ON-DEMAND SYNCHRONIZATION SIGNAL BLOCK TRANSMISSION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to techniques for on-demand transmission at least one synchronization signal (SS) or at least one essential system information (SI).

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, which may be known as a network equipment (NE), supporting wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like)). Additionally, the wireless communications system may support wireless communications across various radio access technologies (RATs) including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., 5G-Advanced (5G-A), sixth generation (6G)).

SUMMARY

[0003] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an

example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on.” Further, as used herein, including in the claims, a “set” may include one or more elements.

[0004] A UE for wireless communication is described. The UE may be configured to, capable of, or operable to transmit a wake-up signal that requests one or more of at least one SS or at least one essential SI; receive cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and receive the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI includes one or more of a master information block (MIB) or a system information block type 1 (SIB1) or timing information of the at least one SS.

[0005] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to transmit a wake-up signal that requests one or more of at least one SS or at least one essential SI; receive cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and receive the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI includes one or more of a MIB or a SIB1 or timing information of the at least one SS.

[0006] A method performed or performable by a UE for wireless communication is described. The method may include transmitting a wake-up signal that requests one or more of at least SS or at least one essential SI; receiving cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and receiving the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI includes one or more of a MIB or a SIB1 or timing information of the at least one SS.

[0007] A base station for wireless communication is described. The base station may be configured to, capable of, or operable to receive a wake-up signal that requests one or more of at least one SS or at least one essential SI; transmit cell information corresponding to at least one cell associated with an on-demand transmission of the one

or more of at least one SS or at least one essential SI; and transmit the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI comprises one or more of a MIB, or a SIB1, or timing information of the at least one SS.

[0008] A processor for wireless communication by a base station is described. The processor may be configured to, capable of, or operable to receive a wake-up signal that requests one or more of at least one SS or at least one essential SI; transmit cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and transmit the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI comprises one or more of a MIB, or a SIB1, or timing information of the at least one SS.

[0009] A method performed or performable by an anchor base station for wireless communication is described. The method may include receiving a wake-up signal that requests one or more of at least one SS or at least one essential SI; transmitting cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and transmitting the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI comprises one or more of a MIB, or a SIB1, or timing information of the at least one SS.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0011] Figure 2 illustrates an example of a protocol stack in accordance with aspects of the present disclosure.

[0012] Figure 3 illustrates an example of a secondary serving cell (SCell) configuration in accordance with aspects of the present disclosure.

[0013] Figure 4A illustrates an example of a common serving cell configuration in accordance with aspects of the present disclosure.

[0014] Figure 4B is a continuation of the common serving cell configuration illustrated in Figure 4A.

[0015] Figure 5 illustrates an example of a common downlink (DL) configuration in accordance with aspects of the present disclosure.

[0016] Figure 6 illustrates an example of a DL frequency information configuration in accordance with aspects of the present disclosure.

[0017] Figure 7 illustrates an example of a deployment of energy saving cells in accordance with aspects of the present disclosure.

[0018] Figure 8 illustrates an example of a SCell configuration update information element (IE) in accordance with aspects of the present disclosure.

[0019] Figure 9 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0020] Figure 10 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0021] Figure 11 illustrates an example of a NE in accordance with aspects of the present disclosure.

[0022] Figure 12 illustrates a flowchart of a method performed by a UE in accordance with aspects of the present disclosure.

[0023] Figure 13 illustrates a flowchart of a method performed by an NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0024] The expansion of telecommunication networks has led to increased emissions and energy consumption, which adversely impact the environment. A significant contributor to network energy usage is the transmission of SS and physical broadcast channel (SS/PBCH), which are necessary for initial access to a radio access network (RAN). However, these transmissions continue even when no UE is attempting to access the network (e.g., a cell), leading to unnecessary energy consumption.

[0025] Additionally, operating expenses for telecommunication services are substantial, driven by rising mobile data traffic, increasing spectrum costs, and the need for continual investment in network infrastructure. As mobile data traffic is projected to triple in the coming years, efficient energy management in network operations has become a critical challenge.

[0026] Telecommunication networks supporting technology generations, such as 5G offers significant energy-efficiency improvements per gigabyte compared to previous generations. However, emerging 5G use cases and the adoption of millimeter wave (mmWave) technology requires a higher density of network sites and antennas. This increased infrastructure, while enhancing network performance, also introduces the risk of higher overall energy consumption and emissions unless proactive measures are taken. Without intelligent energy management, the benefits of 5G efficiency gains may be offset by the rising energy demands of additional network components.

[0027] Furthermore, in scenarios where cells and/or network nodes are densely deployed, such as small cells or distributed multiple-input multiple-output (MIMO) configurations, to boost capacity and mitigate signal blockages, improper management can lead to excessive power consumption and inflated operational expenses. During a third generation partnership project (3GPP) Release-18 study on network energy saving study, it was demonstrated that increasing the periodicity of common channels and signals in 3GPP 5G new radio (NR), from 20 milliseconds (ms) to higher values, such as 160 ms, results in significant reduction in power. Specifically, in low-traffic load scenarios, this adjustment was shown to reduce average power consumption by up to 40%.

[0028] To address the shortcomings associated with network energy consumption, the present disclosure provides techniques for on-demand synchronization signal block (SSB) transmission for network energy savings. A first set of techniques applies to triggering a request for on-demand SS and/or essential SI transmission. In one aspect, a UE may receive information of a subset of SSB indices of a first cell and an associated second cell. The UE may send a wake-up signal/channel for the second cell, if the best SSB for the first cell corresponds to one of the received subset of SSB indices. Beneficially, this wake-up signal/channel may assist the UE acquitting determining the SS and/or essential SI without undue delay, while optimizing network energy savings.

[0029] As used herein, the term "wake-up signal/channel" refers to a designated/special signal, a transmission on a designated/special channel, or both. Accordingly, the wake-up signal/channel may be a sequence-based wake-up signal (e.g., physical random access channel (PRACH) preamble on a PRACH occasion, where at least one of the PRACH preamble or the PRACH occasion is designated for requesting a network wake-up, or other reference signal). Alternatively, the wake-up signal may be a transmission made on a physical uplink control channel (PUCCH) and/or physical uplink shared channel (PUSCH) based wake-up channel (e.g., a measurement report transmitted on PUSCH).

[0030] Another set of techniques applies to SSB adaptation with on-demand SSB transmission. In one aspect, a UE may receive cell information for a cell associated with on-demand SSB transmission. The cell information may indicate that the cell is associated with on-demand SSB transmission and may further indicate that one or more of SSB parameters are adapted for the on-demand SSB transmission. When the on-demand SSB transmission is triggered, a RAN may adapt one or more of the SSB parameters and may perform SSB transmission based on the adapted one or more of the SSB parameters. The UE may monitor an indication of SSB transmission and may further receive information of the updated one or more of the SSB parameters. Beneficially, by dynamically adapting the one or more SSB parameters, the RAN may improve access to the network when a UE is present in the cell, while minimizing energy consumption where there is not a demand for the SSB transmissions.

[0031] While presented as distinct solutions, one or more of the solutions described herein may be implemented in combination with each other. Aspects of the present disclosure are described in the context of a wireless communications system.

[0032] **Figure 1** illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a Long-Term Evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system

100 may be an NR network, such as a 5G network, a 5G-A network, or a 5G ultrawideband (5G-UWB) network.

[0033] In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable RAT including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0034] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a RAN, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0035] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0036] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client,

among other examples. Additionally, or alternatively, the UE 104 may be referred to as an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0037] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0038] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0039] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0040] The CN 106 may communicate with a PDN over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The PDN may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or a PDN connection, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0041] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0042] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing (SCS) and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first SCS (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first SCS (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second SCS (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third SCS (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth SCS (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth SCS (e.g., 240 kHz) and a normal cyclic prefix.

[0043] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 ms duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0044] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective SCSs of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively.#

[0045] Each slot may include a number (e.g., quantity) of symbols (e.g., orthogonal frequency division multiplexing (OFDM) symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz SCS), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first SCS (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0046] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the

UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0047] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz SCS; a second numerology (e.g., μ=1), which includes 30 kHz SCS; and a third numerology (e.g., μ=2), which includes 60 kHz SCS. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz SCS; and a fourth numerology (e.g., μ=3), which includes 120 kHz SCS.

[0048] Wireless communication in unlicensed spectrum (also referred to as "shared spectrum") in contrast to licensed spectrum offer some obvious cost advantages allowing communication to obviate overlaying operator's licensed spectrum and rather use license free spectrum according to local regulation in specific geographies. From the 3GPP technology perspective, the unlicensed operation can be on the Uu interface (referred to as NR-U) or also on sidelink interface (e.g., SL-U).

[0049] For initial access, a UE 104 detects a candidate cell and performs DL synchronization. For example, the gNB (e.g., an embodiment of the NE 102) may transmit a SS/PBCH transmission, referred to as an SSB. In various embodiments, the SSB comprises the primary synchronization signal (PSS), the secondary synchronization signal (SSS), and the MIB. The SS (i.e., comprising the PSS and SSS) is a predefined data sequence known to the UE 104 (or derivable using information already stored at the UE 104) and is in a predefined location in time relative to frame/subframe boundaries, etc. The UE 104 searches for the SSB and uses the SSB to obtain DL timing information (e.g., symbol timing) for the DL synchronization. The UE 104 may also decode SI based on the SSB. Note that with beam-based communication, each DL beam may be associated with a respective SSB.

[0050] After performing DL synchronization and acquiring essential system information, such as the MIB and the SIB1, the UE 104 performs uplink (UL)

synchronization and resource request by performing a random-access procedure, referred to as “RACH procedure” by selecting and transmitting a preamble on the PRACH. The PRACH preamble is transmitted during a random access channel (RACH) occasion, i.e., a predetermined set of time-frequency resources that are available for the reception of the PRACH preamble. Note that with beam-based communication, the UE 104 may select a certain DL beam and transmit the PRACH preamble on a corresponding UL beam. In such embodiments, there may be a mapping between SSB and RACH occasion, allowing the network to determine which beam the UE 104 has selected.

[0051] Regarding random access, two types of RACH procedure are supported in a 3GPP wireless communication network: A) a 4-step random-access (RA) type initiated by the sending of a RACH message 1 (Msg1) and B) 2-step RA type with RACH message A (MsgA). Both types of RACH procedure support contention-based random access (CBRA) and contention-free random access (CFRA).

[0052] The UE 104 selects the RA type at the initiation of the RACH procedure, e.g., based on network configuration. In one example, when CFRA resources are not configured, a reference signal received power (RSRP) threshold is used by the UE 104 to select between 2-step RA type and 4-step RA type. In another example, when CFRA resources for 4-step RA type are configured, the UE 104 performs random access with 4-step RA type. In another example, when CFRA resources for 2-step RA type are configured, the UE 104 performs random access with 2-step RA type.

[0053] Note that the network does not configure CFRA resources for 4-step and 2-step RA types at the same time for a bandwidth part (BWP). Additionally, the CFRA with 2-step RA type is only supported for handover.

[0054] The Msg1 of the 4-step RA type consists of a preamble transmitted on a PRACH. After the Msg1 transmission, the UE 104 monitors for a response from the network within a configured window. For CFRA, a dedicated preamble for Msg1 transmission is assigned by the network and upon receiving a random access response (RAR) from the network, the UE 104 ends the random access procedure. For CBRA, upon reception of the RAR, the UE 104 sends a RACH message 3 (Msg3) using a UL grant scheduled in the RAR and monitors for contention resolution. If contention resolution is not successful after Msg3 (re)transmission(s), then the UE 104 goes back to Msg1 transmission.

[0055] The MsgA of the 2-step RA type includes a preamble on the PRACH and a payload on a PUSCH. After the MsgA transmission, the UE 104 monitors for a response from the network within a configured window. For CFRA, a dedicated preamble and PUSCH resource are configured for MsgA transmission and upon receiving the network response, the UE 104 ends the random access procedure. For CBRA, if contention resolution is successful upon receiving the network response, then the UE 104 ends the random access procedure; however, if a fallback indication is received in a RACH message B (MsgB), the UE 104 performs Msg3 transmission using the UL grant scheduled in the fallback indication and monitors for contention resolution. If contention resolution is not successful after Msg3 (re)transmission(s), the UE 104 goes back to MsgA transmission.

[0056] If the random access procedure with 2-step RA type is not completed after a number of MsgA transmissions, the UE 104 can be configured to switch to CBRA with 4-step RA type.

[0057] In 3GPP NR, the gNB may transmit the maximum 64 SSBs and the maximum 64 corresponding copies of physical downlink control channel (PDCCH) and/or physical downlink shared channel (PDSCH) for delivery of SIB1 in high frequency bands (e.g., 28 GHz). This may cause significant network energy consumption even for a very low traffic load condition. According to 3GPP Technical Report (TR) 38.864 (v18.1.0), for network energy savings, on-demand SSB and/or SIB1 (SSB/SIB1) transmissions and a cell without SSB/SIB1 transmission were considered. When a cell does not transmit SSB/SIB1, for a UE 104 to access the cell, the UE 104 should obtain SI of the cell from other associated carriers/cells and synchronize from other associated carriers/cells. When a cell is in a long period of cell inactivity, a UE 104 served by the cell can trigger SSB/SIB1 transmissions by sending a request to the cell.

[0058] **Figure 2** illustrates an example of a protocol stack 200, in accordance with aspects of the present disclosure. While Figure 2 shows a UE 206, a RAN node 208, and a 5GC 210 (e.g., comprising at least an AMF), these are representative of a set of UEs 104 interacting with an NE 102 (e.g., base station) and a CN 106. As depicted, the protocol stack 200 comprises a user plane protocol stack 202 and a control plane protocol stack 204. The user plane protocol stack 202 includes a physical (PHY) layer 212, a medium access control (MAC) sublayer 214, a radio link control (RLC) sublayer 216, a packet

data convergence protocol (PDCP) sublayer 218, and a service data adaptation protocol (SDAP) sublayer 220. The control plane protocol stack 204 includes a PHY layer 212, a MAC sublayer 214, a RLC sublayer 216, and a PDCP sublayer 218. The control plane protocol stack 204 also includes a radio resource control (RRC) layer 222 and a NAS layer 224.

[0059] The access stratum (AS) layer 226 (also referred to as "AS protocol stack") for the user plane protocol stack 202 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The AS layer 228 for the control plane protocol stack 204 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The layer-1 (L1) includes the PHY layer 212. The layer-2 (L2) is split into the SDAP sublayer 220, PDCP sublayer 218, RLC sublayer 216, and MAC sublayer 214. The layer-3 (L3) includes the RRC layer 222 and the NAS layer 224 for the control plane and includes, e.g., an internet protocol (IP) layer and/or PDU Layer (not depicted) for the user plane. L1 and L2 are referred to as "lower layers," while L3 and above (e.g., transport layer, application layer) are referred to as "higher layers" or "upper layers."

[0060] The PHY layer 212 offers transport channels to the MAC sublayer 214. The PHY layer 212 may perform a beam failure detection procedure using energy detection thresholds, as described herein. In certain embodiments, the PHY layer 212 may send an indication of beam failure to a MAC entity at the MAC sublayer 214. The MAC sublayer 214 offers logical channels to the RLC sublayer 216. The RLC sublayer 216 offers RLC channels to the PDCP sublayer 218. The PDCP sublayer 218 offers radio bearers to the SDAP sublayer 220 and/or RRC layer 222. The SDAP sublayer 220 offers QoS flows to the core network (e.g., 5GC). The RRC layer 222 provides for the addition, modification, and release of carrier aggregation and/or dual connectivity. The RRC layer 222 also manages the establishment, configuration, maintenance, and release of signaling radio bearers (SRBs) and data radio bearers (DRBs).

[0061] The NAS layer 224 is between the UE 206 and an AMF in the 5GC 210. NAS messages are passed transparently through the RAN. The NAS layer 224 is used to manage the establishment of communication sessions and for maintaining continuous communications with the UE 206 as it moves between different cells of the RAN. In contrast, the AS layers 226 and 228 are between the UE 206 and the RAN (i.e., RAN node 208) and carry information over the wireless portion of the network. While not

depicted in Figure 2, the IP layer exists above the NAS layer 224, a transport layer exists above the IP layer, and an application layer exists above the transport layer.

[0062] The MAC sublayer 214 is the lowest sublayer in the L2 architecture of the NR protocol stack. Its connection to the PHY layer 212 below is through transport channels, and the connection to the RLC sublayer 216 above is through logical channels. The MAC sublayer 214 therefore performs multiplexing and demultiplexing between logical channels and transport channels: the MAC sublayer 214 in the transmitting side constructs MAC PDUs (also known as transport blocks (TBs)) from MAC service data units (SDUs) received through logical channels, and the MAC sublayer 214 in the receiving side recovers MAC SDUs from MAC PDUs received through transport channels.

[0063] The MAC sublayer 214 provides a data transfer service for the RLC sublayer 216 through logical channels, which are either control logical channels which carry control data (e.g., RRC signaling) or traffic logical channels which carry user plane data. On the other hand, the data from the MAC sublayer 214 is exchanged with the PHY layer 212 through transport channels, which are classified as UL or DL. Data is multiplexed into transport channels depending on how it is transmitted over the air.

[0064] The PHY layer 212 is responsible for the actual transmission of data and control information via the air interface, i.e., the PHY layer 212 carries all information from the MAC transport channels over the air interface on the transmission side. Some of the important functions performed by the PHY layer 212 include coding and modulation, link adaptation (e.g., adaptive modulation and coding (AMC)), power control, cell search and random access (for initial synchronization and handover purposes) and other measurements (inside the 3GPP system (i.e., NR and/or LTE system) and between systems) for the RRC layer 222. The PHY layer 212 performs transmissions based on transmission parameters, such as the modulation scheme, the coding rate (i.e., the modulation and coding scheme (MCS)), the number of physical resource blocks (PRBs), etc.

[0065] In some embodiments, the protocol stack 200 may be a NR protocol stack used in a 5G NR system. Note that an LTE protocol stack comprises similar structure to the protocol stack 200, with the differences that the LTE protocol stack lacks the SDAP sublayer 220 in the AS layer 226, that an EPC replaces the 5GC 210, and that the NAS

layer 224 is between the UE 206 and an MME in the EPC. Also note that the present disclosure distinguishes between a protocol layer (such as the aforementioned PHY layer 212, MAC sublayer 214, RLC sublayer 216, PDCP sublayer 218, SDAP sublayer 220, RRC layer 222 and NAS layer 224) and a transmission layer in MIMO communication (also referred to as a "MIMO layer" or a "data stream").

[0066] Regarding RRC states, 3GPP defines three different RRC states/modes for 5G NR: RRC_IDLE, RRC_INACTIVE, and RRC_CONNECTED. Initially, i.e., upon powering up, the UE is in an idle mode corresponding to the RRC_IDLE state. Before performing data transfer (including placing calls), the UE must establish a connection with the network which is done using initial access via RRC connection establishment procedure. Once RRC connection is established, the UE is in the RRC_CONNECTED state. The RRC connection may be suspended due to inactivity, wherein the UE transitions to the RRC_INACTIVE state. Via the RRC release procedure, the RRC connection is released and the UE transitions to the RRC_IDLE state.

[0067] For network energy savings, a SSB-less SCell may be deployed for an intra-band or inter-band carrier aggregation (CA). In certain embodiments, a UE may obtain a timing reference and automatic gain control (AGC) source from another serving cell, if the UE is provided with neither SSB nor SSB measurement timing configuration (SMTC) for the SCell.

[0068] **Figure 3** depicts an exemplary Abstract syntax notation #1 (ASN.1) representation of an SCell configuration 300 comprising the IE *SCellConfig* in accordance with aspects of the present disclosure. The IE *SCellConfig* is used to signal details of the SCell configuration. Various field descriptions of the IE *SCellConfig* are described in Table 1, below.

Table 1: *SCellConfig* field descriptions

The field "***sCellState***" indicates whether the SCell shall be considered to be in activated state upon SCell configuration. If the field is included for an SCell configured with TRS for fast activation of the SCell, such TRS is not used for the corresponding SCell.
The field "***smtc***" indicates the SSB periodicity/offset/duration configuration of target cell for NR SCell addition. The network sets the *periodicityAndOffset* to indicate the same periodicity as *ssb-periodicityServingCell* in *sCellConfigCommon*. The *smtc* is based on the timing of the special cell (SpCell) of associated cell group. In case of inter-RAT handover to NR, the timing reference is the NR primary serving cell (PCell). In case of intra-NR PCell change (standalone NR) or NR primary secondary cell (PSCell) change (EN-DC), the timing reference is the target SpCell. If the field is absent, the UE uses the SMTC in the *measObjectNR* having the same SSB frequency and subcarrier spacing, as configured before the reception of the RRC message.
The field "***SCellAddSync***" is optionally present, Need N, in the parameter *masterCellGroup* at 1) SCell addition, 2) reconfiguration with sync, or 3) resume of an RRC connection; alternatively, in the parameter *secondaryCellGroup*, when the secondary cell group (SCG) is not indicated as deactivated at: A) SCG activation while the SCG was previously deactivated, B) SCell addition, or C) reconfiguration with sync. The field is absent otherwise.

[0069] **Figure 4A** and **Figure 4B** depict an exemplary ASN.1 representation of a common serving cell configuration 400 comprising the IE *ServingCellConfigCommon* in accordance with aspects of the present disclosure. The IE *ServingCellConfigCommon* may be carried in SIB1 and is used to signal details of the common serving cell configuration. Various field descriptions of the IE *ServingCellConfigCommon* are described in Table 2, below.

Table 2: *ServingCellConfigCommon* field descriptions

The field "***dmrs-TypeA-Position***" indicates the position of (first) DM-RS for downlink (see 3GPP technical specification (TS) 38.211, clause 7.4.1.1.1) and uplink (see 3GPP TS 38.211, clause 6.4.1.1.3).
The field "***downlinkConfigCommon***" indicates the common downlink configuration of the serving cell, including the frequency information configuration and the initial downlink BWP common configuration. The parameters provided herein should match the parameters configured by MIB and SIB1 (if provided) of the serving cell, with the exception of *controlResourceSetZero* and *searchSpaceZero* which can be configured in *ServingCellConfigCommon* even if MIB indicates that they are absent.
The field "***longBitmap***" is a bitmap that indicates when the maximum number of SS/PBCH blocks per half frame equals to 64 (e.g. as defined in 3GPP TS 38.213, clause 4.1).
The field "***mediumBitmap***" is a bitmap that indicates when the maximum number of SS/PBCH blocks per half frame equals to 8 (e.g., as defined in TS 38.213, clause 4.1).
The field "***shortBitmap***" is a bitmap that indicates when the maximum number of SS/PBCH blocks per half frame equals to 4 (e.g., as defined in TS 38.213, clause 4.1).

The field "***ss-PBCH-BlockPower***" indicates the average energy per resource element (EPRE) of the resources elements (REs) that carry secondary synchronization signals in dBm that the network used for SSB transmission.
The field "***ssb-periodicityServingCell***" indicates the SSB periodicity in ms for the rate matching purpose. If the field is absent, the UE applies the value ms5 (see TS 38.213, clause 4.1).
For operation in licensed spectrum, the field "***ssb-PositionsInBurst***" indicates the time domain positions of the transmitted SS-blocks in a half frame with SS/PBCH blocks (e.g., as defined in TS 38.213, clause 4.1). The first/leftmost bit corresponds to SS/PBCH block index 0, the second bit corresponds to SS/PBCH block index 1, and so on. Value 0 in the bitmap indicates that the corresponding SS/PBCH block is not transmitted while value 1 indicates that the corresponding SS/PBCH block is transmitted. The network configures the same pattern in this field as in the corresponding field in ServingCellConfigCommonSIB. Otherwise, for operation with shared spectrum channel access, the UE assumes that one or more SS/PBCH blocks indicated by *ssb-PositionsInBurst* may be transmitted within the discovery burst transmission window and have candidate SS/PBCH blocks indexes corresponding to SS/PBCH block indexes provided by *ssb-PositionsInBurst* (see TS 38.213, clause 4.1). If the k-th bit of *ssb-PositionsInBurst* is set to 1, the UE assumes that one or more SS/PBCH blocks within the discovery burst transmission window with candidate SS/PBCH block indexes corresponding to SS/PBCH block index equal to k – 1 may be transmitted; if the k-th bit is set to 0, the UE assumes that the corresponding SS/PBCH block(s) are not transmitted. The k-th bit is set to 0, where k > *ssb-PositionQCL* and the number of actually transmitted SS/PBCH blocks is not larger than the number of 1's in the bitmap. The network configures the same pattern in this field as in the corresponding field in *ServingCellConfigCommonSIB*. For operation with shared spectrum channel access in FR1, only *mediumBitmap* is used, and for FR2-2, *longBitmap* is used.
The field "***ssbSubcarrierSpacing***" indicates the SCS of the SSB. Only the following values are applicable depending on the used frequency. For FR1: 15 or 30 kHz; for FR2-1: 120 or 240 kHz; for FR2-2: 120, 480, or 960 kHz.
The field "***tdd-UL-DL-ConfigurationCommon***" indicates a cell-specific TDD UL/DL configuration.
For the conditional presence of the field "***AbsFreqSSB***", this field is absent when *absoluteFrequencySSB* in frequencyInfoDL is absent, otherwise the field is mandatory present
For the conditional presence of the field "***HOAndServCellAdd***", this field is mandatory present upon SpCell change (including path switch between a serving cell and a L2 U2N Relay UE) and upon serving cell (e.g., PSCell or SCell) addition. Otherwise, the field is absent.
For the conditional presence of the field "***HOAndServCellWithSSB***", this field is mandatory present upon SpCell change and upon serving cell (SCell with SSB or PSCell) addition. Otherwise, the field is absent.

[0070] **Figure 5** depicts an exemplary ASN.1 representation of a common downlink configuration 500 comprising the IE *DownlinkConfigCommon* in accordance with aspects of the present disclosure. The IE *DownlinkConfigCommon* is used to provide common downlink parameters of a cell. Various field descriptions of the IE *DownlinkConfigCommon* are described in Table 3, below.

Table 3: *DownlinkConfigCommon* field descriptions

The field "***frequencyInfoDL***" indicates the basic parameters of a downlink carrier and transmission thereon.
The field "***initialDownlinkBWP***" indicates the initial downlink BWP configuration for a serving cell. The network configures the *locationAndBandwidth* so that the initial downlink BWP contains the entire CORESET#0 of this serving cell in the frequency domain.
The field "***downlinkConfigCommon***", if present, indicates that (e)RedCap UEs are to use this DL BWP instead of *initialDownlinkBWP*. If absent, the (e)RedCap UEs are to use *initialDownlinkBWP* provided that it does not exceed the (e)RedCap UE maximum bandwidth.

[0071] **Figure 6** depicts an exemplary ASN.1 representation of a downlink frequency configuration 600 comprising the IE *FrequencyInfoDL* in accordance with aspects of the present disclosure. The IE *FrequencyInfoDL* is used to provide basic parameters of a downlink carrier and transmission thereon. Various field descriptions of the IE *FrequencyInfoDL* are described in Table 4, below.

Table 4: *FrequencyInfoDL* field descriptions

The field "***absoluteFrequencyPointA***" indicates the absolute frequency position of the reference resource block (e.g. Common RB 0). Its lowest subcarrier is also known as Point A (see TS 38.211, clause 4.4.4.2). Note that the lower edge of the actual carrier is not defined by this field but rather in the *scs-SpecificCarrierList*.
The field "***absoluteFrequencySSB***" indicates the frequency of the SSB to be used for this serving cell. SSB related parameters (e.g. SSB index) provided for a serving cell refer to this SSB frequency unless mentioned otherwise. The CD-SSB of the PCell is always on the sync raster. Frequencies are considered to be on the sync raster if they are also identifiable with a GSCN value (see TS 38.101-1 or TS 38.101-5). If the field is absent, the SSB related parameters should be absent, e.g. *ssb-PositionsInBurst*, *ssb-periodicityServingCell* and *subcarrierSpacing* in *ServingCellConfigCommon* IE. If the field is absent, the UE obtains timing reference from the SpCell or an SCell if applicable as described in TS 38.213, clause 4.1, or from the SpCell or an SCell indicated by *referenceCell,* or from the "default cell" defined in TS [xx]. This is supported in case the SCell for which the UE obtains the timing reference is in the same or different frequency band as the cell (i.e. the SpCell or the SCell, respectively) from which the UE obtains the timing reference. For cells supporting (e)RedCap, this field corresponds to the CD-SSB.

The field "***frequencyBandList***" is a list containing only one frequency band to which this carrier(s) belongs. Multiple values are not supported.
The field "***referenceCell***" indicates the reference cell, i.e. the cell which provides the timing reference and AGC source for the SSB-less SCell. If the reference cell is an SCell or PSCell, it should be an activated SCell or activated PSCell
The field "***scs-SpecificCarrierList***" indicates a set of carriers for different subcarrier spacings (numerologies). Defined in relation to Point A. The network configures a *scs-SpecificCarrier* at least for each numerology (i.e., SCS) that is used, e.g., in a BWP (see TS 38.211, clause 5.3).
For the conditional presence of the field "***SpCellAdd***", this field is mandatory present if this *FrequencyInfoDL* is for SpCell. Otherwise the field is optionally present, Need S.
For the conditional presence of the field "***SSBlessSCell***", this field is optionally present, Need S, if the SSB-less SCell is configured for this cell and absoluteFrequencySSB is absent. It is absent otherwise.

[0072] Cell search is a procedure for a UE to acquire time and frequency synchronization with a cell and to detect the physical layer cell identity of the cell. In 3GPP 5G NR, for a UE to access to a network, the UE performs cell search, acquires essential system information of a cell such as MIB and SIB1, and selects a suitable cell among detected cells.

[0073] For initial cell selection, i.e., when there is no prior knowledge of which radio frequency (RF) channels are NR frequencies, a UE scans all RF channels (also referred to as frequency layers) in the NR bands according to its capabilities to find a suitable cell. On each carrier frequency of the RF channels/frequency layers, the UE only needs to search for the strongest cell (e.g., the cell with the highest RSRP and/or reference signal received quality (RSRQ) value), except for operation with shared spectrum channel access where the UE may search for the next/second strongest cell(s). Once a suitable cell is found, this cell is to be selected. If a UE has stored information of frequencies and optionally also information on cell parameters from previously received measurement control information elements or from previously detected cells and once the UE has found a suitable cell, the UE is to select it. If no suitable cell is found, the UE is to scan all RF channels in the NR bands according to its capabilities to find a suitable cell.

[0074] Regarding cell selection, the cell selection criterion *S* is fulfilled when: Srxlev > 0 AND Squal > 0, where:

$$Srxlev = Q_{rxlevmeas} - (Q_{rxlevmin} + Q_{rxlevminoffset}) - P_{compensation} - Qoffset_{temp}$$

$$Squal = Q_{qualmeas} - (Q_{qualmin} + Q_{qualminoffset}) - Qoffset_{temp}$$

[0075] Note that for initial cell selection (i.e., having no stored cell selection parameters), the UE can compute Srxlev and Squal after acquiring system information of a cell. The terms of the above equations are defined in Table 5, below:

Table 5: Cell selection parameters

Name	**Description**
Srxlev	Cell selection reception (RX) level value [in dB]
Squal	Cell selection quality value [in dB]
$Qoffset_{temp}$	Offset temporarily applied to a cell [in dB]
$Q_{rxlevmeas}$	Measured cell RX level value (e.g., RSRP)
$Q_{qualmeas}$	Measured cell quality value (e.g., RSRQ)
$Q_{rxlevmin}$	Minimum required RX level in the cell [in dBm]. If the UE supports supplementary uplink (SUL) frequency for this cell, $Q_{rxlevmin}$ is obtained from *q-RxLevMinSUL*, if present, in *SIB1*, *SIB2* and *SIB4*, additionally, if $Q_{rxlevminoffsetcellSUL}$ is present in *SIB3* and *SIB4* for the concerned cell, this cell specific offset is added to the corresponding Qrxlevmin to achieve the required minimum RX level in the concerned cell; else $Q_{rxlevmin}$ is obtained from *q-RxLevMin* in *SIB1, SIB2* and *SIB4*, additionally, if $Q_{rxlevminoffsetcell}$ is present in *SIB3* and *SIB4* for the concerned cell, this cell specific offset is added to the corresponding Qrxlevmin to achieve the required minimum RX level in the concerned cell.
$Q_{qualmin}$	Minimum required quality level in the cell [in dB]. Additionally, if $Q_{qualminoffsetcell}$ is signaled for the concerned cell, this cell specific offset is added to achieve the required minimum quality level in the concerned cell.
$Q_{rxlevminoffset}$	Offset to the signaled $Q_{rxlevmin}$ taken into account in the Srxlev evaluation as a result of a periodic search for a higher priority PLMN while camped normally in a visited PLMN (VPLMN).
$Q_{qualminoffset}$	Offset to the signaled $Q_{qualmin}$ taken into account in the Squal evaluation as a result of a periodic search for a higher priority PLMN while camped normally in a VPLMN.

$P_{compensation}$	For FR1, if the UE supports the *additionalPmax* in the *NR-NS-PmaxList*, if present, in *SIB1, SIB2* and *SIB4:* max(P_{EMAX1} –$P_{PowerClass}$, 0) – (min(P_{EMAX2}, $P_{PowerClass}$) – min(P_{EMAX1}, $P_{PowerClass}$)) [in dB]; else: max(P_{EMAX1} –$P_{PowerClass}$, 0) [in dB] For FR2, $P_{compensation}$ is set to 0. For IAB-MT, $P_{compensation}$ is set to 0.
P_{EMAX1}, P_{EMAX2}	Maximum transmission (TX) power level of a UE may use when transmitting on the uplink in the cell [in dBm] defined as P_{EMAX}. If UE supports SUL frequency for this cell, P_{EMAX1} and P_{EMAX2} are obtained from the *p-Max* for SUL in *SIB1* and *NR-NS-PmaxList* for SUL respectively in *SIB1, SIB2* and *SIB4*, else P_{EMAX1} and P_{EMAX2} are obtained from the *p-Max* and *NR-NS-PmaxList* respectively in *SIB1*, *SIB2* and *SIB4* for normal UL.
$P_{PowerClass}$	Maximum RF output power of the UE [in dBm] according to the UE power class.

[0076] **Figure 7** depicts an exemplary RAN deployment 700 for energy saving cells with on-demand SSB transmission, in accordance with aspects of the disclosure. The RAN deployment 700 comprises a plurality of cells, including a first cell (denoted "Cell 1") 702, a second cell (denoted "Cell 2") 704, a third cell (denoted "Cell 3") 706, a fourth cell (denoted "Cell 4") 708, and a fifth cell (denoted "Cell 5") 710. In some embodiments, the first cell 702 is deployed in a first frequency layer and the Cells 2-5 are deployed in a second frequency layer different than the first. A frequency layer, also referred to as an RF channel, refers to the carrier frequency where a cell transmitting SS can be expected. In one embodiment, the first frequency layer (i.e., first RF channel) is in the same frequency band as the second frequency layer (i.e., second RF channel). In another embodiment, the first and second RF channels are in different frequency bands. In yet other embodiments, the Cells 1-5 are deployed in the same frequency layer. In various embodiments, the first cell 702 is an anchor cell that may provide coarse synchronization for a neighbor cell (e.g., one or more of Cells 2-5).

[0077] In various embodiments, the first cell 702 uses beam-based communication, where different beams are associated with different SSB transmission. As depicted, the first cell 702 uses a first beam (associated with the transmission of SSB1) that overlaps the second cell 704 and a second beam (associated with the transmission of SSB2) that overlaps the third cell 706. The first cell 702 also uses a fourth beam (associated with the transmission of SSB4) that overlaps the fourth cell 708 and a fifth beam (associated with the transmission of SSB5) that overlaps the fifth cell 710. Additionally, the first cell 702 uses a third beam (associated with the transmission of SSB3) that provides to one or more UEs located outside the coverage areas of Cells 2-5. Moreover, it is assumed that SSB1 through SSB5 are periodically transmitted in the first cell 702.

[0078] In some embodiments, one or more of the cells 1-6 may transmit SS and/or essential SI with a periodic (i.e., regular) transmission pattern. However, to save energy a respective cell may instead transmit the SS and/or the essential SI on demand. In the depicted embodiment, the first cell 702, the fourth cell 708, and the fifth cell 710 each transmit SS and essential SI periodically and serve UEs 714 in an RRC connected state. However, the second cell 704 and the fifth cell 710 transmit SS and essential SI on-demand and may serve one or more UEs 716 in an RRC idle or inactive state.

[0079] In some embodiments, an energy saving cell (e.g., the second cell 704 and/or the fifth cell 710) transmits its SS and/or essential SI only on demand when it is not serving any UE 714 in the RRC connected state. In certain embodiments, the energy saving cell may switch to transmitting its SS and/or essential SI with the periodic transmission pattern when it serves a UE 714 in the RRC connected state.

[0080] As used herein, a "periodic transmission pattern" or "periodic basis for transmission" refers to the regular transmission, e.g., of the SS and/or essential SI, at regular intervals. In contrast, an "on-demand transmission pattern" or "on-demand basis for transmission" refers to the transmission, e.g., of the SS and/or essential SI, only in response to a request (e.g., a "demand" from a UE) for the SS and/or essential SI and not according to a regular pattern.

[0081] As depicted in Figure 7, there is a first UE 712 located in the coverage areas of Cells 1-2. The first UE 712 is in RRC_CONNECTED state and is configured with CA such that the first cell 702 is configured as the PCell and the second cell 704 is a configured and deactivated SCell. Further, the first UE 712 receives information that SSB1 (i.e., of the first cell 702) is associated with the second cell 704.

[0082] If the first UE 712 identifies (i.e., based on cell measurements) that SSB1 of the first cell 702 is the strongest SSB (e.g., having the highest RSRP and/or RSRQ value) among the SSB1– SSB5 of the first cell 702, and that a measurement value of the SSB1 is less than a configured or predefined threshold value, then the first UE 712 may send a wake-up signal/channel to trigger on-demand SSB transmission in the second cell 704.

[0083] While a SSB-less SCell can save network energy consumption, usage of the SSB-less SCell may be limited to a deployment scenario, where the SSB-less SCell and an associated active reference cell should be co-located and both cells should be deployed

in FR1 bands. In case that SSB is configured for an SCell, updating SSB related parameters of the SCell requires deconfiguration (i.e., SCell release) and re-configuration of the SCell, which causes higher signaling overhead.

[0084] Techniques are disclosed herein to enable network energy saving by minimization of SSB/ MIB/ SI transmission, e.g., by using an on-demand basis for transmission of the SSB/ MIB/ SI, without adversely affecting the user experience due to longer call setup time, or without delaying system information change notification. Further, techniques disclosed herein can be used even for non-co-located deployment of an active serving cell and an SCell with on-demand SSB transmission and allows a network to send only necessary SSBs with necessary transmit power at the time of SSB transmission based on minimal signaling overhead.

[0085] Aspects of a first solution describe techniques for triggering a request for on-demand SS and/or essential SI. A UE receives an indication that a subset of SSB indices of an active serving cell is spatially associated with an SCell with on-demand SSB transmission. Selecting a SSB index of the subset of SSB indices of the active serving cell for the best SSB implicitly indicates that the UE is within the coverage of the SCell.

[0086] In some embodiments, a UE receives information of at least one subset of reference signal (RS) resource indices of a first cell and at least one second cell (or a list of cells) associated with a subset of RS resource indices from the at least one subset of RS resource indices, where the first cell is a serving cell for the UE. The UE sends a wake-up signal/channel for the second cell(s), if the best RS resource (e.g., RS resource with the highest RSRP, RSRQ, or signal-to-interference and noise ratio (SINR)) for the first cell corresponds to a RS resource index of the subset of RS resource indices.

[0087] In one example, RS resource indices comprise one or more of SSB indices, channel state information RS (CSI-RS) resource indices, or tracking RS (TRS) resource indices. In one example, the wake-up signal/channel is sent to the first cell. In another example, the wake-up signal/channel is sent to the second cell(s).

[0088] In one implementation, a UE is in RRC_IDLE or RRC_INACTIVE state and camps on a first cell. A second cell adjacent to the first cell or overlapping with the first cell in coverage is in an energy saving state with deactivation of the transmission of SS and/or essential SI. The UE receives association information between a subset of SSB

indices of the first cell and the second cell, where SSBs corresponding to the subset of SSB indices have spatial coverage related to the second cell, e.g., as described with reference to Figure 7.

[0089] In one example, the UE sends the wake-up signal/channel to request SS and/or essential SI transmission of the second cell, if the first cell measurement value is below a threshold value, for example, Squal < $\text{Thresh}_{\text{Serving, LowQ}}$ or Srxlev < $\text{Thresh}_{\text{Serving, LowP}}$, and the best SSB of the first cell corresponds to one SSB index of the subset of SSB indices. There could be a case that a current cell may not provide good coverage for idle (or inactive) UEs, so it may be better to setup (or resume) RRC connection with a dormant cell (i.e., a cell not transmitting SS and/or essential SI periodically) after the dormant cell waking up.

[0090] In another implementation, a UE is in RRC_CONNECTED state, and a first cell is configured as a PCell or PSCell for the UE. A second cell with on-demand SSB and/or essential SI transmission is either a neighbor cell or a configured but deactivated SCell for the UE. The UE receives an indication that a subset of SSB indices of the first cell is spatially associated with the second cell.

[0091] Since measurement reference signals including SSBs have not been transmitted from the second cell for the UE, the UE cannot measure the neighbor cell or the SCell directly. Selecting a SSB index of the subset of SSB indices of the first cell for the best SSB implicitly indicates that the UE is within the coverage of the neighbor cell or within the coverage of the deactivated SCell, and the UE can send an event-triggered measurement report to the first cell.

[0092] In one example, a wake-up signal/channel requesting for on-demand SSB and/or essential SI transmission from the second cell carries the event-triggered measurement report, where definition of the relevant event X is provided below. In this example, it is assumed that the UE is configured (or pre-configured) with an entering condition of the event and a leaving condition of the event, defined as follows:

[0093] The entering condition for event X is considered to be satisfied when the inequality $Ms + Hys < Thresh$ is fulfilled and when the SSB index i_{ssb} corresponding to Ms is included in I_{ssb}.

[0094] The leaving condition for event X is considered to be satisfied when the inequality *Ms – Hys > Thresh* is fulfilled and when the SSB index i_{ssb} corresponding to *Ms* is included in I_{ssb}, or when the SSB index i_{ssb} corresponding to *Ms* is not included in I_{ssb}.

[0095] The variables in the above formulae are defined as follows:

[0096] ***Ms*** is the measurement result of the serving cell, not taking into account any offsets. ***Ms*** is expressed in dBm in case of RSRP, or in dB in case of RSRQ and RS-SINR.

[0097] $\boldsymbol{I_{ssb}}$ is a subset of SSB indices configured for this event.

[0098] ***Hys*** is the hysteresis parameter for this event (i.e., *hysteresis* as defined within the parameter *reportConfigNR* for this event). ***Hys*** is expressed in dB.

[0099] ***Thresh*** is the threshold parameter for this event (i.e., *X-Threshold* as defined within the parameter *reportConfigNR* for this event). ***Thresh*** is expressed in the same unit as ***Ms***.

[0100] With a wake-up mechanism that allows for a UE to request for SS and/or essential SI transmission, a network can perform more aggressive cell muting for network energy savings. In one example, a wake-up signal/channel is a PRACH preamble, which is transmitted with transmit timing advance (TA) value of zero. In another example, a PRACH preamble as a wake-up signal/channel is sent to an energy saving cell with on-demand SSB transmission, and an anchor-cell associated with the energy saving cell can indicate a TA value specific to the energy saving cell (e.g., the first UE 712 sends a wake-up signal/channel to Cell 2). Considering that the energy saving cell is likely to be a small cell, the cell-specific TA value based on deployment knowledge may be sufficient to detect or decode the wake-up signal/channel.

[0101] According to aspects of a second solution, a RAN transmits SSB of a cell upon receiving a request for on-demand SSB transmission, the RAN may adapt one or more of a SSB transmission pattern (e.g., SSB positions within a 5ms time window, SSB periodicity), a SSB transmit power, an absolute frequency of SSB including a frequency location of an initial DL BWP (and additionally a frequency location of an initial UL

BWP in time division duplex (TDD)), or an index to a DL BWP configured for the UE, or a SSB SCS value.

[0102] In one embodiment, a UE receives at least one cell information corresponding to at least one cell, where the at least one cell is associated with on-demand SSB transmission. The at least one cell information indicates that the corresponding at least one cell is associated with on-demand SSB transmission. Further, the at least one cell information indicates that one or more of SSB parameters, initial DL/UL BWP parameters, or an index to a configured DL BWP, or other cell-specific parameters (e.g., a TDD DL/UL configuration) are adapted with the on-demand SSB transmission.

[0103] When the on-demand SSB transmission is triggered, a RAN adapts one or more of the SSB parameters, the initial DL/UL BWP parameters, or other cell-specific parameters and performs SSB transmission and cell operation at least partly based on the adapted one or more of the cell-specific parameters. The UE monitors an indication of SSB transmission and further receives information of the updated one or more of the cell-specific parameters.

[0104] In one implementation, a UE detects a downlink control information (DCI) format in a first cell in response to sending a wake-up signal/channel for a second cell, where the DCI format indicates whether SSB transmission of the second cell is triggered and whether one or more of cell-specific parameters of the second cell are updated and, if updated, further schedules a PDSCH carrying the updated one or more of the cell-specific parameters of the second cell. Conversely in an implementation a network element transmits such a DCI to at least one UE in a first cell.

[0105] In another implementation, a UE detects a DCI format in a first cell in response to sending a wake-up signal/channel for a second cell, where the DCI format includes an indication whether SSB transmission of the second cell is triggered and, if triggered, includes updated one or more of cell-specific parameters of the second cell. For example, the DCI format includes a bitfield indicating an updated SSB location within a configured PRB grid of the second cell. Conversely in an implementation a network element transmits such a DCI to at least one UE.

[0106] According to an implementation, the first cell is a PCell, alternatively a PCell or an activated SCell. According to an implementation, the second cell is an SCell, alternatively a deactivated SCell.

[0107] According to a specific implementation, a DCI format that indicates at least whether SSB transmission of the second cell is triggered has the following characteristics. The DCI format includes at least one of the following fields or indicators:

[0108] First, an indicator/field that indicates whether and/or on which second cell the SSB transmission occurs. For example, this can be a cell index (such as for a configured SCell) or even multiple such indices to indicate multiple cells with the same DCI format.

[0109] Second, an indicator/field that indicates a DL BWP of the second cell where the SSB transmission occurs, such as a DL BWP index. A specific value may indicate that the initial DL BWP is used.

[0110] Third, an indicator/field that indicates resource block information for the SSB transmission on the second cell.

[0111] Fourth, the parameter "absoluteFrequencyPointA", which indicates the absolute frequency position of the reference RB (i.e., Common RB 0). The lowest subcarrier of the reference RB is also known as Point A (see TS 38.211, clause 4.4.4.2). Note that the lower edge of the actual carrier is not defined by this field but rather in the scs-SpecificCarrierList.

[0112] Fifth, the frequency of the SSB to be used for the second cell (like RRC parameter *absoluteFrequencySSB*, see background).

[0113] Sixth, an indicator for the time domain positions of the transmitted SS-blocks (like RRC parameter *ssb-PositionsInBurst*, see background).

[0114] Seventh, an SSB index for the SSB on the second cell.

[0115] Eighth, a reference cell indicator, such as a cell index, for the cell which provides the timing reference and AGC source for the second cell (like RRC parameter *referenceCell*, see background).

[0116] Ninth, a field indicating which one or more of PSS, SSS, PBCH, MIB, PBCH payload, DM-RS related to PBCH are part of the SSB transmission on the second cell.

[0117] Tenth, a time duration field indicating how long the information included in the DCI is applicable. The time of applicability may start with or after the slot where the DCI is received, and then lasts for as many slots/subframes/frames/… as indicated by this field. After this duration, the UE reverts to SSB-related information as was (pre-)configured for the second cell, e.g., by RRC (see background). According to a specific example, the duration is expressed as a value representing a factor applied to the SMTC periodicity configured for the second cell, e.g., if the SMTC periodicity is configured as 5 slots and a factor of 4 is indicated, a UE determines the duration to be 4x5 slots = 20 slots.

[0118] Eleventh, an indicator for the average EPRE of the resources elements that carry secondary synchronization signals in dBm that is used for SSB transmission (like RRC parameter *ss-PBCH-BlockPower*, see background).

[0119] Additionally, a cyclic redundancy check (CRC) of the DCI format may be scrambled with a radio network temporary identifier (RNTI) specific to indicating SSB or MIB transmission, e.g., an SSB-RNTI different from a SI-RNTI. Alternatively, the CRC of the DCI may be scrambled with an RNTI used for indicating SI/SIB1 information, e.g., SI-RNTI.

[0120] In such a case, a field or field combination in the DCI indicates whether SSB, SIB1, or SI is indicated by the DCI. If SSB is indicated, a UE ignores a Modulation and coding scheme indicator or a redundancy version indicator, if present respectively. Alternatively, if a modulation and coding scheme indicator is present, one or more of values indicating a ‘reserved’ target code rate, such as values 29-31 according to 38.214 table 5.1.3.1-1 or values 28-31 according to 38.214 table 5.1.3.1-2, (optionally with a System Information Indicator indicating SIB1 at the same time) is used to indicate that SSB is indicated by the DCI.

[0121] In one implementation, when a UE is configured with a SCell for operating in a CA mode, a serving cell configuration (e.g., an information element (IE) *ServingCellConfigCommon*) corresponding to the SCell includes an indication of on-demand SSB transmission.

[0122] If the indication of on-demand SSB transmission is included or set to be “True” and additionally (or optionally) an indication of cell adaptation is set to be “True”,

the UE expects to receive updated one or more of SSB parameters and other cell-specific parameters upon on-demand SSB transmission being triggered, such as in an SCell update IE (e.g., the *sCellConfigUpdate* IE as depicted in Figure 8). The UE assumes that the SSB parameters and other cell-specific parameters not included in the SCell update IE keep the same values/setting as indicated in the serving cell configuration.

[0123] For example, the adapted one or more of the cell-specific parameters comprise one or more of parameters *absoluteFrequencySSB*, *ssb-PositionsInBurst*, *ssb-periodicityServingCell*, *ssbSubcarrierSpacing*, *ss-PBCH-BlockPower*, *tdd-UL-DL-ConfigurationCommon*, or *locationAndBandwidth*.

[0124] Figure 8 illustrates an exemplary ASN.1 representation of the Scell update IE *sCellConfigUpdate* 800 in accordance with aspects of the present disclosure. The IE *sCellConfigUpdate* 800 is used to update SSB related parameters and other cell-specific parameters such as initial DL/UL BWP related parameters and a cell-specific TDD UL/DL configuration parameter of an already configured SCell, upon on-demand SSB transmission being triggered.

[0125] The parameter *locationAndBandwith* indicates the frequency domain location and bandwidth of the respective bandwidth part. The value of the field is to be interpreted as resource indicator value (RIV) (e.g., as defined in 3GPP TS 38.214 with assumptions as described in TS 38.213, clause 12, i.e., setting N_{BWP}^{size}=275). The first PRB is a PRB determined by the parameter *subcarrierSpacing* of this BWP and the parameter *offsetToCarrier* (configured in *SCS-SpecificCarrier* contained within parameters *FrequencyInfoDL* or *FrequencyInfoUL* or *FrequencyInfoUL-SIB* or *FrequencyInfoDL-SIB* within the IE *ServingCellConfigCommon* or *ServingCellConfigCommonSIB*) corresponding to this SCS. In the case of TDD, a BWP-pair (i.e., UL BWP and DL BWP with the same *bwp-Id*) must have the same center frequency.

[0126] In one example, when on-demand SSB transmission is triggered for a first cell at least partly based on reception of UE's event-triggered measurement report for a second cell, a RAN determines an appropriate SSB transmit power and/or SSB positions within a 5ms time window for the first cell at least partly based on a measurement value(s) and a corresponding measurement RS resource index(es), e.g., SSB index, CSI-RS resource index, of the second cell in the measurement report.

[0127] In another example, when on-demand SSB transmission is triggered for a first cell based on RAN's detection of a PRACH preamble configured in a second cell for a request for SSB transmission, the RAN determines a SSB transmit power of the first cell at least partly based on the PRACH preamble received power in the second cell and/or determines SSB positions within a 5ms time window based on a RS resource index, e.g., SSB index, associated with the PRACH preamble of the second cell. In one implementation, the first and second cells are the same cell. In another implementation, the first cell is different from the second cell.

[0128] In yet another example, when on-demand SSB transmission is triggered for a cell, a RAN adapts an absolute frequency of SSB of the cell and locations and/or bandwidths of initial DL/UL BWPs of the cell, taking into account at least partly operating conditions (e.g., traffic loads, frequency location of initial DL/UL BWPs) of co-channel neighboring cells and/or cells deployed in an adjacent RF channel(s).

[0129] Figure 9 illustrates an example of a UE 900 in accordance with aspects of the present disclosure. The UE 900 may include a processor 902, a memory 904, a controller 906, and a transceiver 908. The processor 902, the memory 904, the controller 906, or the transceiver 908, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0130] The processor 902, the memory 904, the controller 906, or the transceiver 908, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0131] The processor 902 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a central processing unit (CPU), an ASIC, a field programmable gate array (FPGA), or any combination thereof). In some implementations, the processor 902 may be configured to operate the memory 904. In some other implementations, the memory 904 may be integrated into the processor 902. The

processor 902 may be configured to execute computer-readable instructions stored in the memory 904 to cause the UE 900 to perform various functions of the present disclosure.

[0132] The memory 904 may include volatile or non-volatile memory. The memory 904 may store computer-readable, computer-executable code including instructions that, when executed by the processor 902, cause the UE 900 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 904 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0133] In some implementations, the processor 902 and the memory 904 coupled with the processor 902 may be configured to cause the UE 900 to perform various functions (e.g., operations, signaling) described herein (e.g., executing, by the processor 902, instructions stored in the memory 904). In some implementations, the processor 902 may include multiple processors and the memory 904 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the UE 900 as disclosed herein.

[0134] The processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 may be configured to support a means for transmitting a wake-up signal that requests one or more of at least one SS or at least one essential SI, where the at least one essential SI includes a MIB, or a SIB1, or timing information of the at least one SS, or a combination thereof.

[0135] The processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to receive cell information corresponding to at least one cell associated with an on-demand transmission of the at least one SS, or the at least one essential SI, or both.

[0136] In some embodiments, the cell information indicates one or more parameters adapted based on the wake-up signal, the one or more parameters comprising: A) a SSB parameter associated with at least one of a time location, or a frequency location, or a

periodicity of a SSB transmission, or a SSB transmit power, or one or more SSB positions in a SSB burst, or a SSB subcarrier spacing, wherein the SSB transmission comprises a PSS, a SSS, and a physical channel indicating at least SSB timing information; B) an initial DL BWP configuration; C) an initial UL BWP configuration; D) a TDD DL/UL configuration; or a combination thereof.

[0137] The processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to receive the at least one SS, or the at least one essential SI, or both, in response to the wake-up signal. In some embodiments, the wake-up signal comprises a sequence-based signal, or a transmission on a specific channel, or both.

[0138] In some embodiments, the wake-up signal is associated with a second cell. In such embodiments, the processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to receive DCI in a first cell in response to a transmission of the wake-up signal. In certain embodiments, the DCI may indicate a pending SSB transmission in the second cell. In certain embodiments, the DCI may indicate whether cell information of the second cell is updated.

[0139] In certain embodiments, the processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to receive a PDSCH transmission in the first cell, where the PDSCH transmission comprises the updated cell information of the second cell. In certain embodiments, the DCI comprises a bitfield associated with a location of the pending SSB transmission. In certain embodiments, the DCI comprises a bitfield associated with a BWP index.

[0140] In certain embodiments, a CRC of the DCI is scrambled with a RNTI associated with one or more of a respective SSB transmission, or a respective MIB transmission, or a respective SI transmission. In certain embodiments, the first cell is a PCell, and the second cell is configured as a SCell for the UE 900.

[0141] In some embodiments, the processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to: A) receive information of at least one subset of RS resource indices of a first cell and at least one second cell associated with a second subset of RS resource indices from the at least one subset of RS resource indices; B) perform cell measurement for the first cell; and C) transmit the wake-

up signal in response to a RS resource with a highest measurement value for the first cell corresponding to a RS resource index of the second subset of RS resource indices, wherein the wake-up signal is associated with the at least one second cell.

[0142] In certain embodiments, to transmit the wake-up signal, the processor 902 coupled with the memory 904 may be configured to, capable of, or operable to cause the UE 900 to transmit an event-triggered measurement report to the first cell, wherein the event-triggered measurement report is based at least in part on the RS resource with the highest measurement value for the first cell corresponding to the RS resource index of the second subset of RS resource indices.

[0143] In certain embodiments, to perform the cell measurement, the processor may be configured to measure one or more of: A) a RSRP value, B) a RSRQ value, C) a SINR value, or a combination thereof.

[0144] The controller 906 may manage input and output signals for the UE 900. The controller 906 may also manage peripherals not integrated into the UE 900. In some implementations, the controller 906 may utilize an operating system (OS) such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 906 may be implemented as part of the processor 902.

[0145] In some implementations, the UE 900 may include at least one transceiver 908. In some other implementations, the UE 900 may have more than one transceiver 908. The transceiver 908 may represent a wireless transceiver. The transceiver 908 may include one or more receiver chains 910, one or more transmitter chains 912, or a combination thereof.

[0146] A receiver chain 910 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 910 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 910 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 910 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 910 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0147] A transmitter chain 912 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 912 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 912 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 912 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0148] Figure 10 illustrates an example of a processor 1000 in accordance with aspects of the present disclosure. The processor 1000 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1000 may include a controller 1002 configured to perform various operations in accordance with examples as described herein. The processor 1000 may optionally include at least one memory 1004, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 1000 may optionally include one or more arithmetic-logic units (ALUs) 1006. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0149] The processor 1000 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1000)) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0150] The controller 1002 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1000 to cause the processor 1000 to support various operations in accordance with examples as described herein. For example, the controller 1002 may operate as a control unit of the processor 1000, generating control signals that manage the operation of various components of the processor 1000. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0151] The controller 1002 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1004 and determine subsequent instruction(s) to be executed to cause the processor 1000 to support various operations in accordance with examples as described herein. The controller 1002 may be configured to track memory address of instructions associated with the memory 1004. The controller 1002 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1002 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1000 to cause the processor 1000 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 1002 may be configured to manage flow of data within the processor 1000. The controller 1002 may be configured to control transfer of data between registers, ALUs, and other functional units of the processor 1000.

[0152] The memory 1004 may include one or more caches (e.g., memory local to or included in the processor 1000) or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 1004 may reside within or on a processor chipset (e.g., local to the processor 1000). In some other implementations, the memory 1004 may reside external to the processor chipset (e.g., remote to the processor 1000).

[0153] The memory 1004 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1000, cause the processor 1000 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory.

The controller 1002 and/or the processor 1000 may be configured to execute computer-readable instructions stored in the memory 1004 to cause the processor 1000 to perform various functions. For example, the processor 1000 and/or the controller 1002 may be coupled with or to the memory 1004, the processor 1000, the controller 1002, and the memory 1004 may be configured to perform various functions described herein. In some examples, the processor 1000 may include multiple processors and the memory 1004 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0154] The one or more ALUs 1006 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 1006 may reside within or on a processor chipset (e.g., the processor 1000). In some other implementations, the one or more ALUs 1006 may reside external to the processor chipset (e.g., the processor 1000). One or more ALUs 1006 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1006 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1006 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1006 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1006 to handle conditional operations, comparisons, and bitwise operations.

[0155] In some implementations, the processor 1000 may support various functions (e.g., operations, signaling) of a UE, in accordance with examples as disclosed herein. For example, the controller 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the processor 1000 to transmit a wake-up signal that requests one or more of at least one SS or at least one essential SI; receive cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and receive the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI includes a MIB, or a SIB1, or timing information of the

at least one SS, or a combination thereof. Additionally, the processor 1000 to perform one or more functions (e.g., operations, signaling) of the UE as described herein.

[0156] Additionally, or alternatively, in some other implementations, the processor 1000 may support various functions (e.g., operations, signaling) of a NE (e.g., base station), in accordance with examples as disclosed herein. For example, the controller 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the processor 1000 to receive a wake-up signal that requests one or more of at least one SS or at least one essential SI; transmit cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI; and transmit the one or more of at least one SS or at least one essential SI in response to the wake-up signal, where the at least one essential SI includes a MIB, or a SIB1, or timing information of the at least one SS, or a combination thereof. Additionally, the controller 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the processor 1000 to perform one or more functions (e.g., operations, signaling) of the NE as described herein.

[0157] Figure 11 illustrates an example of a NE 1100 in accordance with aspects of the present disclosure. The NE 1100 may include a processor 1102, a memory 1104, a controller 1106, and a transceiver 1108. The processor 1102, the memory 1104, the controller 1106, or the transceiver 1108, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0158] The processor 1102, the memory 1104, the controller 1106, or the transceiver 1108, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a DSP, an ASIC, or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0159] The processor 1102 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 1102 may be configured to operate the memory 1104. In some other implementations, the memory 1104 may be integrated into

the processor 1102. The processor 1102 may be configured to execute computer-readable instructions stored in the memory 1104 to cause the NE 1100 to perform various functions of the present disclosure.

[0160] The memory 1104 may include volatile or non-volatile memory. The memory 1104 may store computer-readable, computer-executable code including instructions when executed by the processor 1102 cause the NE 1100 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1104 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0161] In some implementations, the processor 1102 and the memory 1104 coupled with the processor 1102 may be configured to cause the NE 1100 to perform various functions (e.g., operations, signaling) described herein (e.g., executing, by the processor 1102, instructions stored in the memory 1104). In some implementations, the processor 1102 may include multiple processors and the memory 1104 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the NE 1100 as disclosed herein.

[0162] The processor 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the NE 1100 to receive a wake-up signal that requests one or more of at least one SS or at least one essential SI, where the at least one essential SI comprises one or more of a MIB, or a SIB1, or timing information of the at least one SS.

[0163] The processor 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the NE 1100 to transmit cell information corresponding to at least one cell associated with an on-demand transmission of the at least one SS or the at least one essential SI, or both.

[0164] In some embodiments, the cell information indicates one or more parameters adapted based on the wake-up signal, the one or more parameters comprising: A) a SSB

parameter associated with at least one of a time location, or a frequency location, or a periodicity of a SSB transmission, or a SSB transmit power, or one or more SSB positions in a SSB burst, or a SSB subcarrier spacing, wherein the SSB transmission comprises a PSS, a SSS, and a physical channel indicating at least SSB timing information; B) an initial DL BWP configuration; C) an initial UL BWP configuration; D) a TDD DL/UL configuration; or a combination thereof.

[0165] The processor 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the NE 1100 to transmit the at least one SS or the at least one essential SI, or both, in response to the wake-up signal. In some embodiments, the wake-up signal comprises a sequence-based signal, or a transmission on a specific channel, or both.

[0166] In some embodiments, the wake-up signal is associated with a second cell. In such embodiments, the processor 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the NE 1100 may be configured to transmit DCI in a first cell in response to a transmission of the wake-up signal. In certain embodiments, the DCI may indicate a pending SSB transmission in the second cell. In certain embodiments, the DCI may indicate whether cell information of the second cell is updated.

[0167] In certain embodiments, the processor 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the NE 1100 to transmit a PDSCH transmission in the first cell, where the PDSCH transmission comprises the updated cell information of the second cell. In certain embodiments, the DCI comprises a bitfield associated with a location of the pending SSB transmission. In certain embodiments, the DCI comprises a bitfield associated with a BWP index.

[0168] In certain embodiments, a CRC of the DCI is scrambled with a RNTI associated with one or more of a respective SSB transmission, or a respective MIB transmission, or a respective SI transmission. In certain embodiments, the first cell is a PCell for a UE, and the second cell is configured as a SCell for the UE.

[0169] The controller 1106 may manage input and output signals for the NE 1100. The controller 1106 may also manage peripherals not integrated into the NE 1100. In some implementations, the controller 1106 may utilize an operating system such as iOS®,

ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1106 may be implemented as part of the processor 1102.

[0170] In some implementations, the NE 1100 may include at least one transceiver 1108. In some other implementations, the NE 1100 may have more than one transceiver 1108. The transceiver 1108 may represent a wireless transceiver. The transceiver 1108 may include one or more receiver chains 1110, one or more transmitter chains 1112, or a combination thereof.

[0171] A receiver chain 1110 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1110 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 1110 may include at least one amplifier (e.g., an LNA) configured to amplify the received signal. The receiver chain 1110 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1110 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0172] A transmitter chain 1112 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1112 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as AM, FM, or digital modulation schemes like PSK or QAM. The transmitter chain 1112 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1112 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0173] Figure 12 depicts one embodiment of a method 1200 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 1200 may be implemented by a UE as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions.

[0174] At step 1202, the method 1200 may include transmitting a wake-up signal that requests one or more of at least one SS or at least one essential SI. Here, the at least one essential SI includes one or more of a MIB, or a SIB1, or timing information of the at least one SS. The operations of step 1202 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1202 may be performed by a UE, as described with reference to Figure 9.

[0175] At step 1204, the method 1200 may include receiving cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI. The operations of step 1204 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1204 may be performed by a UE, as described with reference to Figure 9.

[0176] At step 1206, the method 1200 may include receiving the one or more of at least one SS or at least one essential SI in response to the wake-up signal. The operations of step 1206 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1206 may be performed by a UE, as described with reference to Figure 9.

[0177] It should be noted that the method 1200 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0178] Figure 13 depicts one embodiment of a method 1300 in accordance with aspects of the present disclosure. The operations of the method 1300 may be implemented by a NE, e.g., in a RAN, as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0179] At step 1302, the method 1300 may include receiving a wake-up signal that requests one or more of at least one SS or at least one essential SI. Here, the at least one essential SI includes one or more of a MIB, or a SIB1, or timing information of the at least one SS. The operations of step 1302 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1302 may be performed by a NE, as described with reference to Figure 11.

[0180] At step 1304, the method 1300 may include transmitting cell information corresponding to at least one cell associated with an on-demand transmission of the one or more of at least one SS or at least one essential SI. The operations of step 1304 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1304 may be performed by a NE, as described with reference to Figure 11.

[0181] At step 1306, the method 1300 may include transmitting the one or more of at least one SS or at least one essential SI in response to the wake-up signal. The operations of step 1306 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1306 may be performed by a NE, as described with reference to Figure 11.

[0182] It should be noted that the method 1300 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0183] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.