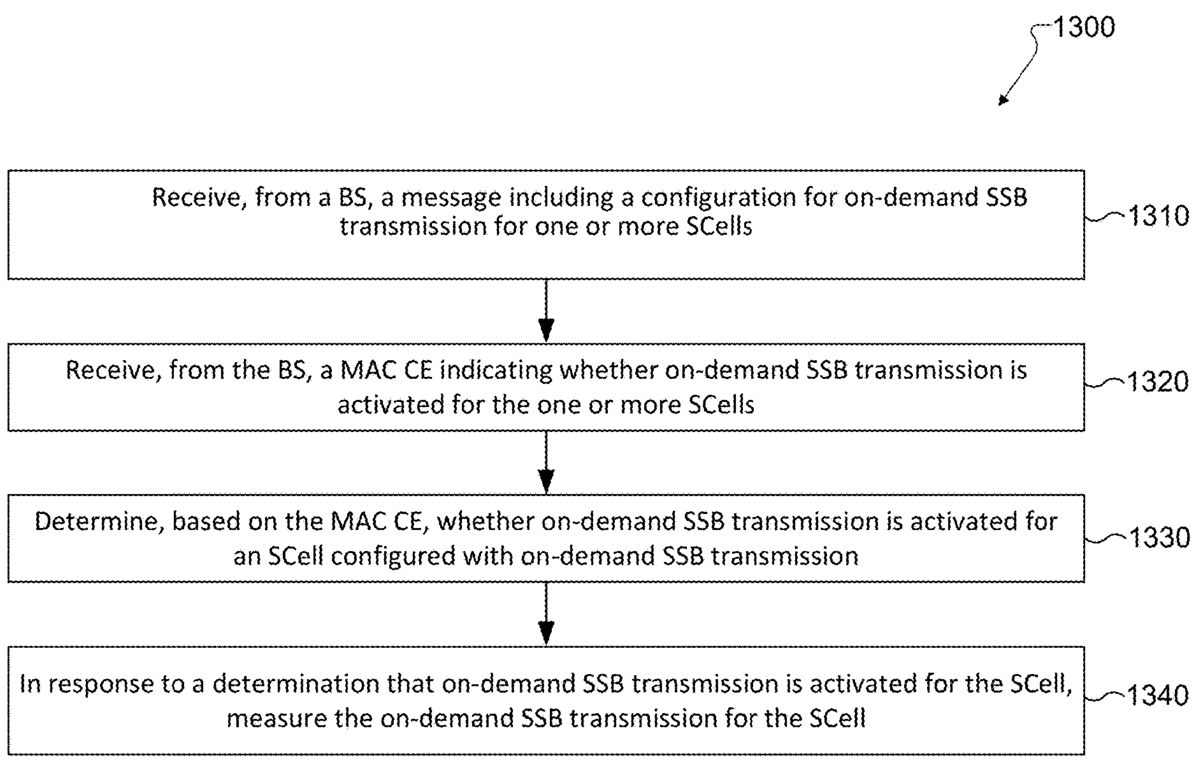
CPC ***H04W 48/08*** (2013.01); ***H04W 72/1273*** (2013.01)

(57) **ABSTRACT**

A user equipment (UE) includes a transceiver. The transceiver is configured to receive, from a base station (BS), a message including a configuration for on-demand synchronization signal block (SSB) transmission for one or more secondary cells (SCells), and receive, from the BS, a medium access control (MAC) control element (CE) indicating whether on-demand SSB transmission is activated for the one or more SCells. The UE also includes a processor operably coupled to the transceiver. The processor is configured to determine, based on the MAC CE, whether on-demand SSB transmission is activated for an SCell configured with on-demand SSB transmission, and in response to a determination that on-demand SSB transmission is activated for the SCell, measure the on-demand SSB transmission for the SCell.



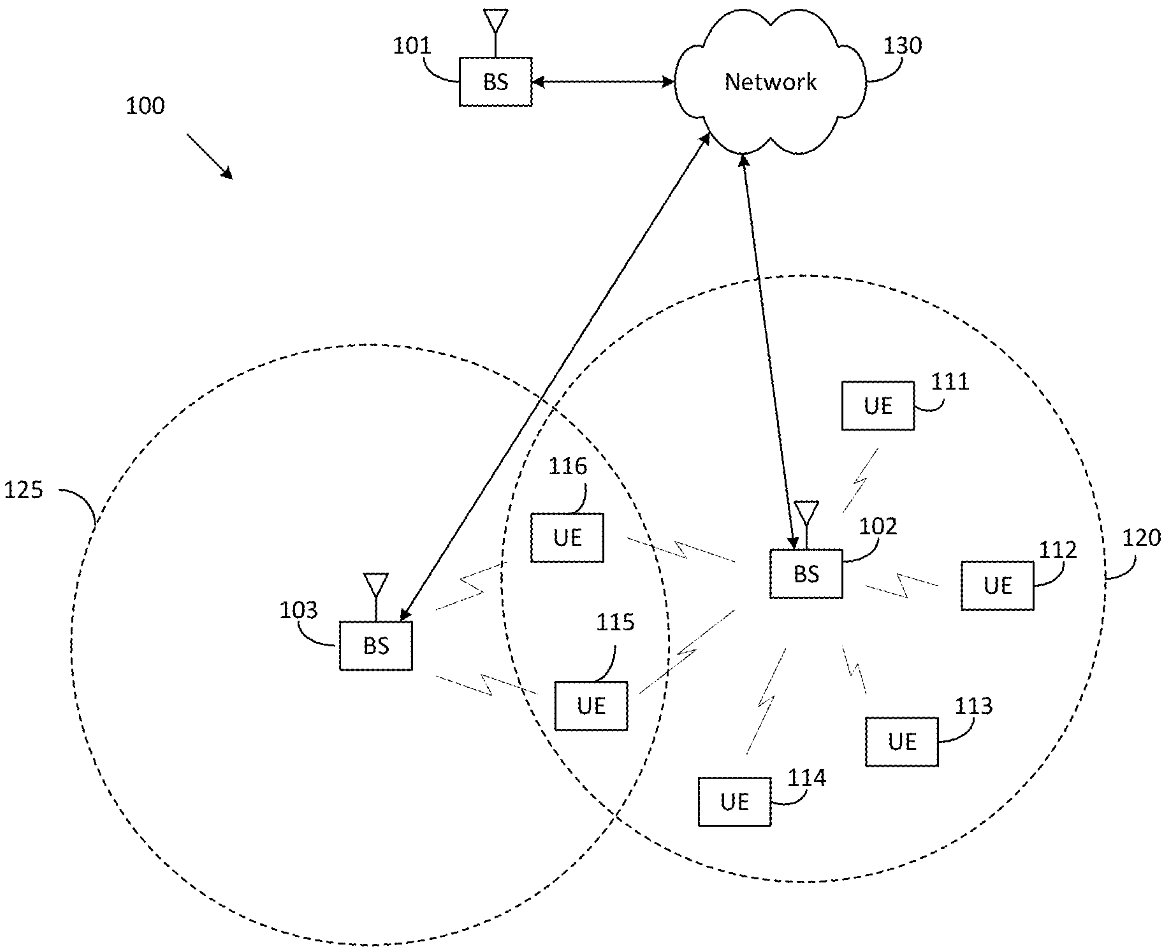

100
101
BS
Network
130
125
116
UE
111
UE
102
BS
112
UE
120
103
BS
115
UE
113
UE
114
UE

FIG. 1

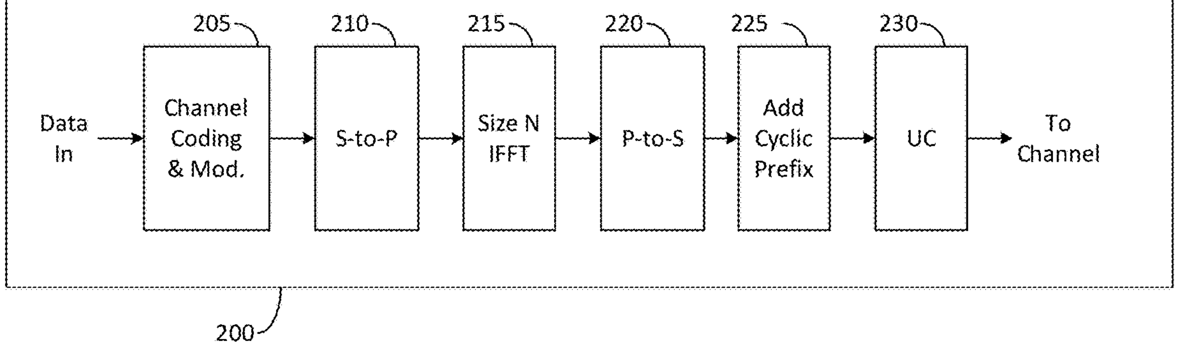

205
210
215
220
225
230
Data In
Channel Coding & Mod.
S-to-P
Size N IFFT
P-to-S
Add Cyclic Prefix
UC
To Channel
200

FIG. 2A

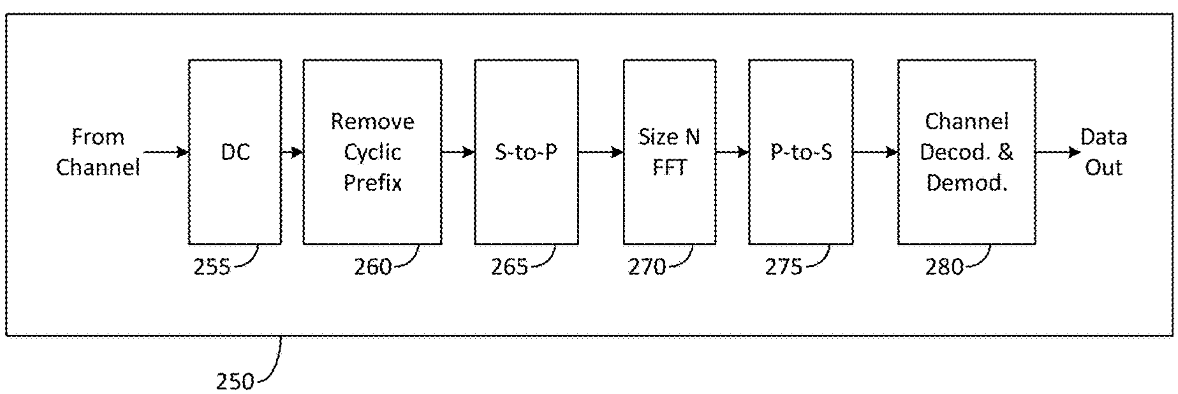

From Channel
DC
Remove Cyclic Prefix
S-to-P
Size N FFT
P-to-S
Channel Decod. & Demod.
Data Out
255
260
265
270
275
280
250

FIG. 2B

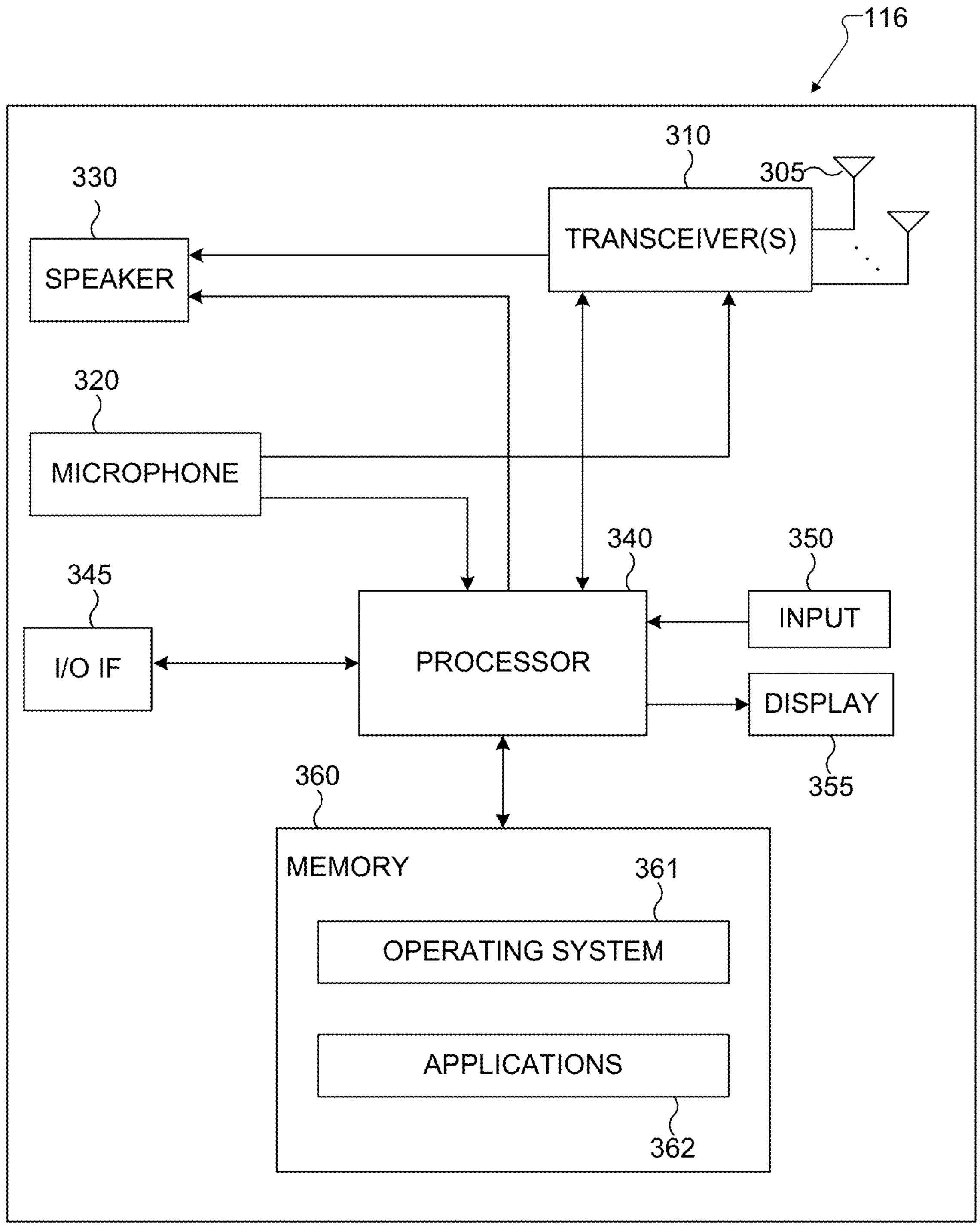

116
310
305
330
TRANSCEIVER(S)
SPEAKER
320
MICROPHONE
340
350
345
INPUT
I/O IF
PROCESSOR
DISPLAY
355
360
MEMORY
361
OPERATING SYSTEM
APPLICATIONS
362

FIG. 3A

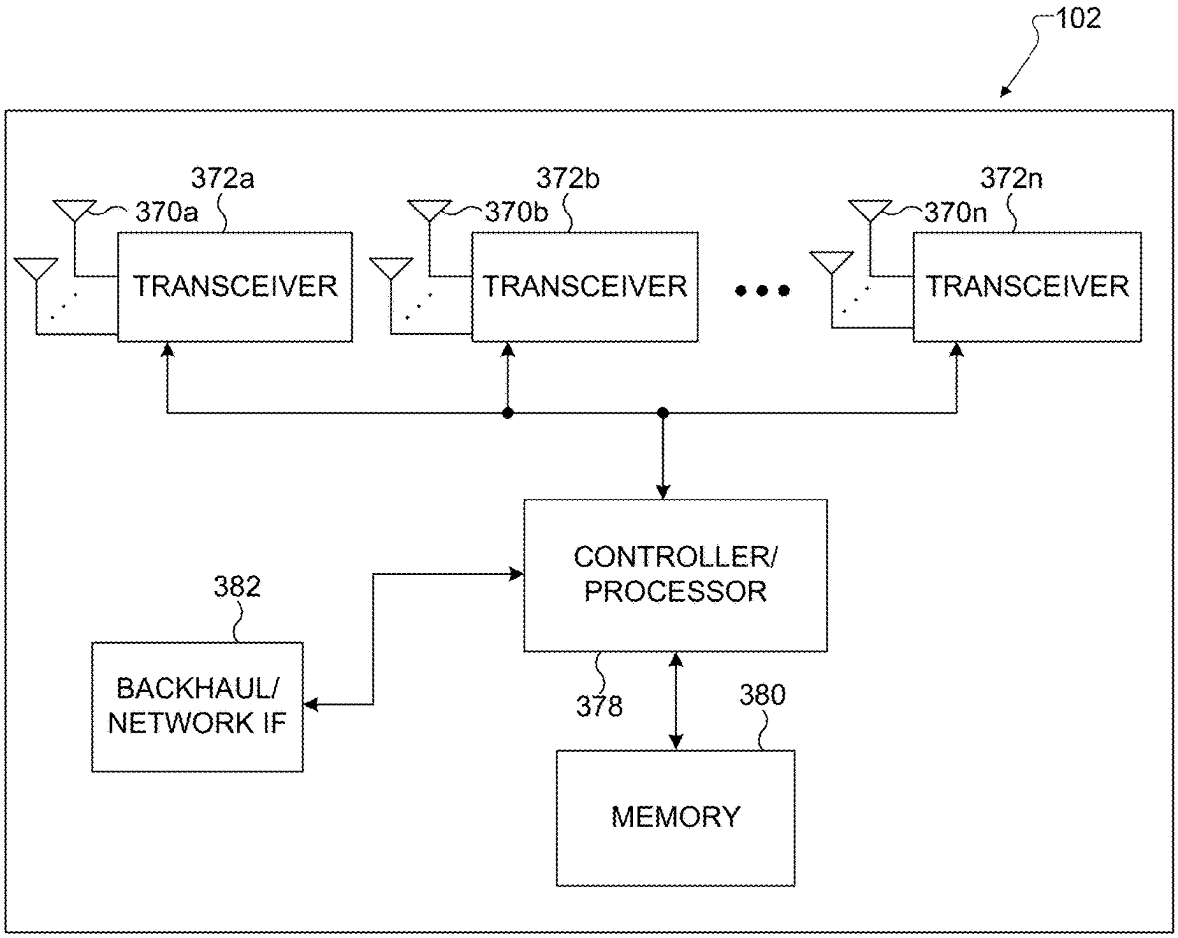

102
372a
370a
TRANSCEIVER
372b
370b
TRANSCEIVER
372n
370n
TRANSCEIVER
CONTROLLER/
PROCESSOR
382
BACKHAUL/
NETWORK IF
378
380
MEMORY

FIG. 3B

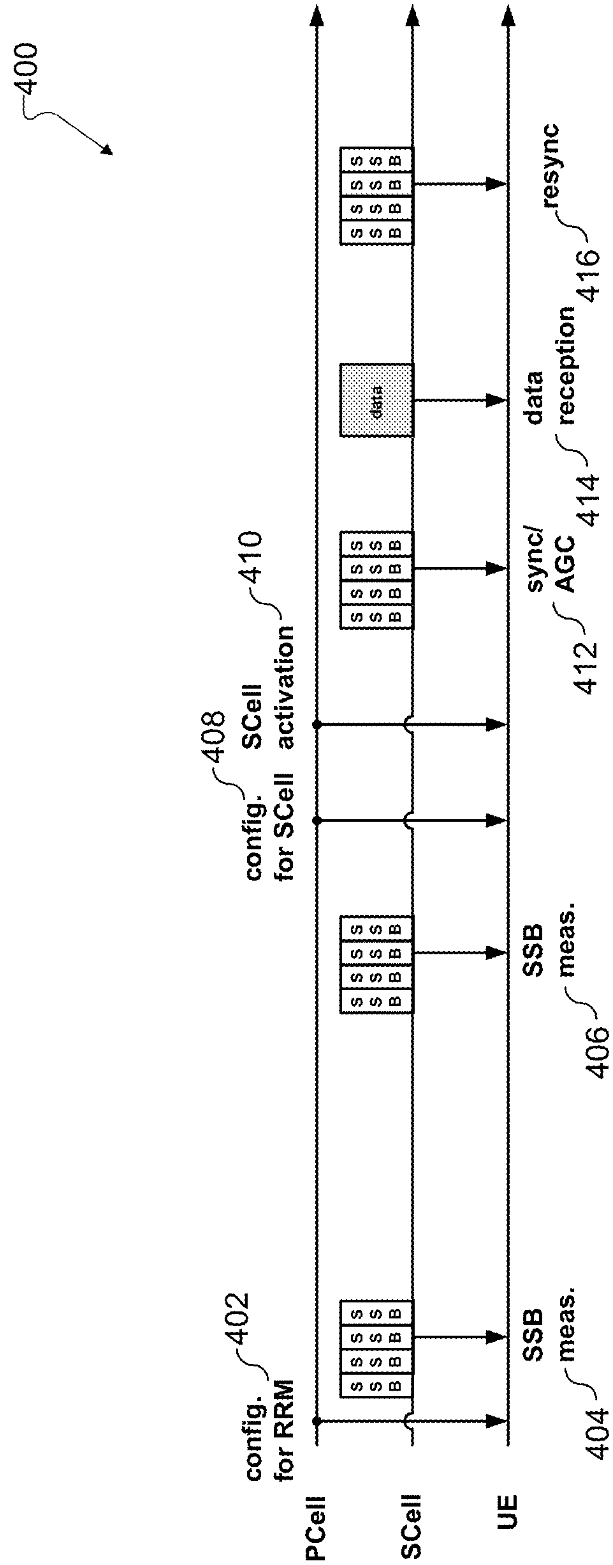

400
PCell
SCell
UE
config. for RRM
402
SSB meas.
404
SSB meas.
406
config. for SCell
408
SCell activation
410
sync/ AGC
412
data
data reception
414
resync
416
SSB

FIG. 4

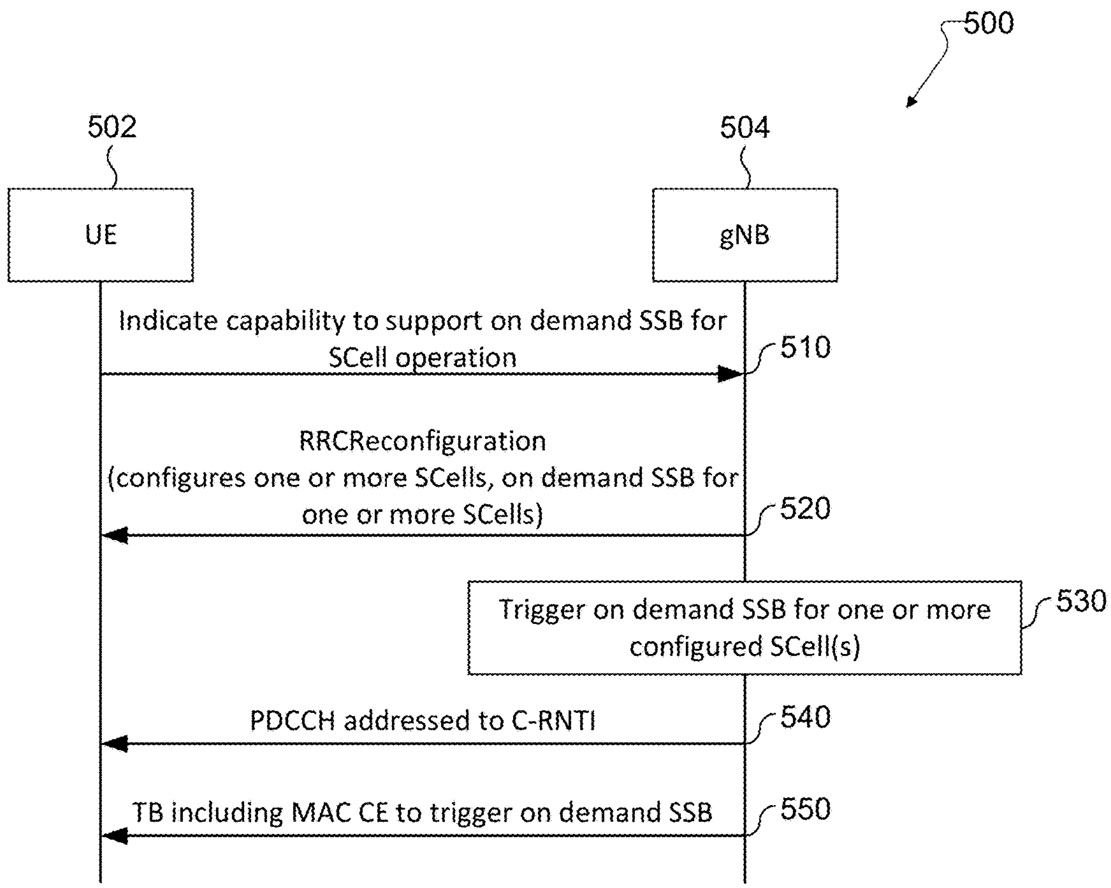

500
502
504
UE
gNB
Indicate capability to support on demand SSB for SCell operation
510
RRCReconfiguration (configures one or more SCells, on demand SSB for one or more SCells)
520
Trigger on demand SSB for one or more configured SCell(s)
530
PDCCH addressed to C-RNTI
540
TB including MAC CE to trigger on demand SSB
550

FIG. 5

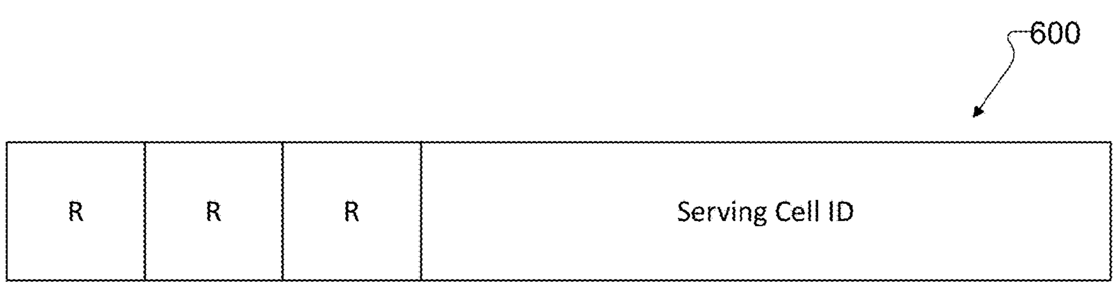

600
R
R
R
Serving Cell ID

FIG. 6

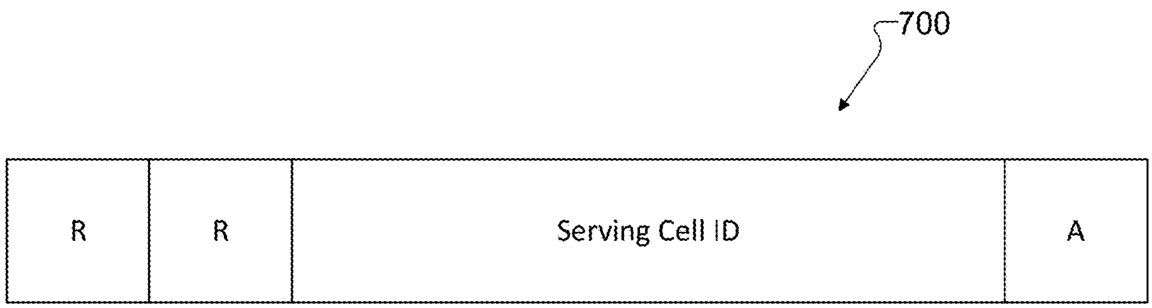


FIG. 7

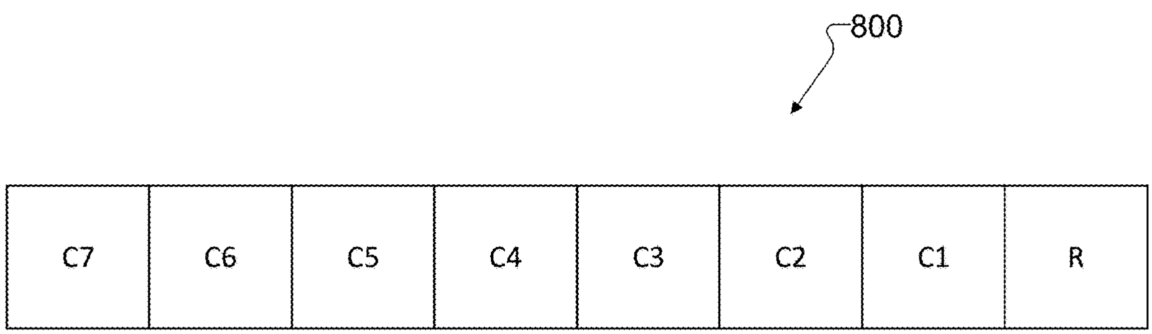


FIG. 8A

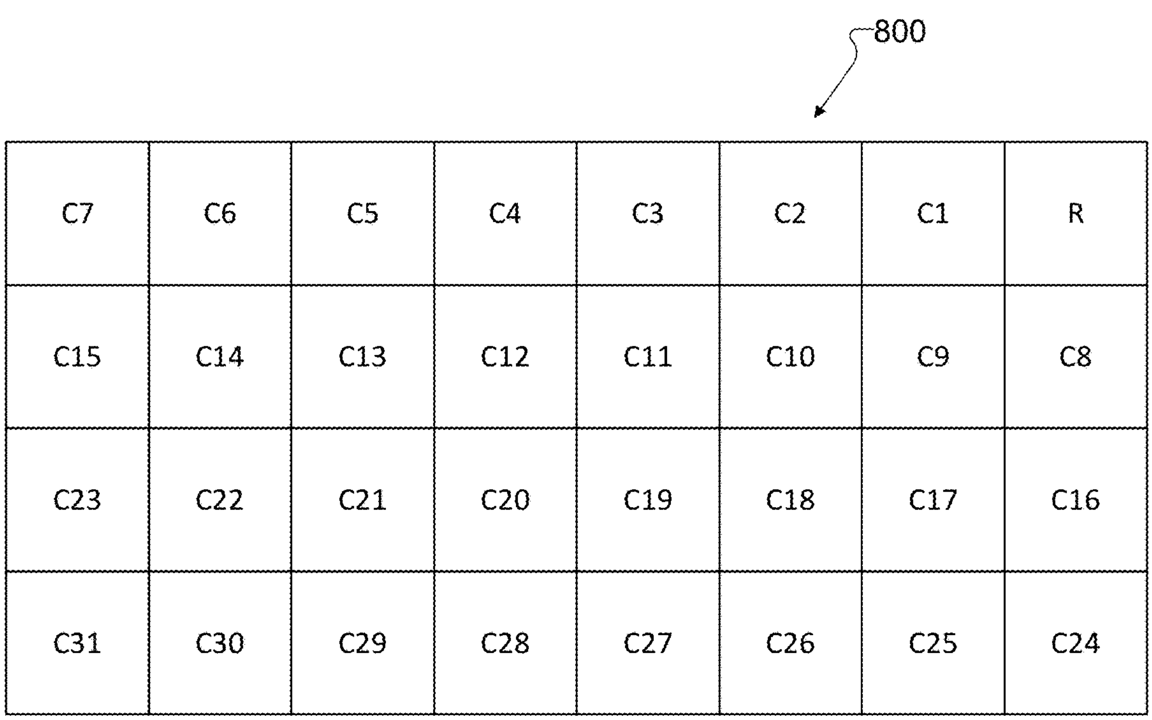


FIG. 8B

900

C7	C6	C5	C4	C3	C2	C1	R
A7	A6	A5	A4	A3	A2	A1	R

FIG. 9A

900

C7	C6	C5	C4	C3	C2	C1	R
C15	C14	C13	C12	C11	C10	C9	C8
C23	C22	C21	C20	C19	C18	C17	C16
C31	C30	C29	C28	C27	C26	C25	C24
A7	A6	A5	A4	A3	A2	A1	R
A15	A14	A13	A12	A11	A10	A9	A8
A23	A22	A21	A20	A19	A18	A17	A16
A31	A30	A29	A28	A27	A26	A25	A24

FIG. 9B

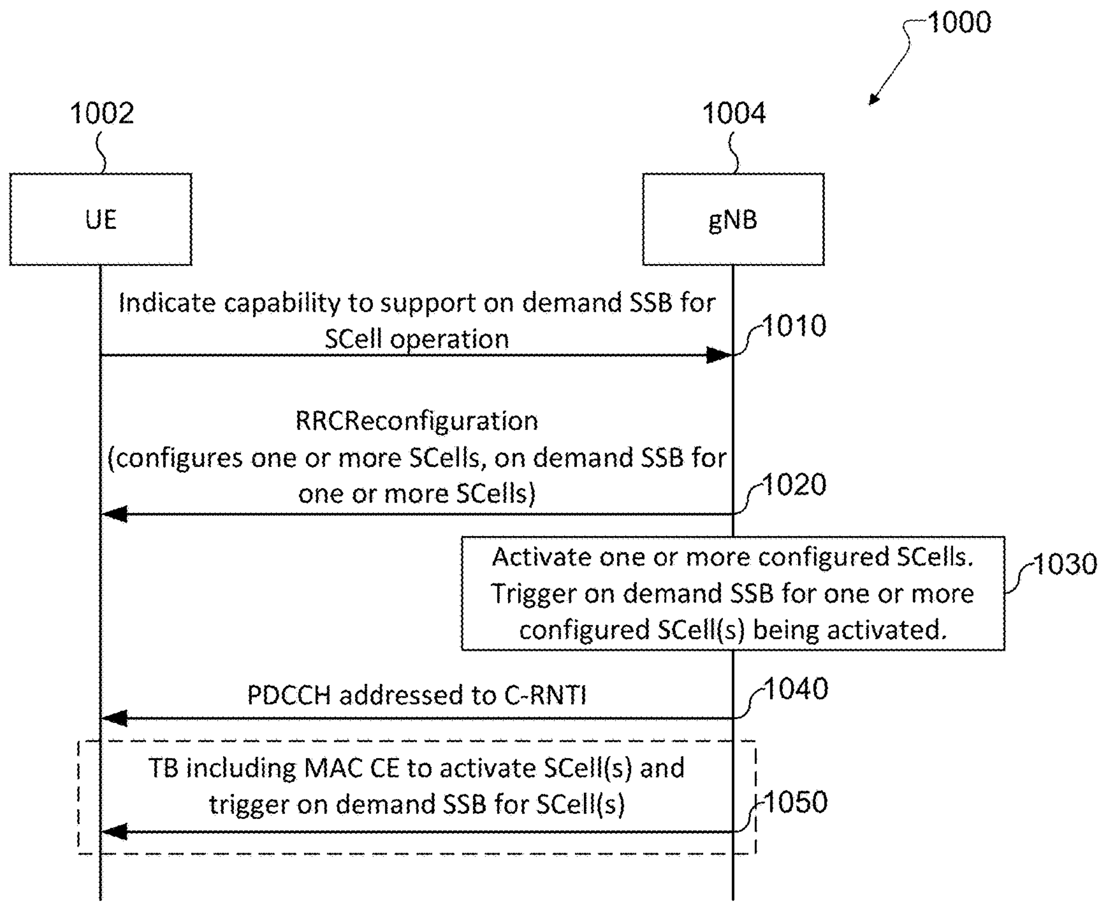


FIG. 10

1100

C7	C6	C5	C4	C3	C2	C1	R
A7	A6	A5	A4	A3	A2	A1	R

FIG. 11A

1100

C7	C6	C5	C4	C3	C2	C1	R
C15	C14	C13	C12	C11	C10	C9	C8
C23	C22	C21	C20	C19	C18	C17	C16
C31	C30	C29	C28	C27	C26	C25	C24
A7	A6	A5	A4	A3	A2	A1	R
A15	A14	A13	A12	A11	A10	A9	A8
A23	A22	A21	A20	A19	A18	A17	A16
A31	A30	A29	A28	A27	A26	A25	A24

FIG. 11B

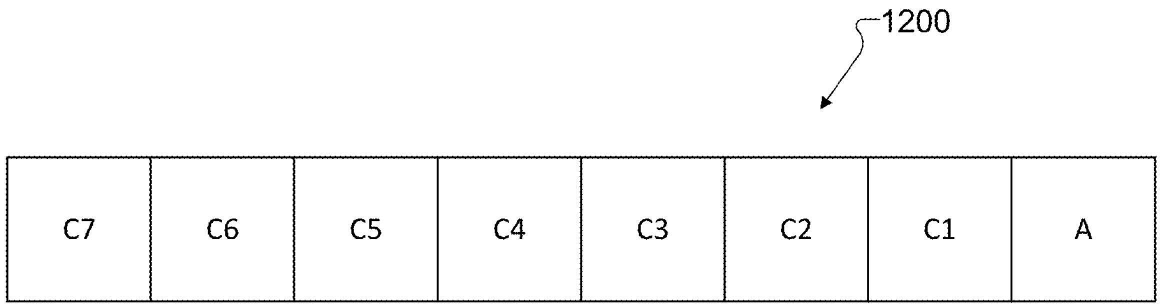


FIG. 12A

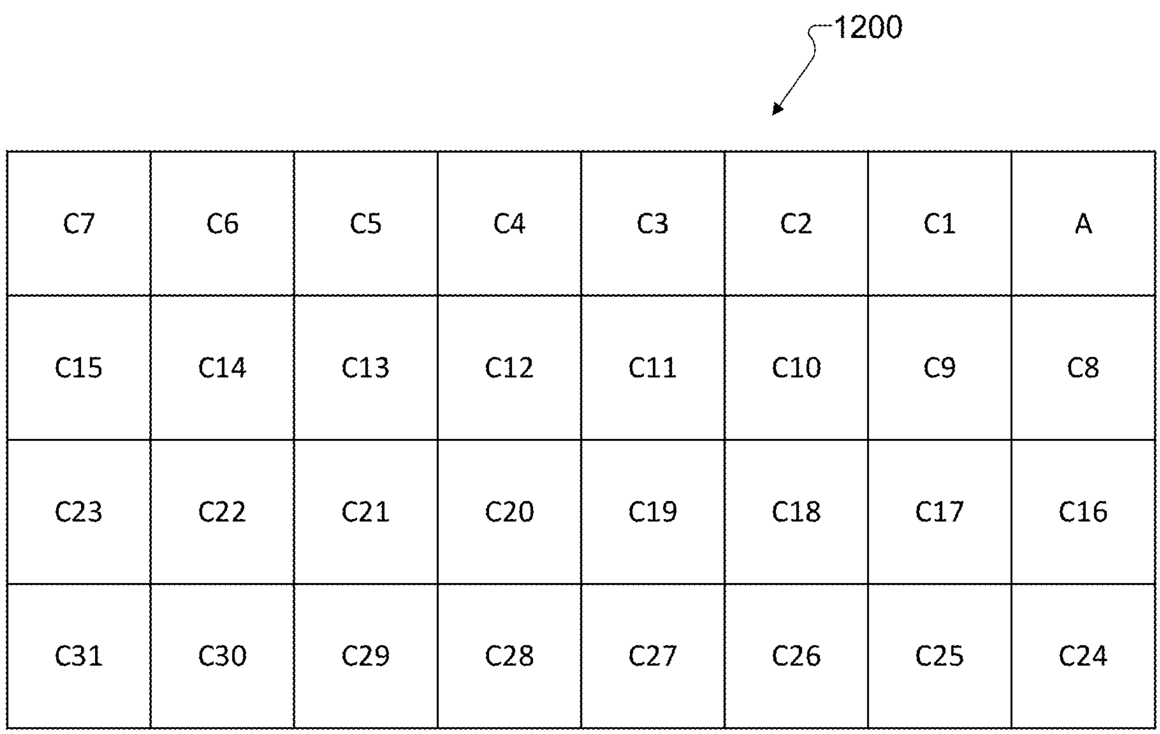


FIG. 12B

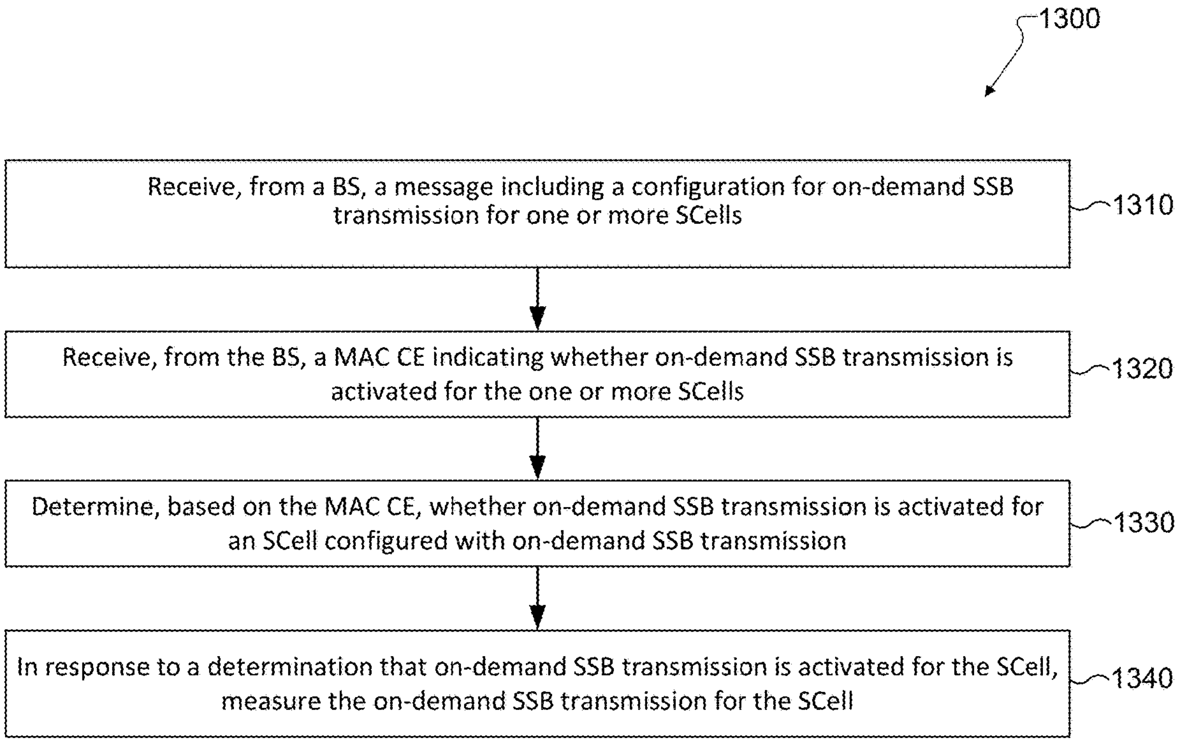

1300
Receive, from a BS, a message including a configuration for on-demand SSB transmission for one or more SCells
1310
Receive, from the BS, a MAC CE indicating whether on-demand SSB transmission is activated for the one or more SCells
1320
Determine, based on the MAC CE, whether on-demand SSB transmission is activated for an SCell configured with on-demand SSB transmission
1330
In response to a determination that on-demand SSB transmission is activated for the SCell, measure the on-demand SSB transmission for the SCell
1340

FIG. 13

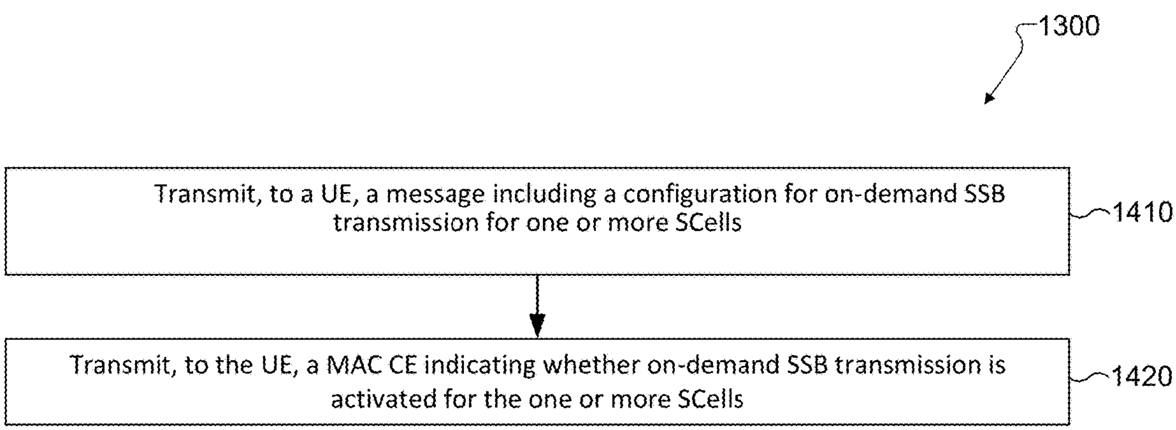

1300
Transmit, to a UE, a message including a configuration for on-demand SSB transmission for one or more SCells
1410
Transmit, to the UE, a MAC CE indicating whether on-demand SSB transmission is activated for the one or more SCells
1420

FIG. 14

CONFIGURING AND ACTIVATING ON DEMAND SSB IN SCELL

CROSS-REFERENCE TO RELATED APPLICATIONS AND CLAIM OF PRIORITY

[0001] This application claims priority under 35 U.S.C. § 119 (e) to U.S. Provisional Patent Application No. 63/643,660 filed on May 7, 2024, and U.S. Provisional Patent Application No. 63/655,256 filed on Jun. 3, 2024. The above-identified provisional patent applications are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] This disclosure relates generally to wireless networks. More specifically, this disclosure relates to configuring and activating on demand SSB transmission in secondary cells (SCells).

BACKGROUND

[0003] The demand of wireless data traffic is rapidly increasing due to the growing popularity among consumers and businesses of smart phones and other mobile data devices, such as tablets, "note pad" computers, net books, eBook readers, and machine type of devices. In order to meet the high growth in mobile data traffic and support new applications and deployments, improvements in radio interface efficiency and coverage are of paramount importance.

[0004] To meet the demand for wireless data traffic having increased since deployment of 4G communication systems, and to enable various vertical applications, 5G communication systems have been developed and are currently being deployed. The enablers for the 5G/NR mobile communications include massive antenna technologies, from legacy cellular frequency bands up to high frequencies, to provide beamforming gain and support increased capacity, new waveforms (e.g., new radio access technologies [RATs]) to flexibly accommodate various services/applications with different requirements, new multiple access schemes to support massive connections, etc.

SUMMARY

[0005] This disclosure provides apparatuses and methods for configuring and activating on demand SSB transmission in SCells.

[0006] In one embodiment, a user equipment (UE) is provided. The UE includes a transceiver. The transceiver is configured to receive, from a base station (BS), a message including a configuration for on-demand synchronization signal block (SSB) transmission for one or more secondary cells (SCells), and receive, from the BS, a medium access control (MAC) control element (CE) indicating whether on-demand SSB transmission is activated for the one or more SCells. The UE also includes a processor operably coupled to the transceiver. The processor is configured to determine, based on the MAC CE, whether on-demand SSB transmission is activated for an SCell configured with on-demand SSB transmission, and in response to a determination that on-demand SSB transmission is activated for the SCell, measure the on-demand SSB transmission for the SCell.

[0007] In another embodiment, a BS is provided. The BS includes a processor, and a transceiver operatively coupled to the processor. The transceiver is configured to transmit, to a UE, a message including a configuration for on-demand synchronization SSB transmission for one or more SCells, and transmit, to the UE, a MAC CE indicating whether on-demand SSB transmission is activated for the one or more SCells.

[0008] Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

[0009] Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The term "couple" and its derivatives refer to any direct or indirect communication between two or more elements, whether or not those elements are in physical contact with one another. The terms "transmit," "receive," and "communicate," as well as derivatives thereof, encompass both direct and indirect communication. The terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation. The term "or" is inclusive, meaning and/or. The phrase "associated with," as well as derivatives thereof, means to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like. The term "controller" means any device, system or part thereof that controls at least one operation. Such a controller may be implemented in hardware or a combination of hardware and software and/or firmware. The functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. The phrase "at least one of," when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, "at least one of: A, B, and C" includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

[0010] Moreover, various functions described below can be implemented or supported by one or more computer programs, each of which is formed from computer readable program code and embodied in a computer readable medium. The terms "application" and "program" refer to one or more computer programs, software components, sets of instructions, procedures, functions, objects, classes, instances, related data, or a portion thereof adapted for implementation in a suitable computer readable program code. The phrase "computer readable program code" includes any type of computer code, including source code, object code, and executable code. The phrase "computer readable medium" includes any type of medium capable of being accessed by a computer, such as read only memory (ROM), random access memory (RAM), a hard disk drive, a compact disc (CD), a digital video disc (DVD), or any other type of memory. A "non-transitory" computer readable medium excludes wired, wireless, optical, or other communication links that transport transitory electrical or other signals. A non-transitory computer readable medium includes media where data can be permanently stored and media where data can be stored and later overwritten, such as a rewritable optical disc or an erasable memory device.

[0011] Definitions for other certain words and phrases are provided throughout this patent document. Those of ordinary skill in the art should understand that in many if not most instances, such definitions apply to prior as well as future uses of such defined words and phrases.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a more complete understanding of this disclosure and its advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

[0013] FIG. **1** illustrates an example wireless network according to embodiments of the present disclosure;

[0014] FIGS. **2**A and **2**B illustrate example wireless transmit and receive paths according to embodiments of the present disclosure;

[0015] FIG. **3**A illustrates an example UE according to embodiments of the present disclosure;

[0016] FIG. **3**B illustrates an example gNB according to embodiments of the present disclosure;

[0017] FIG. **4** illustrates an example of periodic SSB transmission according to embodiments of the present disclosure;

[0018] FIG. **5** illustrates an example signal flow between a UE and a gNB for triggering on demand SSB transmission for SCell operation according to embodiments of the present disclosure;

[0019] FIG. **6** illustrates an example MAC CE format according to embodiments of the present disclosure;

[0020] FIG. **7** illustrates another example MAC CE format according to embodiments of the present disclosure;

[0021] FIGS. **8**A and **8**B illustrate another example MAC CE format according to embodiments of the present disclosure;

[0022] FIGS. **9**A and **9**B illustrate another example MAC CE format according to embodiments of the present disclosure;

[0023] FIG. **10** illustrates another example signal flow between a UE and a gNB for triggering on demand SSB transmission for SCell operation according to embodiments of the present disclosure;

[0024] FIGS. **11**A and **11**B illustrate another example MAC CE format according to embodiments of the present disclosure;

[0025] FIGS. **12**A and **12**B illustrate another example MAC CE format according to embodiments of the present disclosure;

[0026] FIG. **13** illustrates an example method for configuring and activating on demand SSB transmission in SCells according to embodiments of the present disclosure; and

[0027] FIG. **14** illustrates another example method for configuring and activating on demand SSB transmission in SCells according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0028] FIGS. **1** through **14**, discussed below, and the various embodiments used to describe the principles of this disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of this disclosure may be implemented in any suitably arranged wireless communication system.

[0029] To meet the demand for wireless data traffic having increased since deployment of 4G communication systems and to enable various vertical applications, 5G/NR communication systems have been developed and are currently being deployed. The 5G/NR communication system is considered to be implemented in higher frequency (mmWave) bands, e.g., 28 GHz or 60 GHz bands, so as to accomplish higher data rates or in lower frequency bands, such as 6 GHz, to enable robust coverage and mobility support. To decrease propagation loss of the radio waves and increase the transmission distance, the beamforming, massive multiple-input multiple-output (MIMO), full dimensional MIMO (FD-MIMO), array antenna, an analog beam forming, large scale antenna techniques are discussed in 5G/NR communication systems.

[0030] In addition, in 5G/NR communication systems, development for system network improvement is under way based on advanced small cells, cloud radio access networks (RANs), ultra-dense networks, device-to-device (D2D) communication, wireless backhaul, moving network, cooperative communication, coordinated multi-points (COMP), reception-end interference cancelation and the like.

[0031] The discussion of 5G systems and frequency bands associated therewith is for reference as certain embodiments of the present disclosure may be implemented in 5G systems. However, the present disclosure is not limited to 5G systems or the frequency bands associated therewith, and embodiments of the present disclosure may be utilized in connection with any frequency band. For example, aspects of the present disclosure may also be applied to deployment of 5G communication systems, 6G or even later releases which may use terahertz (THz) bands.

[0032] FIGS. **1-3**B below describe various embodiments implemented in wireless communications systems and with the use of orthogonal frequency division multiplexing (OFDM) or orthogonal frequency division multiple access (OFDMA) communication techniques. The descriptions of FIGS. **1-3**B are not meant to imply physical or architectural limitations to the manner in which different embodiments may be implemented. Different embodiments of the present disclosure may be implemented in any suitably arranged communications system.

[0033] FIG. **1** illustrates an example wireless network **100** according to embodiments of the present disclosure. The embodiment of the wireless network shown in FIG. **1** is for illustration only. Other embodiments of the wireless network **100** could be used without departing from the scope of this disclosure.

[0034] As shown in FIG. **1**, the wireless network includes a gNB **101** (e.g., base station, BS), a gNB **102**, and a gNB **103**. The gNB **101** communicates with the gNB **102** and the gNB **103**. The gNB **101** also communicates with at least one network **130**, such as the Internet, a proprietary Internet Protocol (IP) network, or other data network.

[0035] The gNB **102** provides wireless broadband access to the network **130** for a first plurality of user equipments (UEs) within a coverage area **120** of the gNB **102**. The first plurality of UEs includes a UE **111**, which may be located in a small business; a UE **112**, which may be located in an enterprise; a UE **113**, which may be a WiFi hotspot; a UE **114**, which may be located in a first residence; a UE **115**, which may be located in a second residence; and a UE **116**, which may be a mobile device, such as a cell phone, a wireless laptop, a wireless PDA, or the like. The gNB **103** provides wireless broadband access to the network **130** for a second plurality of UEs within a coverage area **125** of the gNB **103**. The second plurality of UEs includes the UE **115**

and the UE **116**. In some embodiments, one or more of the gNBs **101-103** may communicate with each other and with the UEs **111-116** using 5G/NR, long term evolution (LTE), long term evolution-advanced (LTE-A), WiMAX, WiFi, or other wireless communication techniques.

[0036] Depending on the network type, the term "base station" or "BS" can refer to any component (or collection of components) configured to provide wireless access to a network, such as transmit point (TP), transmit-receive point (TRP), an enhanced base station (eNodeB or eNB), a 5G/NR base station (gNB), a macrocell, a femtocell, a WiFi access point (AP), or other wirelessly enabled devices. Base stations may provide wireless access in accordance with one or more wireless communication protocols, e.g., 5G/NR 3rd generation partnership project (3GPP) NR, long term evolution (LTE), LTE advanced (LTE-A), high speed packet access (HSPA), Wi-Fi 802.11a/b/g/n/ac, etc. For the sake of convenience, the terms "BS" and "TRP" are used interchangeably in this patent document to refer to network infrastructure components that provide wireless access to remote terminals. Also, depending on the network type, the term "user equipment" or "UE" can refer to any component such as "mobile station," "subscriber station," "remote terminal," "wireless terminal," "receive point," or "user device." For the sake of convenience, the terms "user equipment" and "UE" are used in this patent document to refer to remote wireless equipment that wirelessly accesses a BS, whether the UE is a mobile device (such as a mobile telephone or smartphone) or is normally considered a stationary device (such as a desktop computer or vending machine).

[0037] Dotted lines show the approximate extents of the coverage areas **120** and **125**, which are shown as approximately circular for the purposes of illustration and explanation only. It should be clearly understood that the coverage areas associated with gNBs, such as the coverage areas **120** and **125**, may have other shapes, including irregular shapes, depending upon the configuration of the gNBs and variations in the radio environment associated with natural and man-made obstructions.

[0038] As described in more detail below, one or more of the UEs **111-116** include circuitry, programing, or a combination thereof, for configuring and activating on demand SSB transmission in SCells. In certain embodiments, one or more of the gNBs **101-103** includes circuitry, programing, or a combination thereof, to support configuring and activating on demand SSB transmission in SCells in a wireless communication system.

[0039] Although FIG. **1** illustrates one example of a wireless network, various changes may be made to FIG. **1**. For example, the wireless network could include any number of gNBs and any number of UEs in any suitable arrangement. Also, the gNB **101** could communicate directly with any number of UEs and provide those UEs with wireless broadband access to the network **130**. Similarly, each gNB **102-103** could communicate directly with the network **130** and provide UEs with direct wireless broadband access to the network **130**. Further, the gNBs **101**, **102**, and/or **103** could provide access to other or additional external networks, such as external telephone networks or other types of data networks.

[0040] FIGS. **2**A and **2**B illustrate example wireless transmit and receive paths according to embodiments of the present disclosure. In the following description, a transmit path **200** may be described as being implemented in a gNB (such as gNB **102**), while a receive path **250** may be described as being implemented in a UE (such as UE **116**). However, it will be understood that the receive path **250** can be implemented in a gNB and that the transmit path **200** can be implemented in a UE. In some embodiments, the transmit path **200** and/or the receive path **250** is configured to implement and/or support configuring and activating on demand SSB transmission in SCells as described in embodiments of the present disclosure.

[0041] The transmit path **200** includes a channel coding and modulation block **205**, a serial-to-parallel (S-to-P) block **210**, a size N Inverse Fast Fourier Transform (IFFT) block **215**, a parallel-to-serial (P-to-S) block **220**, an add cyclic prefix block **225**, and an up-converter (UC) **230**. The receive path **250** includes a down-converter (DC) **255**, a remove cyclic prefix block **260**, a serial-to-parallel (S-to-P) block **265**, a size N Fast Fourier Transform (FFT) block **270**, a parallel-to-serial (P-to-S) block **275**, and a channel decoding and demodulation block **280**.

[0042] In the transmit path **200**, the channel coding and modulation block **205** receives a set of information bits, applies coding (such as a low-density parity check (LDPC) coding), and modulates the input bits (such as with Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM)) to generate a sequence of frequency-domain modulation symbols. The serial-to-parallel block **210** converts (such as de-multiplexes) the serial modulated symbols to parallel data in order to generate N parallel symbol streams, where N is the IFFT/FFT size used in the gNB **102** and the UE **116**. The size N IFFT block **215** performs an IFFT operation on the N parallel symbol streams to generate time-domain output signals. The parallel-to-serial block **220** converts (such as multiplexes) the parallel time-domain output symbols from the size N IFFT block **215** in order to generate a serial time-domain signal. The add cyclic prefix block **225** inserts a cyclic prefix to the time-domain signal. The up-converter **230** modulates (such as up-converts) the output of the add cyclic prefix block **225** to an RF frequency for transmission via a wireless channel. The signal may also be filtered at baseband before conversion to the RF frequency.

[0043] A transmitted RF signal from the gNB **102** arrives at the UE **116** after passing through the wireless channel, and reverse operations to those at the gNB **102** are performed at the UE **116**. The down-converter **255** down-converts the received signal to a baseband frequency, and the remove cyclic prefix block **260** removes the cyclic prefix to generate a serial time-domain baseband signal. The serial-to-parallel block **265** converts the time-domain baseband signal to parallel time domain signals. The size N FFT block **270** performs an FFT algorithm to generate N parallel frequency-domain signals. The parallel-to-serial block **275** converts the parallel frequency-domain signals to a sequence of modulated data symbols. The channel decoding and demodulation block **280** demodulates and decodes the modulated symbols to recover the original input data stream.

[0044] Each of the gNBs **101-103** may implement a transmit path **200** that is analogous to transmitting in the downlink to UEs **111-116** and may implement a receive path **250** that is analogous to receiving in the uplink from UEs **111-116**. Similarly, each of UEs **111-116** may implement a transmit path **200** for transmitting in the uplink to gNBs

101-103 and may implement a receive path **250** for receiving in the downlink from gNBs **101-103**.

[0045] Each of the components in FIGS. **2**A and **2**B can be implemented using only hardware or using a combination of hardware and software/firmware. As a particular example, at least some of the components in FIGS. **2**A and **2**B may be implemented in software, while other components may be implemented by configurable hardware or a mixture of software and configurable hardware. For instance, the FFT block **270** and the IFFT block **215** may be implemented as configurable software algorithms, where the value of size N may be modified according to the implementation.

[0046] Furthermore, although described as using FFT and IFFT, this is by way of illustration only and should not be construed to limit the scope of this disclosure. Other types of transforms, such as Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT) functions, can be used. It will be appreciated that the value of the variable N may be any integer number (such as 1, 2, 3, 4, or the like) for DFT and IDFT functions, while the value of the variable N may be any integer number that is a power of two (such as 1, 2, 4, 8, 16, or the like) for FFT and IFFT functions.

[0047] Although FIGS. **2**A and **2**B illustrate examples of wireless transmit and receive paths, various changes may be made to FIGS. **2**A and **2**B. For example, various components in FIGS. **2**A and **2**B can be combined, further subdivided, or omitted and additional components can be added according to particular needs. Also, FIGS. **2**A and **2**B are meant to illustrate examples of the types of transmit and receive paths that can be used in a wireless network. Any other suitable architectures can be used to support wireless communications in a wireless network.

[0048] FIG. **3**A illustrates an example UE **116** according to embodiments of the present disclosure. The embodiment of the UE **116** illustrated in FIG. **3**A is for illustration only, and the UEs **111-115** of FIG. **1** could have the same or similar configuration. However, UEs come in a wide variety of configurations, and FIG. **3**A does not limit the scope of this disclosure to any particular implementation of a UE.

[0049] As shown in FIG. **3**A, the UE **116** includes antenna (s) **305**, a transceiver(s) **310**, and a microphone **320**. The UE **116** also includes a speaker **330**, a processor **340**, an input/output (I/O) interface (IF) **345**, an input **350**, a display **355**, and a memory **360**. The memory **360** includes an operating system (OS) **361** and one or more applications **362**.

[0050] The transceiver(s) **310** receives from the antenna **305**, an incoming RF signal transmitted by a gNB of the network **100**. The transceiver(s) **310** down-converts the incoming RF signal to generate an intermediate frequency (IF) or baseband signal. The IF or baseband signal is processed by RX processing circuitry in the transceiver(s) **310** and/or processor **340**, which generates a processed baseband signal by filtering, decoding, and/or digitizing the baseband or IF signal. The RX processing circuitry sends the processed baseband signal to the speaker **330** (such as for voice data) or is processed by the processor **340** (such as for web browsing data).

[0051] TX processing circuitry in the transceiver(s) **310** and/or processor **340** receives analog or digital voice data from the microphone **320** or other outgoing baseband data (such as web data, e-mail, or interactive video game data) from the processor **340**. The TX processing circuitry encodes, multiplexes, and/or digitizes the outgoing baseband data to generate a processed baseband or IF signal. The transceiver(s) **310** up-converts the baseband or IF signal to an RF signal that is transmitted via the antenna(s) **305**.

[0052] The processor **340** can include one or more processors or other processing devices and execute the OS **361** stored in the memory **360** in order to control the overall operation of the UE **116**. For example, the processor **340** could control the reception of DL channel signals and the transmission of UL channel signals by the transceiver(s) **310** in accordance with well-known principles. In some embodiments, the processor **340** includes at least one microprocessor or microcontroller.

[0053] The processor **340** is also capable of executing other processes and programs resident in the memory **360**, for example, processes for configuring and activating on demand SSB transmission in SCells as discussed in greater detail below. The processor **340** can move data into or out of the memory **360** as required by an executing process. In some embodiments, the processor **340** is configured to execute the applications **362** based on the OS **361** or in response to signals received from gNBs or an operator. The processor **340** is also coupled to the I/O interface **345**, which provides the UE **116** with the ability to connect to other devices, such as laptop computers and handheld computers. The I/O interface **345** is the communication path between these accessories and the processor **340**.

[0054] The processor **340** is also coupled to the input **350**, which includes for example, a touchscreen, keypad, etc., and the display **355**. The operator of the UE **116** can use the input **350** to enter data into the UE **116**. The display **355** may be a liquid crystal display, light emitting diode display, or other display capable of rendering text and/or at least limited graphics, such as from web sites.

[0055] The memory **360** is coupled to the processor **340**. Part of the memory **360** could include a random-access memory (RAM), and another part of the memory **360** could include a Flash memory or other read-only memory (ROM).

[0056] Although FIG. **3**A illustrates one example of UE **116**, various changes may be made to FIG. **3**A. For example, various components in FIG. **3**A could be combined, further subdivided, or omitted and additional components could be added according to particular needs. As a particular example, the processor **340** could be divided into multiple processors, such as one or more central processing units (CPUs) and one or more graphics processing units (GPUs). In another example, the transceiver(s) **310** may include any number of transceivers and signal processing chains and may be connected to any number of antennas. Also, while FIG. **3**A illustrates the UE **116** configured as a mobile telephone or smartphone, UEs could be configured to operate as other types of mobile or stationary devices.

[0057] FIG. **3**B illustrates an example gNB **102** according to embodiments of the present disclosure. The embodiment of the gNB **102** illustrated in FIG. **3**B is for illustration only, and the gNBs **101** and **103** of FIG. **1** could have the same or similar configuration. However, gNBs come in a wide variety of configurations, and FIG. **3**B does not limit the scope of this disclosure to any particular implementation of a gNB.

[0058] As shown in FIG. **3**B, the gNB **102** includes multiple antennas **370*a*-370*n***, multiple transceivers **372*a*-372*n***, a controller/processor **378**, a memory **380**, and a backhaul or network interface **382**.

[0059] The transceivers **372**a-**372**n receive, from the antennas **370**a-**370**n, incoming RF signals, such as signals transmitted by UEs in the network **100**. The transceivers **372**a-**372**n down-convert the incoming RF signals to generate IF or baseband signals. The IF or baseband signals are processed by receive (RX) processing circuitry in the transceivers **372**a-**372**n and/or controller/processor **378**, which generates processed baseband signals by filtering, decoding, and/or digitizing the baseband or IF signals. The controller/processor **378** may further process the baseband signals.

[0060] Transmit (TX) processing circuitry in the transceivers **372**a-**372**n and/or controller/processor **378** receives analog or digital data (such as voice data, web data, e-mail, or interactive video game data) from the controller/processor **378**. The TX processing circuitry encodes, multiplexes, and/or digitizes the outgoing baseband data to generate processed baseband or IF signals. The transceivers **372**a-**372**n up-converts the baseband or IF signals to RF signals that are transmitted via the antennas **370**a-**370**n.

[0061] The controller/processor **378** can include one or more processors or other processing devices that control the overall operation of the gNB **102**. For example, the controller/processor **378** could control the reception of uplink (UL) channel signals and the transmission of downlink (DL) channel signals by the transceivers **372**a-**372**n in accordance with well-known principles. The controller/processor **378** could support additional functions as well, such as more advanced wireless communication functions. For instance, the controller/processor **378** could support beam forming or directional routing operations in which outgoing/incoming signals from/to multiple antennas **370**a-**370**n are weighted differently to effectively steer the outgoing signals in a desired direction. Any of a wide variety of other functions could be supported in the gNB **102** by the controller/processor **378**.

[0062] The controller/processor **378** is also capable of executing programs and other processes resident in the memory **380**, such as an OS and, for example, processes to support configuring and activating on demand SSB transmission in SCells as discussed in greater detail below. The controller/processor **378** can move data into or out of the memory **380** as required by an executing process.

[0063] The controller/processor **378** is also coupled to the backhaul or network interface **382**. The backhaul or network interface **382** allows the gNB **102** to communicate with other devices or systems over a backhaul connection or over a network. The interface **382** could support communications over any suitable wired or wireless connection(s). For example, when the gNB **102** is implemented as part of a cellular communication system (such as one supporting 5G/NR, LTE, or LTE-A), the interface **382** could allow the gNB **102** to communicate with other gNBs over a wired or wireless backhaul connection. When the gNB **102** is implemented as an access point, the interface **382** could allow the gNB **102** to communicate over a wired or wireless local area network or over a wired or wireless connection to a larger network (such as the Internet). The interface **382** includes any suitable structure supporting communications over a wired or wireless connection, such as an Ethernet or transceiver.

[0064] The memory **380** is coupled to the controller/processor **378**. Part of the memory **380** could include a RAM, and another part of the memory **380** could include a Flash memory or other ROM.

[0065] Although FIG. **3**B illustrates one example of gNB **102**, various changes may be made to FIG. **3**B. For example, the gNB **102** could include any number of each component shown in FIG. **3**B. Also, various components in FIG. **3**B could be combined, further subdivided, or omitted and additional components could be added according to particular needs.

[0066] The next generation wireless communication system (e.g., 5G, beyond 5G, 6G) supports not only lower frequency bands but also higher frequency (mmWave) bands (e.g., 10 GHz to 100 GHz bands), so as to accomplish higher data rates. To mitigate propagation loss of the radio waves and increase the transmission distance, beamforming, massive Multiple-Input Multiple-Output (MIMO), Full Dimensional MIMO (FD-MIMO), array antenna, analog beam forming, and large scale antenna techniques are being considered in the design of the next generation wireless communication system. In addition, the next generation wireless communication system is expected to address different use cases having quite different requirements in terms of data rate, latency, reliability, mobility etc. However, it is expected that the design of the air-interface of the next generation wireless communication system would be flexible enough to serve UEs having quite different capabilities depending on the use case and market segment the UE caters service to the end customer. A few example use cases the next generation wireless communication system wireless system is expected to address is enhanced Mobile Broadband (eMBB), massive Machine Type Communication (m-MTC), ultra-reliable low latency communication (URLL), etc. eMBB requirements like tens of Gbps data rate, low latency, high mobility, etc. address the market segment representing conventional wireless broadband subscribers needing internet connectivity everywhere, all the time and on the go. m-MTC requirements like very high connection density, infrequent data transmission, very long battery life, low mobility, etc. address the market segment representing Internet of Things (IoT)/Internet of Everything (IoE) envisioning connectivity of billions of devices. URLL requirements like very low latency, very high reliability and variable mobility, address the market segment representing industrial automation applications, and vehicle-to-vehicle/vehicle-to-infrastructure communication, which is foreseen as one of the enablers for autonomous cars.

[0067] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G) operating in higher frequency (mmWave) bands, UEs and gNBs communicate with each other using beamforming. Beamforming techniques are used to mitigate propagation path losses and to increase the propagation distance for communication at higher frequency bands. Beamforming enhances transmission and reception performance using a high-gain antenna. Beamforming can be classified into transmission (TX) beamforming performed in a transmitting end and reception (RX) beamforming performed in a receiving end. In general, TX beamforming increases directivity by allowing an area in which propagation reaches to be densely located in a specific direction by using a plurality of antennas. In this situation, aggregation of the plurality of antennas can be referred to as an antenna array, and each antenna included in the array can be referred to as an array element. The antenna array can be configured in various forms such as a linear array, a planar array, etc. The use of TX beamforming results in an increase in the directivity of a signal, thereby increasing a propagation distance. Further, since the signal is almost not transmitted in a direction other than a directivity direction, a signal interference acting on another receiving end is significantly decreased. The receiving end can perform beamforming on a RX signal by using a RX antenna array. RX beamforming increases the RX signal strength transmitted in a specific direction by allowing propagation to be concentrated in a specific direction and excludes a signal transmitted in a direction other than the specific direction from the RX signal, thereby providing an effect of blocking an interference signal. By using beamforming techniques, a transmitter can generate a plurality of transmit beam patterns of different directions. Each of these transmit beam patterns can be also referred to as a TX beam. Wireless communication systems operating at high frequency use a plurality of narrow TX beams to transmit signals in the cell, as each narrow TX beam provides coverage to a part of the cell. The narrower the TX beam, the higher the antenna gain and hence the larger the propagation distance of a signal transmitted using beamforming. A receiver can also generate a plurality of RX beam patterns of different directions. Each of these receive patterns can also be referred to as an RX beam.

[0068] The next generation wireless communication system (e.g., 5G, beyond 5G, 6G) supports standalone modes of operation as well dual connectivity (DC). In DC a multiple Rx/Tx UE may be configured to utilize resources provided by two different nodes (or NBs) connected via non-ideal backhaul. One node acts as the Master Node (MN) and the other nodes acts as the Secondary Node (SN). The MN and SN are connected via a network interface and at least the MN is connected to the core network. NR also supports Multi-RAT Dual Connectivity (MR-DC) operation whereby a UE in an RRC_CONNECTED state is configured to utilize radio resources provided by two distinct schedulers, located in two different nodes connected via a non-ideal backhaul and providing either E-UTRA (i.e., if the node is an ng-eNB) or NR access (i.e., if the node is a gNB). In NR for a UE in an RRC_CONNECTED state not configured with carrier aggregation (CA)/DC there is only one serving cell comprising the primary cell. For a UE in an RRC_CONNECTED state configured with CA/DC the term 'serving cells' is used to denote the set of cells comprising the Special Cell(s) (SpCell[s]) and all secondary cells (SCells). In NR the term Master Cell Group (MCG) refers to a group of serving cells associated with the Master Node, comprising the primary cell (PCell) and optionally one or more (SCells. In NR the term Secondary Cell Group (SCG) refers to a group of serving cells associated with the Secondary Node, comprising the primary SCG cell (PSCell) and optionally one or more SCells. In NR, PCell refers to a serving cell in a MCG, operating on the primary frequency, in which the UE either performs the initial connection establishment procedure or initiates the connection re-establishment procedure. In NR, for a UE configured with CA, an SCell is a cell providing additional radio resources on top of the SpCell. PSCell refers to a serving cell in a SCG in which the UE performs random access when performing the Reconfiguration with Sync procedure. For Dual Connectivity operation the term SpCell refers to the PCell of the MCG or the PSCell of the SCG. Otherwise, the term SpCell refers to the PCell.

[0069] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G), a next generation node B (gNB) or base station in cell broadcast Synchronization Signal and physical broadcast channel (PBCH) block (SSB) comprises primary and secondary synchronization signals (PSS, SSS) and system information (SI). SI includes common parameters needed to communicate in cell. In the fifth generation wireless communication system (also referred to as next generation radio or NR), SI is divided into the master information block (MIB) and a number of s (SIBs) where: the MIB is always transmitted on the broadcast channel (BCH) with a periodicity of 80 ms and repetitions made within 80 ms and the MIB includes parameters that are used to acquire SIB1 from the cell. The SIB1 is transmitted on the downlink shared channel (DL-SCH) with a periodicity of 160 ms and variable transmission repetition. The default transmission repetition periodicity of SIB1 is 20 ms but the actual transmission repetition periodicity is up to network implementation. For SSB and CORESET multiplexing pattern 1, the SIB1 repetition transmission period is 20 ms. For SSB and CORESET multiplexing pattern 2/3, the SIB1 transmission repetition period is the same as the SSB period. SIB1 includes information regarding the availability and scheduling (e.g., mapping of SIBs to SI messages, periodicity, SI-window size) of other SIBs with an indication whether one or more SIBs are only provided on-demand and, in that case, the configuration needed by the UE to perform the SI request. SIB1 is a cell-specific SIB. SIBs other than SIB1 and posSIBs are carried in SystemInformation (SI) messages, which are transmitted on the DL-SCH. Only SIBs or positioning SIBs (posSIBs) having the same periodicity can be mapped to the same SI message. SIBs and posSIBs are mapped to the different SI messages. Each SI message is transmitted within periodically occurring time domain windows (referred to as SI-windows with the same length for all SI messages). Each SI message is associated with an SI-window and the SI-windows of different SI messages do not overlap. That is to say, within one SI-window only the corresponding SI message is transmitted. An SI message may be transmitted a number of times within the SI-window. Any SIB or posSIB except SIB1 can be configured to be cell specific or area specific, using an indication in the SIB1. A cell specific SIB is applicable only within a cell that provides the SIB while an area specific SIB is applicable within an area referred to as an SI area, which comprises one or several cells and is identified by systemInformationAreaID. The mapping of SIBs to SI messages is configured in schedulingInfoList, while the mapping of posSIBs to SI messages is configured in pos-SchedulingInfoList. Each SIB is contained only in a single SI message and each SIB and posSIB is contained at most once in that SI message. For a UE in an RRC_CONNECTED state, the network can provide system information through dedicated signaling using an RRCReconfiguration message (e.g., if the UE has an active BWP with no common search space configured to monitor system information), paging, or upon request from the UE. In an RRC_CONNECTED state, the UE acquires the required SIB(s) only from the PCell. For PSCell and SCells, the network provides the required SI by dedicated signaling (i.e., within an RRCReconfiguration message). Nevertheless, the UE shall acquire the MIB of the PSCell to get system frame number (SFN) timing of the SCG (which may be different from MCG). Upon a change of relevant SI for the SCell, the network releases and adds the concerned SCell. For the PSCell, the required SI can only be changed with Reconfiguration with Sync.

[0070] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G), random access (RA) is supported. RA is used to achieve UL time synchronization. RA is used during initial access, handover, RRC connection re-establishment procedure, scheduling request transmission, SCG addition/modification, beam failure recovery and data or control information transmission in the UL by a non-synchronized UE in an RRC_CONNECTED state. Several types of RA procedures are supported, such as contention based random access, and contention free random access. Each of these can be one of 2 step or 4 step random access.

[0071] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G), A physical downlink control channel (PDCCH) is used to schedule DL transmissions on a physical downlink shared channel (PDSCH) and UL transmissions on a physical uplink shared channel (PUSCH), where Downlink Control Information (DCI) on the PDCCH includes: downlink assignments containing at least modulation and coding format, resource allocation, and hybrid-ARQ information related to DL-SCH; and uplink scheduling grants containing at least modulation and coding format, resource allocation, and hybrid-ARQ information related to UL-SCH. In addition to scheduling, the PDCCH can be used to for: activation and deactivation of configured PUSCH transmission with configured grant; activation and deactivation of PDSCH semi-persistent transmission; notifying one or more UEs of the slot format; notifying one or more UEs of the physical resource block(s) (PRB[s]) and OFDM symbol(s) where the UE may assume no transmission is intended for the UE; transmission of transmit power control (TPC) commands for the physical uplink control channel (PUCCH) and PUSCH; transmission of one or more TPC commands for sounding reference signal (SRS) transmissions by one or more UEs; switching a UE's active bandwidth part; and initiating a random access procedure. A UE monitors a set of PDCCH candidates in the configured monitoring occasions in one or more configured Control REsource SETs (CORESETs) according to the corresponding search space configurations. A CORESET comprises a set of PRBs with a time duration of 1 to 3 OFDM symbols. The resource units Resource Element Groups (REGs) and Control Channel Elements (CCEs) are defined within a CORESET with each CCE comprising a set of REGs. Control channels are formed by aggregation of CCEs. Different code rates for the control channels are realized by aggregating a different number of CCEs. Interleaved and non-interleaved CCE-to-REG mappings are supported in a CORESET. Polar coding is used for the PDCCH. Each resource element group carrying the PDCCH carries its own demodulation reference signal (DMRS). Quadrature phase shift keying (QPSK) modulation is used for the PDCCH.

[0072] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G), a list of search space configurations is signaled by the gNB for each configured BWP of the serving cell, wherein each search configuration is uniquely identified by a search space identifier. Each search space identifier is unique amongst the BWPs of a serving cell. An identifier of a search space configuration to be used for a specific purpose such as paging reception, SI reception, random access response reception, etc. is explicitly signaled by the gNB for each configured BWP. In NR, a search space configuration comprises the parameters Monitoring-periodicity-PDCCH-slot, Monitoring-offset-PDCCH-slot, Monitoring-symbols-PDCCH-within-slot and duration. A UE determines PDCCH monitoring occasion(s) within a slot using the parameters PDCCH monitoring periodicity (Monitoring-periodicity-PDCCH-slot), the PDCCH monitoring offset (Monitoring-offset-PDCCH-slot), and the PDCCH monitoring pattern (Monitoring-symbols-PDCCH-within-slot). PDCCH monitoring occasions are in slots 'x' to x+duration, where the slot with number 'x' in a radio frame with number 'y' satisfies the equation below:

$$\left(y * (\text{number of slots in a radio frame}) + x - \text{Monitoring-offset-}PDCCH\text{-slot}\right) \bmod \left(\text{Monitoring-periodicity-}PDCCH\text{-slot}\right) = 0.$$

[0073] The starting symbol of a PDCCH monitoring occasion in each slot having a PDCCH monitoring occasion is given by Monitoring-symbols-PDCCH-within-slot. The length (in symbols) of a PDCCH monitoring occasion is given in the CORESET associated with the search space. The search space configuration includes the identifier of the CORESET configuration associated with it. A list of CORESET configurations is signaled by the gNB for each configured BWP of the serving cell, wherein each CORESET configuration is uniquely identified by a CORESET identifier. A CORESET identifier is unique amongst the BWPs of a serving cell. Note that each radio frame is of 10 ms duration. A radio frame is identified by a radio frame number or system frame number. Each radio frame comprises several slots, wherein the number of slots in a radio frame and duration of slots depends on sub carrier spacing (SC). The number of slots in a radio frame and duration of slots depends on radio frame for each supported SCS is predefined in NR. Each CORESET configuration is associated with a list of Transmission configuration indicator (TCI) states. One DL RS ID (SSB or CSI RS) is configured per TCI state. The list of TCI states corresponding to a CORESET configuration is signaled by the gNB via radio resource control (RRC) signaling. One of the TCI states in a TCI state list is activated and indicated to the UE by the gNB. The TCI state indicates the DL TX beam (the DL TX beam is QCLed with the SSB/CSI RS of the TCI state) used by the gNB for transmission of the PDCCH in the PDCCH monitoring occasions of a search space.

[0074] In the next generation wireless communication system (e.g., 5G, beyond 5G, 6G), bandwidth adaptation (BA) is supported. With BA, the receive and transmit bandwidth of a UE need not be as large as the bandwidth of the cell and can be adjusted: the width can be ordered to change (e.g., to shrink during a period of low activity to save power); the location can move in the frequency domain (e.g., to increase scheduling flexibility); and the subcarrier spacing can be ordered to change (e.g., to allow different services). A subset of the total cell bandwidth of a cell is referred to as a Bandwidth Part (BWP). BA is achieved by configuring an RRC connected UE with BWP(s) and telling the UE which of the configured BWPs is currently the active one. When BA is configured, the UE can monitor the PDCCH only on the one active BWP (i.e., the UE does not have to monitor the PDCCH on the entire DL frequency of the serving cell). In an RRC connected state, the UE is configured with one or more DL and UL BWPs, for each configured Serving Cell (i.e., PCell or SCell). For an activated Serving Cell, there is always one active UL and DL BWP at any point in time. BWP switching for a Serving Cell is used to activate an inactive BWP and deactivate an active BWP at a particular moment in time. BWP switching is controlled by the PDCCH indicating a downlink assignment or an uplink grant, by the bwp-InactivityTimer, by RRC signaling, or by the MAC entity itself upon initiation of a random-access procedure. Upon addition of a SpCell or activation of an SCell, the DL BWP and UL BWP indicated by firstActiveDownlinkBWP-Id and firstActiveUplinkBWP-Id respectively is active without receiving a PDCCH indicating a downlink assignment or an uplink grant. The active BWP for a Serving Cell is indicated by either RRC or the PDCCH. For unpaired spectrum, a DL BWP is paired with a UL BWP, and BWP switching is common for both the UL and DL. Upon expiry of the BWP inactivity timer, the UE switches the active DL BWP to the default DL BWP or initial DL BWP (if a default DL BWP is not configured).

[0075] In wireless communication systems, a UE can be configured with SSB based radio resource management (RRM) measurement to discover SCell(s). The UE reports the RRM measurement results to a gNB on the quality of the measured SSB. The gNB can further provide the SCell configuration by RRC to the UE. At the time of configuration, an SCell can be initially activated or deactivated. If the SCell is deactivated, the gNB can activate the SCell via an SCell activation command in a MAC CE. The UE uses the SCell's SSB (or tracking reference signal [TRS] if configured) for automatic gain control (AGC) and synchronization purposes to be ready for transmitting or receiving data on the activated SCell. After the SCell is activated, the UE can still use the SSB to re-synchronize with the SCell, by the UE's implementation.

[0076] An example of the legacy NR operation of an SCell is shown in FIG. **4**, wherein the SSB is transmitted by the SCell and is periodic.

[0077] FIG. **4** illustrates an example of periodic SSB transmission **400** according to embodiments of the present disclosure. The embodiment of periodic SSB transmission of FIG. **4** is for illustration only. Different embodiments of periodic SSB transmission could be used without departing from the scope of this disclosure.

[0078] In the example of FIG. **4**, at time point **402**, a UE receives an RRM configuration from a PCell, and begins to monitor periodic SSB transmissions from an SCell. The UE reports the RRM measurement results to a gNB of the PCell on the quality of the measured SSB at time points **404** and **406**. At time point **408**, the UE receives a configuration for the SCell from the PCell, and at time point **410** the SCell is activated for the UE by the PCell. At time point **412**, the UE uses the SSB from the SCell to perform synchronization and AGC. At time point **414**, the UE receives data from the SCell. At time point **416**, the UE uses the SSB from the SCell to perform resynchronization.

[0079] Although FIG. **4** illustrates one example of periodic SSB transmission **400**, various changes may be made to FIG. **4**. For example, various changes to the periodicity could be made, the number of SSBs per period could be changed, etc. according to particular needs.

[0080] In the case of an SSB-less SCell, operation is the same as shown in FIG. **4**, except that SSB measurements of a reference serving cell (SpCell or another SCell) are used for the SSB-less SCell.

[0081] The periodic transmission of SSBs for the SCell operation affects the network energy consumption. For network energy savings two cases can be considered for on demand SSB transmission in an SCell:

- **[0082]** Case #1: The cell does not have always-on periodic SSB transmission. Upon an on demand SSB transmission trigger, SSBs are periodically transmitted.
- **[0083]** Case #2: SSBs are periodically transmitted by the cell in an SSB burst/window. On demand SSB transmission can be additionally provided. Note that periodic SSB transmissions can be at a longer periodicity to reduce energy consumption, but this affects performance (e.g., (re) sync/AGC delay, etc.). Additional on demand SSB transmissions can improve performance.

[0084] A gNB can trigger on demand SSB transmission for one or more configured SCells. For example:

[0085] On demand SSB transmission can be triggered when an SCell is configured to a UE but before the UE receives an SCell activation command.

[0086] On demand SSB transmission can be triggered when a UE receives an SCell activation command.

[0087] On demand SSB transmission can be triggered after a UE receives an SCell activation command until SCell activation is completed.

[0088] On demand SSB transmission can be triggered when or after SCell activation is completed and the SCell is activated.

[0089] One of the issues for adequately supporting on demand SSB transmission for SCell operation is defining the signaling mechanism and information to be signaled to the UE when the gNB decides to trigger on demand SSB transmission for the SCell operation. Various embodiments of the present disclosure provide signaling mechanisms for on demand SSB transmission for SCell operation.

[0090] FIG. **5** illustrates an example signal flow **500** between a UE and a gNB for triggering on demand SSB transmission for SCell operation according to embodiments of the present disclosure. An embodiment of the signal flow illustrated in FIG. **5** is for illustration only. One or more of the components illustrated in FIG. **5** may be implemented in specialized circuitry configured to perform the noted functions or one or more of the components may be implemented by one or more processors executing instructions to perform the noted functions. Other embodiments of a signal flow between a UE and a gNB for triggering on demand SSB transmission for SCell operation could be used without departing from the scope of this disclosure.

[0091] In the example of FIG. **5**, signal flow **500** is shown between a UE **502** and a gNB **504**. UE **502** is in an RRC_CONNECTED state. Signal flow **500** begins at step **510**. At step **510**, UE **502** indicates UE **502**'s capability to support on demand SSB transmission for SCell operation to gNB **504**. UE **502**'s capability can be indicated in an RRC message, UCI, MAC CE, etc. This capability can be a per UE capability, or this capability can be a per frequency capability, or this capability can be a per frequency band capability, or this capability can be a per frequency range (FR1, FR2-1, FR2-2, FR2-NTN, etc.) capability. For example, FR1 can be a frequency range from 410 MHz-7125 MHz, FR2-1 can be a frequency range from 24250 MHz-52600 MHZ, FR2-2 can be a frequency range from 52600 MHZ-71000 MHz, FR2-NTN can be a frequency range from 17300 MHz-30000 MHz, etc.

[0092] At step **520**, gNB **504** sends an RRCReconfiguration message to UE **502**, wherein the message includes a configuration of one or more SCells. The message may indicate whether gNB **504** supports on demand SSB transmission for the configured SCell(s). This indication can be common for all configured SCells, or this indication can be per configured SCell. gNB **504** may indicate support of on demand SSB transmission for zero, one or more configured SCells. For each configured SCell for which gNB **504** supports on demand SSB transmission, gNB **504** may provide/signal (e.g., in an RRCReconfiguration message) the on demand SSB configuration indicating the time (e.g., one or more periodicities) and frequency location(s) (e.g., one or more SSB frequencies) of on demand SSB transmissions. This configuration can be per BWP of the configured SCell(s) or can be common for all BWPs of the configured SCell(s).

[0093] At step **530**, gNB **504** triggers (i.e., activates or deactivates) on demand SSB transmission for one or more of the configured SCell(s).

[0094] At step **540**, gNB **504** transmits a PDCCH addressed to a C-RNTI or addressed to an RNTI which can be pre-defined or configured previously in an RRCReconfiguration message. The PDCCH includes scheduling information for a DL transport block (TB).

[0095] At step **550**, gNB **504** then transmits a TB including a MAC subPDU. The MAC subPDU includes a MAC subheader and MAC CE to trigger (i.e., activate or deactivate) on demand SSB transmission.

[0096] Although FIG. **5** illustrates one example signal flow **500** between a UE and a gNB for triggering (i.e., activating or deactivating) on demand SSB transmission for SCell operation, various changes may be made to FIG. **5**. For example, while shown as a series of steps, various steps in FIG. **5** could overlap, occur in parallel, occur in a different order, occur any number of times, be omitted, or replaced by other steps.

[0097] In some embodiments, the MAC subheader of the MAC CE to trigger on demand SSB transmission may include a logical channel ID (LCID)/extended LCID (eLCID). An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger on demand SSB transmission can be pre-defined. A MAC CE format to trigger (i.e., activate or deactivate) on demand SSB transmission for SCell operation is shown in FIG. **6**.

[0098] FIG. **6** illustrates an example MAC CE format **600** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIG. **6** is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0099] In the example of FIG. **6**, MAC CE format **600** includes three R or reserved bits and a 5 bit Serving Cell ID. The Serving Cell ID indicates the identity of the SCell/serving cell for which the MAC CE applies. The Serving Cell ID can be set to the value of ServCellIndex or SCellIndex in the configuration of the SCell for which the MAC CE applies.

[0100] Although FIG. **6** illustrates one example MAC CE format **600**, various changes may be made to FIG. **6**. For example, various changes to number of reserved bits could be made, the size of the Serving Cell ID, etc. according to particular needs.

[0101] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE with the MAC CE format **600** to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** may then identify the serving cell/SCell for which the MAC CE applies. UE **502** may determine that an on demand SSB transmission is transmitted by a gNB for the serving cell/SCell identified by the Serving Cell ID field in the MAC CE. UE **502** may monitor/measure the on demand SSB transmission in the time/frequency locations configured by the network (e.g., in and RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE.

[0102] Alternately, in some embodiments, the MAC subheader of the MAC CE to trigger (i.e., activate or deactivate) on demand SSB transmission may include a LCID/eLCID. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger (i.e., activate or deactivate) on demand SSB transmission can be pre-defined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIG. **7**.

[0103] FIG. **7** illustrates another example MAC CE format **700** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIG. **7** is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0104] In the example of FIG. **7**, MAC CE format **700** includes two R or reserved bits, a 5 bit Serving Cell ID, and a 1 bit 'A' field (activation/deactivation). The Serving Cell ID indicates the identity of the SCell/serving cell for which the MAC CE applies. The Serving Cell ID can be set to the value of ServCellIndex or SCellIndex in the configuration of the SCell for which the MAC CE applies. The 'A' field may be set to 1 to indicate that on demand SSB transmission for the SCell is activated/triggered/transmitted. The 'A' field may be set to 0 to indicate that on demand SSB transmission for the SCell is deactivated/not transmitted.

[0105] Although FIG. **7** illustrates one example MAC CE format **700**, various changes may be made to FIG. **7**. For example, various changes to number of reserved bits could be made, the size of the Serving Cell ID, etc. according to particular needs.

[0106] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE with the MAC CE format **700** to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** then may identify the serving cell/SCell for which the MAC CE applies. If the 'A' field is set to 1, UE **502** may determine that an on demand SSB transmission is transmitted (or activated/triggered) by the gNB for the serving cell/SCell identified by the Serving Cell ID field in the MAC CE. UE **502** may monitor/measure the on demand SSB transmission in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). If the 'A' field is set to 0, UE **502** may determine that an on demand SSB transmission is not transmitted (or is deactivated) by the gNB for the serving cell/SCell identified by the Serving Cell ID field in the MAC CE. UE **502** may stop monitoring/measuring the on demand SSB transmission in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE.

[0107] Alternately, in some embodiments, the MAC subheader may include a LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger on demand SSB transmission can be predefined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **8**A and **8**B. The LCID/eLCID may be different for the formats shown in FIGS. **8**A and **8**B.

[0108] FIGS. **8**A and **8**B illustrate another example MAC CE format **800** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIGS. **8**A and **8**B is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0109] In the example of FIG. **8**A, MAC CE format **800** includes one R bit and 7 Cj bits. In some embodiments, the format shown in FIG. **8**A may be used for a case where the highest ServCellIndex or SCellIndex for which on demand SSB transmission is configured is <8. In some embodiments, the format shown in FIG. **8**B may be used for a case where the total number of SCells for which on demand SSB is configured is <8.

[0110] In the example of FIG. **8**B, MAC CE format **800** includes one R bit and 31 Cj bits. In some embodiments, the format shown in FIG. **8**B may be used for a case where the highest ServCellIndex or SCellIndex for which on demand SSB transmission is configured is >=8. In some embodiments, the format shown in FIG. **8**B may be used for a case where the total number of SCells for which on demand SSB is configured is >=8. In these embodiments, MAC CE format **800** may include between 8 and 31 Cj bits.

[0111] Although FIGS. **8**A and **8**B illustrate one example MAC CE format **800**, various changes may be made to FIGS. **8**A and **8**B. For example, various changes to number of R bits could be made, the number of Cj bits could vary, etc. according to particular needs.

[0112] In some embodiments, for MAC CE format **800**, a field Cj may be set to 1 to indicate that on demand SSB transmission for an SCell identified by ServCellIndex j or SCellIndex j is activated/triggered/transmitted. Alternately, in some embodiments, a field Cj may be set to 0 to indicate that on demand SSB transmission for the SCell identified by ServCellIndex j or SCellIndex j is deactivated/not transmitted. ServCellIndex j or SCellIndex j for each SCell is included in the configuration of the SCell received from gNB **504**.

[0113] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE with the MAC CE format **800** to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **502** may determine that an on demand SSB transmission is transmitted (or activated/triggered) by a gNB for the serving cell/SCell identified by ServCellIndex j or SCellIndex j. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell identified by ServCellIndex j or SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Cj set to 1 can be included sequentially in the MAC CE in increasing order of ServCellIndex j or SCellIndex j. If a field Cj is set to 0, UE **502** may determine that an on demand SSB transmission is not transmitted (or is deactivated) by the gNB for the serving cell/SCell identified by ServCellIndex j or SCellIndex j. UE **502** may stop monitoring/measuring the on demand SSB transmission for the serving cell/SCell identified by ServCellIndex j or SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE.

[0114] In some embodiments, the duration for which on demand SSB is transmitted for an SCell can be included/indicated in the MAC CE or in an RRC message. If a bit Cj is set to 1 and a duration is included/indicated in the MAC CE or RRC message for the serving cell/SCell identified by ServCellIndex j or SCellIndex j, UE **502** may start the on demand SSB activation timer for the serving cell/SCell or UE **502** may restart the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is already running or UE **502** may stop the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer or UE **502** may continue the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is not running. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is running. The on demand SSB activation timer for the serving cell/SCell is stopped when serving cell/SCell is deactivated or when on demand SSB for serving cell/SCell is deactivated.

[0115] Alternately, in some embodiments, the MAC subheader may include a LCID/eLCID. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger on demand SSB transmission can be pre-defined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **8**A and **8**B.

[0116] In some embodiments, for MAC CE format **800**, SCells configured with on demand SSB transmission are sequentially indexed in increasing order of ServCellIndex or SCellIndex. The indexing begins from 1. For example, three SCells with ServCellIndex or SCellIndex 5, 9 and 15 may be configured with on demand SSB transmission. As a result of indexing, the index j of the SCell with ServCellIndex or SCellIndex 5 is 1, the index j of the SCell with ServCellIndex or SCellIndex 9 is 2, and the index j of the SCell with ServCellIndex or SCellIndex 15 is 3. In some embodiments, if there is an SpCell/PCell configured with on demand SSB, the SpCell/PCell's index j is set to 0 and the R bit is used as CO for the SpCell/PCell. A single octet Cj bitmap may be included in the MAC CE format **800** if the total number of SCells for which on demand SSB transmission is configured is greater than 0 and less than 8. A two octets Cj bitmap may be included in the MAC CE format **800** if the total number of SCells for which on demand SSB transmission is configured is greater than 7 and less than 16. A three octets Cj bitmap may be included in the MAC CE format **800** if the total number of SCells for which on demand SSB transmission is configured is greater than 15 and less than 24. A four octets Cj bitmap may include in the MAC CE format **800** if the total number of SCells for which on demand SSB transmission is configured is greater than 23. A field Cj may be set to 1 to indicate that an on demand SSB transmission for the j^{th} SCell configured with on demand SSB transmission is activated/triggered/transmitted. A field Cj may be set to 0 to indicate that the on demand SSB transmission for the j^{th} SCell configured with on demand SSB transmission is deactivated/not transmitted.

[0117] Alternately, in some embodiments, a single octet Cj bitmap may be included in the MAC CE format **800** if the total number of serving cells (SCells+SpCell/PCell) for which on demand SSB transmission is configured is greater than 0 and less than 9. A two octets Cj bitmap may be included in the MAC CE format **800** if the total number of serving cells (SCells+SpCell/PCell) for which on demand SSB transmission is configured is greater than 8 and less than 17. A three octets Cj bitmap may be included in the MAC CE format **800** if the total number of serving cells (SCells+SpCell/PCell) for which on demand SSB transmission is configured is greater than 16 and less than 25. A four octets Cj bitmap may include in the MAC CE format **800** if the total number of serving cells (SCells+SpCell/PCell) for which on demand SSB transmission is configured is greater than 24. A field Cj may be set to 1 to indicate that an on demand SSB transmission for the j^{th} SCell configured with on demand SSB transmission is activated/triggered/transmitted. A field Cj may be set to 0 to indicate that the on demand SSB transmission for the j^{th} serving cell configured with on demand SSB transmission is deactivated/not transmitted.

[0118] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE with the MAC CE format **800** to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **502** may determine that an on demand SSB transmission is transmitted (or activated/triggered) by a gNB for the j^{th} serving cell/SCell configured with on demand SSB transmission. UE **502** may monitor/measure the on demand SSB transmission for the j^{th} serving cell/SCell configured with on demand SSB transmission in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Cj set to 1 can be included sequentially in the MAC CE in increasing order of j. If a field Cj is set to 0, UE **502** may determine that an on demand SSB transmission is not transmitted (or is deactivated) by the gNB for the j^{th} serving cell/SCell configured with on demand SSB transmission. UE **502** may stop monitoring/measuring the on demand SSB transmission for the j^{th} serving cell/SCell configured with on demand SSB in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0119] In some embodiments, the duration for which on demand SSB is transmitted for SCell can be included/indicated in the MAC CE or in an RRC message. If a bit Cj is set to 1 and a duration is included/indicated in the MAC CE or RRC message for the j^{th} serving cell/SCell, UE **502** may start the on demand SSB activation timer for the serving cell/SCell or UE **502** may restart the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is already running or UE may stop the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer or UE **502** may continue the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is not running. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is running. The on demand SSB activation timer for the serving cell/SCell is stopped when serving cell/SCell is deactivated or when on demand SSB for serving cell/SCell is deactivated.

[0120] Alternately, in some embodiments, the MAC subheader may include a LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger on demand SSB transmission can be predefined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **9**A and **9**B. The LCID/eLCID may be different for the formats shown in FIGS. **9**A and **9**B.

[0121] FIGS. **9**A and **9**B illustrate another example MAC CE format **900** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIGS. **9**A and **9**B is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0122] In the example of FIG. **9**A, MAC CE format **900** includes a first octet including one R bit and 7 Cj bits, and a second octet including one R bit, and 7 Aj (or Ak) bits. In some embodiments, the format shown in FIG. **9**A may be used for a case where a highest ServCellIndex or SCellIndex for which on demand SSB transmission is configured is <8.

[0123] In the example of FIG. **9**B, MAC CE format **900** includes four octets including one R bit and 31 Cj bits, and in some embodiments another four octets including one R bit, and 31 Aj (or Ak) bits. In some embodiments, the additional four octets may include 32 Ak bits and no R bits (i.e., A0 replaces R).

[0124] In some embodiments, the format shown in FIG. **9**B may be used for a case where highest ServCellIndex or SCellIndex for which on demand SSB transmission is configured is >=8.

[0125] Although FIGS. **9**A and **9**B illustrate one example MAC CE format **900**, various changes may be made to FIGS. **9**A and **9**B. For example, various changes to number of R bits could be made, the number of Cj bits could vary, etc. according to particular needs.

[0126] In some embodiments, for MAC CE format **900**, a field Cj may be set to 1 to indicate that on demand SSB transmission for an SCell identified by ServCellIndex j or SCellIndex j is indicated by bit Aj. Alternately, in some embodiments, a field Cj may be set to 0 to indicate that on demand SSB transmission for the SCell identified by Serv-

CellIndex j or SCellIndex j is not indicated in this MAC CE. In some embodiments, a field Aj may be set to 1 to indicate that on demand SSB transmission for the SCell identified by ServCellIndex j or SCellIndex j is activated/triggered/transmitted. Alternately, in some embodiments, a field Aj may be set to 0 to indicate that on demand SSB transmission for the SCell identified by ServCellIndex j or SCellIndex j is deactivated/not transmitted.

[0127] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **502** determines that the status of on demand SSB transmission for an SCell identified by ServCellIndex j or SCellIndex j is indicated by a bit Aj. If a field Aj is set to 1, UE **502** may determine that an on demand SSB transmission is transmitted (or activated/triggered) by a gNB for the serving cell/SCell identified by ServCellIndex j or SCellIndex j. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell identified by ServCellIndex j or SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE for a serving cell/SCell for which Aj is set to 1. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Aj set to 1 can be included sequentially in the MAC CE in increasing order of ServCellIndex j or SCellIndex j. If a field Aj is set to 0, UE **502** may determine that on an demand SSB transmission is not transmitted (or is deactivated) by the gNB for the serving cell/SCell identified by ServCellIndex j or SCellIndex j. UE **502** may stop monitoring/measuring the on demand SSB transmission for the serving cell/SCell identified by ServCellIndex j or SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand may not be included in the MAC CE for a serving cell/SCell for which Cj or Aj is set to 0.

[0128] In some embodiments, the duration for which on demand SSB is transmitted for an SCell can be included/indicated in the MAC CE or in an RRC message. If a bit Aj is set to 1 and a duration is included/indicated in the MAC CE or RRC message for the serving cell/SCell for which the bit Aj applies, UE **502** may start the on demand SSB activation timer for the serving cell/SCell or UE **502** may restart the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is already running or UE **502** may stop the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer or UE **502** may continue the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is not running. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is running. The on demand SSB activation timer for the serving cell/SCell is stopped when serving cell/SCell is deactivated or when on demand SSB for serving cell/SCell is deactivated.

[0129] Alternately, in some embodiments, the MAC subheader may include an LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is a MAC CE to trigger on demand SSB transmission can be predefined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **9**A and **9**B. The LCID/eLCID may be different for the formats shown in FIGS. **9**A and **9**B.

[0130] In some embodiments, for MAC CE format **900**, a field Cj may be set to 1 to indicate that on demand SSB transmission for an SCell identified by ServCellIndex j or SCellIndex j is indicated in the MAC CE. Alternately, in some embodiments, a field Cj may be set to 0 to indicate that the status of on demand SSB transmission for the SCell identified by ServCellIndex j or SCellIndex j is not indicated in this MAC CE.

[0131] In some embodiments, if the "R" bit in an Ak bit map is used as A0, SCells for which a field Cj is set to 1 are sequentially indexed starting from zero in increasing order of ServCellIndex or SCellIndex. In some embodiments, a single octet Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 0 and less than 9. In some embodiments, a two octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 8 and less than 17. In some embodiments, a three octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 16 and less than 25. In some embodiments, a four octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is configured is greater than 24. Otherwise, if the "R" bit in the Ak bit map is not used as A0, SCells for which Cj field is set to 1 are sequentially indexed starting from one in increasing order of ServCellIndex or SCellIndex. In some embodiments, a single octet Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 0 and less than 8. In some embodiments, a two octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 7 and less than 16. In some embodiments, a three octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is greater than 15 and less than 24. In some embodiments, a four octets Ak bitmap may be included in MAC CE format **900** if the total number of SCells for which a bit Cj is set to 1 is configured is greater than 23.

[0132] In some embodiments, a field Ak set to 1 may indicate that on demand SSB transmission for a kth SCell for which a Cj bit is set to 1 is activated/triggered/transmitted. In some embodiments, a field Ak set to 0 may indicate that on demand SSB transmission for the kth SCell for which a bit Cj is set to 1 is deactivated/not transmitted.

[0133] In some embodiments, the duration for which on demand SSB is transmitted for an SCell can be included/indicated in the MAC CE or in an RRC message. If a bit Ak is set to 1 and a duration is included/indicated in the MAC CE or RRC message for the serving cell/SCell for which the bit Ak applies, UE **502** may start the on demand SSB activation timer for the serving cell/SCell or UE **502** may restart the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is already running or UE **502** may stop the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer or UE **502** may continue the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer is already running or UE **502** may start the on demand SSB activation timer for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is not running. UE **502** may monitor/measure the on demand SSB transmission for the serving cell/SCell if the on demand SSB activation timer for the serving cell/SCell is running. The on demand SSB activation timer for the serving cell/SCell is stopped when serving cell/SCell is deactivated or when on demand SSB for serving cell/SCell is deactivated.

[0134] Upon receiving the TB at step **550**, UE **502** may identify that the TB includes a MAC CE to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **502** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **502** may determine that the status of on demand SSB transmission for an SCell identified by ServCellIndex j or SCellIndex j is indicated in the MAC CE. If a field Ak is set to 1, UE **502** may determine that an on demand SSB transmission is transmitted (activated/triggered) by a gNB for the kth serving cell/SCell for which the field Cj is set to 1. UE **502** may monitor/measure the on demand SSB transmission for the kth serving cell/SCell for which the field Cj is set to 1 in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message) and Ak is set to 1. In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Ak set to 1 can be included sequentially in the MAC CE in increasing order of k. If a field Ak is set to 0, UE **502** may determine that an on demand SSB transmission is not transmitted (or is deactivated) by the gNB for the kth serving cell/SCell for which the field Cj is set to 1. UE **502** may stop monitoring/measuring the on demand SSB transmission for the kth serving cell/SCell for which the field Cj is set to 1 in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0135] In some embodiments, an RRCReconfiguration message (e.g., as transmitted at step **520**) may configure one or more SCells. The RRCReconfiguration message may indicate an SCell state as activated for one or more configured SCells. For an SCell configured in the message and with the SCell state as activated (or for an SCell configured in the message), if the on demand SSB transmission for SCell operation is configured for this SCell, UE **502** may determine/assume that on demand SSB transmission is transmitted (activated/triggered) by a gNB for the SCell. UE **502** may monitor/measure the on demand SSB transmission for the SCell in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0136] In some embodiments, an RRCReconfiguration message (e.g., as transmitted at step **520**) may configure one or more SCells. The RRCReconfiguration message may indicate an SCell state as activated for one or more configured SCells. For an SCell configured in the message and with the SCell state as activated (or for an SCell configured in the message), if the on demand SSB transmission for SCell operation is configured for this SCell, the RRCReconfiguration message may indicate whether an on demand SSB is transmitted (activated/triggered) by a gNB for the SCell or not. If the RRCReconfiguration message indicates that on an demand SSB is transmitted (activated/triggered) by the gNB for the SCell, UE **502** may monitor/measure the on demand SSB transmission for the SCell in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0137] In some embodiments, an RRCReconfiguration message (e.g., as transmitted at step **520**) may configure one or more SCells. For an SCell configured in the message, if the on demand SSB transmission for SCell operation is configured for this SCell, the RRCReconfiguration message may indicate that on demand SSB is transmitted (activated/triggered) by a gNB for the SCell when the SCell is activated. In this case upon receiving the activation command for the SCell or if the RRCReconfiguration message indicates that the SCell state for the SCell is activated, on demand SSB transmission is considered as being transmitted (activated/triggered) by the gNB for the SCell and UE **502** may monitor/measure the on demand SSB transmission for the SCell in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0138] FIG. **10** illustrates another example signal flow **1000** between a UE and a gNB for triggering on demand SSB transmission for SCell operation according to embodiments of the present disclosure. An embodiment of the signal flow illustrated in FIG. **10** is for illustration only. One or more of the components illustrated in FIG. **10** may be implemented in specialized circuitry configured to perform the noted functions or one or more of the components may be implemented by one or more processors executing instructions to perform the noted functions. Other embodiments of a signal flow between a UE and a gNB for triggering on demand SSB transmission for SCell operation could be used without departing from the scope of this disclosure.

[0139] In the example of FIG. **10**, signal flow **1000** is between a UE **1002** and a gNB **1004**. UE **1002** is in an RRC_CONNECTED state.

[0140] Signal flow **1000** begins at step **1010**. At step **1010**, UE **1002** indicates UE **1002**'s capability to support on demand SSB transmission for SCell operation. UE **502**'s capability can be indicated in an RRC message, UCI, MAC CE, etc. This capability can be a per UE capability, or this capability can be a per frequency capability, or this capability can be a per frequency band capability, or this capability can be a per frequency range (FR1, FR2-1, FR2-2, FR2-NTN, etc.) capability. For example, FR1 can be a frequency range from 410 MHz-7125 MHz, FR2-1 can be a frequency range from 24250 MHz-52600 MHZ, FR2-2 can be a frequency range from 52600 MHz-71000 MHz, FR2-NTN can be frequency range from 17300 MHz-30000 MHz, etc.

[0141] At step **1020**, gNB **1004** sends an RRCReconfiguration message, wherein the message includes a configuration of one or more SCells. The message may indicate whether gNB **1004** supports on demand SSB transmission for the configured SCell(s). This indication can be common for all configured SCells, or this indication can be per configured SCell. gNB **1004** may indicate support of on demand SSB transmission for zero, one or more configured SCells. For each configured SCell for which gNB **1004** supports on demand SSB transmission, gNB **1004** may provide/signal (e.g., in an RRCReconfiguration message) the configuration indicating time and frequency location(s) of on demand SSB transmissions. This configuration can be per BWP of the configured SCell(s) or can be common for all BWPs of the configured SCell(s).

[0142] At step **1030**, gNB **1004** determines to activate one or more SCells and triggers on demand SSB transmission for one or more configured SCell(s).

[0143] At step **1040**, gNB **1004** transmits a PDCCH addressed to a C-RNTI or addressed to an a RNTI which can be pre-defined or configured previously in an RRCReconfiguration message. The PDCCH includes scheduling information for a DL TB.

[0144] At step **1050**, gNB **1004** then transmits a TB including a MAC subPDU. The MAC subPDU includes a MAC subheader and MAC CE which triggers on demand SSB transmission for one or more SCell(s) and also activates one or more SCell(s). This MAC CE can also be referred to as an Enhanced SCell Activation/Deactivation MAC CE.

[0145] Although FIG. **10** illustrates one example signal flow **1000** between a UE and a gNB for triggering on demand SSB transmission for SCell operation, various changes may be made to FIG. **10**. For example, while shown as a series of steps, various steps in FIG. **10** could overlap, occur in parallel, occur in a different order, occur any number of times, be omitted, or replaced by other steps.

[0146] In some embodiments, the MAC subheader may include an LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is an Enhanced SCell Activation/Deactivation MAC CE to activate and trigger on demand SSB transmission can be pre-defined. A MAC CE format to activate and trigger on demand SSB transmission for SCell operation is shown in FIGS. **11**A and **11**B. The LCID/eLCID may be different for the formats shown in FIGS. **11**A and **11**B.

[0147] FIGS. **11**A and **11**B illustrate another example MAC CE format **1100** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIGS. **11**A and **11**B is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0148] In the example of FIG. **11**A, MAC CE format **1100** includes a first octet including one R bit and 7 Cj bits, and a second octet including one R bit, and 7 Aj (or Ak) bits.

[0149] In the example of FIG. **11**B, MAC CE format **1100** includes four octets including one R bit and 31 Cj bits, and in some embodiments another four octets including one R bit, and 31 Aj (or Ak) bits.

[0150] Although FIGS. **11**A and **11**B illustrate one example MAC CE format **1100**, various changes may be made to FIGS. **11**A and **11**B. For example, various changes to number of R bits could be made, the number of Cj bits could vary, etc. according to particular needs.

[0151] In some embodiments, for MAC CE format **1100**, if there is an SCell configured for the MAC entity with SCellIndex j, a field Cj may indicate the activation/deactivation status of the SCell with SCellIndex j. A field Cj may be set to 1 to indicate that an SCell identified by SCellIndex j is activated. A field Cj may be set to 0 to indicate that and SCell identified by SCellIndex j is not activated (or deactivated). In some embodiments, if there is an SCell configured with on demand SSB transmission for the MAC entity with SCellIndex j, a field Aj may indicate the activation/deactivation status of on demand SSB transmission for the SCell with SCellIndex j. A field Aj may be set to 1 to indicate that on demand SSB transmission for the SCell identified by SCellIndex j is activated/triggered/transmitted. A field Aj may be set to 0 to indicate that on demand SSB transmission for the SCell identified by ServCellIndex j or SCellIndex j is deactivated/not transmitted.

[0152] Upon receiving the TB at step **1050**, UE **1002** may identify that the TB includes an enhanced SCell Activation/Deactivation MAC CE. If a field Cj is set to 1, UE **1002** may determine that the field Cj is an activation command for an SCell identified by SCellIndex j. If a field Cj is set to 0, UE **1002** may determine that the field Cj is a deactivation command for the SCell identified by SCellIndex j. If a field Aj is set to 1, UE **1002** may determine that an on demand SSB transmission is transmitted (activated/triggered) by gNB **1004** for the SCell identified by SCellIndex j. UE **1002** may monitor/measure the on demand SSB transmission for the SCell identified by SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Aj set to 1 can be included sequentially in the MAC CE in increasing order of j. If a field Aj is set to 0, UE **1002** may determine that an on demand SSB is not transmitted (or deactivated) by gNB **1004** for the SCell identified by SCellIndex j. UE **1002** may stop monitoring/measuring the on demand SSB transmission for the SCell identified by SCellIndex j in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0153] Alternately, in some embodiments, the MAC subheader may include a LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is an Enhanced SCell Activation/Deactivation MAC CE to activate and trigger on demand SSB transmission can be predefined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **11**A and **11**B. The LCID/eLCID may be different for the formats shown in FIGS. **11**A and **11**B.

[0154] In some embodiments, for MAC CE format **1100**, if there is an SCell configured for the MAC entity with SCellIndex j, a field Cj may indicate the activation/deactivation status of the SCell with SCellIndex j. A field set to 1 may indicate that an SCell identified by SCellIndex j is activated. A field Cj set to 0 may indicate that the SCell identified by SCellIndex j is not activated (or deactivated).

[0155] In some embodiments, SCells for which a field Cj is set to 1 are sequentially indexed starting from one in increasing order of SCellIndex. A single octet Ak bitmap may be included in the MAC CE format **1100** if the total number of SCells for which a bit Cj is set to 1 is greater than 0 and less than 8. A two octets Ak bitmap may be included in the MAC CE format **1100** if the total number of SCells for which a bit Cj is set to 1 is greater than 7 and less than 16. A three octets Ak bitmap may be included in the MAC CE format **1100** if the total number of SCells for which a bit Cj is set to 1 is greater than 15 and less than 24. A four octets Ak bitmap may be included in the MAC CE format **1100** if the total number of SCells for which a bit Cj is set to 1 is configured is greater than 23. A field Ak may be set to 1 to indicate that on demand SSB transmission for the kth SCell for which bit Cj is set to 1 is activated/triggered/transmitted. An Ak field may be set to 0 to indicate that on demand SSB transmission for the kth SCell for which a bit Cj is set to 1 is deactivated/not transmitted.

[0156] Upon receiving the TB at step **1050**, UE **1002** may identify that the TB includes a MAC CE to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **1002** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **1002** may determine that the field Cj is an activation command for an SCell identified by SCellIndex j. If a field Cj is set to 0, UE **1002** may determine that the field Cj is an deactivation command for the SCell identified by SCellIndex j. If a field Ak is set to 1, UE **1002** may determine that on demand SSB is transmitted (activated/triggered) by gNB **1004** for the kth SCell for which a field Cj is set to 1. UE **1002** may monitor/measure the on demand SSB transmission for the kth SCell for which a field Cj is set to 1 in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with an Ak field is set to 1 can be included sequentially in the MAC CE in increasing order of k. If a field Ak is set to 0, UE **1002** may determine that an on demand SSB is not transmitted (or deactivated) by gNB **1004** for the kth SCell for which a field Cj is set to 1. The UE stops to monitor/measure the on demand SSB transmission for the kth SCell for which a Cj field is set to 1 in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0157] Alternately, in some embodiments, the MAC subheader may include a LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is an (Enhanced) SCell Activation/Deactivation MAC CE to activate the SCell and trigger on demand SSB transmission can be pre-defined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **12**A and **12**B. The LCID/eLCID may be different for the formats shown in FIGS. **12**A and **12**B.

[0158] FIGS. **12**A and **12**B illustrate an example MAC CE format **1200** according to embodiments of the present disclosure. The embodiment of a MAC CE format of FIGS. **12**A and **12**B is for illustration only. Different embodiments of a MAC CE format could be used without departing from the scope of this disclosure.

[0159] In the example of FIG. **12**A, MAC CE format **1200** includes one A bit and 7 Cj bits.

[0160] In the example of FIG. **12**B, MAC CE format **1200** includes one R bit and 31 Cj bits.

[0161] Although FIGS. **12**A and **12**B illustrate one example MAC CE format **1200**, various changes may be made to FIGS. **12**A and **12**B. For example, various changes to number of A bits could be made, the number of Cj bits could vary, etc. according to particular needs.

[0162] In some embodiments, for MAC CE format **1200**, if there is an SCell configured for the MAC entity with SCellIndex j, a field Cj may indicate the activation/deactivation status of the SCell with SCellIndex j. A field Cj set to 1 may indicate that the SCell identified by SCellIndex j is activated. A field Cj set to 0 may indicate that the SCell identified by SCellIndex j is not activated (or deactivated). The 'A' field set to 1 may indicate that on demand SSB transmission for SCell(s) for which a bit Cj is set to 1 and for which on demand SSB transmission is configured (or the activated/status is activated in RRCReconfiguration or for which the RRC indicates that activation is via the MAC CE), is activated/triggered/transmitted. The 'A' field set to 0 may indicate that on demand SSB transmission for SCell(s) for which a bit Cj is set to 1 and on demand SSB transmission is configured is deactivated/not transmitted.

[0163] Upon receiving the TB at step **1050**, UE **1002** may identify that the TB includes a MAC CE to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **1002** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies.

[0164] If a field Cj is set to 1, UE **1002** may determine that the field Cj is an activation command for the SCell identified by SCellIndex j. If the field Cj is set to 0, UE **1002** may determine that the field Cj is a deactivation command for the SCell identified by SCellIndex j. If the 'A' field is set to 1, UE **1002** may determine/assume/consider that an on demand SSB transmission is transmitted (activated/triggered) by gNB **1004** for the SCell(s) for which the field Cj is set to 1 and for which on demand SSB transmission is configured (or activated/status is activated in RRCReconfiguration or for which RRC indicates that activation is via the MAC CE). UE **1002** may monitor/measure the on demand SSB transmission for the SCell(s) for which a field Cj is set to 1 and for which on demand SSB transmission is configured (or activated/status is activated in RRCReconfiguration or for which RRC indicates that activation is via the MAC CE), in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell with a field Cj set to 1 and for which on demand SSB transmission is configured (or activated/status is activated in RRCReconfiguration or for which RRC indicates that activation is via the MAC CE) can be included sequentially in the MAC CE in increasing order of j. If the 'A' field is set to 0, UE **1002** may determine/assume/consider that an on demand SSB is not transmitted (or deactivated) by gNB **1004** for the SCell(s) for which a field Cj is set to 1 and for which on demand SSB transmission is configured (or activated/status is activated in RRCReconfiguration or for which RRC indicates that activation is via the MAC CE). UE **1002** may stop monitoring/measuring the on demand SSB transmission for the SCell(s) for which a field Cj is set to 1 and for which on demand SSB transmission is configured, in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message).

[0165] Alternately, in some embodiments, the MAC subheader may include an LCID/eLCID. The MAC subheader may also include a length field. An LCID/eLCID to indicate that the MAC CE in the MAC subPDU payload is an (Enhanced) SCell Activation/Deactivation MAC CE to activate the SCell and trigger on demand SSB transmission can be pre-defined. A MAC CE format to trigger on demand SSB transmission for SCell operation is shown in FIGS. **12**A and

12B. The LCID/eLCID may be different for the formats shown in FIGS. 12A and 12B.

[0166] In some embodiments, for MAC CE format **1200**, if there is an SCell configured for the MAC entity with a SCellIndex j, a field Cj may indicate the activation/deactivation status of the SCell with the SCellIndex j. A field Cj set to 1 may indicate that the SCell identified by SCellIndex j is activated. A field Cj set to 0 may indicate that the SCell identified by SCellIndex j is not activated (or deactivated). The 'A' field set to 1 may indicate that on demand SSB transmission for SCell(s) for which on demand SSB transmission is configured is activated/triggered/transmitted. The 'A' field set to 0 may indicate that on demand SSB transmission for SCell(s) for which on demand SSB transmission is configured is deactivated/not transmitted.

[0167] Upon receiving the TB at step **1050**, UE **1002** may identify that the TB includes a MAC CE to trigger on demand SSB transmission based on the LCID/eLCID field in the MAC subheader. UE **1002** then may identify the serving cell(s)/SCell(s) for which the MAC CE applies. If a field Cj is set to 1, UE **1002** may determine that the field Cj is an activation command for the SCell identified by SCellIndex j. If a field Cj is set to 0, UE **1002** may determine that the field Cj is a deactivation command for the SCell identified by SCellIndex j. If the 'A' field is set to 1, UE **1002** may determine/assume/consider that on an demand SSB is transmitted (activated/triggered) by a gNB for the SCell(s) for which on demand SSB transmission is configured. UE **1002** may monitor/measure the on demand SSB transmission for the SCell(s) for which on demand SSB transmission is configured, in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE. The time/frequency location(s) and/or SSB(s) transmitted on demand for each SCell for which on demand SSB transmission is configured can be included sequentially in the MAC CE in increasing order of SCellIndex j. If the 'A' field is set to 0, UE **1002** may determine/assume/consider that an on demand SSB transmission is not transmitted (or deactivated) by a gNB for the SCell(s) for which on demand SSB transmission is configured. UE **1002** may stop monitoring/measuring the on demand SSB transmission for the SCell(s) for which on demand SSB transmission is configured, in the time/frequency locations configured by the network (e.g., in an RRCReconfiguration message). In some embodiments, the time/frequency location(s) and/or SSB(s) transmitted on demand can be included in the MAC CE.

[0168] FIG. **13** illustrates an example method **1300** for configuring and activating on demand SSB transmission in SCells according to embodiments of the present disclosure. An embodiment of the method illustrated in FIG. **13** is for illustration only. One or more of the components illustrated in FIG. **13** may be implemented in specialized circuitry configured to perform the noted functions or one or more of the components may be implemented by one or more processors executing instructions to perform the noted functions. Other embodiments of a method for configuring and activating on demand SSB transmission in SCells could be used without departing from the scope of this disclosure.

[0169] In the example of FIG. **13**, method **1300** begins at step **1310**, at step **1310**, a UE (such as UE **502** or UE **1002**) receives, from a BS (such as gNB **504** or gNB **1004**), a message including a configuration for on-demand SSB transmission for one or more SCells. In some embodiments, the message including the configuration for on-demand SSB transmission for the one or more SCells is a radio resource control (RRC) message. In some embodiments, the RRC message indicates whether on-demand SSB transmission is activated for an SCell configured with on demand SSB transmission.

[0170] At step **1320**, the UE receives, from the BS, a MAC CE indicating whether on-demand SSB transmission is activated for the one or more SCells. In some embodiments, a downlink transport block including the MAC CE may be scheduled by a PDCCH addressed to one of a RNTI configured for on-demand SSB transmission by the BS or a C-RNTI of the UE. In some embodiments, the MAC CE may include information indicating an on demand SSB configuration for the one or more SCells for which on-demand SSB transmission is activated.

[0171] At step **1330**, the UE determines, based on the MAC CE, whether on-demand SSB transmission is activated for an SCell configured with on-demand SSB transmission.

[0172] At step **1340**, in response to a determination that on-demand SSB transmission is activated for the SCell, the UE measures the on-demand SSB transmission for the SCell.

[0173] In some embodiments, the MAC CE may include a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells, and the UE may determine a size of the bitmap based on a highest serving cell index amongst serving cell indexes of the one or more SCells configured for on-demand SSB transmission. When the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is less than eight, the MAC CE may include a bitmap of size eight. When the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is not less than eight, the MAC CE may include a bitmap of size thirty-two.

[0174] In some embodiments, the UE may determine if a j^{th} bit of the bitmap corresponding to a serving cell index j of an SCell configured with on demand SSB transmission is set to one or zero. When the j^{th} bit of the bitmap corresponding to the serving cell index j of an SCell configured with on demand SSB transmission is set to one, on demand SSB transmission for the SCell may be activated. When the j^{th} bit of the bitmap corresponding to the serving cell index j of the SCell configured with on demand SSB transmission is set to zero, on demand SSB transmission for the SCell may be deactivated.

[0175] In some embodiments, the MAC CE may include a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells, and the UE may determine a size of the bitmap based on a total number of SCells configured for on-demand SSB transmission. When the total number of SCells configured for on-demand SSB transmission is greater than zero and less than eight, the MAC CE may include a bitmap of size eight. When the total number of SCells configured for on-demand SSB transmission is greater than seven and less than sixteen, the MAC CE may include a bitmap of size sixteen. When the total number of SCells configured for on-demand SSB transmission is greater than fifteen and less than twenty-four, the MAC CE may include a bitmap of size twenty-four. When the total number of SCells configured for on-demand SSB transmission is greater than twenty-three, the MAC CE may include a bitmap of size thirty-two.

[0176] In some embodiments, the UE may determine whether a j^{th} bit of the bitmap corresponding to a serving cell index j of an SCell configured with on demand SSB transmission is set to one or zero. When the j^{th} bit of the bitmap corresponding to the serving cell index j of an SCell configured with on demand SSB transmission is set to one, on demand SSB transmission for the SCell may be activated. When the j^{th} bit of the bitmap corresponding to the serving cell index j of the SCell configured with on demand SSB transmission is set to zero, on demand SSB transmission for the SCell may be deactivated.

[0177] In some embodiments, the MAC CE may include a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells, and the UE may determine a size of the bitmap based on a total number of SCells configured for on-demand SSB transmission. When the total number of SCells configured for on-demand SSB transmission is greater than zero and less than eight, the MAC CE may include a bitmap of size eight. When the total number of SCells configured for on-demand SSB transmission is greater than seven and less than sixteen, the MAC CE may include a bitmap of size sixteen. When the total number of SCells configured for on-demand SSB transmission is greater than fifteen and less than twenty-four, the MAC CE may include a bitmap of size twenty-four. When the total number of SCells configured for on-demand SSB transmission is greater than twenty-three, the MAC CE may include a bitmap of size thirty-two.

[0178] In some embodiments, the UE may sequentially index the SCells configured with on demand SSB transmission in increasing order of a respective serving cell index of each SCell configured with on demand SSB transmission.

[0179] In some embodiments, the UE may determine whether a j^{th} bit of the bitmap corresponding to a j^{th} SCell configured with on demand SSB transmission is set to one or zero. When the j^{th} bit of the bitmap corresponding to the j^{th} SCell configured with on demand SSB transmission is set to one, on demand SSB transmission for the j^{th} SCell may be activated. When the j^{th} bit of the bitmap corresponding to the j^{th} SCell configured with on demand SSB transmission is set to zero, on demand SSB transmission for the j^{th} SCell may be deactivated.

[0180] Although FIG. **13** illustrates one example method **1300** for configuring and activating on demand SSB transmission in SCells, various changes may be made to FIG. **13**. For example, while shown as a series of steps, various steps in FIG. **13** could overlap, occur in parallel, occur in a different order, occur any number of times, be omitted, or replaced by other steps.

[0181] FIG. **14** illustrates another example method **1400** for configuring and activating on demand SSB transmission in SCells according to embodiments of the present disclosure. An embodiment of the method illustrated in FIG. **14** is for illustration only. One or more of the components illustrated in FIG. **14** may be implemented in specialized circuitry configured to perform the noted functions or one or more of the components may be implemented by one or more processors executing instructions to perform the noted functions. Other embodiments of a method for configuring and activating on demand SSB transmission in SCells could be used without departing from the scope of this disclosure.

[0182] In the example of FIG. **14**, method **1400** begins at step **1410**, at step **1410**, a BS (such as gNB **504** or gNB **1004**) transmits, to a UE (such as UE **502** or UE **1002**), a message including a configuration for on-demand SSB transmission for one or more SCells. In some embodiments, the message including the configuration for on-demand SSB transmission for the one or more SCells may be a radio resource control (RRC) message. In some embodiments, the RRC message may indicate whether on-demand SSB transmission is activated for an SCell configured with on demand SSB transmission.

[0183] At step **1420**, the BS transmits, to the UE, a MAC CE indicating whether on-demand SSB transmission is activated for the one or more SCells. In some embodiments, the MAC CE may include information indicating an on demand SSB configuration for the one or more SCells for which on-demand SSB transmission is activated.

[0184] In some embodiments, a downlink transport block including the MAC CE is scheduled by a physical downlink control channel addressed to one of a radio network temporary identifier (RNTI) configured for on-demand SSB transmission by the BS or a cell RNTI (C-RNTI) of the UE.

[0185] In some embodiments, the MAC CE may include a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells, and the BS may generate the bitmap with a size based on a highest serving cell index amongst serving cell indexes of the one or more SCells configured for on-demand SSB transmission. When the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is less than eight, the MAC CE may include a bitmap of size eight. When the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is not less than eight, the MAC CE may include a bitmap of size thirty-two.

[0186] In some embodiments, the BS may determine whether on demand SSB transmission is activated for an SCell configured with on demand SSB transmission with a serving cell index j, set a j^{th} bit of the bitmap corresponding to the serving cell index j to one when on demand SSB transmission is activated for the SCell configured with on demand SSB, and set the j^{th} bit of the bitmap corresponding to the serving cell index j to zero when on demand SSB transmission is not activated for the SCell configured with on demand SSB.

[0187] In some embodiments, the MAC CE includes a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells, and the BS may generate the bitmap with a size based on a total number of SCells configured for on-demand SSB transmission. When the total number of SCells configured for on-demand SSB transmission is greater than zero and less than eight, the MAC CE may include a bitmap of size eight. When the total number of SCells configured for on-demand SSB transmission is greater than seven and less than sixteen, the MAC CE may include a bitmap of size sixteen. When the total number of SCells configured for on-demand SSB transmission is greater than fifteen and less than twenty-four, the MAC CE may include a bitmap of size twenty-four. When the total number of SCells configured for on-demand SSB transmission is greater than twenty-three, the MAC CE may include a bitmap of size thirty-two.

[0188] In some embodiments, the BS may sequentially index the SCells configured with on demand SSB transmission in increasing order of a respective serving cell index of each SCell configured with on demand SSB transmission.

[0189] In some embodiments, the BS may determine whether on demand SSB transmission is activated for a j^{th} SCell configured with on demand SSB transmission, set a j^{th} bit of the bitmap corresponding to the one when on demand SSB transmission is activated for the j^{th} SCell configured with on demand SSB, and set the j^{th} bit of the bitmap to zero when on demand SSB transmission is not activated for the j^{th} SCell configured with on demand SSB.

[0190] Although FIG. **14** illustrates one example method **1400** for configuring and activating on demand SSB transmission in SCells, various changes may be made to FIG. **14**. For example, while shown as a series of steps, various steps in FIG. **14** could overlap, occur in parallel, occur in a different order, occur any number of times, be omitted, or replaced by other steps.

[0191] Any of the above variation embodiments can be utilized independently or in combination with at least one other variation embodiment. The above flowcharts illustrate example methods that can be implemented in accordance with the principles of the present disclosure and various changes could be made to the methods illustrated in the flowcharts herein. For example, while shown as a series of steps, various steps in each figure could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

[0192] Although the present disclosure has been described with exemplary embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims. None of the description in this application should be read as implying that any particular element, step, or function is an essential element that must be included in the claim scope. The scope of patented subject matter is defined by the claims.

1. A user equipment (UE) comprising:
a transceiver configured to:
receive, from a base station (BS), a message including a configuration for on-demand synchronization signal block (SSB) transmission for one or more secondary cells (SCells); and
receive, from the BS, a medium access control (MAC) control element (CE) indicating whether on-demand SSB transmission is activated for the one or more SCells; and
a processor operably coupled to the transceiver, the processor configured to:
determine, based on the MAC CE, whether on-demand SSB transmission is activated for an SCell configured with on-demand SSB transmission; and
in response to a determination that on-demand SSB transmission is activated for the SCell, measure the on-demand SSB transmission for the SCell.

2. The UE of claim **1**, wherein a downlink transport block including the MAC CE is scheduled by a physical downlink control channel (PDCCH) addressed to one of a radio network temporary identifier (RNTI) configured for on-demand SSB transmission by the BS or a cell RNTI (C-RNTI) of the UE.

3. The UE of claim **1**, wherein:
the MAC CE includes a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells;
the processor is further configured to determine a size of the bitmap based on a highest serving cell index amongst serving cell indexes of the one or more SCells configured for on-demand SSB transmission;
when the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is less than eight, the MAC CE includes a bitmap of size eight; and
when the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is not less than eight, the MAC CE includes a bitmap of size thirty-two.

4. The UE of claim **3**, wherein:
the processor is further configured to determine whether a j^{th} bit of the bitmap corresponding to a serving cell index j of an SCell configured with on demand SSB transmission is set to one or zero;
when the j^{th} bit of the bitmap corresponding to the serving cell index j of an SCell configured with on demand SSB transmission is set to one, on demand SSB transmission for the SCell is activated; and
when the j^{th} bit of the bitmap corresponding to the serving cell index j of the SCell configured with on demand SSB transmission is set to zero, on demand SSB transmission for the SCell is deactivated.

5. The UE of claim **1**, wherein:
the MAC CE includes a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells;
the processor is further configured to determine a size of the bitmap based on a total number of SCells configured for on-demand SSB transmission;
when the total number of SCells configured for on-demand SSB transmission is greater than zero and less than eight, the MAC CE includes a bitmap of size eight;
when the total number of SCells configured for on-demand SSB transmission is greater than seven and less than sixteen, the MAC CE includes a bitmap of size sixteen;
when the total number of SCells configured for on-demand SSB transmission is greater than fifteen and less than twenty-four, the MAC CE includes a bitmap of size twenty-four; and
when the total number of SCells configured for on-demand SSB transmission is greater than twenty-three, the MAC CE includes a bitmap of size thirty-two.

6. The UE of claim **5**, wherein the processor is further configured to sequentially index the SCells configured with on demand SSB transmission in increasing order of a respective serving cell index of each SCell configured with on demand SSB transmission.

7. The UE of claim **6**, wherein:
the processor is further configured to determine whether a j^{th} bit of the bitmap corresponding to a j^{th} SCell configured with on demand SSB transmission is set to one or zero;
when the j^{th} bit of the bitmap corresponding to the j^{th} SCell configured with on demand SSB transmission is set to one, on demand SSB transmission for the j^{th} SCell is activated; and

when the j^{th} bit of the bitmap corresponding to the j^{th} SCell configured with on demand SSB transmission is set to zero, on demand SSB transmission for the j^{th} SCell is deactivated.

8. The UE of claim **1**, wherein the MAC CE includes information indicating an on demand SSB configuration for the one or more SCells for which on-demand SSB transmission is activated.

9. The UE of claim **1**, wherein the message including the configuration for on-demand SSB transmission for the one or more SCells is a radio resource control (RRC) message.

10. The UE of claim **9**, wherein the RRC message indicates whether on-demand SSB transmission is activated for an SCell configured with on demand SSB transmission.

11. A base station (BS) comprising:

a processor; and

a transceiver operatively coupled to the processor, the transceiver configured to:

transmit, to a user equipment (UE), a message including a configuration for on-demand synchronization signal block (SSB) transmission for one or more secondary cells (SCells); and

transmit, to the UE, a medium access control (MAC) control element (CE) indicating whether on-demand SSB transmission is activated for the one or more SCells.

12. The BS of claim **11**, wherein a downlink transport block including the MAC CE is scheduled by a physical downlink control channel addressed to one of a radio network temporary identifier (RNTI) configured for on-demand SSB transmission by the BS or a cell RNTI (C-RNTI) of the UE.

13. The BS of claim **11**, wherein:

the MAC CE includes a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells;

the processor is configured to generate the bitmap with a size based on a highest serving cell index amongst serving cell indexes of the one or more SCells configured for on-demand SSB transmission;

when the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is less than eight, the MAC CE includes a bitmap of size eight; and

when the highest serving cell index amongst the serving cell indexes of the one or more SCells configured with on demand SSB transmission is not less than eight, the MAC CE includes a bitmap of size thirty-two.

14. The BS of claim **13**, wherein the processor is further configured to:

determine whether on demand SSB transmission is activated for an SCell configured with on demand SSB transmission with a serving cell index j;

set a j^{th} bit of the bitmap corresponding to the serving cell index j to one when on demand SSB transmission is activated for the SCell configured with on demand SSB; and

set the j^{th} bit of the bitmap corresponding to the serving cell index j to zero when on demand SSB transmission is not activated for the SCell configured with on demand SSB.

15. The BS of claim **13**, wherein:

the MAC CE includes a bitmap indicating whether on-demand SSB transmission is activated for the one or more SCells;

the processor is further configured generate the bitmap with a size based on a total number of SCells configured for on-demand SSB transmission;

when the total number of SCells configured for on-demand SSB transmission is greater than zero and less than eight, the MAC CE includes a bitmap of size eight;

when the total number of SCells configured for on-demand SSB transmission is greater than seven and less than sixteen, the MAC CE includes a bitmap of size sixteen;

when the total number of SCells configured for on-demand SSB transmission is greater than fifteen and less than twenty-four, the MAC CE includes a bitmap of size twenty-four; and

when the total number of SCells configured for on-demand SSB transmission is greater than twenty-three, the MAC CE includes a bitmap of size thirty-two.

16. The BS of claim **15**, wherein the processor is further configured to sequentially index the SCells configured with on demand SSB transmission in increasing order of a respective serving cell index of each SCell configured with on demand SSB transmission.

17. The BS of claim **16**, wherein the processor is further configured to:

determine whether on demand SSB transmission is activated for a j^{th} SCell configured with on demand SSB transmission;

set a j^{th} bit of the bitmap corresponding to the one when on demand SSB transmission is activated for the j^{th} SCell configured with on demand SSB; and

set the j^{th} bit of the bitmap to zero when on demand SSB transmission is not activated for the j^{th} SCell configured with on demand SSB.

18. The BS of claim **11**, wherein the MAC CE includes information indicating an on demand SSB configuration for the one or more SCells for which on-demand SSB transmission is activated.

19. The BS of claim **11**, wherein the message including the configuration for on-demand SSB transmission for the one or more SCells is a radio resource control (RRC) message.

20. The BS of claim **19**, wherein the RRC message indicates whether on-demand SSB transmission is activated for an SCell configured with on demand SSB transmission.

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