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- (71) **Applicant:** INTEL IP CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).
- (72) **Inventors:** XIONG, Gang; 16682 NW Arizona Dr., Beaverton, Oregon 97006 (US). MONDAL, Bishwarup; 7130 Rainbow Dr., Unit 2, San Jose, California 95129 (US). NIMBALKER, Ajit; 4241 Stanley Ave., Fremont, California 94538 (US). FWU, Jong-Kae; 1519 Dminion Ave., Sunnyvale, California 94087 (US). BENDLIN, Ralf; 15447 NW Nightshade Dr., Portland, Oregon 97229 (US).
- (74) **Agent:** ESCHWEILER, Thomas G.; ESCHWEILER & POTASHNIK, LLC, 629 Euclid Ave., Suite 1000, Cleveland, Ohio 44114 (US).

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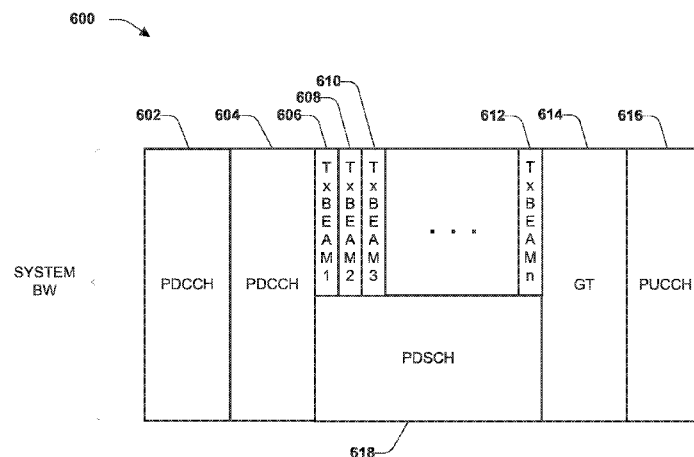


FIG. 6

(57) **Abstract:** Beamforming systems and network devices with mid-band carrier to high-band carrier (e.g., about 6 GHz to about 30 GHz) can more efficiently operate paging communications with various paging channel operations. Paging can be utilized to provide user equipments (UEs) with a system information change and a paging message. A system information change indication can be provided to a UE over a physical broadcast channel (PBCH) and the paging message can be provided to the UE over another physical channel, such as entirely in a physical downlink control channel (PDCCH) or a dedicated physical paging channel (PPGCH) without the physical downlink shared channel (PDSCH).

PAGING DESIGN FOR STAND-ALONE BEAMFORMED SYSTEM

REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Numbers 62/318,057 filed April 4, 2016, entitled "PAGING DESIGN FOR STAND-ALONE BEAMFORMED SYSTEM", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to wireless technology, and more specifically to techniques for signalling transmissions for paging in a beamformed system.

BACKGROUND

[0003] The explosive wireless traffic growth leads to an urgent need of rate improvement. With mature physical layer techniques, further improvement in the spectral efficiency could be marginal. On the other hand, the scarcity of licensed spectrum in low frequency band results in a deficit in the data rate boost. The next generation wireless communication system, 5G, will provide access to information and sharing of data anywhere, anytime by various users and applications. 5G is expected to be a unified network / system that target to meet vastly different and sometime conflicting performance dimensions and services. Such diverse multi-dimensional requirements are driven by different services and applications. In general, 5G will evolve based on 3GPP LTE-Adv with additional potential new Radio Access Technologies (RATs) to enrich people lives with better, simple and seamless wireless connectivity solutions. 5G will enable many devices to be connected by wireless communications and deliver fast, rich contents and services.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] **FIG. 1** illustrates a block diagram of an example wireless communications network environment for a network device (e.g., UE, gNB / eNB) according to various aspects or embodiments.

[0005] **FIG. 2** illustrates another block diagram of an example of wireless communications network environment for a network device according to various aspects or embodiments.

[0006] **FIG. 3** is a block diagram of a UE transmission according to various aspects or embodiments described herein.

[0007] **FIG. 4** illustrates an example of processing chain for a paging channel in accordance with various aspects or embodiments described herein.

[0008] **FIG. 5** illustrates a self-contained subframe for paging transmission according to various aspects or embodiments described herein.

[0009] **FIG. 6** illustrates structure for a paging transmission according to various aspects or embodiments described herein.

[0010] **FIG. 7** illustrates an example of localized or distributed schemes for paging transmission according to various aspects or embodiments described herein.

[0011] **FIGs. 8-10** illustrate examples of DMRS patterns for a single port transmission and a multi-port transmission in accordance with various aspects or embodiments herein.

[0012] **FIG. 11** illustrates a process flow of processing or generating a paging transmission according to various aspects or embodiments described herein.

[0013] **FIG. 12** illustrates another process flow of processing or generating a paging transmission according to various aspects or embodiments described herein.

[0014] **FIG. 13** illustrates an example system or network device operable with one or more components configured for various aspects or embodiments described herein.

[0015] **FIG. 14** illustrates another example system or network device operable with one or more components configured for various aspects or embodiments described herein.

DETAILED DESCRIPTION

[0016] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (UE) (e.g., mobile / wireless phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a

component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0017] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0018] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0019] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

OVERVIEW

[0020] In consideration of the above, various aspects / embodiments are disclosed for communications in a beamformed system or beamforming network device (e.g., user equipment, evolved NodeB, a next generation NodeB (gNB), new radio (NR) base station, a multi-input multi-output (MIMO) device, single-input multi-output (SIMO) device, or the like). Paging communication(s), for example, can operate to transmit paging information to a UE in radio resource control idle mode (e.g., RRC_IDLE), to inform UEs in RRC_IDLE or an RRC connected mode (e.g., RRC_CONNECTED) about a system information change, an Earthquake and Tsunami Warning service (ETWS) primary notification / ETWS secondary notification, or to inform about a Commercial Mobile Alert System (CMAS) notification.

[0021] In the idle mode, the UE can monitor for paging messages or system information change notifications regularly within its paging occasion. When the UE is not connected to the gNodeB, meaning UE is in an RRC idle state / mode, the UE is not required to monitor/receive the physical downlink control channel (or PDCCH) in every subframe/slot, but only on certain subframes/slots or locations does the UE receive the PDCCH. This PDCCH can carry the information about a paging information (or message) transmission such as timing or frequency domain information. As such, the UE can reconnect (or process reception) for a certain period of time only to receive the information. If a UE receives a paging message including an indication field (e.g., *systemInfoModification* or a corresponding information element (IE)) as being set to TRUE (or other system information change / update indication), the UE can detect that the system information will change at the next modification period boundary. Therefore, the UE can re-acquire the system information in the next broadcast control channel BCCH modification period, for example. For RRC connected mode or state, the UE is in a constant connection with the gNB, with ongoing traffic between eNB and the UE, meaning the UE monitors the PDCCH channel in every configured subframe (based on gNB indication) and can also receive paging operations in this state as well.

[0022] For mid-band (carrier frequency between 6GHz and 30GHz) and high-band carrier frequency (e.g., about 30GHz or beyond), beamforming can operate to improve the signal quality and reduce the inter user interference (external signalling noise) by directing the narrow radiate beaming toward the target user or UE. For mid and high-band systems with a mid-band or high-band carrier antenna, respectively, the path loss caused by weather like rain, fog, or object block, can also severely deteriorate the signal strength and damage the performance of the communications. A beam forming gain can

thus compensate the severe path loss, and thereby improve coverage range. As such, various aspects of paging, especially with respect to 5G physical channels and network devices, but not necessarily limited thereto, can be optimized with certain mechanism or process flow designs.

[0023] For a standalone deployment scenario, when the eNB or gNB transmits the paging message to the UE in idle mode, for example, the eNB may not initially know the location or beamforming direction for the one UE or a group of UEs. In this case, transmit (Tx) beam sweeping can be utilized by the eNB for transmission of the paging message to ensure good coverage and robust performance in the mid- to high-band frequency operations, especially when considering the support of an emergency message carried in a paging channel. Tx beam sweeping operations can involve transmitting the paging information or system information change update along a range of angles, which can ensure broadcasting to particular UEs or different groups of UEs.

[0024] Embodiments herein relate to design or techniques for a paging channel / paging operations in a standalone beamformed wireless system or device that can utilize cmWave or mmWave carriers (e.g., about 3 GHz to about 60 GHz or higher band reception / transmission) with devices having mid- to high-band antennas. In particular, embodiments can include aspects of mechanisms for a system information change notification, an ETWS notification, or a CMAS notification.

[0025] Additionally, aspects can relate to transmitting the paging information or paging record, or operating a paging channel designed as a PDCCH-less operation. These embodiments, for example, can include paging channel communication / operation without scheduling by the PDCCH or utilizing a physical downlink shared channel (PDSCH) to carry the paging message. The embodiment / aspects, can also include beamforming(ed) systems or devices that utilize the PDCCH for scheduling the paging message over the PDSCH. Additional aspects and details of the disclosure are further described below with reference to figures.

[0026] **FIG. 1** illustrates an example non-limiting wireless communications environment 100 that can enable a downlink (DL) transmission with indications (e.g., resource allocation or system information change indication) for uplink (UL) communication based on such indications, especially in conjunction with paging processes. The resources or related system indications discussed herein can include data / indications / bits / power / bandwidth / or other network parameters / properties / resources for UL by a user equipment (UE) or other network device with standalone

carrier operations (e.g., multiple carrier aggregation) for paging, beamforming operations or the like, and is not limited to these aspects alone, but can also include licensed assisted access (LAA) operations, for example, as well as other systems like in a MulteFire network, or other radio access technologies (RATs). Some of the resources can comprise one or more of: time domain resource (e.g. which subframe/slot), an interlace assignment, an orthogonal covering code (OCC), or a demodulation reference symbol (DMRS) sequence and cyclic shift (CS) / DMRS sequence pattern, to enable a HARQ-ACK feedback of an uplink control information (UCI) in the UL transmission. UCI can include HARQ-ACK feedback for physical downlink shared channel (PDSCH) or other physical channel, a scheduling request (SR), a physical random access channel (PRACH), other resource related to other feedback or channels such as paging communications and a dedicated paging channel as a physical paging channel (PPGCH), for example.

[0027] Wireless communications environment 100, for example, can include one or more cellular broadcast servers or macro cell network devices 102, 104 (e.g., primary cell devices, base stations, eNBs, access points (APs)) as well as one or more other network devices such as small cell network devices or APs (e.g., secondary cell device, small eNBs, micro-eNBs, pico-eNBs, femto-eNBs, home eNBs (HeNBs), Wi-Fi nodes, or other similar network device) 106, 108 deployed within the wireless communications environment 100 and servicing one or more UE devices 110, 112, 114, 116, 118 for wireless communications. Each wireless communications network (e.g., cellular broadcast servers 102, 104 and small cell network devices 106, 108) can comprise one or more network devices (e.g., a set of network devices (NDs)) that operate in conjunction in order to process network traffic for the one or more wireless / mobile devices or UE devices 110, 112, 114, 116, or 118. For example, macro cell NDs 102, 104 can comprise a set of network devices that are cellular enabled network devices. In another example, the small cell network devices 106, 108 can include a set of network devices that operate with a smaller coverage zone than the macro cell network devices 102 and 104, for example, or control similar coverage zones as the macro cell devices. As one of ordinary skill in the art can appreciate, this disclosure is not limited to any one network environment architecture / deployment.

[0028] Although NDs 106 and 108 are described as small cell network devices, these devices can also be Wi-Fi enabled devices or wireless local area network (WLAN) devices, as well as macro cell network devices, small cell network devices, or some

other type of ND operable as a base station, eNB, or a primary cell network device, for example, and capable of generating standalone multi-carrier aggregation operations, licensed assisted access operations, or the like. As such, one or more of the macro cell NDs 102 and 104 could also be small cell network devices or other NDs of a different radio access technology (RAT) that operate with different frequency carriers, for example, as small eNBs, micro-eNBs, pico-eNBs, femto-eNBs, home eNBs (HeNBs), Wi-Fi nodes, or secondary cell device.

[0029] As illustrated, each of the one or more Wi-Fi access points 106, 108, for example, can have a corresponding service area 120, 122. Additionally, each of the one or more cellular broadcast servers or macro cell NDs 102, 104 can have a corresponding service area 124, 126. However, it should be understood that the wireless communications environment 100 is not limited to this implementation. For example, any number of APs or NDs with respective service areas can be deployed within the wireless communications environment 100. Further, any number of cellular broadcast servers and respective service areas can be deployed within the wireless communications environment 100 as well. Although only five UE devices 110, 112, 114, 116, 118 are illustrated, any number of UE devices can be deployed within the wireless communications environment 100 as well. A UE device can contain some or all of the functionality of a system, subscriber unit, subscriber station, mobile station, mobile, wireless terminal, similar network device, mobile device, remote station, remote terminal, access terminal, user terminal, terminal, wireless communication device, wireless communication apparatus, user agent, user device, or other ND, for example.

[0030] In an example scenario, UE devices 110, 112, 114, 116, 118 can be serviced by networks through one of the macro cell NDs 102, 104, or small cell NDs 106, 108. As a UE device moves within the wireless communications environment 100, the respective user equipment device could move in and out of the coverage area of the associated serving network. For example, as a user is sending / receiving communications through their respective UE device, the user might be walking, riding in a car, riding on a train, moving around a densely populated urban area (e.g., a large city), wherein the movement could cause the mobile device to be moved between various wireless communication networks. In such cases, it can be beneficial for the UE to route the network traffic (e.g., handoff) from a serving ND to a target ND in order to continue the communication (e.g., avoid dropped calls) or facilitate offloading for load distribution or other efficiency purposes, such as via LAA to unlicensed bands.

[0031] Cellular broadcast servers or macro cell NDs 102, 104 and small cell NDs 106, 108 can operate to monitor their surrounding radio conditions (e.g., by employing respective measurement components). For example, each of the macro cell NDs 102, 104 and small cell NDs 106, 108 can determine network traffic load on its respective network by performing a network diagnostic process. Various parameters associated with macro cell NDs 102, 104, small cell NDs 106, 108, or UE devices 110, 112, 114, 116, 118 can be detected during the network diagnostic or measurements, such as, but not limited to, frequency bands, scrambling codes, common channel pilot power, bandwidth across respective networks, universal mobile telecommunications system terrestrial radio access receive signal strength indicator, as well as frequency carrier priorities for particular cell groups (e.g., a normal group or a reduced group) and so on.

[0032] Resource allocations from the eNB 102 /106 to a UE 110 / 112, or through a WiFi node or other network device from the eNB 102 /106 to the UE 110 / 112 for scheduling UL transmissions (e.g., paging transmissions), especially for paging channel operations in standalone beamformed wireless systems to meet the ever increasing need of wireless traffic with limited resources. Standalone / configurations / operations, in particular can refer to operations where LTE-based technology solely operates in unlicensed spectrum without requiring an “anchor” in licensed spectrum; This can also refer to unlicensed communications with time domain multiple carrier aggregation operations without any licensed assistance from one carrier or without transmit (Tx) beam sweeping operations on more than carrier regardless of the carriers being licensed or unlicensed in particular.

[0033] In an aspect, resources or parameters in a DL communication (e.g., a system information change / update, a system information change indication, or a paging message can be used for related UL communications (e.g., PRACH signal, SR signal, etc.), and can be semi-statically configured by higher layer signalling or signalling at the RRC layer or a higher layer, for example. Any layer above the PHY layer can be envisioned as a higher layer signalling as well. Resources can include time domain resources (e.g., a frame index, a slot index, a subframe index, a symbol index subframe) or other parameters such as a physical cell identifier (ID), a virtual cell ID or a UE ID, as well as indications, scheduling parameters, or signal resources such as a scheduling request (SR) resource, a physical random access channel (PRACH) resource, a frequency resource / band, an interlace, an orthogonal covering code (OCC), a demodulation reference symbol (DMRS) sequence and DMRS cyclic shift

(DMRS CS), or other network signalling parameter or resource for the UL transmission, for example, which can be used for an uplink transmission. The higher layer signalling can be in conjunction with dynamic signalling or other techniques from the eNB 102 /106 to the UE 110 / 112, for example, in a combination, independently or alone.

[0034] Referring to **FIG. 2**, illustrated is an example network configured to enable the operation of legacy network devices, NextGen network devices (network devices based on a 5G network), new radio (NR) network devices, or for standalone systems (e.g., MulteFire systems, or the like), which can be independent or communicatively coupled in one or more networks. These network devices can be configured to communicate via a communication protocol stack, which can be based on an Open Source Interconnected (OSI) model and defines the networking framework for implementing communication protocols among the various layers. Control can be passed from one layer to the next, starting at an application layer in one station or node, for example, proceeding to a bottom layer (e.g., a PHY layer), over a channel to a next station and back up the hierarchy. In particular, various embodiments and aspects herein are directed to a paging channel / paging operations in a standalone beamformed wireless system or device that can utilize cmWave or mmWave carriers (e.g., about 3 GHz to about 60 GHz or higher) with devices having one or more mid- to high-band antennas or corresponding reception and processing. In particular, embodiments can include aspects of mechanisms for a system information change notification, an ETWS notification, or a CMAS notification to better ensure emergency services and emergency reception. Additionally, aspects can relate to transmitting the paging information or paging record, or operating as paging channel as a PDCCH-less operation, where there is no scheduling operation / transmitting of a scheduling grant from the PDCCH for the paging message especially.

[0035] The network system 200 is an example of an interworking architecture for potential interworking between a legacy network (e.g., the evolved packet core (EPC) 204 in the LTE on the left hand side) and the next generation (NextGen) core 206 (as a 5G based core) with a 5G radio (e.g., the RAN 210 based on 5G RAT on the right hand side). Each component, individually or together can be a component of an eNB, separate eNBs, next generation NodeBs (gNBs), new radio (NR) basestations, WiFi nodes or the like as either of the RANs 208 or 210 operatively coupled to or comprising both the EPC 204 and the NextGen core 206. Thus, the UE signalling treatment or operation can be based on whether the UE is

5G capable or not to determine if the communication flow would be steered either to the EPC core 204 or the NextGen core 206. For example, UE 212 can be a legacy UE with bearer based operation handling, while a UEs 214 or 216 can be 5G UEs operable for a bearer based or a flow based operation, in which QoS or other communication parameters are based on a certain communication protocol flow, for example. Other configurations for communication with multiple different technologies or RATS can be envisioned.

[0036] On the left side, a legacy UE 212 and the 5G UE 214 can connect to the LTE eNB with RAN based on LTE 208, and the legacy UE 212 can have traffic handled over the S1 interface to the EPC 204, in one example, while the 5G UE 214 can have communications directed to the NextGen core 206 over the NG2 / NG3 interface(s), which can support infrastructure that can include licensed assisted accessed (LAA), enhanced LAA (eLAA), New radio, MulteFire, standalone beamforming operations, related carrier aggregation or the like. Thus, the communication handling can be different for different UEs so that one type of communication handling can be enabled for the 5G UE 214.

[0037] The components of the RAN based on LTE 208 can be employed in or as an eNB of a RAN based LTE or evolved LTE 208 configured to generate and manage cell coverage area / zone 220, while another eNB of a RAN based on 5G RAT / new RAT (NRAT) or MulteFire 210 can control the 5G based cell area 222. Although depicted as multiple coverage areas, this is only one example architecture and is not confined to any one or more cell coverage areas as illustrated on the right and left of the system 200.

[0038] In one embodied aspect, paging can be used to inform one or more UEs 212-216 in an RRC idle state (RRC_IDLE) as well as in an RRC connected state (RRC_CONNECTED) about changes / updates of system information, ETWS notification or CMAS notification. A terminal or UE being paged for this reason responds to being indicated or detecting that the system information will change, and thus, operates to acquire the updated system information. For mmWave and cmWave system devices, a Tx beam sweeping (beamforming or shaping across a range of beamforming angles) is utilized to broadcast this system information change, ETWS notification or CMAS notification to a UE or to a group of UEs, which could help to ensure the good coverage and robust performance. The transmission can be done based on UE ID or a group UE ID, for example.

[0039] A system information change indication (e.g., a *systemInfoModification* field as True or False) can be included in a master information block (MIB) such as a 5G master information block (xMIB) carried by 5G physical broadcast channel (xPBCH). A UE 212-216 can then monitor the MIB at certain occasions or paging occasions in time to check whether the system information is updated. For example, a paging radio frame (e.g., a paging frame (PF)) and subframe within that PF (e.g., a paging occasion (PO)) can be defined as a function of a UE ID, an international mobile subscriber identity (IMSI), or a system architecture evolution IMSI (S-IMSI). Further, to enable the UE 216 to read the MIB update, the PO can be aligned with the subframe used to transmit the MIB / xMIB, for example. In one option, after the UE 216 derives the PF and PO, it could monitor the next available broadcast subframe, e.g., subframe 0 or subframe 25 used to carry the MIB. For example, when the UE calculates the PO as a subframe 4 within one frame, it will monitor subframe 25 and read the MIB / xMIB content for potential system information change.

[0040] In addition, the ETWS / CMAS notification can be included in the MIB (xMIB) or the SIB (xSIB) as carried by the physical broadcast channel (PBCH). In response to the ETWS / CMAS notification being indicated in the SIB, the UE 216, for example, can first check the MIB content to determine whether the SIB is updated. If the system information modification or system information change indication is indicated as true, then the UE 216 can decode the next available SIB to acquire the updated system information, which can include the ETWS notification or the CMAS notification, for example.

[0041] In another embodiment, the paging message can include a paging record list, system information change / modification / update indication, the ETWS notification, or the CMAS notification. One paging record can include one paging UE ID, as a one-to-one correspondence, for example. Additionally, the paging UE ID can be an IMSI or S-TMSI. To receive paging messages, a UE or group of UEs in idle mode can monitor the PDCCH channel for a Paging Radio Network Temporary Identifier (P-RNTI) value. After successful decoding of the PDCCH channel, the UE 216 can operate to decode the PDSCH to acquire the paging record.

[0042] For standalone systems in particular, various embodiments of transmission schemes for the paging channel are envisioned. In one embodiment, the PDCCH with a cyclic redundancy check (CRC) masked with a P-RNTI can be used to schedule the PDSCH carrying a paging record. This can be performed in response to or when the

eNB / gNB 210 and UE 216 has acquired and maintained one or more Tx and Rx beams in connection between them. In this case, the eNB 210 can employ the proper or selected optimum beams (e.g., with highest signal strength, SNR or other parameter) to transmit the PDCCH and PDSCH for paging messages.

[0043] Additionally for beamforming systems and related network devices (e.g. mmWave or cmWave), the eNB / gNB 210 can use one or more directional beams to transmit the data and control channel. Thus, multiple paging records are not multiplexed in one paging message, and the PDSCH carries one paging record. Such paging record can define the UEs, a list of UE identities or other identity values associated with the transmission / communication, for example. Given that the number is limited to one paging record size, a compact downlink control information (DCI) can be enabled to further reduce signalling overhead, in which the compact DCI is reduced from an original or otherwise standard DCI being transmitted, for example.

[0044] In a further embodiment of standalone systems, the PDCCH can be used to carry one paging record for one UE, as a one-to-one correspondence. In this case, the paging transmission procedure can be simplified so as to allow a UE to directly acquire the paging message in the PDCCH itself, instead of obtaining the control or scheduling data from the PDCCH and based on this information obtaining the paging message from the PDSCH. Further, a maximum paging record size can be defined. In the case when a serving temporary mobile subscriber identity (S-TMSI) is used in the transmissions, zero padding can be used or performed in the transmission generation to match with the maximum paging record size in the DCI to reduce the number of blind decoding attempts by the UE 216, for example, and reduce UE power consumption.

[0045] Additionally or alternatively, when beam-pair directions between the eNB / gNB 210 and the UE 216, for example, are not maintained, Tx beam sweeping can be utilized for the PDCCH and the associated paging message transmission in PDSCH to ensure good coverage and robust performance. Although this could increase system overhead and reduce spectrum efficiency, the Tx beam sweeping could provide transmission over a range of angles to ensure transmission signalling for the paging message to one or more UEs or groups of UEs 212-216.

[0046] To simplify the procedure and reduce system overhead, PDCCH-less operation can be performed for paging message transmission, in which the PDCCH is not used to schedule the PDSCH. More specifically, a dedicated paging channel (PPGCH) can be defined to carry the paging record without also utilizing the PDSCH.

The size of the paging message and the modulation and coding scheme (MCS) used can be predefined / fixed in the specification or configured by higher layers via the MIB, the SIB, RRC signalling, or the like. For a fixed or pre-configured paging message size and when the actual paging record size is less than the fixed paging message size, zero padding can be generated therein to match with the fixed / predetermined message size. Zero padding can refer to adding zeros somewhere in the signal (e.g., the end) in order to reach the pre-configured paging message size, for example.

[0047] Additionally or alternatively, before a paging occasion, the UE 216, for example, can transmit the physical random access channel (PRACH) signal or a scheduling request (SR) signal to help or assist the eNB 210 to identify a proper or optimal eNB Tx beam(s) for the subsequent PDCCH / PDSCH / PPGCH transmission, which can be used to carry a paging message. The PO can refer to a subframe where there can be a P-RNTI on a physical channel (e.g., PDCCH), which can carry the paging message. The PF can be a frame comprising one or more POs for example. The SR can refer to a signal that can be a special PHY layer signal / message in which the UE 216 or other UE, for example, can send a request to obtain a UL grant (e.g., DCI format 0 or the like), and thus transmit an uplink communication, which can be PUSCH. In this case, the SR signal can be utilized to provide a directional beam from among a range of beamforming angle rather than communicate via a transmit beam sweeping operation. Alternatively or additionally, the PRACH signal can also be sent by the UE 216, for example, and used by the eNB 210 in order to determine an optimal directional beam and avoid transmit beam sweeping as well. The PRACH signal can carry a preamble with a cyclic prefix, a sequence or guard time, for example.

[0048] As such, the aspects / embodiments herein can be applicable to UE specific target beams. In addition, aspects / embodiments can be applicable to broadcast beaming transmission to a UE or groups of UEs in a set, along with mid-band to high-band transmission and reception as part of the beam forming technology to improve the signal quality.

[0049] Referring now to **FIG. 3** illustrates an example of UE assisted paging channel transmission(s) 300. In particular, a UE assisted communication 300 can be a one-to-one resource association between a beam reference signal (BRS) antenna port and an SR resource or a PRACH resource 304 in a time domain / frequency domain as defined.

[0050] For example, the UE (e.g., 216 of FIG. 2 or otherwise) can select the time resource / frequency resource for an SR or a PRACH transmission, which can be a one-to-one association 308 on the time and frequency resource where the eNB's best / optimal Tx beam is located. Upon successful detection of the SR and PRACH signal from the UE 216, the eNB 210 can then identify the best eNB Tx beam for the corresponding PDCCH and PDSCH transmission, which is used to carry paging message.

[0051] For example, before this paging transmission 302 is communicated, the UE 216 can transmit an SR or PRACH from one UE site, so after the gNB 210 acquires this signal, it can know what specific Tx beam can be used to transmit the paging message 300. With the UE assisted information, the gNB 210 can form a direct beam and transmit the paging, while enabling the reduction of overhead of Tx beam sweeping and only one beam is needed to transmit the paging message, especially where the UE's initial location or group of UE's initial locations are initially unknown.

[0052] The paging radio frame 302 (e.g., the Paging Frame (PF)) and subframe 306 within that PF (e.g., PO)) can be defined as a function of UE ID or an International mobile subscriber identity (IMSI), for example. Further, to enable the UE 216, for example, to read the MIB update, the PO 306 can be aligned with the subframe used to transmit the MIB.

[0053] In an aspect, after the UE derives the PF and PO 306, it would monitor the next available broadcast subframe, e.g., subframe 0 or 25 used to carry the xMIB. For instance, when UE calculates PO 306 as subframe 4 within one frame, it will monitor subframe 25 and read the MIB content for potential system information change or an indication thereof. In particular, the ETWS and CMAS notification can be included in the MIB or 5G system information block (SIB). In the case when the ETWS / CMAS notification is indicated in the SIB, UE 216, for example, can first check the MIB content to determine whether the SIB is updated. If the system information modification or change indication is true, the UE would decode the next available SIB to acquire the updated system information, which can include the ETWS and CMAS notification.

[0054] Referring to **FIG. 4**, illustrated is an example of a paging channel and related components of a network device (e.g., an eNB / gNB, UE or the like) in accordance with various aspects / embodiments. As mentioned above, to reduce the signalling overhead, a fixed paging message size as well as the modulation and coding scheme (MCS) can be defined for a paging channel. Further, this fixed paging message size can

be defined in a cell specific or a UE specific manner. In the latter case, the paging message size and MCS can be configured by UE specific RRC signalling.

[0055] The system or device 400 can include an encoder or coder 402 connected to a scrambling component 402 coupled to a modulation component 406, which is connected to a mapping component 608. Via the coding component 402, coding can be performed or applied to data for the paging information bit, i.e., X bits, wherein X can be an integer greater than zero, for example. In one example, a tail-biting convolutional coder (TBCC) operation can be applied for the paging channel. In another example, Turbo code or a low-density parity-check (LDPC) can be applied for the paging information bits. In particular, a cyclic redundancy check (CRC) or CRC bits can be appended on the paging information bit first prior to the encoding.

[0056] After the coding operations via the coder 402, the scrambling component 404 receives the coder / coding output and performs a scrambling of the output to further randomize the interference. In one example, a scrambling seed can be generated or defined as a function of a physical or virtual cell ID, a subframe index, a slot index, or a symbol index for the transmission of paging channel. In one example, the scrambling seed can be represented by the following:

$$\text{[0057]} \quad C_{init} = 2^{10} \cdot (7 \cdot (n_s + 1) + l + 1) \cdot (2 \cdot N_{ID}^{cell} + 1) + 2 \cdot N_{ID}^{cell} + 1;$$

[0058] where n_s is the slot index; l is the orthogonal frequency division multiplexing (OFDM) symbol index and N_{ID}^{cell} is the physical cell ID or a virtual identifier acquired by the UE, which could be a physical cell ID or a virtual index indicated by the gNB in a synchronization/broadcast message). In another option, the scrambling seed can be defined in a UE specific manner, i.e., it can be defined as a function of one or more following parameters: physical or virtual cell ID, subframe/slot/symbol index, UE ID (in a form of IMSI or S-IMSI). For instance, the scrambling seed can be given by $C_{init} = f(n_s, N_{ID}^{cell}, \text{IMSI})$, in which the scrambling seed is based on or a function of the slot index, the physical cell / UE ID, or IMSI or system architecture evolution (SAE) temporary mobile subscriber identity (S-TMSI).

[0059] Subsequently, binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) can be performed for the modulation by the modulation component 406 to ensure robust performance. In the last component or element, modulated symbols are mapped to the allocated resources by the mapping component 408.

[0060] The component signalling chain 400 can detail the paging channel design when there is no PDCCH involved (or PDCCH-less paging). The paging channel 400

can follow the procedure illustrated in FIG. 4 with coding the information bits, by coding, scrambling, modulation and resource mapping operations. In a particular aspect, the coding can follow TBCC or LDPC and CRC. After coding, the scrambling seed can be defined as a function of the cell ID, or symbol or timing index, with the modulation being used for obtaining the modulation BPSK or QPSK.

[0061] From a UE perspective, for example, similar components can be involved in receiving and processing the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH. The received paging transmission can be processed by demodulating via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are mapped to one or more allocated resources of the PPGCH. A de-scrambling operation can be applied at a scrambling component for generating a (de) scrambling sequence based on a scrambling seed and the de-scrambled bits can be decoded (via a coding component) for one or more information bits of the PPGCH.

[0062] Referring to **FIG. 5**, to enable low latency transmission, a self-contained TDD subframe 500 can be introduced for a 5G system or other RAT in accordance with various embodiments. As shown in **FIG. 5**, an uplink communication such as a physical uplink control channel (PUCCH) 508 (e.g., a hybrid automatic repeat request (HARQ) acknowledgement (ACK) / NACK feedback) can be transmitted in a same subframe 500 when a physical downlink shared channel (PDSCH) 504, for example is being scheduled by a PDCCH. In particular, the PDSCH 504 can be scheduled by a PDCCH 502, and can be transmitted right after the PDCCH 502. After decoding the PDSCH 504, the UE (e.g., 216) can then feedback the ACK or NACK in the PUCCH in the last part of subframe 500. A guard time (GT) 506 can be (or not) inserted between the PDSCH 504 and the PUCCH 508 in order to accommodate the DL to UL and UL to DL switching time or round-trip propagation delay, for example.

[0063] As such, FIG. 5 illustrates an example of the resource mapping that can be generated in part by the mapping component 408 of FIG. 4. In generating the resource mapping, a so called self-contained time division duplex (TDD) subframe structure can thus be generated, in which the PDCCH 502, the PDSCH 504, associated downlink control and downlink data and a gap 506 are configured where the PUCCH 508 is used to carry the ACK / NACK information from the UE 216. As such a downlink and uplink structure in the same transmission opportunity can be generated and processed. In particular, the Tx beam sweeping for the paging transmission can be contained within

this self-contained structure or subframe 500, which means also that the paging channel can initiate or start after the PDCCH and before the gap guard time.

[0064] Referring now to **FIG. 6**, illustrated is an example of another embodiment, in which the structure or mode of paging transmission 600 can depend on the payload size. To allow Tx beam sweeping for a paging channel transmission 600, for example, one paging channel can span one or several OFDM symbol(s). Depending on the payload size of the paging transmission 600, one paging channel transmission can occupy a partial or a full system bandwidth. Further, different Tx beams (e.g., Tx Beam 1 606 – Tx Beam n 612) can be applied on each one or several OFDM symbol(s) to ensure good cell coverage. The same paging information can also be transmitted in each one or several OFDM symbol(s).

[0065] As such, depending on a payload size of the paging transmission, one paging channel transmission can occupy a partial or full system bandwidth, in which a full / complete system bandwidth spans a range of bands. In contrast, the Tx Beams 1-n 606-612 and the PDSCH 618 reside in the same location in time but span a partial system bandwidth. On different symbols, a different Tx beam (e.g., Tx Beam 1-n) can be applied. Thus, the paging 600 transmission of FIG. 6 also demonstrates a form of Tx beam sweeping, where each beam (e.g., Tx Beam 1-n, or 606-612) can represent a different Tx beam direction.

[0066] Depending on the exact payload size for a paging channel, and also the system bandwidth, the paging channel can occupy a partial system bandwidth as in the paging transmission 600 of **FIG. 6**. The payload size can be a fixed or predetermined size, so that if the paging transmission is above this size, then a fully system bandwidth is used for the paging channel (e.g., a dedicated PPGCH without scheduling from the PDCCH, the PDSCH scheduled by PDCCH or the PDCCH alone without scheduling of the PDSCH). If the payload is below this predetermined size, then a complete or full system bandwidth can be used for the paging transmissions 618 (e.g., a dedicated PPGCH without scheduling from the PDCCH, the PDSCH scheduled by PDCCH or the PDCCH alone without scheduling of the PDSCH). This predetermined sized, for example, can be about 100 bits or some other number.

[0067] Referring now to **FIG. 7**, illustrates is an example of localized and distributed transmission schemes 700 for paging channel communication. The paging transmissions 700, for example, can be configured according to localized and distributed transmission modes. As stated above, depending on the exact payload size

for a paging channel, and also the system bandwidth, the paging channel can occupy a partial system bandwidth as in the paging transmission 600 of FIG. 6. As in one example of a partial symbol transmission, four sub-bands 702-708 (or subframes) and one paging channel can be occupied by one sub-band as a localized transmission 720. Additionally, a distributed transmission 720 can be a paging transmission with different sub-bands 710-714 distributed within the system bandwidth, and equally dividing within the system bandwidth. Here, in this one the benefit of frequency diversity can be attained.

[0068] For the localized transmission scheme 720, the full system bandwidth can be divided into L sub-bands 702-708, with each sub-band comprising K subcarriers, which can be represented as: $L = \lceil N_{sc}/K \rceil$ or $L = \lfloor N_{sc}/K \rfloor$; where N_{sc} is the total number of subcarriers within the system bandwidth.

[0069] For the distributed transmission scheme 730, each sub-band 702-708 can be divided into M subcarrier blocks 710-714, and each subcarrier block 710-714 can occupy N subcarriers. Thus, the number of sub-bands can be then represented as $L = \lceil N_{sc}/(MN) \rceil$ or $L = \lfloor N_{sc}/(MN) \rfloor$.

[0070] In the options, for localized transmission, the system bandwidth can be divided into 4 sub-bands, i.e., $L = 4$. For distributed transmission, system bandwidth is divided into 4 sub-bands, i.e., $L = 4$ and each sub-band occupies 3 subcarrier blocks, i.e., $M = 3$.

[0071] A set of possible frequency resources or sub-bands for the transmission of a paging channel can be predefined or configured in the MIB or SIB or in RRC signaling. Further, the exact frequency resource used for generation or transmission via the paging channel (e.g., a dedicated PPGCH without scheduling from the PDCCH, the PDSCH scheduled by PDCCH or PDCCH without scheduling for the PSDCH, or otherwise) can be either configured by a higher layer via UE specific RRC signalling or derived from this set of possible frequency resources according to a function of one or more of the following parameters: physical cell ID, virtual cell ID, a frame/slot/subframe(subband)/symbol index or a UE ID, for example.

[0072] In an example, L frequency resources can be configured in the SIB. The exact frequency resource index can be defined or represented as: $I_{freq} = (c_0 \cdot N_{ID}^{cell} + c_1 \cdot n_{SF} + c_2 \cdot UE_{ID} + c_3) \bmod L$; where $\bmod$ is a modulo operation, c_0, c_1, c_2, c_3 are constants, which can be predefined in the specification or configured by higher layers via MIB; N_{ID}^{cell} can be the physical cell ID; n_{SF} can be the subframe index; I_{freq} can be

the frequency resource index; UE_{ID} can be the UE ID, which can be defined as a form of IMSI or S-IMSI, and L can be the number of frequency resources or sub-bands for the paging channel transmission. In another example, the exact frequency resource for paging channel transmission can be defined or represented as $I_{freq} = (UE_{ID}) \bmod L$.

[0073] Referring to **FIGs. 8-10**, illustrated are examples of DMRS patterns for a single port transmission and a multi-port transmission in accordance with various aspects or embodiments herein. Depending on the number of resource elements allocated for each paging block (e.g., a subcarrier block of M) and the number of antenna points (APs) for paging channel transmission, different options for the DM-RS pattern can be provided.

[0074] **FIG. 8** and **FIG. 9** illustrate examples of DM-RS patterns 600 and 700 for single port transmission when the paging channel occupies 8 resource elements (REs) and 12 REs, respectively. Additionally or alternatively, a similar pattern can be defined for two port paging channel transmission as illustrated in **FIG. 10**, for example.

[0075] The DMRS reference symbols (or pilot symbols) can be inserted in the OFDM time-frequency grid to allow for channel estimation, for example. Each DMRS can comprises a pseudo-random signal generated in the frequency domain to be utilized for channel estimation. As such, a UE (e.g., 216) can find out the frequency resource for the transmission paging, which can be done depending on the UE ID. For example, with four sub-bands, where to decode the paging channel can be found depending on the UE ID. For example, a UE # 100 only needs to monitor the sub-band in the sub-blocks color with dark highlighting as AP #100 depending on the UE specific UE ID.

[0076] In particular, different potential DMRS patterns (e.g., 802-806) for transmission of paging channel are illustrated as options. **FIG. 8** illustrates options for DMRS patterns 802-806 for a single port with 8 REs at each of the three optional patterns for a paging block. **FIG. 9** illustrates options for DMRS patterns 902-910 for a single antenna port (as one or more antennas for a particular direction, UE, group of UEs) with 12 REs as a paging block at each of the options for a single transmission.

[0077] **FIG. 10** illustrates an example of a DM-RS pattern for a paging channel with two APs when paging channel occupies 12 REs. The DM-RS for these two APs can be multiplexed in Frequency-division multiplexing (FDM) or Code Division Multiplexing (CDM) manner. In the case of CDM multiplexing between two APs, orthogonal cover code (OCC) can be applied on each AP, which can be defined as below in the Table 1.

Table 1. OCC for two APs

<i>Antenna Port p</i>	$[w_p(0)w_p(1)]$
100	[1 1]
101	[1 -1]

[0078] The generation of a DMRS sequence can be defined as a function of one or more parameters: physical cell ID, virtual cell ID, frame/slot/subframe/symbol index or a UE ID. In one example, the pseudo-random sequence generator shall be initialized with the following representative expressions, as discussed above:

[0079] $C_{init} = 2^{10} \cdot (7 \cdot (n_s + 1) + l + 1) \cdot (2 \cdot N_{ID}^{cell} + 1) + 2 \cdot N_{ID}^{cell} + 1$ as the start of each OFDM symbol. In the case when a space frequency block code (SFBC) can be applied for the paging channel transmission, two consecutive REs can then be used for the paging channel transmission. As such, in response to receiving the paging message based on the multiple port transmission, processing of the transmission can be done based on a SFBC with at least two consecutive resource elements (REs) grouped for an SFBC transmission scheme.

[0080] While the methods described within this disclosure are illustrated in and described herein as a series of acts or events, it will be appreciated that the illustrated ordering of such acts or events are not to be interpreted in a limiting sense. For example, some acts may occur in different orders and/or concurrently with other acts or events apart from those illustrated and/or described herein. In addition, not all illustrated acts may be required to implement one or more aspects or embodiments of the description herein. Further, one or more of the acts depicted herein may be carried out in one or more separate acts and/or phases.

[0081] Referring to **FIG. 11**, illustrated is an example process flow 1100 for transmitting / receiving / processing / generating one or more system information notifications, related updated, or paging communications in accordance with one or more aspects or embodiments herein. A computer-readable storage medium, device (e.g., a gNB / eNB) or system storing executable instructions that, in response to execution, cause one or more processors to perform operations of the process flow or method. The method 1100 can initiate at 1102 with identifying a system information change, which can include an update indication, an emergency warning service, a paging record, an Earthquake and Tsunami Warning Service (ETWS), or a Commercial Mobile Alert System (CMAS) notification, for example. Each of these system

notifications or related indications can be held or carried within the MIB or the SIB, for example.

[0082] At 1104, a system information change indication can be generated based on one or more of: the system information change or the paging message.

[0083] At 1106 the system information change indication can be transmitted via a physical broadcast channel (PBCH) and the paging message can be transmitted via another physical channel.

[0084] The process flow 1100 can further comprise generating a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit the MIB. The paging message can be transmitted via a PDSCH scheduled by a PDCCH, the PDCCH without utilizing the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel. The paging message can be transmitted, for example, by generating a beam sweeping operation along a range of beamforming angles, or with UE assisted beam forming whereby a particular beam can be generated based on a signal from the UE.

[0085] The paging message can include the system information change, a paging record that can correspond to only one user equipment (UE) via the PDCCH. This can enable further generation of compact or decreased downlink control information (DCI). The DCI can be zero padded as well to make up a predetermined size or larger size also, which can decrease a number of blind detections by the UE.

[0086] Further, the method 1100 can include providing a dedicated SR resource or a dedicated PRACH resource to enable a communication based on the dedicated SR resource or the dedicated PRACH resource. A physical random access channel (PRACH) signal or a scheduling request (SR) signal can be generated and processed based on the dedicated SR resource or the dedicated PRACH resource. A beam can then be identified based on the PRACH signal or the SR signal, and the paging message can then be transmitted by eNB or gNB based on the identified beam.

[0087] Referring to **FIG. 12**, illustrated is another example process flow 1100 for transmitting / receiving / processing / generating one or more system information notifications, related updated, or paging communications in accordance with one or more aspects or embodiments herein. A computer-readable storage medium, device

(e.g., a UE) or system storing executable instructions that, in response to execution, cause one or more processors to perform operations of the process flow or method.

[0088] At 1202, process a system information update based on a system information change indication via a physical broadcast channel (PBCH) and a paging message via another physical channel.

[0089] At 1204, a communication interface, coupled to the one or more processors, configured can operate to receive the system information change indication via the PBCH and the paging message via the another physical channel.

[0090] At 1206, the method 1200 can further include receiving the paging message via a PDSCH that is scheduled by a PDCCH, the PDCCH without scheduling by the PDSCH, or a dedicated PPGCH without scheduling from the PDCCH, as the another physical channel. This can also include receiving or processing the system information change indication in a field of at least one of: a master information block (MIB) or a system information block (SIB) carried by the PBCH.

[0091] The method can further include receiving the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH. At 1208 the method comprises demodulating via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are mapped to one or more allocated resources of the PPGCH.

[0092] At 1210, a de-scrambling operation can be applied for generating a scrambling sequence based on a scrambling seed and the de-scrambled bits can be decoded for one or more information bits of the PPGCH.

[0093] In other embodiments, the UE can transmit a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on a PRACH resource or an SR resource to enable an identification of a beam for transmission of the paging message. The paging message can then be received via the beam based on the PRACH signal or the SR signal, as a UE assisted signal.

[0094] One PPGCH transmission can span one or more orthogonal frequency division multiplexing (OFDM) symbol and occupy a partial system bandwidth or a full system bandwidth based on the payload size, for example. In response to the PPGCH transmission occupying the partial system bandwidth, the PPGCH transmission is based on a localized transmission scheme or a distributed transmission scheme according to a payload size of the PPGCH transmission.

[0095] Embodiments described herein can be implemented into a system using any suitably configured hardware and/or software. **FIG. 13** illustrates, for at least one embodiment, example components of a network device such as an eNB 102 / 106, a UE 110, 216, eNB / gNB 208, 210 or other similar network device 1300. In some embodiments, the network device 1300 can include application circuitry 1302, baseband circuitry 1304, Radio Frequency (RF) circuitry 1306, front-end module (FEM) circuitry 1308 and one or more antennas 1310, coupled together at least as shown and can operate any one, all or a combination of operations or processes described within embodiments / aspects herein.

[0096] The application circuitry 1302 can include one or more application processors. For example, the application circuitry 1302 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors can be coupled with and/or can include memory/storage and can be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0097] The baseband circuitry 1304 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1304 can include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1306 and to generate baseband signals for a transmit signal path of the RF circuitry 1306. Baseband processing circuitry 1304 can interface with the application circuitry 1302 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1306. For example, in some embodiments, the baseband circuitry 1304 can include a second generation (2G) baseband processor 1304a, third generation (3G) baseband processor 1304b, fourth generation (4G) baseband processor 1304c, and/or other baseband processor(s) 1304d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1304 (e.g., one or more of baseband processors 1304a-d) can handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1306. The radio control functions can include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the

baseband circuitry 1304 can include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping / demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1304 can include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and can include other suitable functionality in other embodiments.

[0098] In some embodiments, the baseband circuitry 1304 can include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1304e of the baseband circuitry 1304 can be configured to run elements of the protocol stack for signalling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry can include one or more audio digital signal processor(s) (DSP) 1304f. The audio DSP(s) 1304f can include elements for compression/decompression and echo cancellation and can include other suitable processing elements in other embodiments. Components of the baseband circuitry can be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1304 and the application circuitry 1302 can be implemented together such as, for example, on a system on a chip (SOC).

[0099] In some embodiments, the baseband circuitry 1304 can provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1304 can support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1304 is configured to support radio communications of more than one wireless protocol can be referred to as multi-mode baseband circuitry.

[00100] RF circuitry 1306 can enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1306 can include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1306 can include a

receive signal path which can include circuitry to down-convert RF signals received from the FEM circuitry 1308 and provide baseband signals to the baseband circuitry 1304. RF circuitry 1306 can also include a transmit signal path which can include circuitry to up-convert baseband signals provided by the baseband circuitry 1304 and provide RF output signals to the FEM circuitry 1308 for transmission.

[00101] In some embodiments, the RF circuitry 1306 can include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1306 can include mixer circuitry 1306a, amplifier circuitry 1306b and filter circuitry 1306c. The transmit signal path of the RF circuitry 1306 can include filter circuitry 1306c and mixer circuitry 1306a. RF circuitry 1306 can also include synthesizer circuitry 1306d for synthesizing a frequency for use by the mixer circuitry 1306a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1306a of the receive signal path can be configured to down-convert RF signals received from the FEM circuitry 1308 based on the synthesized frequency provided by synthesizer circuitry 1306d. The amplifier circuitry 1306b can be configured to amplify the down-converted signals and the filter circuitry 1306c can be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals can be provided to the baseband circuitry 1304 for further processing. In some embodiments, the output baseband signals can be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1306a of the receive signal path can comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00102] In some embodiments, the mixer circuitry 1306a of the transmit signal path can be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1306d to generate RF output signals for the FEM circuitry 1308. The baseband signals can be provided by the baseband circuitry 1304 and can be filtered by filter circuitry 1306c. The filter circuitry 1306c can include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[00103] In some embodiments, the mixer circuitry 1306a of the receive signal path and the mixer circuitry 1306a of the transmit signal path can include two or more mixers and can be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 1306a of the receive signal path and the

mixer circuitry 1306a of the transmit signal path can include two or more mixers and can be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1306a of the receive signal path and the mixer circuitry 1306a can be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 1306a of the receive signal path and the mixer circuitry 1306a of the transmit signal path can be configured for super-heterodyne operation.

[00104] In some embodiments, the output baseband signals and the input baseband signals can be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals can be digital baseband signals. In these alternate embodiments, the RF circuitry 1306 can include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1304 can include a digital baseband interface to communicate with the RF circuitry 1306.

[00105] In some dual-mode embodiments, a separate radio IC circuitry can be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00106] In some embodiments, the synthesizer circuitry 1306d can be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers can be suitable. For example, synthesizer circuitry 1306d can be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00107] The synthesizer circuitry 1306d can be configured to synthesize an output frequency for use by the mixer circuitry 1306a of the RF circuitry 1306 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1306d can be a fractional $N/N+1$ synthesizer.

[00108] In some embodiments, frequency input can be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input can be provided by either the baseband circuitry 1304 or the applications processor 1302 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) can be determined from a look-up table based on a channel indicated by the applications processor 1302.

[00109] Synthesizer circuitry 1306d of the RF circuitry 1306 can include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider can be a dual modulus divider (DMD) and the phase accumulator can be a

digital phase accumulator (DPA). In some embodiments, the DMD can be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL can include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements can be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00110] In some embodiments, synthesizer circuitry 1306d can be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency can be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency can be a LO frequency (f_{LO}). In some embodiments, the RF circuitry 1306 can include an IQ/polar converter.

[00111] FEM circuitry 1308 can include a receive signal path which can include circuitry configured to operate on RF signals received from one or more antennas 1310, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1306 for further processing. FEM circuitry 1308 can also include a transmit signal path which can include circuitry configured to amplify signals for transmission provided by the RF circuitry 1306 for transmission by one or more of the one or more antennas 1310.

[00112] In some embodiments, the FEM circuitry 1308 can include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry can include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry can include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1306). The transmit signal path of the FEM circuitry 1308 can include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1306), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1310).

[00113] In some embodiments, the device 1300 can include additional elements such as, for example, memory/storage, display, camera, sensor, or an input/output (I/O)

interface. In addition, the device 1300 can include the components discussed herein to further generate or process resource allocations, related indications, paging communications, and related measurements for signaling in 5G based RATs or various other RATs.

[00114] To provide further context for various aspects of the disclosed subject matter, **FIG. 14** illustrates a block diagram of an embodiment of access (or user) equipment related to access of a network (e.g., network device, base station, wireless access point, femtocell access point, and so forth) that can enable and/or exploit features or aspects disclosed herein.

[00115] Access equipment, a network device (e.g., eNB, network entity, or the like), a UE or software related to access of a network can receive and transmit signal(s) from and to wireless devices, wireless ports, wireless routers, etc. through segments 1402₁-1402_B (B is a positive integer). Segments 1402₁-1402_B can be internal and/or external to access equipment and/or software related to access of a network, and can be controlled by a monitor component 1404 and an antenna component 1406. Monitor component 1404 and antenna component 1406 can couple to communication platform 1408, which can include electronic components and associated circuitry that provide for processing and manipulation of received signal(s) and other signal(s) to be transmitted.

[00116] In an aspect, communication platform 1408 includes a receiver/transmitter 1410 that can convert analog signals to digital signals upon reception of the analog signals, and can convert digital signals to analog signals upon transmission. In addition, receiver/transmitter 1410 (e.g., receiver / transmitter circuitry) can divide a single data stream into multiple, parallel data streams, or perform the reciprocal operation. Coupled to receiver/transmitter 1410 can be a multiplexer / demultiplexer 1412 that can facilitate manipulation of signals in time and frequency space. Multiplexer / demultiplexer 1412 can multiplex information (data/traffic and control/signalling) according to various multiplexing schemes such as time division multiplexing, frequency division multiplexing, orthogonal frequency division multiplexing, code division multiplexing, space division multiplexing. In addition, multiplexer/ demultiplexer component 1412 can scramble and spread information (e.g., codes, according to substantially any code known in the art, such as Hadamard-Walsh codes, Baker codes, Kasami codes, polyphase codes, and so forth).

[00117] A modulator/demodulator 1414 is also a part of communication platform 1408, and can modulate information according to multiple modulation techniques, such as

frequency modulation, amplitude modulation (e.g., M-ary quadrature amplitude modulation, with M a positive integer); phase-shift keying; and so forth).

[00118] Access equipment and/or software related to access of a network also includes a processor 1416 configured to confer, at least in part, functionality to substantially any electronic component in access equipment and/or software. In particular, processor 1416 can facilitate configuration of access equipment and/or software through, for example, monitor component 1404, antenna component 1406, and one or more components therein. Additionally, access equipment and/or software can include display interface 1418, which can display functions that control functionality of access equipment and/or software or reveal operation conditions thereof. In addition, display interface 1418 can include a screen to convey information to an end user. In an aspect, display interface 1418 can be a liquid crystal display, a plasma panel, a monolithic thin-film based electrochromic display, and so on. Moreover, display interface 1418 can include a component (e.g., speaker) that facilitates communication of aural indicia, which can also be employed in connection with messages that convey operational instructions to an end user. Display interface 1418 can also facilitate data entry (e.g., through a linked keypad or through touch gestures), which can cause access equipment and/or software to receive external commands (e.g., restart operation).

[00119] Broadband network interface 1420 facilitates connection of access equipment and/or software to a service provider network (not shown) that can include one or more cellular technologies (e.g., third generation partnership project universal mobile telecommunication system, global system for mobile communication, and so on) through backhaul link(s) (not shown), which enable incoming and outgoing data flow. Broadband network interface 1420 can be internal or external to access equipment and/or software and can utilize display interface 1418 for end-user interaction and status information delivery.

[00120] Processor 1416 can be functionally connected to communication platform 1408 and can facilitate operations on data (e.g., symbols, bits, or chips) for multiplexing / demultiplexing, such as effecting direct and inverse fast Fourier transforms, selection of modulation rates, selection of data packet formats, inter-packet times, and so on. Moreover, processor 1416 can be functionally connected, through data, system, or an address bus 1422, to display interface 1418 and broadband network interface 1420, to confer, at least in part, functionality to each of such components.

[00121] In access equipment and/or software memory 1424 can retain location and/or coverage area (e.g., macro sector, identifier(s)) access list(s) that authorize access to wireless coverage through access equipment and/or software sector intelligence that can include ranking of coverage areas in the wireless environment of access equipment and/or software, radio link quality and strength associated therewith, or the like.

Memory 1424 also can store data structures, code instructions and program modules, system or device information, code sequences for scrambling, spreading and pilot transmission, access point configuration, and so on. Processor 1416 can be coupled (e.g., through a memory bus), to memory 1424 in order to store and retrieve information used to operate and/or confer functionality to the components, platform, and interface that reside within access equipment and/or software.

[00122] In addition, the memory 1424 can comprise one or more machine-readable medium / media including instructions that, when performed by a machine or component herein cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described herein. It is to be understood that aspects described herein can be implemented by hardware, software, firmware, or any combination thereof. When implemented in software, functions can be stored on or transmitted over as one or more instructions or code on a computer-readable medium (e.g., the memory described herein or other storage device). Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media or a computer readable storage device can be any available media that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or other tangible and/or non-transitory medium, that can be used to carry or store desired information or executable instructions. Also, any connection can also be termed a computer-readable medium. For example, if software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium.

[00123] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[00124] As it employed in the subject specification, the term "processor" can refer to substantially any computing processing unit or device including, but not limited to including, single-core processors; single-processors with software multithread execution capability; multi-core processors; multi-core processors with software multithread execution capability; multi-core processors with hardware multithread technology; parallel platforms; and parallel platforms with distributed shared memory. Additionally, a processor can refer to an integrated circuit, an application specific integrated circuit, a digital signal processor, a field programmable gate array, a programmable logic controller, a complex programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions and/or processes described herein. Processors can exploit nano-scale architectures such as, but not limited to, molecular and quantum-dot based transistors, switches and gates, in order to optimize space usage or enhance performance of mobile devices. A processor may also be implemented as a combination of computing processing units.

[00125] In the subject specification, terms such as "store," "data store," data storage," "database," and substantially any other information storage component relevant to operation and functionality of a component and/or process, refer to "memory components," or entities embodied in a "memory," or components including the memory. It is noted that the memory components described herein can be either volatile memory or nonvolatile memory, or can include both volatile and nonvolatile memory.

[00126] By way of illustration, and not limitation, nonvolatile memory, for example, can be included in a memory, non-volatile memory (see below), disk storage (see below), and memory storage (see below). Further, nonvolatile memory can be included in read only memory, programmable read only memory, electrically programmable read only

memory, electrically erasable programmable read only memory, or flash memory. Volatile memory can include random access memory, which acts as external cache memory. By way of illustration and not limitation, random access memory is available in many forms such as synchronous random access memory, dynamic random access memory, synchronous dynamic random access memory, double data rate synchronous dynamic random access memory, enhanced synchronous dynamic random access memory, Synchlink dynamic random access memory, and direct Rambus random access memory. Additionally, the disclosed memory components of systems or methods herein are intended to include, without being limited to including, these and any other suitable types of memory.

[00127] Examples can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including instructions that, when performed by a machine cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described herein.

[00128] Example 1 is an apparatus configured to be employed in a next generation (NextGen) network device comprising: one or more processors configured to: identify a system information change; and generate a system information change indication based on the system information change and a paging message; and one or more radio frequency interfaces that is configured to transmit the system information change indication via a physical broadcast channel (PBCH) and the paging message via another physical channel.

[00129] Example 2 includes the subject matter of Example 1, wherein the one or more processors are further configured to provide the system information change indication in a field within a master information block (MIB) that is carried by the PBCH or a system information block (SIB).

[00130] Example 3 includes the subject matter of any one of Examples 1-2, including or omitting any elements as optional, wherein the one or more processors are further configured to generate a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit an MIB.

[00131] Example 4 includes the subject matter of any one of Examples 1-3, including

or omitting any elements as optional, wherein the one or more processors are further configured to generate the paging message comprising at least one of: a paging record, an Earthquake and Tsunami Warning Service (ETWS), or a Commercial Mobile Alert System (CMAS) notification, within the MIB or the SIB.

[00132] Example 5 includes the subject matter of any one of Examples 1-4, including or omitting any elements as optional, wherein the one or more processors are further configured to transmit a paging record within a physical downlink shared channel (PDSCH) based on a physical downlink control channel (PDCCH) with a cyclic redundancy check (CRC) that is at least in part masked with a paging radio network temporary identifier (P-RNTI).

[00133] Example 6 includes the subject matter of any one of Examples 1-5, including or omitting any elements as optional, wherein the one or more processors are further configured to: transmit the paging message via a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, or PDSCH scheduled by a PDCCH, or via a PDCCH, as the another physical channel; and generate a transmit beam sweeping operation by transmitting the system information change indication and the paging message along a range of beamforming angles.

[00134] Example 7 includes the subject matter of any one of Examples 1-6, including or omitting any elements as optional, wherein the one or more processors are further configured to generate a transmission including a paging record corresponding to only one user equipment (UE) via the PDCCH.

[00135] Example 8 includes the subject matter of any one of Examples 1-7, including or omitting any elements as optional, wherein the one or more processors are further configured to: provide a scheduling request (SR) resource or a physical random access channel (PRACH) resource via the transmit beam to enable a communication based on the dedicated SR resource or the dedicated PRACH resource; process a PRACH signal or an SR signal based on the SR resource or the PRACH resource; identify a beam based on the processed PRACH signal or the SR signal; and transmit the paging message based on the identified beam.

[00136] Example 9 includes the subject matter of any one of Examples 1-8, including or omitting any elements as optional wherein the one or more processors are further configured to: configure a frequency resource of a paging transmission for a paging channel as the another physical channel according to a function of at least one of: a physical cell identifier (ID), a virtual cell ID, a frame index, a slot index, a subframe

index, a symbol index, or a UE identifier; and indicate the frequency resource in a MIB via the PBCH or an SIB.

[00137] Example 10 includes the subject matter of any one of Examples 1-9, including or omitting any elements as optional, wherein the one or more processors are further configured to: transmit the system information change indication via the PBCH and the paging message via a PPGCH configured for the paging transmission without scheduling from the PDCCH; generate the PPGCH by generating a coding to one or more information bits of the PPGCH; apply a scrambling operation to the coding to generate a scrambling sequence; and modulate the scrambling sequence via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) to generate modulated symbols that are mapped to one or more allocated resources of the PPGCH.

[00138] Example 11 includes the subject matter of any one of Examples 1-10, including or omitting any elements as optional wherein the one or more processors are further configured to: generate the PPGCH by generating the coding to the one or more information bits of the PPGCH with a Turbo coding or a low-density parity-check (LDPC), and appending a cyclic redundancy check (CRC) on the information bits first prior to the coding; and configure a scrambling seed based on at least one of: a physical cell ID, a frame index, a slot index, a subframe index, a symbol index, or a UE ID based on an IMSI or a system architecture evolution IMSI (S-IMSI), for the PPGCH.

[00139] Example 12 includes the subject matter of any one of Examples 1-11, including or omitting any elements as optional, wherein the one or more processors are further configured to: transmit the paging message on a PPGCH transmission that spans one or more orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth; and in response to the PPGCH transmission occupying the partial system bandwidth, generating a localized transmission scheme or a distributed transmission scheme.

[00140] Example 13 includes the subject matter of any one of Examples 1-12, including or omitting any elements as optional, wherein the one or more processors are further configured to: transmit the paging message on the PPGCH transmission based on a single port transmission or a multiple port transmission; and in response to transmitting the paging message based on the multiple port transmission, generating a space frequency block code (SFBC) and grouping at least two consecutive resource elements (REs) for an SFBC transmission scheme.

[00141] Example 14 is an apparatus configured to be employed in a user equipment

(UE) comprising: one or more processors configured to: process a system information update based on a system information change indication via a physical broadcast channel (PBCH) and a paging message via another physical channel; and a communication interface, coupled to the one or more processors, configured to receive the system information change indication via the PBCH and the paging message via the another physical channel.

[00142] Example 15 includes the subject matter of Examples 14, wherein the one or more processors are further configured to: process the system information change indication in a field of at least one of: a master information block (MIB) carried by the PBCH or a system information block (SIB); and receive the paging message via a physical downlink shared channel (PDSCH) that is scheduled by a physical downlink control channel (PDCCH), the PDCCH without scheduling by the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel.

[00143] Example 16 includes the subject matter of any one of Examples 14-15, including or omitting any elements as optional, wherein the one or more processors are further configured to: process a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID), an international mobile subscriber identity (IMSI), or a system architecture evolution (SAE) IMSI (S-IMSI), wherein the PO subframe is aligned with another subframe that is used to transmit an MIB.

[00144] Example 17 includes the subject matter of any one of Examples 14-16, including or omitting any elements as optional, wherein the one or more processors are further configured to: transmit a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on a PRACH resource or an SR resource to enable an identification of a beam for transmission of the paging message; and receive the paging message via the beam based on the PRACH signal or the SR signal.

[00145] Example 18 includes the subject matter of any one of Examples 14-17, including or omitting any elements as optional, wherein the one or more processors are further configured to: receive the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH; demodulate via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are mapped to one or more allocated resources of the PPGCH; apply a de-scrambling operation for generating a scrambling sequence based on a

scrambling seed; and decode the de-scrambled bits for one or more information bits of the PPGCH.

[00146] Example 19 includes the subject matter of any one of Examples 14-18, including or omitting any elements as optional, wherein one PPGCH transmission spans one orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth, and wherein, in response to the PPGCH transmission occupying the partial system bandwidth, the PPGCH transmission is based on a localized transmission scheme or a distributed transmission scheme according to a payload size of the PPGCH transmission.

[00147] Example 20 includes the subject matter of any one of Examples 14-19, including or omitting any elements as optional, wherein the one or more processors are further configured to identify at least one of: a size of the paging message, a modulation and coding scheme, a demodulation reference signal (DMRS) sequence, or a frequency resource, based on a set of parameters, an MIB, an SIB or a radio resource control (RRC) signalling, wherein the set of parameters comprise at least one of: a physical cell ID, a virtual cell ID, a frame index, a slot index, a subframe index, a symbol index, or a user equipment identifier (UE ID).

[00148] Example 21 includes the subject matter of any one of Examples 14-20, including or omitting any elements as optional, wherein the one or more processors are further configured to: receive the paging message on the PPGCH based on a single port transmission or a multiple port transmission; and in response to receiving the paging message based on the multiple port transmission, processing based on a space frequency block code (SFBC) with at least two consecutive resource elements (REs) are grouped for an SFBC transmission scheme.

[00149] Example 22 is a computer-readable storage medium storing executable instructions that, in response to execution, cause one or more processors of a new radio base station or a next generation NodeB (gNB) to perform operations, comprising: identifying a system information change; generating a system information change indication based on the system information change and a paging message; and transmitting the system information change indication via a physical broadcast channel (PBCH) and the paging message via another physical channel.

[00150] Example 23 includes the subject matter of Example 22, including or omitting any elements as optional, wherein the operations further comprise: providing the system information change indication within a master information block (MIB) or a system

information block (SIB); and generating a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit the MIB.

[00151] Example 24 includes the subject matter of any one of Examples 22-23, including or omitting any elements as optional, wherein the operations further comprise: transmitting the paging message via a PDSCH scheduled by a PDCCH, the PDCCH without utilizing the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel, by generating a beam sweeping operation along a range of beamforming angles; and generating a paging transmission with the paging message comprising a paging record that corresponds to only one user equipment (UE) via the PDCCH.

[00152] Example 25 includes the subject matter of any one of Examples 22-24, including or omitting any elements as optional, wherein the operations further comprise: providing a dedicated SR resource or a dedicated PRACH resource to enable a communication based on the dedicated SR resource or the dedicated PRACH resource; receiving or process a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on the dedicated SR resource or the dedicated PRACH resource; identifying a beam based on the PRACH signal or the SR signal; and transmitting the paging message based on the identified beam.

[00153] Example 26 is a computer-readable storage medium storing executable instructions that, in response to execution, cause one or more processors of a user equipment (UE) to perform operations, comprising: processing a system information update based on a system information change indication via a physical broadcast channel (PBCH) and a paging message via another physical channel; and receiving the system information change indication via the PBCH and the paging message via the another physical channel.

[00154] Example 27 includes the subject matter of Example 26, including or omitting any elements as optional, wherein the operations further comprise: processing the system information change indication in a field of at least one of: a master information block (MIB) carried by the PBCH or a system information block (SIB); and receiving the paging message via a physical downlink shared channel (PDSCH) that is scheduled by a physical downlink control channel (PDCCH), the PDCCH without scheduling by the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the

PDCCH, as the another physical channel.

[00155] Example 28 is a computer-readable storage medium of claim 26, wherein the operations further comprise: processing a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID), an international mobile subscriber identity (IMSI), or a system architecture evolution (SAE) IMSI (S-IMSI), wherein the PO subframe is aligned with another subframe that is used to transmit an MIB.

[00156] Example 29 is a computer-readable storage medium of any one of claims 26-28, wherein the operations further comprise: transmitting a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on a PRACH resource or an SR resource to enable an identification of a beam for transmission of the paging message; and receiving the paging message via the beam based on the PRACH signal or the SR signal.

[00157] Example 30 includes the subject matter of any one of Examples 26-29, including or omitting any elements as optional, wherein the operations further comprise: receiving the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH; demodulating via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are mapped to one or more allocated resources of the PPGC; applying a de-scrambling operation for generating a scrambling sequence based on a scrambling seed; and decoding the de-scrambled bits for one or more information bits of the PPGCH.

[00158] Example 31 includes the subject matter of any one of Examples 26-30, including or omitting any elements as optional, wherein one PPGCH transmission spans one orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth, and wherein, in response to the PPGCH transmission occupying the partial system bandwidth, the PPGCH transmission is based on a localized transmission scheme or a distributed transmission scheme according to a payload size of the PPGCH transmission.

[00159] Example 32 includes the subject matter of any one of Examples 26-31, including or omitting any elements as optional, wherein the operations further comprise: identifying at least one of: a size of the paging message, a modulation and coding scheme, a demodulation reference signal (DMRS) sequence, or a frequency resource, based on a set of parameters, an MIB, an SIB or a radio resource control (RRC) signalling, wherein the set of parameters comprise at least one of: a physical cell ID, a

virtual cell ID, a frame index, a slot index, a subframe index, a symbol index, or a user equipment identifier (UE ID).

[00160] Example 33 includes the subject matter of any one of Examples 26-32, including or omitting any elements as optional, wherein the operations further comprise: receiving the paging message on the PPGCH based on a single port transmission or a multiple port transmission; and in response to receiving the paging message based on the multiple port transmission, processing based on a space frequency block code (SFBC) with at least two consecutive resource elements (REs) are grouped for an SFBC transmission scheme.

[00161] Example 34 is an apparatus of a new radio base station or a next generation NodeB (gNB) comprising: means for identifying a system information change; means for generating a system information change indication based on the system information change and a paging message; and means for transmitting the system information change indication via a physical broadcast channel (PBCH) and the paging message via another physical channel.

[00162] Example 35 includes the subject matter of Examples 34, including or omitting any elements as optional, further comprising: means for providing the system information change indication within a master information block (MIB) or a system information block (SIB); and means for generating a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit the MIB.

[00163] Example 36 includes the subject matter of any one of Examples 34-35, including or omitting any elements as optional, further comprising: means for transmitting the paging message via a PDSCH scheduled by a PDCCH, the PDCCH without utilizing the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel, by generating a beam sweeping operation along a range of beamforming angles; and means for generating a paging transmission with the paging message comprising a paging record that corresponds to only one user equipment (UE) via the PDCCH.

[00164] Example 37 includes the subject matter of any one of Examples 34-36, including or omitting any elements as optional, further comprising: means for providing a dedicated SR resource or a dedicated PRACH resource to enable a communication based on the dedicated SR resource or the dedicated PRACH resource; means for

receiving or process a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on the dedicated SR resource or the dedicated PRACH resource; means for identifying a beam based on the PRACH signal or the SR signal; and means for transmitting the paging message based on the identified beam.

[00165] Example 38 is an apparatus of a user equipment (UE) comprising: means for processing a system information update based on a system information change indication via a physical broadcast channel (PBCH) and a paging message via another physical channel; and means for receiving the system information change indication via the PBCH and the paging message via the another physical channel.

[00166] Example 39 includes the subject matter of Examples 40, including or omitting any elements as optional, further comprising: means for processing the system information change indication in a field of at least one of: a master information block (MIB) carried by the PBCH or a system information block (SIB); and means for receiving the paging message via a physical downlink shared channel (PDSCH) that is scheduled by a physical downlink control channel (PDCCH), the PDCCH without scheduling by the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel.

[00167] Example 40 includes the subject matter of any one of Examples 38-39, including or omitting any elements as optional, further comprising: means for processing a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID), an international mobile subscriber identity (IMSI), or a system architecture evolution (SAE) IMSI (S-IMSI), wherein the PO subframe is aligned with another subframe that is used to transmit an MIB.

[00168] Example 41 includes the subject matter of any one of Examples 38-40, including or omitting any elements as optional, further comprising: means for transmitting a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on a PRACH resource or an SR resource to enable an identification of a beam for transmission of the paging message; and means for receiving the paging message via the beam based on the PRACH signal or the SR signal.

[00169] Example 42 includes the subject matter of any one of Examples 38-41, including or omitting any elements as optional, further comprising: means for receiving the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH; means for demodulating via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are

mapped to one or more allocated resources of the PPGC; means for applying a de-scrambling operation for generating a scrambling sequence based on a scrambling seed; and means for decoding the de-scrambled bits for one or more information bits of the PPGCH.

[00170] Example 43 includes the subject matter of any one of Examples 38-42, including or omitting any elements as optional wherein one PPGCH transmission spans one orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth, and wherein, in response to the PPGCH transmission occupying the partial system bandwidth, the PPGCH transmission is based on a localized transmission scheme or a distributed transmission scheme according to a payload size of the PPGCH transmission.

[00171] Example 44 includes the subject matter of any one of Examples 38-43, including or omitting any elements as optional, further comprising: means for identifying at least one of: a size of the paging message, a modulation and coding scheme, a demodulation reference signal (DMRS) sequence, or a frequency resource, based on a set of parameters, an MIB, an SIB or a radio resource control (RRC) signalling, wherein the set of parameters comprise at least one of: a physical cell ID, a virtual cell ID, a frame index, a slot index, a subframe index, a symbol index, or a user equipment identifier (UE ID).

[00172] Example 45 includes the subject matter of any one of Examples 38-44, including or omitting any elements as optional, further comprising: means for receiving the paging message on the PPGCH based on a single port transmission or a multiple port transmission; and in response to receiving the paging message based on the multiple port transmission, processing based on a space frequency block code (SFBC) with at least two consecutive resource elements (REs) are grouped for an SFBC transmission scheme.

[00173] It is to be understood that aspects described herein can be implemented by hardware, software, firmware, or any combination thereof. When implemented in software, functions can be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media or a computer readable storage device can be any available media that can be accessed by a general purpose or special purpose computer. By way of example, and

not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or other tangible and/or non-transitory medium, that can be used to carry or store desired information or executable instructions. Also, any connection is properly termed a computer-readable medium. For example, if software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where *disks* usually reproduce data magnetically, while *discs* reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[00174] Various illustrative logics, logical blocks, modules, and circuits described in connection with aspects disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform functions described herein. A general-purpose processor can be a microprocessor, but, in the alternative, processor can be any conventional processor, controller, microcontroller, or state machine. A processor can also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Additionally, at least one processor can comprise one or more modules operable to perform one or more of the s and/or actions described herein.

[00175] For a software implementation, techniques described herein can be implemented with modules (*e.g.*, procedures, functions, and so on) that perform functions described herein. Software codes can be stored in memory units and executed by processors. Memory unit can be implemented within processor or external to processor, in which case memory unit can be communicatively coupled to processor through various means as is known in the art. Further, at least one processor can include one or more modules operable to perform functions described herein.

[00176] Techniques described herein can be used for various wireless communication systems such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other systems. The terms “system” and “network” are often used interchangeably. A CDMA system can implement a radio technology such as Universal Terrestrial Radio Access (UTRA), CDMA1800, *etc.* UTRA includes Wideband-CDMA (W-CDMA) and other variants of CDMA. Further, CDMA1800 covers IS-1800, IS-95 and IS-856 standards. A TDMA system can implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system can implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.18, *etc.* UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) is a release of UMTS that uses E-UTRA, which employs OFDMA on downlink and SC-FDMA on uplink. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). Additionally, CDMA1800 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). Further, such wireless communication systems can additionally include peer-to-peer (*e.g.*, mobile-to-mobile) *ad hoc* network systems often using unpaired unlicensed spectrums, 802.xx wireless LAN, BLUETOOTH and any other short- or long- range, wireless communication techniques.

[00177] Single carrier frequency division multiple access (SC-FDMA), which utilizes single carrier modulation and frequency domain equalization is a technique that can be utilized with the disclosed aspects. SC-FDMA has similar performance and essentially a similar overall complexity as those of OFDMA system. SC-FDMA signal has lower peak-to-average power ratio (PAPR) because of its inherent single carrier structure. SC-FDMA can be utilized in uplink communications where lower PAPR can benefit a mobile terminal in terms of transmit power efficiency.

[00178] Moreover, various aspects or features described herein can be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term “article of manufacture” as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer-readable media can include but are not limited to magnetic storage devices (*e.g.*, hard disk, floppy disk, magnetic strips, *etc.*), optical disks (*e.g.*, compact disk (CD), digital versatile disk (DVD), *etc.*), smart cards, and flash memory devices (*e.g.*, EPROM, card, stick, key drive, *etc.*). Additionally,

various storage media described herein can represent one or more devices and/or other machine-readable media for storing information. The term “machine-readable medium” can include, without being limited to, wireless channels and various other media capable of storing, containing, and/or carrying instruction(s) and/or data. Additionally, a computer program product can include a computer readable medium having one or more instructions or codes operable to cause a computer to perform functions described herein.

[00179] Communications media embody computer-readable instructions, data structures, program modules or other structured or unstructured data in a data signal such as a modulated data signal, e.g., a carrier wave or other transport mechanism, and includes any information delivery or transport media. The term “modulated data signal” or signals refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in one or more signals. By way of example, and not limitation, communication media include wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media.

[00180] Further, the actions of a method or algorithm described in connection with aspects disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or a combination thereof. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium can be coupled to processor, such that processor can read information from, and write information to, storage medium. In the alternative, storage medium can be integral to processor. Further, in some aspects, processor and storage medium can reside in an ASIC. Additionally, ASIC can reside in a user terminal. In the alternative, processor and storage medium can reside as discrete components in a user terminal. Additionally, in some aspects, the s and/or actions of a method or algorithm can reside as one or any combination or set of codes and/or instructions on a machine-readable medium and/or computer readable medium, which can be incorporated into a computer program product.

[00181] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are

possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00182] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00183] In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, systems, *etc.*), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (*e.g.*, that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus configured to be employed in a next generation (NextGen) network device comprising:
 - one or more processors configured to:
 - identify a system information change; and
 - generate a system information change indication based on the system information change and a paging message; and
 - one or more radio frequency interfaces that is configured to transmit the system information change indication via a physical broadcast channel (PBCH) and the paging message via another physical channel.
2. The apparatus of claim 1, wherein the one or more processors are further configured to provide the system information change indication in a field within a master information block (MIB) that is carried by the PBCH or a system information block (SIB).
3. The apparatus of claim 2, wherein the one or more processors are further configured to generate a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit an MIB.
4. The apparatus of claim 2, wherein the one or more processors are further configured to generate the paging message comprising at least one of: a paging record, an Earthquake and Tsunami Warning Service (ETWS), or a Commercial Mobile Alert System (CMAS) notification, within the MIB or the SIB.
5. The apparatus of any one of claims 1-4, wherein the one or more processors are further configured to transmit a paging record within a physical downlink shared channel (PDSCH) based on a physical downlink control channel (PDCCH) with a cyclic redundancy check (CRC) that is at least in part masked with a paging radio network temporary identifier (P-RNTI).

6. The apparatus of any one of claims 1-5, wherein the one or more processors are further configured to:

transmit the paging message via a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, or PDSCH scheduled by a PDCCH, or via a PDCCH, as the another physical channel; and

generate a transmit beam sweeping operation by transmitting the system information change indication and the paging message along a range of beamforming angles.

7. The apparatus of claim 6, wherein the one or more processors are further configured to generate a transmission including a paging record corresponding to only one user equipment (UE) via the PDCCH.

8. The apparatus of any one of claims 1-7, wherein the one or more processors are further configured to:

provide a scheduling request (SR) resource or a physical random access channel (PRACH) resource via the transmit beam to enable a communication based on the dedicated SR resource or the dedicated PRACH resource;

process a PRACH signal or an SR signal based on the SR resource or the PRACH resource;

identify a beam based on the processed PRACH signal or the SR signal; and
transmit the paging message based on the identified beam.

9. The apparatus of any one of claims 1-8, wherein the one or more processors are further configured to:

configure a frequency resource of a paging transmission for a paging channel as the another physical channel according to a function of at least one of: a physical cell identifier (ID), a virtual cell ID, a frame index, a slot index, a subframe index, a symbol index, or a UE identifier; and

indicate the frequency resource in a MIB via the PBCH or an SIB.

10. The apparatus of any one of claims 1-9, wherein the one or more processors are further configured to:

transmit the system information change indication via the PBCH and the paging

message via a PPGCH configured for the paging transmission without scheduling from the PDCCH;

generate the PPGCH by generating a coding to one or more information bits of the PPGCH;

apply a scrambling operation to the coding to generate a scrambling sequence; and

modulate the scrambling sequence via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) to generate modulated symbols that are mapped to one or more allocated resources of the PPGCH.

11. The apparatus of claim 10, wherein the one or more processors are further configured to:

generate the PPGCH by generating the coding to the one or more information bits of the PPGCH with a Turbo coding or a low-density parity-check (LDPC), and appending a cyclic redundancy check (CRC) on the information bits first prior to the coding; and

configure a scrambling seed based on at least one of: a physical cell ID, a frame index, a slot index, a subframe index, a symbol index, or a UE ID based on an IMSI or a system architecture evolution IMSI (S-IMSI), for the PPGCH.

12. The apparatus of claim 10, wherein the one or more processors are further configured to:

transmit the paging message on a PPGCH transmission that spans one or more orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth;

in response to the PPGCH transmission occupying the partial system bandwidth, generating a localized transmission scheme or a distributed transmission scheme.

13. The apparatus of claim 12, wherein the one or more processors are further configured to:

transmit the paging message on the PPGCH transmission based on a single port transmission or a multiple port transmission; and

in response to transmitting the paging message based on the multiple port transmission, generating a space frequency block code (SFBC) and grouping at least two consecutive resource elements (REs) for an SFBC transmission scheme.

14. An apparatus configured to be employed in a user equipment (UE) comprising:
one or more processors configured to:

process a system information update based on a system information change indication via a physical broadcast channel (PBCH) and a paging message via another physical channel;

a communication interface, coupled to the one or more processors, configured to receive the system information change indication via the PBCH and the paging message via the another physical channel.

15. The apparatus of claim 14, wherein the one or more processors are further configured to:

process the system information change indication in a field of at least one of: a master information block (MIB) carried by the PBCH or a system information block (SIB);

receive the paging message via a physical downlink shared channel (PDSCH) that is scheduled by a physical downlink control channel (PDCCH), the PDCCH without scheduling by the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel.

16. The apparatus of any one of claims 14-15, wherein the one or more processors are further configured to:

process a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID), an international mobile subscriber identity (IMSI), or a system architecture evolution (SAE) IMSI (S-IMSI), wherein the PO subframe is aligned with another subframe that is used to transmit an MIB.

17. The apparatus of any one of claims 14-16, wherein the one or more processors are further configured to:

transmit a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on a PRACH resource or an SR resource to enable an

identification of a beam for transmission of the paging message; and

receive the paging message via the beam based on the PRACH signal or the SR signal.

18. The apparatus of any one of claims 14-17, wherein the one or more processors are further configured to:

receive the paging message via a PPGCH configured for a communication without a scheduling communication from a PDCCH; and

demodulate via a binary phase-shift keying (BPSK) or a quadrature phase-shift keying (QPSK) for modulated symbols that are mapped to one or more allocated resources of the PPGCH.

apply a de-scrambling operation for generating a scrambling sequence based on a scrambling seed; and

decode the de-scrambled bits for one or more information bits of the PPGCH.

19. The apparatus of claim 18, wherein one PPGCH transmission spans one orthogonal frequency division multiplexing (OFDM) symbol, and occupies a partial system bandwidth or a full system bandwidth, and wherein, in response to the PPGCH transmission occupying the partial system bandwidth, the PPGCH transmission is based on a localized transmission scheme or a distributed transmission scheme according to a payload size of the PPGCH transmission.

20. The apparatus of claim 18, wherein the one or more processors are further configured to identify at least one of: a size of the paging message, a modulation and coding scheme, a demodulation reference signal (DMRS) sequence, or a frequency resource, based on a set of parameters, an MIB, an SIB or a radio resource control (RRC) signalling, wherein the set of parameters comprise at least one of: a physical cell ID, a virtual cell ID, a frame index, a slot index, a subframe index, a symbol index, or a user equipment identifier (UE ID).

21. The apparatus of claim 18, wherein the one or more processors are further configured to receive the paging message on the PPGCH based on a single port transmission or a multiple port transmission; and

in response to receiving the paging message based on the multiple port transmission, processing based on a space frequency block code (SFBC) with at least two consecutive resource elements (REs) are grouped for an SFBC transmission scheme.

22. A computer-readable storage medium storing executable instructions that, in response to execution, cause one or more processors of a new radio base station or a next generation NodeB (gNB) to perform operations, comprising:

- identifying a system information change; and
- generating a system information change indication based on the system information change and a paging message; and
- transmit the system information change indication via a physical broadcast channel (PBCH) and the paging message via another physical channel.

23. The computer-readable storage medium of claim 22, wherein the operations further comprise:

- providing the system information change indication within a master information block (MIB) or a system information block (SIB); and
- generating a paging frame (PF) and a paging occasion (PO) subframe within the PF based on a user equipment identity (UE ID) or an international mobile subscriber identity (IMSI) by aligning the PO subframe with another subframe that is used to transmit the MIB.

24. The computer-readable storage medium of any one of claims 22-23, wherein the operations further comprise:

- transmitting the paging message via a PDSCH scheduled by a PDCCH, the PDCCH without utilizing the PDSCH, or a dedicated physical paging channel (PPGCH) without scheduling from the PDCCH, as the another physical channel, by generating a beam sweeping operation along a range of beamforming angles;
- generating a paging transmission with the paging message comprising a paging record that corresponds to only one user equipment (UE) via the PDCCH.

25. The computer-readable storage medium of any one of claims 22-24, wherein the operations further comprise:

providing a dedicated SR resource or a dedicated PRACH resource to enable a communication based on the dedicated SR resource or the dedicated PRACH resource;

receiving or process a physical random access channel (PRACH) signal or a scheduling request (SR) signal based on the dedicated SR resource or the dedicated PRACH resource;

identifying a beam based on the PRACH signal or the SR signal; and

transmitting the paging message based on the identified beam.

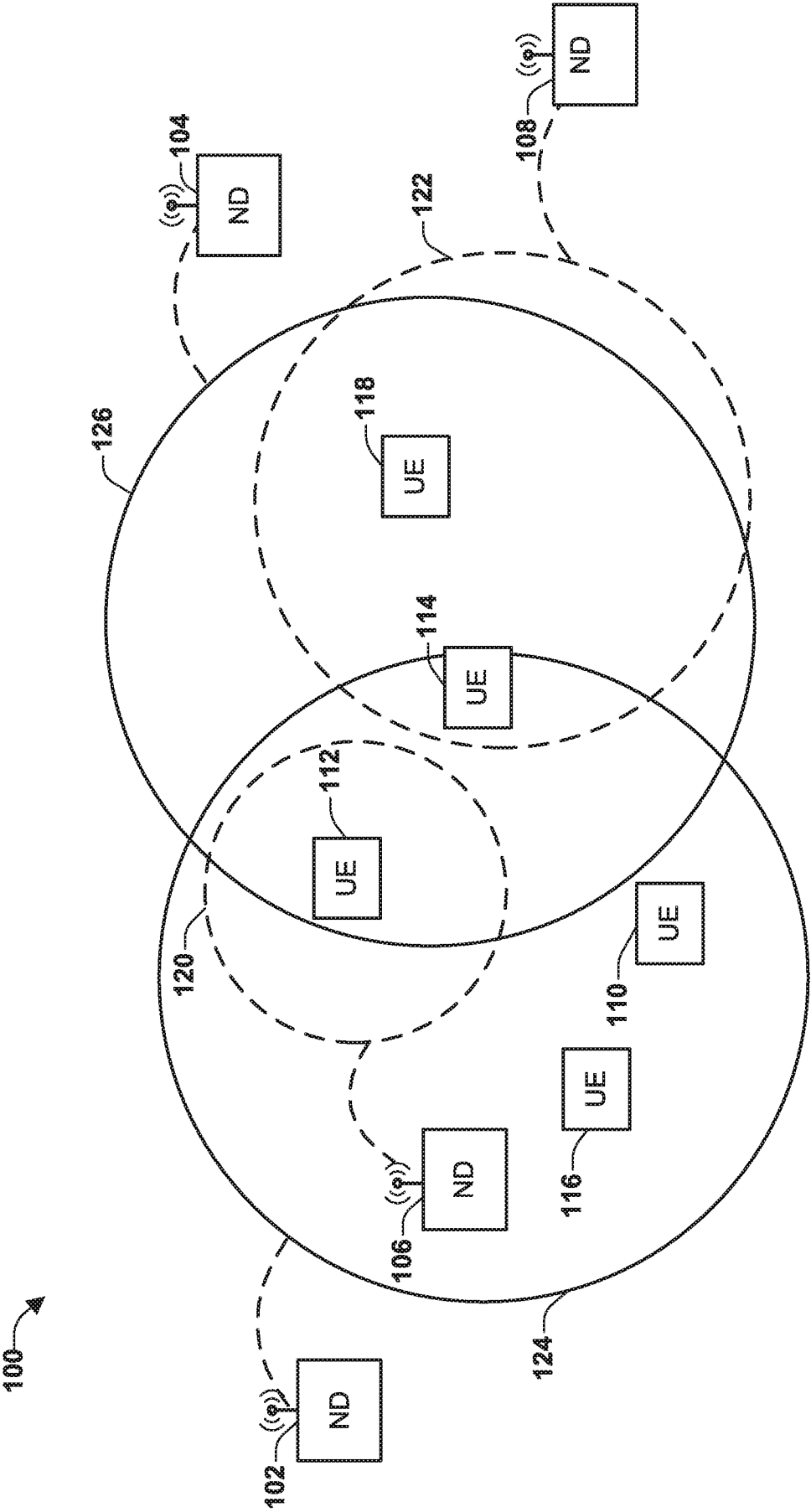


FIG. 1

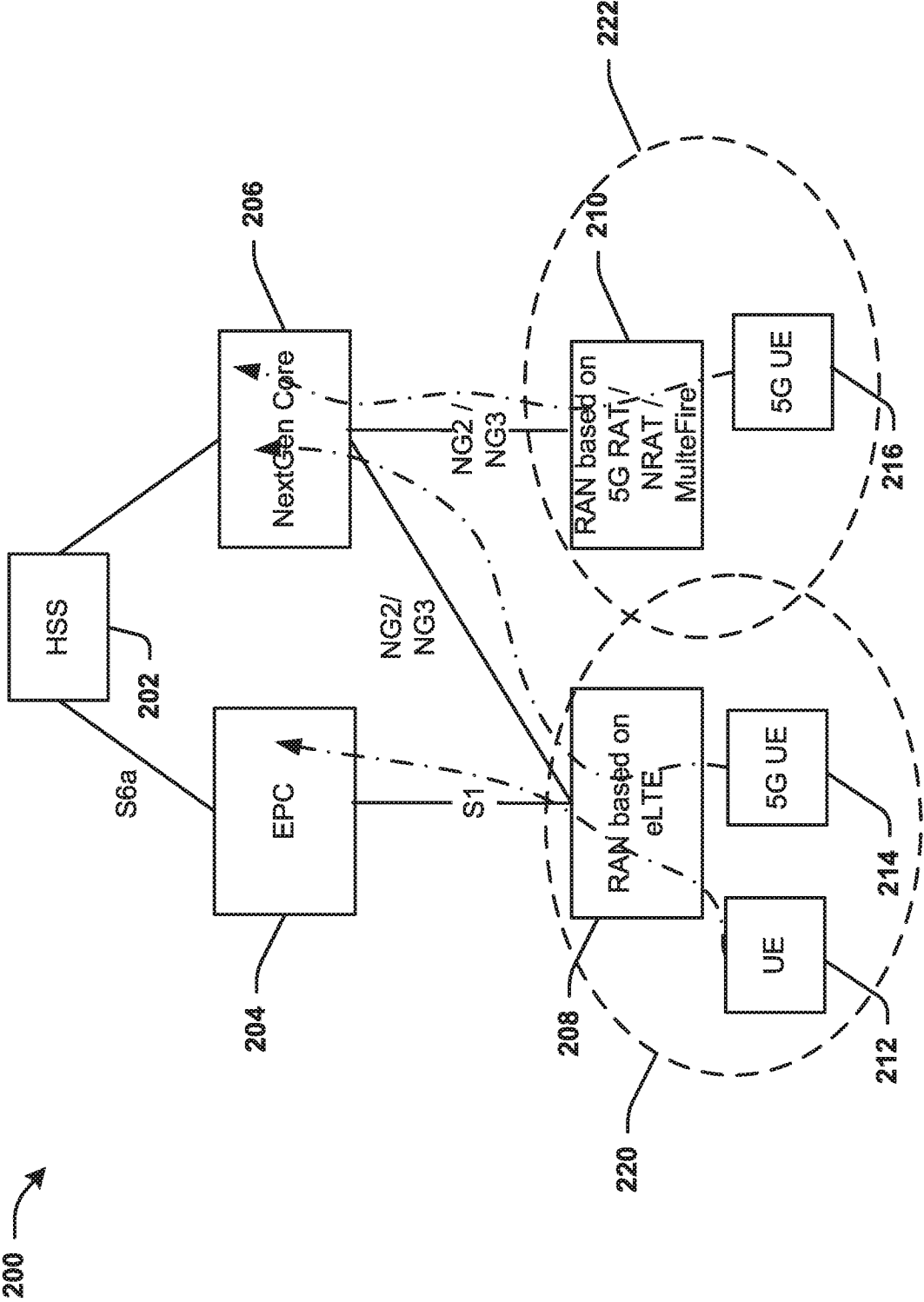


FIG. 2

300 →

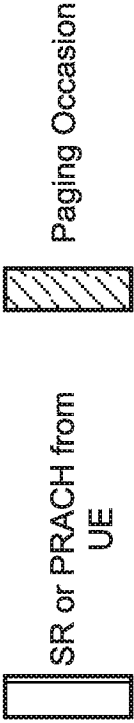
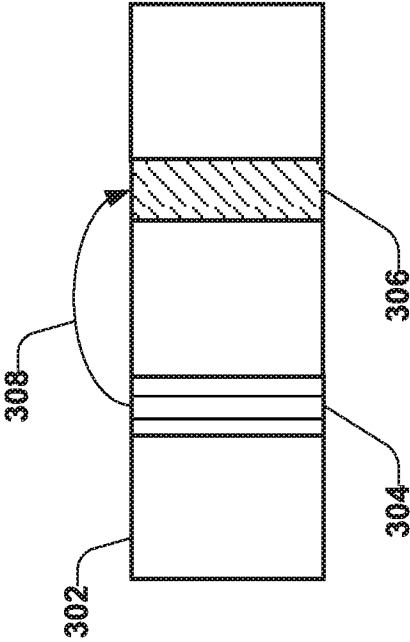


FIG. 3

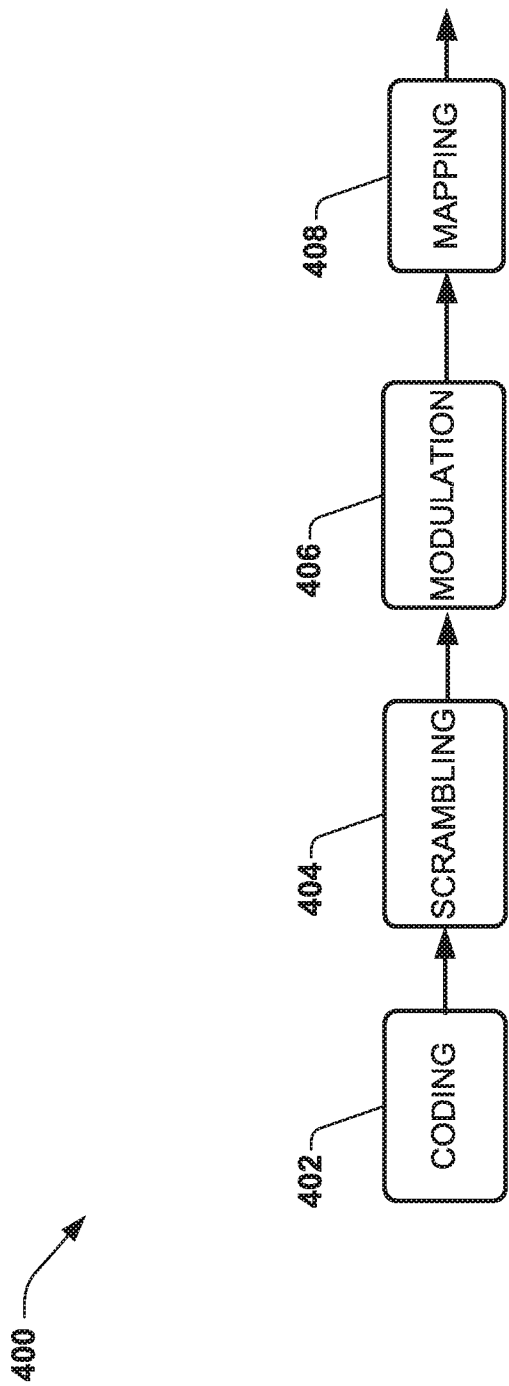


FIG. 4

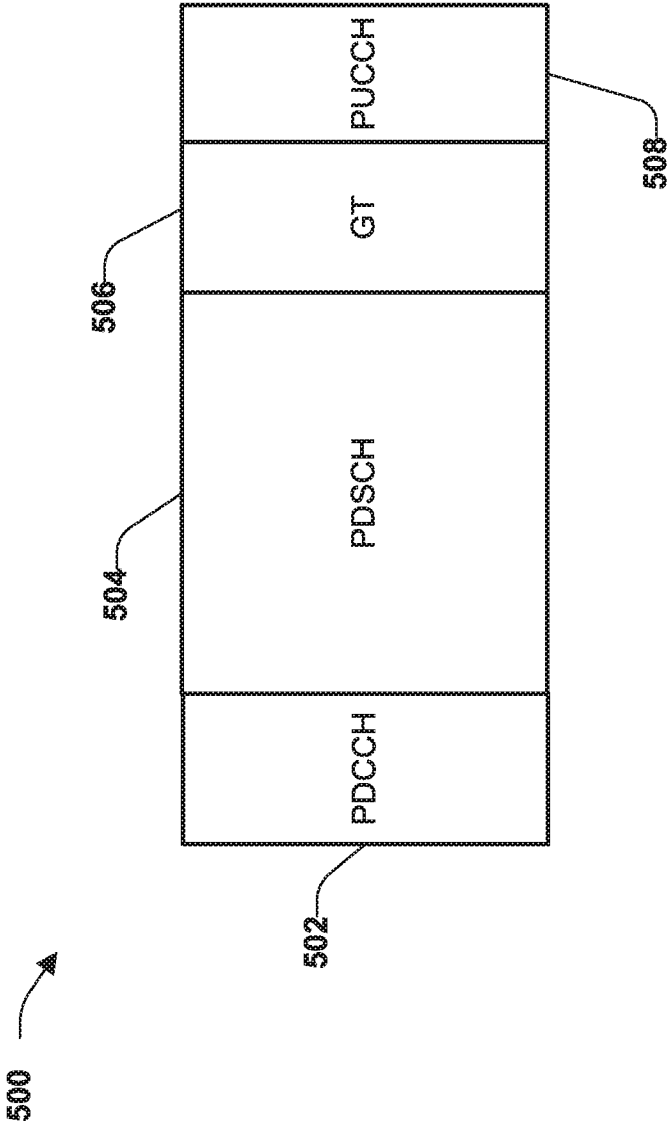
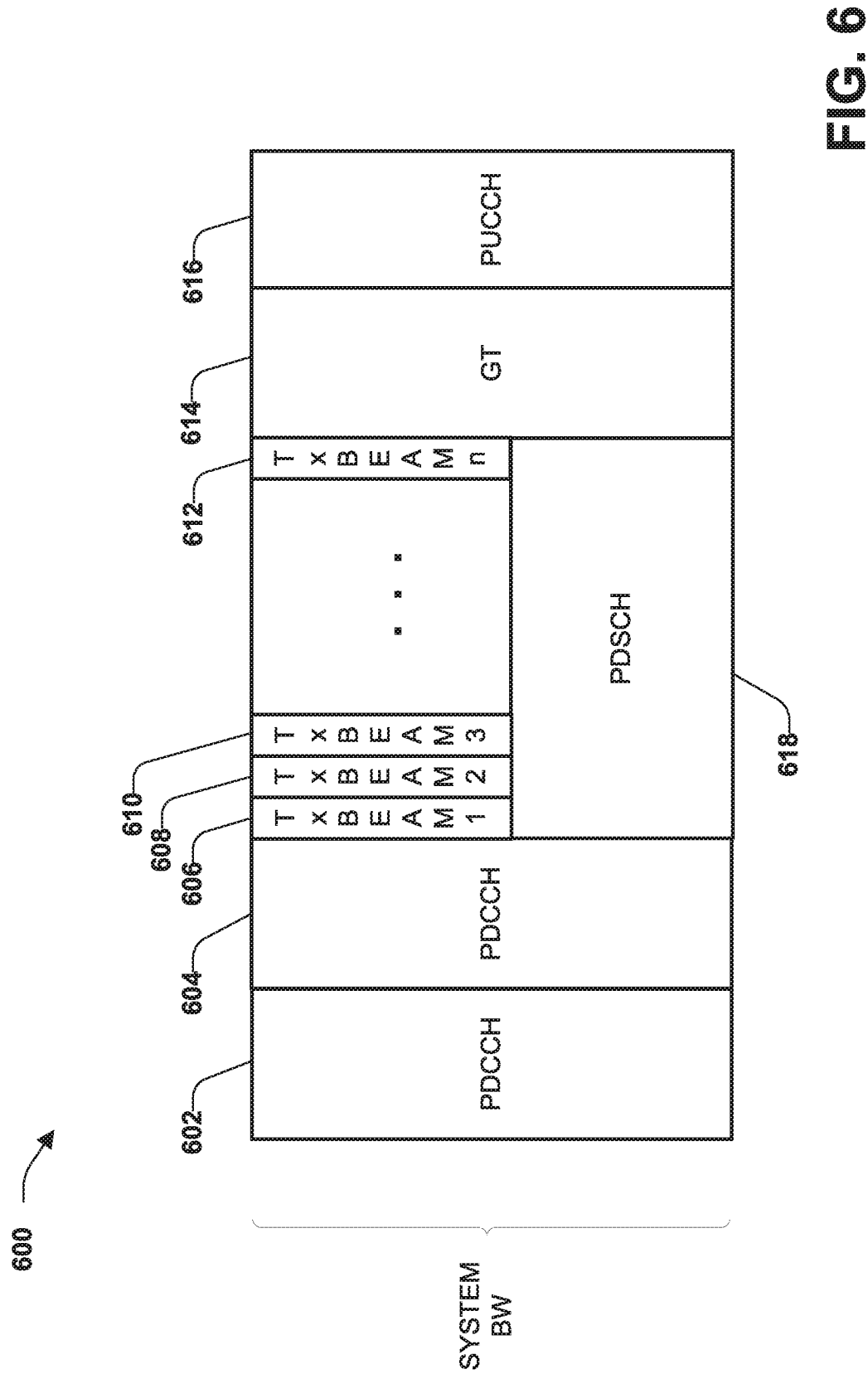


FIG. 5



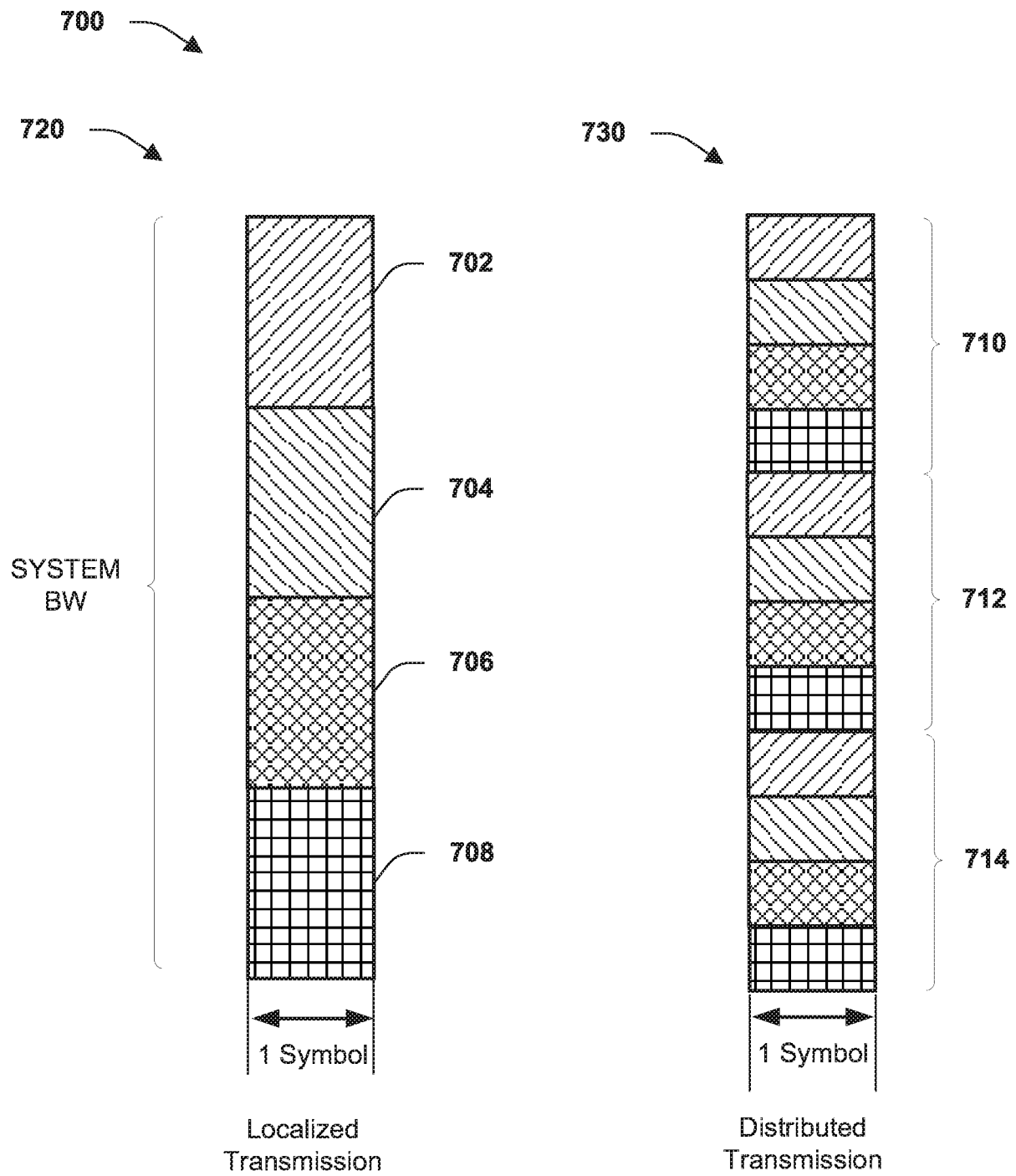


FIG. 7

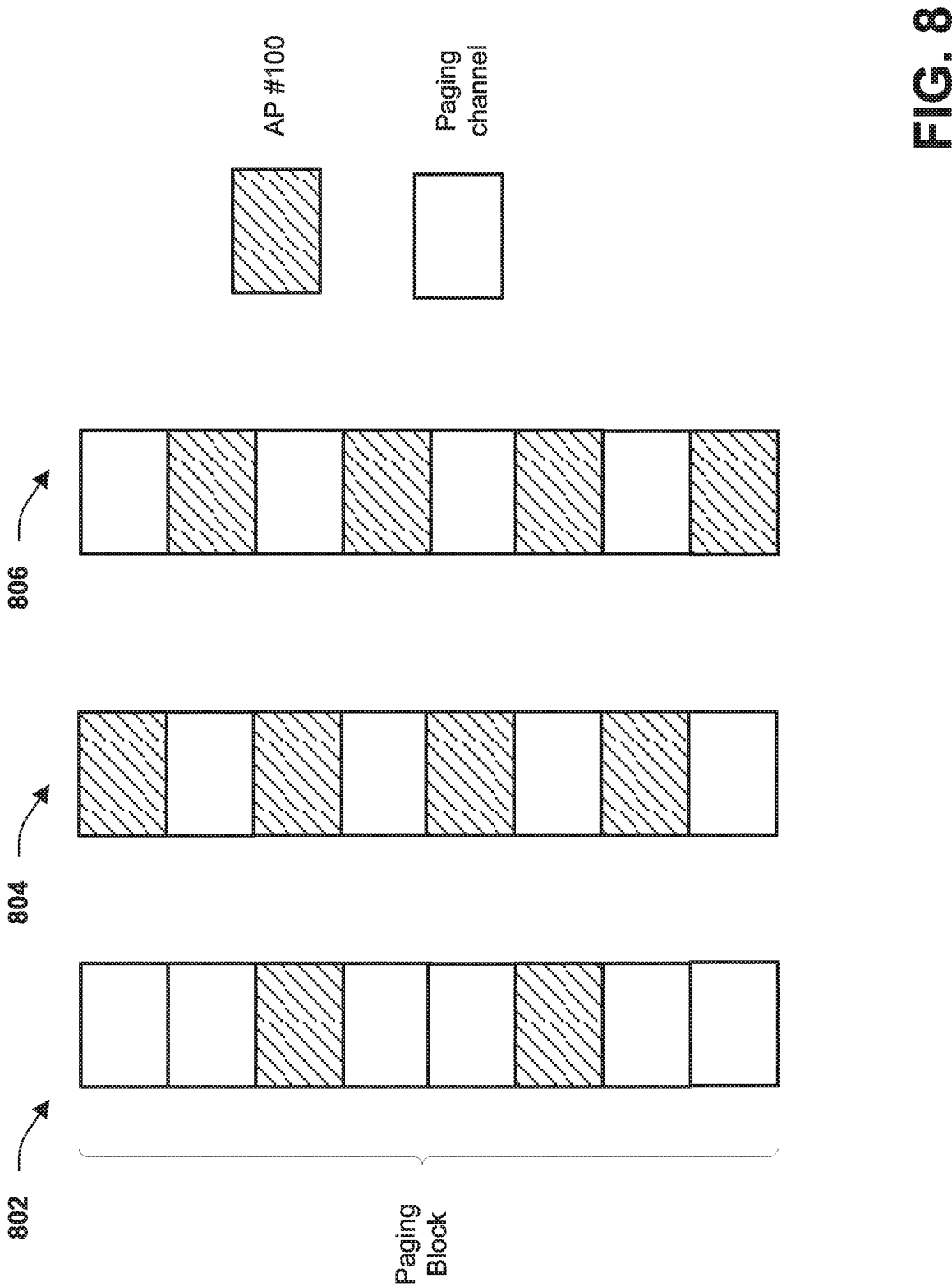


FIG. 8

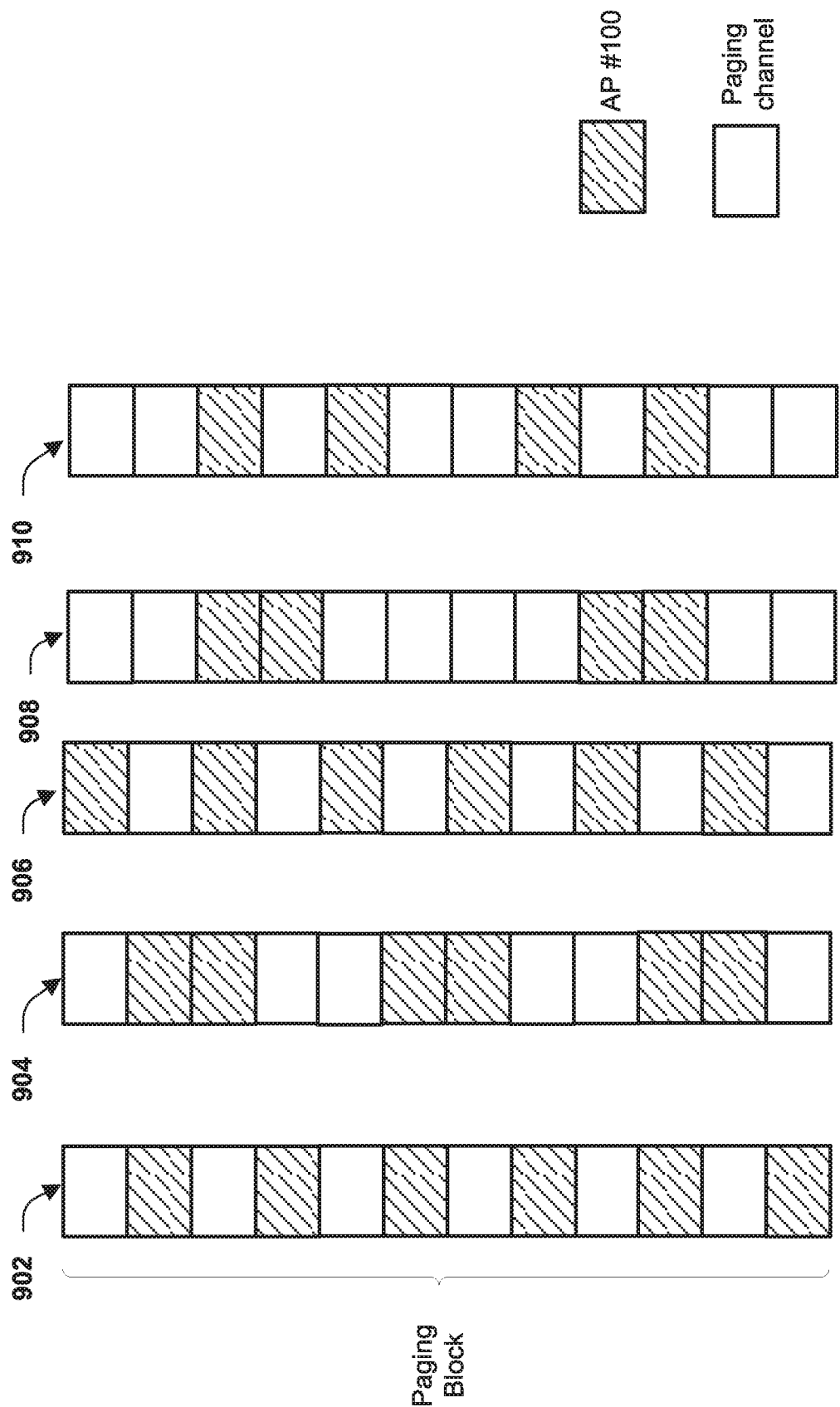


FIG. 9

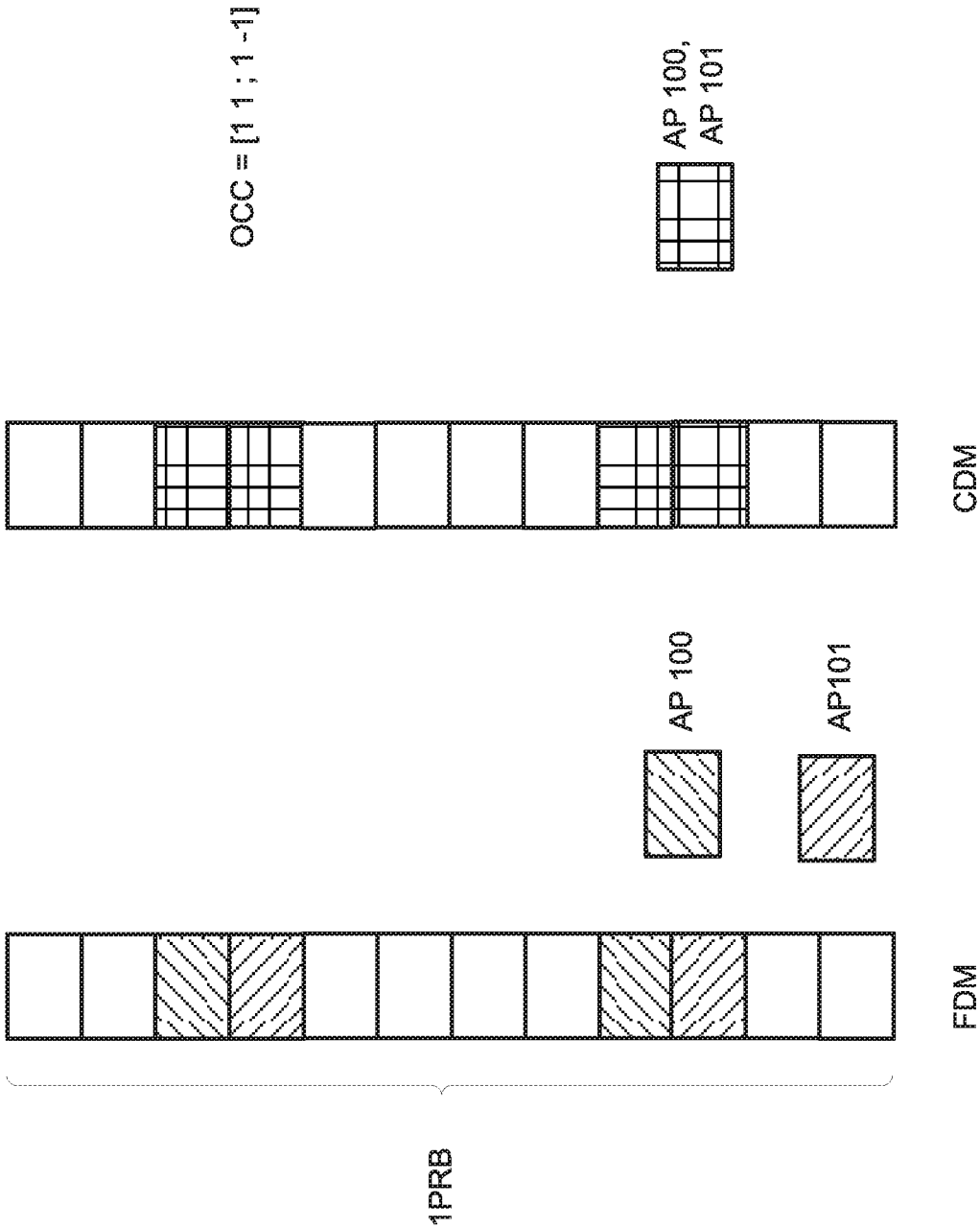


FIG. 10

11 / 14

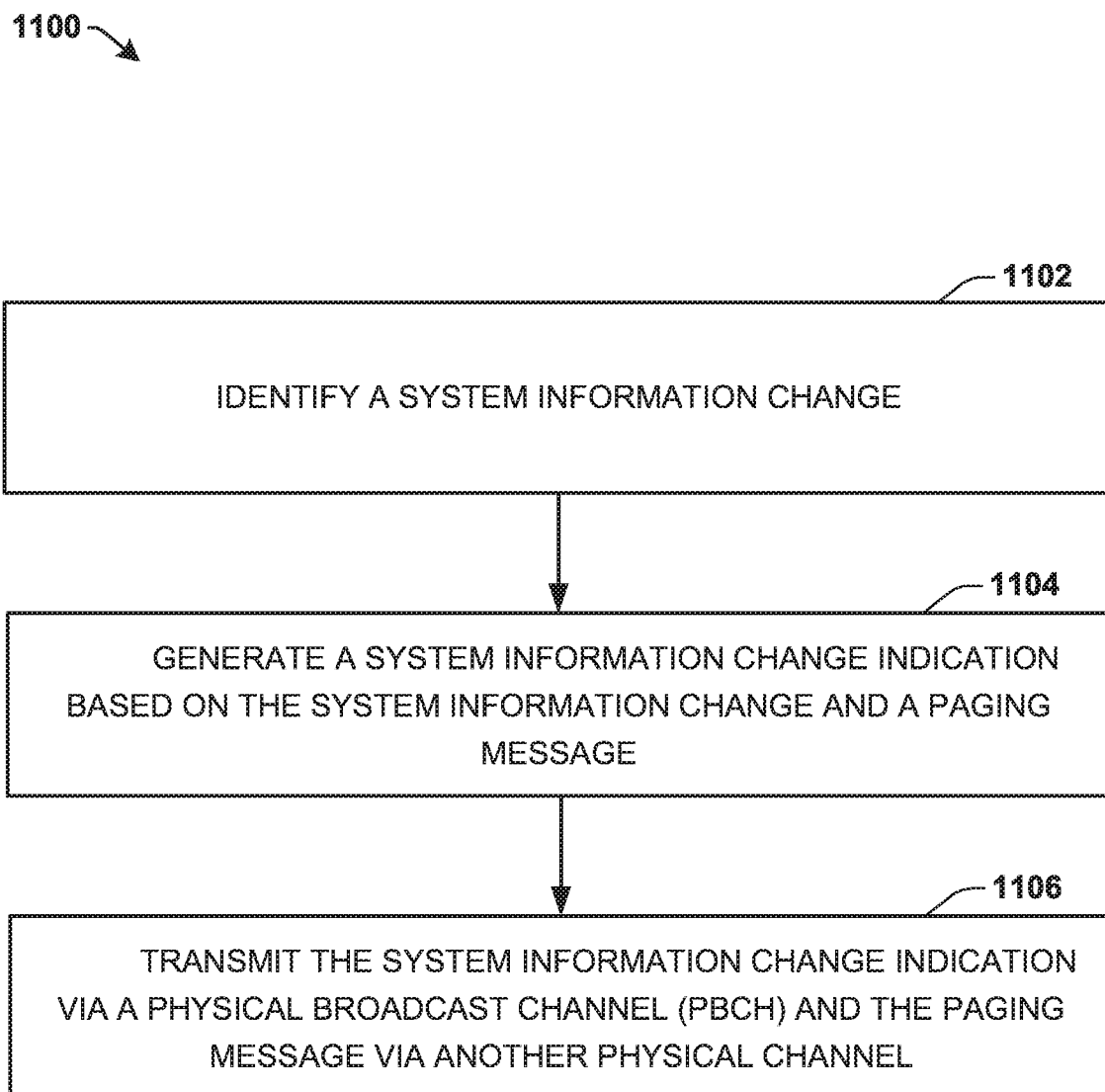
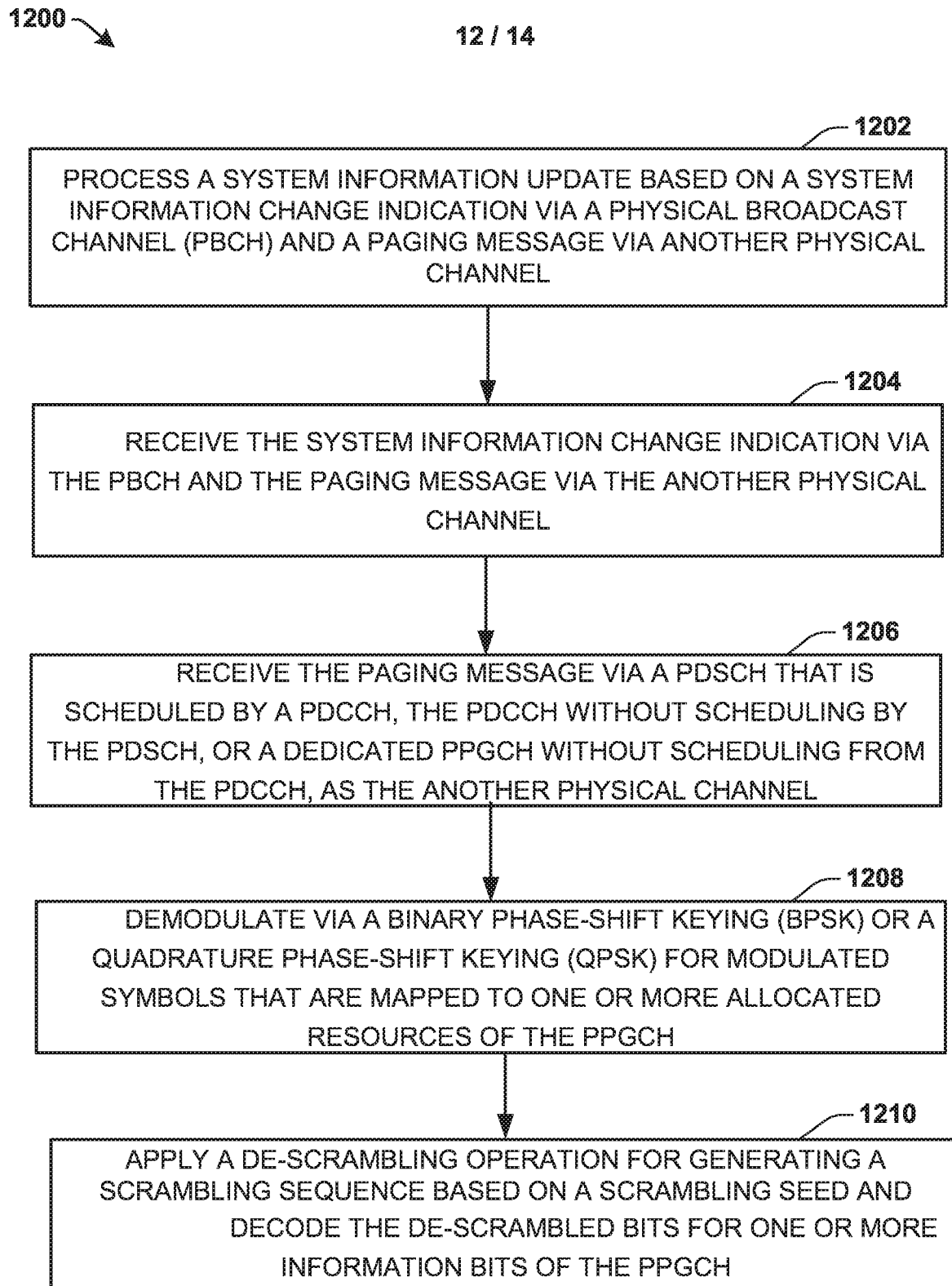


FIG. 11

**FIG. 12**

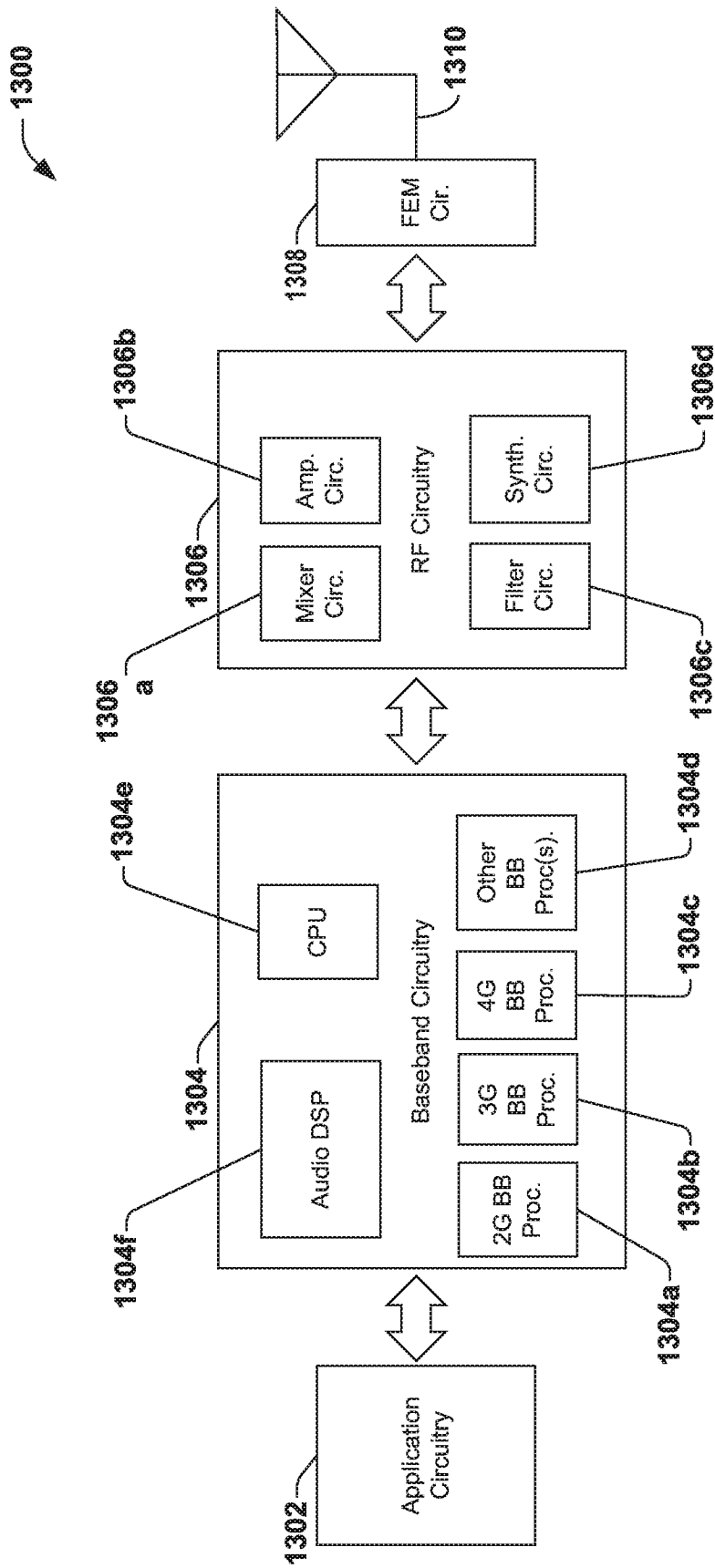
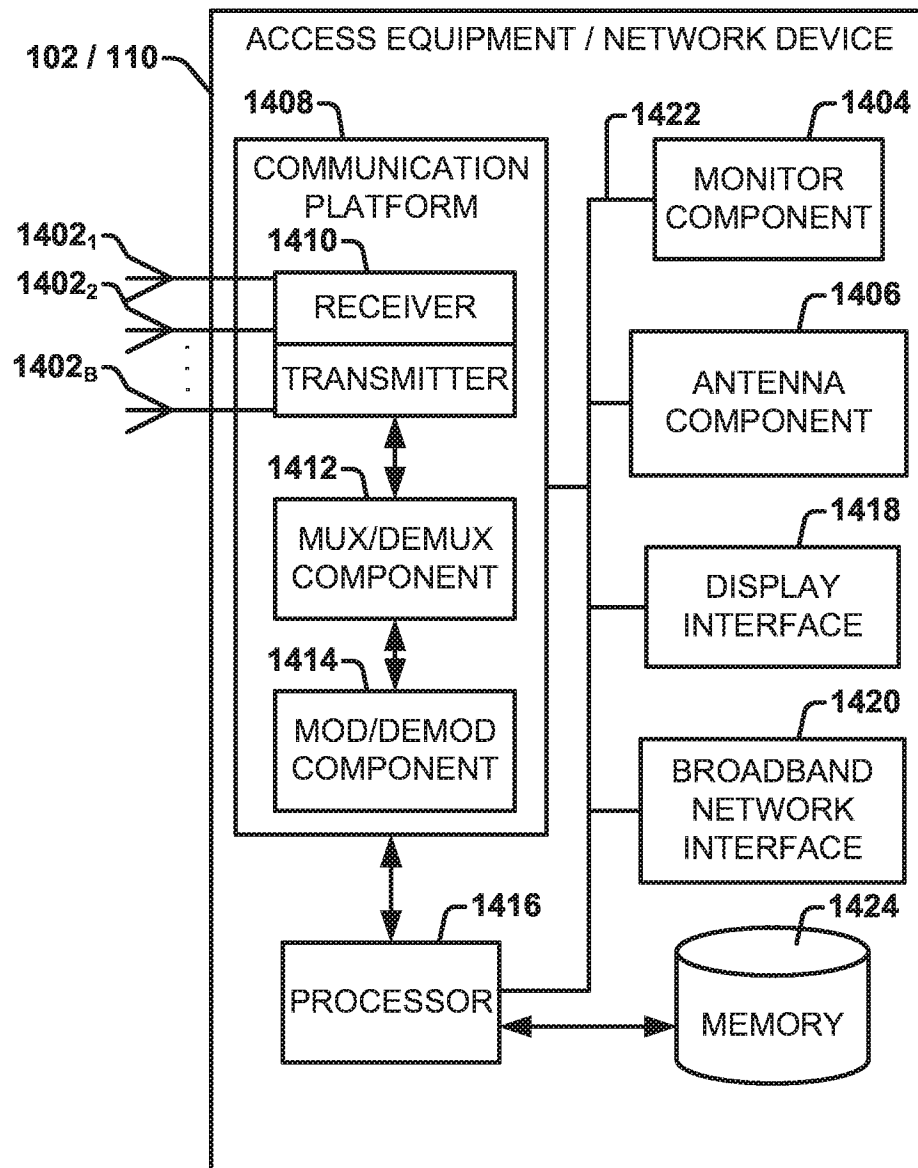


FIG. 13

**FIG. 14**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/022914

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W48/10 H04W68/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/014317 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 23 January 2014 (2014-01-23)	1-5, 14-16, 22,23
Y	paragraph [0001] - paragraph [0007]	6-8,17,
A	paragraph [0037]	24,25
	paragraph [0047] - paragraph [0051]	9-13,
	figures 2,3	18-21

Y	US 2015/341911 A1 (WAKABAYASHI HIDEJI [GB] ET AL) 26 November 2015 (2015-11-26) paragraph [0228]	6-8,24, 25

X	US 2012/122495 A1 (WENG JIANFENG [CA] ET AL) 17 May 2012 (2012-05-17)	1-5, 14-17, 22,23
Y	paragraph [0221] - paragraph [0229]	6-8,17,
	paragraph [0355]	24,25
	figure 9	

	-/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 May 2017

Date of mailing of the international search report

07/06/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Richel, Arnaud

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/022914

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 941 072 A1 (SHARP KK [JP]) 4 November 2015 (2015-11-04) paragraph [0001] - paragraph [0007] paragraph [0036] - paragraph [0040] figure 3 -----	1-5, 14-16, 22,23

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/022914

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