(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
21 April 2022 (21.04.2022)

WIPO | PCT

(10) **International Publication Number**
WO 2022/077334 A1

(51) **International Patent Classification:**
H04W 72/12 (2009.01)

(21) **International Application Number:**
PCT/CN2020/121142

(22) **International Filing Date:**
15 October 2020 (15.10.2020)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicant: ZTE CORPORATION** [CN/CN]; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN).

(72) **Inventors: SHI, Jing**; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN). **HAO, Peng**; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN). **WEI, Xingguang**; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN). **LI, Jian**; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN). **XIAO, Kai**; ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan, Shenzhen, Guangdong 518057 (CN).

(74) **Agent: BEYOND ATTORNEYS AT LAW**; F6, Xijin Centre, 39 Lianhuachi East Rd., Haidian District, Beijing 100036 (CN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** METHOD AND DEVICE FOR CROSS-CARRIER SCHEDULING PRIMARY CELL

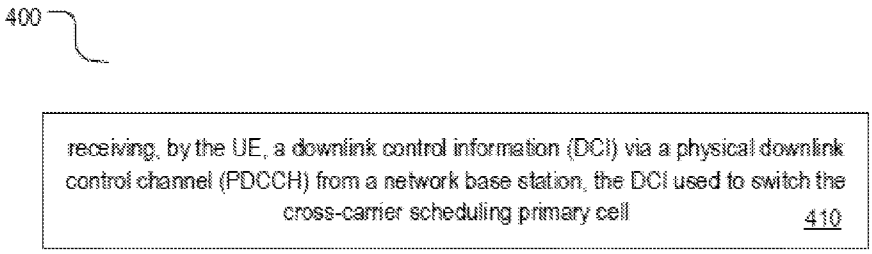

FIG. 4

(57) **Abstract:** The present disclosure describes methods, systems and devices for switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell. One method includes receiving, by the UE, a downlink control information (DCI) via a physical downlink control channel (PDCCH) from a network base station, the DCI used to switch the cross-carrier scheduling primary cell. Another method includes receiving, by the UE, a medium access control (MAC) control element (CE) from a network base station, the MAC CE used to switch the cross-carrier scheduling primary cell. Another method includes performing switching off cross-carrier scheduling primary cell by a secondary cell for a UE, and restoring, by the UE, a factor in the primary cell for scheduling the primary cell, and/or restoring, by the UE, a non-fallback downlink control information (DCI) in the primary cell for scheduling the primary cell.

WO 2022/077334 A1

METHOD AND DEVICE FOR CROSS-CARRIER SCHEDULING PRIMARY CELL

TECHNICAL FIELD

The present disclosure is directed generally to wireless communications. Particularly, the present disclosure relates to methods and devices for a physical downlink control channel (PDCCH) of a secondary cell (SCell) scheduling a physical downlink shared channel (PDSCH) or physical uplink shared channel (PUSCH) on a primary cell (PCell) or a primary secondary cell (PSCell).

BACKGROUND

Wireless communication technologies are moving the world toward an increasingly connected and networked society. High-speed and low-latency wireless communications rely on efficient network resource management and allocation between user equipment and wireless access network nodes (including but not limited to wireless base stations). A new generation network is expected to provide high speed, low latency and ultra-reliable communication capabilities and fulfil the requirements from different industries and users.

For the 5th Generation mobile communication technology, a primary cell may schedule a secondary cell. There are some issues and/or problems associated with the existing systems. One issue/problem may include that physical downlink control channel (PDCCH) of a primary cell may schedule physical downlink shared channel (PDSCH) or physical uplink shared channel (PUSCH) on a secondary cell, but there are problems/issues with a PDCCH of a secondary cell scheduling PDSCH or PUSCH on a primary cell. The present disclosure may address at least some of issues associated with the existing system to improve the performance of the wireless communication. Another issue/problem may include that, considering dynamic spectrum sharing (DSS) in recent development in wireless communication technology, a resource of a PDCCH of a primary cell may be restricted/limited. To mitigate the restricted/limited PDCCH resource of a primary cell and/or to offload the PDCCH transmission on the primary cell, the present disclosure present various embodiments for cross-carrier scheduling including a secondary cell scheduling a PDSCH or

PUSCH of a primary cell.

SUMMARY

This document relates to methods, systems, and devices for wireless communication, and more specifically, for a physical downlink control channel (PDCCH) of a secondary cell (SCell) scheduling a physical downlink shared channel (PDSCH) or physical uplink shared channel (PUSCH) on a primary cell (PCell) or a primary secondary cell (PSCell).

In one embodiment, the present disclosure describes a method for wireless communication. The method includes switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell, by receiving, by the UE, a downlink control information (DCI) via a physical downlink control channel (PDCCH) from a network base station, the DCI used to switch the cross-carrier scheduling primary cell.

In another embodiment, the present disclosure describes a method for wireless communication. The method includes switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell, by receiving, by the UE, a medium access control (MAC) control element (CE) from a network base station, the MAC CE used to switch the cross-carrier scheduling primary cell.

In another embodiment, the present disclosure describes a method for wireless communication. The method includes switching cross-carrier scheduling primary cell for a user equipment (UE) by a timer, wherein a secondary cell is configured or activated to schedule the primary cell, comprising: in response to, within a time period of the timer, receiving a DCI on the secondary cell to cross-carrier scheduling the primary cell, resetting, by the UE, the timer; and in response to passing the time period of the timer without receiving at least one DCI on the secondary cell to cross-carrier scheduling the primary cell, releasing, by the UE, the cross-carrier scheduling the primary cell by the secondary cell.

In another embodiment, the present disclosure describes a method for wireless communication. The method includes performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and restoring, by the UE, a factor in the primary cell for scheduling the primary cell.

In another embodiment, the present disclosure describes a method for wireless communication. The method includes performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and restoring, by the UE, a non-fallback downlink control information (DCI) in the primary cell for scheduling the primary cell.

In some other embodiments, an apparatus for wireless communication may include a memory storing instructions and a processing circuitry in communication with the memory. When the processing circuitry executes the instructions, the processing circuitry is configured to carry out the above methods.

In some other embodiments, a device for wireless communication may include a memory storing instructions and a processing circuitry in communication with the memory. When the processing circuitry executes the instructions, the processing circuitry is configured to carry out the above methods.

In some other embodiments, a computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the above methods.

The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an example of a wireless communication system include one wireless network node and one or more user equipment.

FIG. 2 shows an example of a network node.

FIG. 3 shows an example of a user equipment.

FIG. 4 shows a flow diagram of a method for wireless communication.

FIG. 5 shows a schematic diagram of an exemplary embodiment for wireless communication.

FIG. 6 shows an exemplary embodiment of a table in an exemplary embodiment for wireless communication.

FIG. 7 shows a flow diagram of a method for wireless communication.

FIG. 8 shows a flow diagram of a method for wireless communication.

FIG. 9 shows a flow diagram of a method for wireless communication.

FIG. 10 shows a flow diagram of a method for wireless communication.

DETAILED DESCRIPTION

The present disclosure will now be described in detail hereinafter with reference to the accompanied drawings, which form a part of the present disclosure, and which show, by way of illustration, specific examples of embodiments. Please note that the present disclosure may, however, be embodied in a variety of different forms and, therefore, the covered or claimed subject matter is intended to be construed as not being limited to any of the embodiments to be set forth below.

Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase “in one embodiment” or “in some embodiments” as used herein does not necessarily refer to the same embodiment and the phrase “in another embodiment” or “in other embodiments” as used herein does not necessarily refer to a different embodiment. The phrase “in one implementation” or “in some implementations” as used herein does not necessarily refer to the same implementation and the phrase “in another implementation” or “in other implementations” as used herein does not necessarily refer to a different implementation. It is intended, for example, that claimed subject matter includes combinations of exemplary embodiments or implementations in whole or in part.

In general, terminology may be understood at least in part from usage in context. For example, terms, such as “and”, “or”, or “and/or,” as used herein may include a variety of meanings that may depend at least in part upon the context in which such terms are used. Typically, “or” if used to associate a list, such as A, B or C, is intended to mean A, B, and C, here used in the inclusive sense, as well as A, B or C, here used in the exclusive sense. In addition, the term “one or more” or “at least one” as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures or characteristics in a plural sense. Similarly, terms, such as "a", "an", or "the", again, may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the term "based on" or "determined by" may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for existence of additional factors not necessarily expressly described, again, depending at least in part on context.

The present disclosure describes methods and devices for scheduling one or more cells with single downlink control information (DCI).

New generation (NG) mobile communication system are moving the world toward an increasingly connected and networked society. High-speed and low-latency wireless communications rely on efficient network resource management and allocation between user equipment and wireless access network nodes (including but not limited to wireless base stations). A new generation network is expected to provide high speed, low latency and ultra-reliable communication capabilities and fulfil the requirements from different industries and users.

The 4th Generation mobile communication technology (4G) Long-Term Evolution (LTE) or LTE-Advance (LTE-A) and the 5th generation mobile communication technology (5G) face more and more demands. Based on the developing trend, 4G and 5G systems may develop supports on features of enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC). Some spectrum used for 4G may be reused for 5G according to dynamic spectrum sharing (DSS).

In the 5G communication system, a secondary serving cell (SCell) may be the only scheduling cell or scheduled cell, while a primary cell (PCell) or a primary secondary cell (PSCell) may be a scheduling cell and may not be a scheduled cell. The primary secondary cell (PSCell) may be a primary cell in a secondary cell group (SCG). Some issues and/or problems associated with the current system. One issue/problem may include that a physical downlink control channel (PDCCH) of PCell/PSCell may schedule physical downlink shared channel (PDSCH) or physical uplink shared channel (PUSCH) on SCell, but PDSCH or PUSCH on PCell/PSCell may not be scheduled by PDCCH of SCell. Considering DSS in NR communication system, a resource of PDCCH of PCell/PSCell may be restricted.

The present disclosure describes various embodiments including NR PDCCH enhancements for cross-carrier scheduling including PDCCH of SCell scheduling PDSCH or PUSCH of PCell/PSCell At least to mitigate the restricted/limited PDCCH resource PCell/PSCell and/or to offload the data transmission on PDCCH of PCell/PSCell,. When a capability restriction of PDCCH of PCell/PSCell changes dynamically, the various embodiments described in the present disclosure support dynamic switching cross-carrier scheduling primary cell by a secondary cell.

FIG. 1 shows a wireless communication system 100 including a wireless network node 118 and one or more user equipment (UE) 110. The wireless network node may include a network base station, which may be a nodeB (NB, e.g., a gNB) in a mobile telecommunications context. Each of the UE may wirelessly communicate with the wireless network node via one or more radio channels 115. For example, a first UE 110 may wirelessly communicate with a wireless network node 118 via a channel including a plurality of radio channels during a certain period of time. The network base station 118 may send high layer signalling to the UE 110. The high layer signalling may include configuration information for communication between the UE and the base station. In one implementation, the high layer signalling may include a radio resource control (RRC) message.

FIG. 2 shows an example of electronic device 200 to implement a network base station. The example electronic device 200 may include radio transmitting/receiving (Tx/Rx) circuitry 208 to transmit/receive communication with UEs and/or other base stations. The electronic device 200 may also include network interface circuitry 209 to communicate the base station with other base stations and/or a core network, e.g., optical or wireline interconnects, Ethernet, and/or other data transmission mediums/protocols. The electronic device 200 may optionally include an input/output (I/O) interface 206 to communicate with an operator or the like.

The electronic device 200 may also include system circuitry 204. System circuitry 204 may include processor(s) 221 and/or memory 222. Memory 222 may include an operating system 224, instructions 226, and parameters 228. Instructions 226 may be configured for the one or more of the processors 124 to perform the functions of the network node. The parameters 228 may include parameters to support execution of the instructions 226. For example, parameters may include network protocol settings, bandwidth parameters, radio frequency mapping assignments, and/or other parameters.

FIG. 3 shows an example of an electronic device to implement a terminal device 300 (for example, user equipment (UE)). The UE 300 may be a mobile device, for example, a smart phone or a mobile communication module disposed in a vehicle. The UE 300 may include communication interfaces 302, a system circuitry 304, an input/output interfaces (I/O) 306, a display circuitry 308, and a storage 309. The display circuitry may include a user interface 310. The system circuitry 304 may include any combination of hardware, software, firmware, or other logic/circuitry. The system circuitry 304 may be implemented, for example, with one or more systems on a chip (SoC), application specific integrated circuits (ASIC), discrete analog and digital circuits, and other circuitry. The system circuitry 304 may be a part of the implementation of any desired functionality in the UE 300. In that regard, the system circuitry 304 may include logic that facilitates, as examples, decoding and playing music and video, e.g., MP3, MP4, MPEG, AVI, FLAC, AC3, or WAV decoding and playback; running applications; accepting user inputs; saving and retrieving application data; establishing, maintaining, and terminating cellular phone calls or data connections for, as one example, internet connectivity; establishing, maintaining, and terminating wireless network connections, Bluetooth connections, or other connections; and displaying relevant information on the user interface 310. The user interface 310 and the inputs/output (I/O) interfaces 306 may include a graphical user interface, touch sensitive display, haptic feedback or other haptic output, voice or facial recognition inputs, buttons, switches, speakers and other user interface elements. Additional examples of the I/O interfaces 306 may include microphones, video and still image cameras, temperature sensors, vibration sensors, rotation and orientation sensors, headset and microphone input / output jacks, Universal Serial Bus (USB) connectors, memory card slots, radiation sensors (e.g., IR sensors), and other types of inputs.

Referring to FIG. 3, the communication interfaces 302 may include a Radio Frequency (RF) transmit (Tx) and receive (Rx) circuitry 316 which handles transmission and reception of signals through one or more antennas 314. The communication interface 302 may include one or more transceivers. The transceivers may be wireless transceivers that include modulation / demodulation circuitry, digital to analog converters (DACs), shaping tables, analog to digital converters (ADCs), filters, waveform shapers, filters, pre-amplifiers, power amplifiers and/or other logic for transmitting and receiving through one or more antennas, or (for some devices) through a physical (e.g., wireline) medium. The transmitted and received signals may adhere to any of a diverse array of formats, protocols, modulations (e.g., QPSK, 16-QAM, 64-QAM, or 256-QAM), frequency channels, bit rates, and encodings. As one specific example, the communication interfaces 302 may include transceivers that support transmission and reception under the 2G, 3G, BT, WiFi, Universal Mobile Telecommunications System (UMTS), High Speed Packet Access (HSPA)+, 4G / Long Term Evolution (LTE) , and 5G standards. The techniques described below, however, are applicable to other wireless communications technologies whether arising from the 3rd Generation Partnership Project (3GPP), GSM Association, 3GPP2, IEEE, or other partnerships or standards bodies.

Referring to FIG. 3, the system circuitry 304 may include one or more processors 321 and memories 322. The memory 322 stores, for example, an operating system 324, instructions 326, and parameters 328. The processor 321 is configured to execute the instructions 326 to carry out desired functionality for the UE 300. The parameters 328 may provide and specify configuration and operating options for the instructions 326. The memory 322 may also store any BT, WiFi, 3G, 4G, 5G or other data that the UE 300 will send, or has received, through the communication interfaces 302. In various implementations, a system power for the UE 300 may be supplied by a power storage device, such as a battery or a transformer.

The present disclosure describes several below embodiments, which may be implemented, partly or totally, on the network base station and/or the user equipment described above in FIGS. 2-3.

Referring to FIG. 4, the present disclosure describes embodiments of a method 400 for switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell. The method 400 may include step 410: receiving, by the UE, a downlink control information (DCI) via a physical downlink control channel (PDCCH) from a network base station, the DCI used to switch the cross-carrier scheduling primary cell. In one implementation, the cross-carrier scheduling primary cell comprises PDCCH of a secondary cell (SCell) scheduling a physical shared channel on the primary cell. The primary cell may include at least one of a primary cell in a master cell group (PCell), or a primary cell in a secondary cell group (PSCell). The physical shared channel on the primary cell comprises at least one of a physical downlink shared channel (PDSCH), or a physical uplink shared channel (PUSCH) on the primary cell.

The present disclosure describe various embodiments of using a bandwidth part (BWP) to support dynamic switching of the cross-carrier scheduling primary cell by a secondary cell. In carrier aggregation (CA) scenario, a primary cell (e.g., PCell or PSCell) may be configured to be scheduled by a secondary cell (e.g., SCell). In one implementation, the secondary cell is configured as a scheduling cell to schedule itself, and also configured to support scheduling the primary cell.

The various embodiments described in the present disclosure improve the wireless communication technology, addressing at least some of the problems/issues with previous systems, leading to benefits. For example, in one embodiment, multiple BWPs are configured to support or not support the cross-carrier scheduling primary cell combined with BWP switching indication, or all of them support the cross-carrier scheduling primary cell together with BWP switching indication and indicate whether the BWP supports SCell-schedule-PCell, to achieve dynamic support of the cross-carrier scheduling primary cell. This may ensure that the change of PDCCH capacity can be flexibly adapted when the SCell supports the scheduling of the PCell/PSCell. Dynamic release of the cross-carrier scheduling primary cell may reduce the complexity of blind detection and save the power consumption of UEs.

In one implementation of the various embodiments, at least two BWPs are configured in a secondary cell. A search space index configured for one BWP of the secondary cell is different from a search space index configured for one BWP of the primary cell. At least one search space index configured in other BWP of the secondary cell is same as a search space index configured for one BWP of the primary cell. The active BWP of the secondary cell is dynamically indicated by a DCI to dynamically support the cross-carrier scheduling primary cell.

The secondary cell may be configured to support the cross-carrier scheduling primary cell. The primary cell may be configured with a bandwidth part (BWP) having a search space index. The secondary cell is configured with a first BWP having a first search space index, and the first search space index of the first BWP is same with the search space index of the BWP in the primary cell; and the secondary cell is also configured with a second BWP having a second search space index, and the second search space index of the second BWP is different from the search space index of the BWP in the primary cell. The DCI comprises a bandwidth part indicator. The bandwidth part indicator may be used to indicate which BWP is active for the cross-carrier scheduling primary cell by a secondary cell. For example but not limited to, a field size of the bandwidth part indicator is configured as 1 bit, the bandwidth part indicator of "0" may be used to indicate that the first BWP is active for the cross-carrier scheduling primary cell by a secondary cell; and the bandwidth part indicator of "1" may be used to indicate that the second BWP is active for the cross-carrier scheduling primary cell by a secondary cell. In response to the bandwidth part indicator indicating the first BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is switched on; and in response to the bandwidth part indicator indicating the second BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is switched off.

For example referring to FIG. 5, cell A 510 is a primary cell and is configured with search space index ={0, 1, 2, 3, 10, 11, 12, and 13} in a BWP. Cell B 520 is a secondary cell, and the configuration of cell B 520 supports the cross-carrier scheduling of cell A 510. Cell B 520 is configured with search space index = {0, 1, 2, and 3} in a first BWP (BWP1) 522, and a search space index = {20, 21, 22, and 23} in a second BWP (BWP2) 524. When the bandwidth part indicator in the DCI used for cross-carrier scheduling primary cell by the secondary cell indicates that active BWP is BWP1, the cross-carrier scheduling primary cell by the secondary cell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index are provided. When the bandwidth part indicator in DCI indicating that active BWP is BWP2, even though that cell B is configured to support cross-carrier scheduling cell A, due to not having the same search space index, the cross-carrier scheduling primary cell is not supported.

In another implementation of the various embodiments, at least two BWPs are configured in the secondary cell, and each BWP is configured whether the each BWP supports the cross-carrier scheduling primary cell. The active BWP of the secondary cell is dynamically indicated to the BWP with supporting the cross-carrier scheduling primary cell or the BWP without supporting the cross-carrier scheduling primary cell to dynamically support the cross-carrier scheduling primary cell.

The primary cell is configured with a bandwidth part (BWP) having a search space index. The secondary cell is configured with a first BWP having a first search space index, and the first BWP is configured to support the cross-carrier scheduling; and the secondary cell is configured with a second BWP having a second search space index, the second BWP configured not to support the cross-carrier scheduling. The DCI may include a bandwidth part indicator. The bandwidth part indicator may be used to indicate which BWP is active to be used by a secondary cell. For example but not limited to, a field size of the bandwidth part indicator is configured as 1 bit, the bandwidth part indicator of "0" may be used to indicate that the first BWP is active; and the bandwidth part indicator of "1" may be used to indicate that the second BWP is active for the cross-carrier scheduling primary cell by a secondary cell. In response to the bandwidth part indicator indicating a first BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the bandwidth part indicator indicating a second BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off.

For example but not limited to, the configuration of a secondary cell (cell B) may support cross-carrier scheduling primary cell (cell A). Cell A is configured with search space index = {0, 1, 2, 3, 10, 11, 12, and 13} in a BWP. Cell B is configured with a search space index = {0, 1, 2, and 3} in a first BWP (BWP1), and a search space index = {10, 11, 12, and 13} in a second BWP (BWP2). The BWP1 is configured to support the cross-carrier scheduling the primary cell by the secondary cell (also referred as SCell-schedule-PCell). The BWP2 is configured not to support the cross-carrier scheduling the primary cell by the secondary cell. When the bandwidth part indicator in the DCI used for the secondary cell scheduling indicates that BWP1 is the active BWP, the cross-carrier scheduling the primary cell by the secondary cell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided and the BWP1 is configured to support SCell-schedule-PCell. When the bandwidth part indicator in the DCI indicates that the BWP2 is the active BWP, even that cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided, due to that the BWP2 is configured not to support SCell-schedule-PCell, SCell-schedule-PCell is not supported.

In another implementation of the various embodiments, at least two BWPs are configured in the secondary cell. The DCI indicates which BWP of the secondary cell is active, and whether the BWP of the secondary cell supports the cross-carrier scheduling primary cell. Thus, the active BWP of the secondary cell is dynamically indicated by the DCI and whether the BWP supports SCell-schedule-PCell or not is also dynamically indicated by the DCI, so as to dynamically support the cross-carrier scheduling primary cell.

The DCI may include a bandwidth part indicator including a cross-carrier scheduling primary cell indicator. The bandwidth part indicator may be used to indicate which BWP is active to be used by a secondary cell. For example but not limited to, a field size of the bandwidth part indicator including a cross-carrier scheduling primary cell indicator is configured as 2 bits, the fisrt bit represent bandwidth part indicator which indication of “0” may be used to indicate that the first BWP is active; and the bandwidth part indicator of “1” may be used to indicate that the second BWP is active. The cross-carrier scheduling primary cell indicator may be used to indicate whether the secondary cell activate or release the cross-carrier scheduling primary cell. For example but not limited to, the second bit represents cross-carrier scheduling primary cell indicator which indication of “0” may be used to indicate that the release of the cross-carrier scheduling primary cell; and the cross-carrier scheduling primary cell indicator of “1” may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In response to the bandwidth part indicator indicating a BWP being active and the cross-carrier scheduling primary cell indicator indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the bandwidth part indicator indicating a BWP being active and the cross-carrier scheduling primary cell indicator indicating a release of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off.

For example but not limited to, the configuration of a secondary cell (cell B) supports cross-carrier scheduling of a primary cell (Cell A). The Cell A is configured with a search space index = {0, 1, 2, 3, 10, 11, 12, and 13} in a BWP. The Cell B is configured with a search space index = {0, 1, 2, and 3} in a first BWP (BWP1), and a search space index ={10, 11, 12, and 13} in a second BWP (BWP2). When the bandwidth part indicator in the DCI used for the secondary cell scheduling indicates that active BWP is BWP1, the cross-carrier scheduling primary cell (also referred to as SCell-schedule-PCell) is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided and the cross-carrier scheduling primary cell indicator indicates to support SCell-schedule-PCell. When the bandwidth part indicator in the DCI indicating that the active BWP is BWP2, even that cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided, due to that the cross-carrier scheduling primary cell indicator indicates not to support SCell-schedule-PCell, SCell-schedule-PCell is not supported.

In another implementation of the various embodiments, at least two BWPs are configured in the secondary cell. The two BWPs are non-dormant BWPs. One non-dormant BWP is configured to supports the cross-carrier scheduling primary cell by a secondary cell; and the other non-dormant BWP is configured not to support the cross-carrier scheduling primary cell by a secondary cell. When a SCell dormancy indicator in the DCI is used, it indicates a non-dormant BWP to support the cross-carrier scheduling primary cell by a secondary cell or a non-dormant BWP not to support the cross-carrier scheduling primary cell by a secondary cell.

The secondary cell may be configured with a first non-dormant BWP to support the cross-carrier scheduling primary cell and the secondary cell is configured with a second non-dormant BWP not to support the cross-carrier scheduling primary cell. The DCI comprises a SCell dormancy indicator. The SCell dormancy indicator may be used to indicate which BWP is active to be used by a secondary cell. For example but not limited to, a field size of the SCell dormancy indicator is configured as 2 bits, the second bit of SCell dormancy indicator which indication of "0" may be used to indicate that the first non-dormant BWP is active; and the SCell dormancy indicator of "1" may be used to indicate that the second non-dormant BWP is active. In response to the SCell dormancy indicator indicating to use the first non-dormant BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; in response to the SCell dormancy indicator indicating to use the second non-dormant BWP being active, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off.

For one example, the configuration of a secondary cell (cell B) may support cross-carrier scheduling of a primary cell (cell A). Cell A is configured with a search space index = {0, 1, 2, 3, 10, 11, 12, and 13} in a BWP. Cell B is configured with a search space index = {0, 1, 2, and 3} in a first non-dormant BWP (BWP1), and a search space index = {10, 11, 12, and 13} in a second dormant BWP (BWP2), and a dormant BWP3. BWP1 is configured to support the cross-carrier scheduling the primary cell by the secondary cell (also referred as

SCell-schedule-PCell), BWP2 is configured not to support SCell-schedule-PCell. In one implementation, when the SCell dormancy indicator indicates BWP1, SCell-schedule-PCell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided and BWP1 is configured to support SCell-schedule-PCell. When the SCell dormancy indicator indicates BWP2, even that cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided, due to that BWP2 is configured not to support SCell-schedule-PCell, SCell-schedule-PCell is not supported. Alternatively in another implementation, when the first bit of a SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘0’ value, SCell dormancy indicator indicates switching to the dormant BWP3. When the SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘1’ value, the SCell dormancy indicator indicates switching to the non-dormant BWP, and further the second bit of a SCell dormancy indicator indicates the index of non-dormant BWP. When the second bit of the SCell dormancy indicator indicates BWP1, SCell-schedule-PCell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided and BWP1 is configured to support SCell-schedule-PCell. When the second bit of the SCell dormancy indicator indicates BWP2, even that cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided, due to that BWP2 is configured not to support SCell-schedule-PCell, SCell-schedule-PCell is not supported.

In another implementation of the various embodiments, at least two BWPs are configured in the secondary cell, one of the BWPs is a non-dormant BWP, the other one of the BWPs is a dormant BWP. When a SCell dormancy indication in the DCI is used to indicate the non-dormant BWP, it also indicates whether the non-dormant BWP supports the cross-carrier scheduling primary cell by a secondary cell or not.

The DCI may include a SCell dormancy indicator including a cross-carrier scheduling primary cell indicator. The SCell dormancy indicator may be used to indicate whether the dormant BWP or the non-dormant BWP is active to be used by a secondary cell. For example but not limited to, a field size of the SCell dormancy indicator including a cross-carrier scheduling primary cell indicator is configured as 2 bits, the first bit of the SCell dormancy indicator which indication of “0” may be used to indicate that the dormant BWP is active; and the SCell dormancy indicator of “1” may be used to indicate that the non-dormant BWP is active. The cross-carrier scheduling primary cell indicator may be used to indicate whether the secondary cell activate or release the cross-carrier scheduling primary cell. For example but not limited to, the second bit of the SCell dormancy indicator is the cross-carrier scheduling primary cell indicator which indication of “0” may be used to indicate that the release of the cross-carrier scheduling primary cell; and the cross-carrier scheduling primary cell indicator of “1” may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In response to the SCell dormancy indicator indicating to use a non-dormant BWP and the cross-carrier scheduling primary cell indicator indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the SCell dormancy indicator indicating to use a non-dormant BWP and the cross-carrier scheduling primary cell indicator indicating a release of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off..

For one example, the configuration of a secondary cell (cell B) supports cross-carrier scheduling of a primary cell (cell A). Cell A is configured with a search space index = {0, 1, 2, 3, 10, 11, 12, and 13} in a BWP. Cell B is configured with a search space index = {0, 1, 2, and 3} in a non-dormant BWP (BWP1), and a dormant BWP (BWP2). When a SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘0’ value, the SCell dormancy indicator indicates switching to the dormant BWP2. When the SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘1’ value, the SCell dormancy indicator indicates switching to the non-dormant BWP1. The SCell dormancy indicator in the DCI may include a cross-carrier scheduling primary cell indicator which may indicate whether the non-dormant BWP1 supports the cross-carrier scheduling the primary cell by the secondary cell or not. When the SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘1’ value and also indicate to support the cross-carrier scheduling the primary cell by the secondary cell (also referred to as SCell-schedule-PCell), SCell-schedule-PCell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided. When the SCell dormancy indicator in the DCI used for SCell scheduling indicates ‘1’ value but indicate not support SCell-schedule-PCell, SCell-schedule-PCell is not supported although cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided.

In another implementation of the various embodiments, dynamic cross-carrier scheduling the primary cell by the secondary cell may be supported by a DCI with indication of activation or release of the cross-carrier scheduling the primary cell by the secondary cell. A non-fallback DCI including a field indicating a configuration of activation/release of the cross-carrier scheduling the primary cell by the secondary cell may be used to indicate whether to support the cross-carrier scheduling the primary cell by the secondary cell dynamically.

The DCI comprises a non-fallback DCI comprising a configurable field indicating the cross-carrier scheduling primary cell. When configured, the field may be used to indicate whether the secondary cell activate or release the cross-carrier scheduling primary cell. For example but not limited to, the field of "0" may be used to indicate that the release of the cross-carrier scheduling primary cell; and the field of "1" may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In one implementation, the field may be a SCell-schedule-PCell field. In response to the field in the non-fallback DCI indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is switched on; and in response to the field in the non-fallback DCI indicating a release of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is switched off.

Optionally in one implementation, an effective time point for switching on or off the cross-carrier scheduling primary cell by the secondary cell includes at least one of the following: a first time based on a time of receiving the DCI and an offset value; and a second time based on a time of the physical shared channel scheduled by the DCI and the offset value. The offset value is an integer being equal to or greater than zero; and the offset value indicates an offset period determined by multiplying the integer with at least one of the following: an absolute time interval, an orthogonal frequency-division multiplexing (OFDM) symbol, or a slot.

For one example, the configuration of a secondary cell (cell B) supports cross-carrier scheduling of a primary cell (cell A). Cell A is configured with a search space index = {0, 1, 2, 3, 10, 11, 12, and 13} in a BWP, and an activation/release of SCell-schedule-PCell field is configured in non-fallback DCI (e.g. DCI format 0_1/1_1) in at least one search space. Cell B is configured with a search space index = {0, 1, 2, and 3} in BWP1 which is also configured with support of SCell-schedule-PCell. When the activation/release of SCell-schedule-PCell field in the non-fallback DCI indicates release of SCell-schedule-PCell, SCell-schedule-PCell is not supported although cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided. When the activation/release of SCell-schedule-PCell field in the non-fallback DCI indicates activation of SCell-schedule-PCell, SCell-schedule-PCell is supported because cell B is configured to support cross-carrier scheduling cell A and the same search space index can be provided.

For another example, the effective time of the activation/release SCell-schedule-PCell may be any one of the following time based on an offset value: (1) the offset value plus the slot/symbol #n of reception of the DCI with indication of activation/release SCell-schedule-PCell; or (2) the offset value plus the slot/symbol #n of the PDSCH/PUSCH scheduled by the DCI with indication of activation/release SCell-schedule-PCell. The offset value is an integer equal to or greater than 0, which may represent by one of the following: the offset value multiplied with an absolute time interval, the offset value multiplied with an OFDM symbol, or the offset value multiplied with a slot or sub-slot.

In another implementation of the various embodiments, dynamic cross-carrier scheduling the primary cell by the secondary cell may be supported by a DCI with indication of activation or release of the cross-carrier scheduling the primary cell by the secondary cell. The DCI may be a fallback DCI indicating whether to support the cross-carrier scheduling the primary cell by the secondary cell. The fallback DCI may include an indicator, which may include one of the following: a cyclic redundancy check (CRC) scrambled by a specific radio network temporary identifier (RNTI); at least one reserved bit in the fallback DCI; and a short message in the fallback DCI.

The DCI may include a fallback DCI comprising an indicator indicating the cross-carrier scheduling primary cell. For example but not limited to, the indicator of “0” may be used to indicate that the release of the cross-carrier scheduling primary cell; and the indicator of “1” may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In response to the indicator in the fallback DCI indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the indicator in the fallback DCI indicating a release of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off. Optionally, the indicator in the fallback DCI comprises at least one of the following: a cyclic redundancy check (CRC) scrambled by a specific radio network temporary identifier (RNTI); at least one reserved bit in the fallback DCI; and a short message in the fallback DCI.

For example, when the DCI may have a format of DCI Format 1_0 with CRC scrambled by system information RNTI (SI-RNTI), paging RNTI (P-RNTI), random access RNTI (RA-RNTI), MsgB-RNTI, or scrambled by cell RNTI (C-RNTI). The "Frequency domain resource assignment" field of the DCI may include all ones, and 1 bit in reserved bit to indicate SCell-schedule-PCell activation/release. In one implementation, when the DCI may have a format of DCI format 1_0 or DCI format 0_0 used for unicast scheduling, a RNTI with specific value to scramble CRC may indicate SCell-schedule-PCell activation/release. In another implementation, when short messages indicator indicates only short message present in the DCI or both scheduling information and short message are present in the DCI, short messages may be used to indicate SCell-schedule-PCell activation/release.

In another implementation of the various embodiments, dynamic cross-carrier scheduling the primary cell by the secondary cell may be supported by a DCI with indication of activation or release of the cross-carrier scheduling the primary cell by the secondary cell. A blind decoding/control channel element (BD/CCE) scaling factor (or a cell weight factor) of the two scheduling cells of the PCell may be configured to implicitly indicate activation/release of the cross-carrier scheduling the primary cell by the secondary cell.

The DCI may include a factor indicating the cross-carrier scheduling primary cell. The factor in the DCI may include one of the following: a blind decoding/control channel element (BD/CCE) scaling factor, or a cell weight factor. When the BD/CCE scaling factor between the PCell and the SCell is (1, 0), i.e., the BD/CCE of the PCell is 1 times that of the per cell, and the BD/CCE of the SCell is 0 times that of the per cell, a release of the the cross-carrier scheduling primary cell is implied. Thus, when the factor in the DCI equals to (1, 0) for PCell and SCell respectively, the factor indicates the release of the cross-carrier scheduling primary cell. In response to the factor in the DCI indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the factor in the DCI indicating a release of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off..

For example, the BD/CCE scaling factors (or cell weight factors, representing the scheduled PCell number counted for its scheduling cell of the PCell and the SCell respectively) of the two scheduling cells of the PCell indicated in the DCI is configured. In one implementation referring to FIG. 6, a factor may include 2-bit value 612, representing a BD/CCE scaling factor between PCell and the SCell 614. The 2-bit value of "00" (621) represents a BD/CCE scaling factor of (0.33, 0.66); the 2-bit value of "01" (622) represents a BD/CCE scaling factor of (0.5, 0.5); the 2-bit value of "10" (623) represents a BD/CCE scaling factor of (0.66, 0.33); and the 2-bit value of "00" (624) represents a BD/CCE scaling factor of (1, 0). When the scaling factor of the BD/CCE of the PCell and SCell is (0.5, 0.5), the budget of the BD/CCE of the PCell for scheduling PCell is 1/2 times of the budget of the BD/CCE of the per cell, and the budget of the SCell for scheduling PCell is 1/2 times of the budget of the BD/CCE of the per cell. When the scaling factor between the PCell and the SCell BD/CCE is (1, 0), the BD/CCE of the PCell is 1 times that of the per cell, and the BD/CCE of the SCell is 0 times that of the per cell, which implicitly releases the SCell-schedule-PCell.

Optionally and/or alternatively in another implementation, the DCI may not need to indicate BWP switching. Optionally and/or alternatively in another implementation, the DCI may be transmitted on the primary cell.

The various embodiments described in the present disclosure improve the wireless communication technology, addressing at least some of the problems/issues with previous systems, leading to benefits. For example, in one embodiment, through explicitly or implicitly indicate activation/release SCell-schedule-PCell, dynamic support of SCell-schedule-PCell is achieved. This may ensure that the change of PDCCH capacity can be flexibly adapted when the SCell supports the scheduling of the PCell/PSCell. Dynamic release of the cross-carrier scheduling primary cell may reduce the complexity of blind detection and save the power consumption of UEs.

Referring to FIG. 7, the present disclosure describes embodiments of a method 700 for switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell. The method 700 may include step 710: receiving, by the UE, a medium access control (MAC) control element (CE) from a network base station, the MAC CE used to switch the cross-carrier scheduling primary cell. In one implementation, the cross-carrier scheduling primary cell comprises PDCCH of a secondary cell (SCell) scheduling a physical shared channel on the primary cell. The primary cell may include at least one of a primary cell in a master cell group (PCell), or a primary cell in a secondary cell group (PSCell). The physical shared channel on the primary cell comprises at least one of a physical downlink shared channel (PDSCH), or a physical uplink shared channel (PUSCH) on the primary cell.

The present disclosure describe various embodiments for supporting dynamic SCell-schedule-PCell by MAC CE with indication of activation or release of SCell-schedule-PCell. In carrier aggregation (CA) scenario, a primary cell (e.g., PCell or PSCell) may be configured to be scheduled by a secondary cell (e.g., SCell). In one implementation, the secondary cell is configured as a scheduling cell to schedule itself, and also configured to support scheduling the primary cell.

The various embodiments described in the present disclosure improve the wireless communication technology, addressing at least some of the problems/issues with previous systems, leading to benefits. For example, in one embodiment, through independent MAC CE or joint coding with other MAC CE indicate activation/release SCell-schedule-PCell, dynamic support of SCell-schedule-PCell is achieved. This may ensure that the change of PDCCH capacity can be flexibly adapted when the SCell supports the scheduling of the PCell/PSCell. Dynamic release of the cross-carrier scheduling primary cell may reduce the complexity of blind detection and save the power consumption of UEs.

In one implementation of the various embodiments, MAC CE may be used to indicate activation/release SCell-schedule-PCell and the MAC CE may include a subheader has a specific logic channel identification (LCID). For example, the MAC CE comprises a specific MAC CE comprising a MAC subheader with a specific logic channel identification (LCID) indicating the cross-carrier scheduling primary cell. For example but not limited to, a field in the MAC CE of “0” may be used to indicate that the release of the cross-carrier scheduling primary cell; and the field in the MAC CE of “1” may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In response to a field in the MAC CE indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the field in the MAC CE indicating a release of the activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched off.

In another implementation of the various embodiments, joint coding with other MAC CE may be used to indicate to activation/release SCell-schedule-PCell. For example, one or more reserved bit in SCell activation/deactivation MAC CE is used to activate/release SCell-schedule-PCell, that is, to activate/release SCell-schedule-PCell while performing activation/deactivation SCell.

The MAC CE comprises a joint MAC CE comprising a reserved bit indicating the cross-carrier scheduling primary cell. Optionally and/or alternatively, the joint MAC CE comprises a SCell activation/deactivation MAC CE. For example but not limited to, the reserved bit in the MAC CE of “0” may be used to indicate that the release of the cross-carrier scheduling primary cell; and the reserved bit in the MAC CE of “1” may be used to indicate that the activation of the cross-carrier scheduling primary cell indicator. In response to the reserved bit indicating an activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell by the secondary cell is dynamically switched on; and in response to the reserved bit indicating a release of the activation of the cross-carrier scheduling primary cell, the cross-carrier scheduling the primary cell of the secondary cell is dynamically switched off.

Referring to FIG. 8, the present disclosure describes embodiments of a method 800 for switching cross-carrier scheduling primary cell for a user equipment (UE) by a timer, wherein a secondary cell is configured or activated to schedule the primary cell. The method 800 may include step 810: in response to, within a time period of the timer, receiving a DCI on the secondary cell to cross-carrier scheduling the primary cell, resetting, by the UE, the timer; and step 820: in response to passing the time period of the timer without receiving at least one DCI on the secondary cell to cross-carrier scheduling the primary cell, releasing, by the UE, the cross-carrier scheduling the primary cell by the secondary cell.

In one implementation, the cross-carrier scheduling primary cell comprises PDCCH of a secondary cell (SCell) scheduling a physical shared channel on the primary cell. The primary cell may include at least one of a primary cell in a master cell group (PCell), or a primary cell in a secondary cell group (PSCell). The physical shared channel on the primary cell comprises at least one of a physical downlink shared channel (PDSCH), or a physical uplink shared channel (PUSCH) on the primary cell.

In the previous embodiments, the cross-carrier scheduling the primary cell by the secondary cell (also referred as SCell-schedule-PCell) is dynamically supported. When the cross-carrier scheduling the primary cell by the secondary cell is released, deactivated, indicated to be dormant, or not supported, the BD/CCE budget scale factor (or cell weight factor) in the PCell for scheduling the PCell may be dynamically restored.

Referring to FIG. 9, the present disclosure describes various embodiments of a method 900 including a portion or all of the following steps: step 910: performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and step 920: restoring, by the UE, a factor in the primary cell for scheduling the primary cell. The factor in the primary cell comprises at least one of the following: a blind decoding/control channel element (BD/CCE) scaling factor; or a cell weight factor.

The various embodiments described in the present disclosure improve the wireless communication technology, addressing at least some of the problems/issues with previous systems, leading to benefits. For example, in one embodiment, when the SCell-schedule-PCell is deactivated or released, the BD/CCE budget scale factor (or cell weight factor) in the PCell for scheduling the PCell is dynamically restored. This may ensure that the change of PDCCH capacity may be flexibly adapted when the SCell supports the scheduling of the PCell. Restoreing BD/CCE budget of PCell self-scheduling with dynamic release of SCell-schedule-PCell may keep scheduling flexibility unchanged.

In one implementation of the various embodiments, by adjusting the BD/CCE scaling factors (or cell weight factors) of the two scheduling cells of the PCell to implicitly indicate release SCell-schedule-PCell, the scaling factor of BD/CCE in the PCell for scheduling PCell is restored.

The UE may switch off the cross-carrier scheduling primary cell by the secondary cell in response to the factor is configured to (1, 0) for PCell and SCell respectively, indicating that the BD/CCE scaling factor is restored.

For one example, the BD/CCE scaling factors (or cell weight factors) of the two scheduling cells of the PCell are configured and indicated in the DCI. In one implementation, the BD/CCE scaling factors may be configured/fixed as 2-bit value as shown in FIG. 6. For example, when the 2-bit value is ‘01’, the scaling factor of the BD/CCE of the PCell and SCell is (0.5, 0.5), which indicates that the budget of the BD/CCE of the PCell for scheduling PCell is 1/2 times of the budget of the BD/CCE of the per cell, and the budget of the SCell for scheduling PCell is 1/2 times of the budget of the BD/CCE of the per cell. When the 2-bit value indication is 11, the scaling factor between the PCell and the SCell BD/CCE is (1, 0), which indicates that the BD/CCE of the PCell is 1 times that of the per cell, and the BD/CCE of the SCell is 0 times that of the per cell, so as to implicitly release the SCell-schedule-PCell, which also means to restore the scaling factor of BD/CCE in the PCell for scheduling PCell.

In another implementation of the various embodiments, through the previous embodiments to release the SCell-schedule-PCell, the scaling factor of BD/CCE in the PCell for scheduling PCell may also be restored.

The UE may switch off the cross-carrier scheduling primary cell by the secondary cell , indicating that the BD/CCE scaling factor is restored to (1, 0) for PCell and SCell respectively.

For example, when dynamic SCell-schedule-PCell is not supported indicated by BWP switching, a DCI, or a MAC CE, the scaling factor of BD/CCE budget in the PCell for scheduling PCell may be implicitly restored, so as that the scaling factor of the PCell and SCell is (1, 0). Thus, the BD/CCE budget of the PCell is 1 times that of the per cell, and the BD/CCE budget of the SCell is 0 times that of the per cell, so as to release the SCell-schedule-PCell, which means to restore the scaling factor of BD/CCE budget in the PCell for scheduling PCell.

In the previous embodiments, the cross-carrier scheduling the primary cell by the secondary cell (also referred as SCell-schedule-PCell) is dynamically supported. When the cross-carrier scheduling the primary cell by the secondary cell is released, deactivated, indicated to be dormant, or not supported, the non-fallback DCI in the PCell for scheduling the PCell may be dynamically restored.

In some wireless systems, when working at the mode of SCell-schedule-PCell, only fallback DCI may be used for PCell self-scheduling, and only non-fallback DCI may be used for PCell PDSCH scheduling by SCell. Once the SCell-schedule-PCell is disabled or released dynamically, the PDSCH of the PCell may only be scheduled by fallback DCI in the PCell, thus the system efficiency will be reduced. Thus, it’s beneficial to restore the non-fallback DCI in the PCell for scheduling the PCell.

Referring to FIG. 10, the present disclosure describes various embodiments of a method 1000 including a portion or all of the following steps: step 1010: performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and step 1020: restoring, by the UE, a non-fallback downlink control information (DCI) in the primary cell for scheduling the primary cell.

The various embodiments described in the present disclosure improve the wireless communication technology, addressing at least some of the problems/issues with previous systems, leading to benefits. For example, in one embodiment, when the SCell is deactivated or released, the non-fallback DCI on the PCell for scheduling the PCell is dynamically restored. This may ensure that the change of PDCCH capacity can be flexibly adapted when the SCell supports the scheduling of the PCell. Restoring a non-fallback DCI on a PCell for self-scheduling with dynamic release of SCell-schedule-PCell may keep scheduling flexibility unchanged.

In one implementation of the various embodiments, the primary cell may support a non-fallback DCI by switching to a BWP configured with a non-fallback DCI when SCell-schedule-PCell is disabled or released dynamically.

When the UE switches off the cross-carrier scheduling primary cell by the secondary cell, the UE may switch from a second BWP configured with a fallback DCI to a first BWP configured with the non-fallback DCI, restoring the non-fallback DCI in the primary cell for scheduling the primary cell. In one implementation, the primary cell may be configured with the first BWP having a first search space index, and the first BWP may be configured with the non-fallback DCI. The primary cell may be configured with the second BWP having a second search space index, and the second BWP may be configured with a fallback DCI.

For example, a secondary cell (Cell B) may be configured to support cross-carrier scheduling of a primary cell (Cell A). Cell A is configured with a search space index = {0, 1, 2, 3} in a first BWP (BWP1) with a non-fallback DCI configured in a search space (SS) (e.g., SS #3), and configured with a search space index = {10, 11, 12, 13} in a second BWP (BWP2) without a non-fallback DCI configured in any search space. Cell B is configured with search space index = {0, 1, 2, and 3} in a first BWP (BWP1), and search space index = {10, 11, 12, and 13} in a second BWP (BWP2). In case the active BWP of cell B is BWP2, the active BWP of cell A is BWP2, and supports SCell-schedule-PCell. When SCell-schedule-PCell is disabled or released dynamically (e.g. not to support SCell-schedule-PCell by BWP switching, or release SCell-schedule-PCell by DCI or MAC CE), the primary cell may work on BWP2 with only fallback DCI. At this time, non-fallback DCI can be supported on the primary cell by BWP switching to BWP1 of the primary cell.

In one implementation of the various embodiments, a non-fallback DCI may be implicitly activated by SCell-schedule-PCell is disabled or released, wherein, when SCell-schedule-PCell is enabled or activated, the non-fallback DCI configured in at least one search space in active BWP on the primary cell is disabled or released.

In response to the UE switching off the cross-carrier scheduling primary cell by the secondary cell, the UE enables the non-fallback DCI in a BWP, the non-fallback DCI in the primary cell for scheduling the primary cell may be restored. In one implementation, the primary cell may be configured with the BWP having a first search space index, and the BWP may be configured with non-fallback DCI. The non-fallback DCI may be disabled when the UE switches on the cross-carrier scheduling primary cell by the secondary cell.

For example, a secondary cell (cell B) may be configured to support cross-carrier scheduling of a primary cell (cell A). Cell A is configured with a search space index = {0, 1, 2, 3} in a first BWP (BWP1) with a non-fallback DCI configured in a SS (e.g., SS #3). Cell B is configured with a search space index = {0, 1, 2, and 3} in a first BWP (BWP1), and a search space index = {10, 11, 12, and 13} in a second BWP (BWP2). In case the active BWP of cell B is BWP1, the active BWP of cell A is BWP1, with support of SCell-schedule-PCell and non-fallback DCI disabled. When SCell-schedule-PCell is disabled or released dynamically (e.g. not to support SCell-schedule-PCell by BWP switching , or release SCell-schedule-PCell by DCI or MAC CE), the primary cell works on BWP1 of the primary cell, which means that disabling or releasing SCell-schedule-PCell also implicitly enables non-fallback DCI in BWP1, so as to restore the support of non-fallback DCI on the primary cell.

The present disclosure describes methods, apparatus, and computer-readable medium for wireless communication. The present disclosure addressed the issues with scheduling a primary cell by a secondary cell. The methods, devices, and computer-readable medium described in the present disclosure may facilitate the performance of wireless transmission between a user equipment and a base station, thus improving efficiency and overall performance. The methods, devices, and computer-readable medium described in the present disclosure may improves the overall efficiency of the wireless communication systems.

Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present solution should be or are included in any single implementation thereof. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present solution. Thus, discussions of the features and advantages, and similar language, throughout the specification may, but do not necessarily, refer to the same embodiment.

Furthermore, the described features, advantages and characteristics of the present solution may be combined in any suitable manner in one or more embodiments. One of ordinary skill in the relevant art will recognize, in light of the description herein, that the present solution can be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the present solution.

1. A method for wireless communication, comprising:

switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell, by:

receiving, by the UE, a downlink control information (DCI) via a physical downlink control channel (PDCCH) from a network base station, the DCI used to switch the cross-carrier scheduling primary cell.

2. The method according to claim 1, wherein:

the cross-carrier scheduling primary cell comprises PDCCH of a secondary cell (SCell) scheduling a physical shared channel on the primary cell;

the primary cell comprises at least one of a primary cell in a master cell group (PCell), and a primary cell in a secondary cell group (PSCell); and

the physical shared channel on the primary cell comprises at least one of a physical downlink shared channel (PDSCH), and a physical uplink shared channel (PUSCH) on the primary cell.

3. The method according to claim 1, wherein:

the DCI comprises a bandwidth part indicator;

the method further comprises:

in response to the bandwidth part indicator indicating a first BWP being active, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the bandwidth part indicator indicating a second BWP being active, switching off the cross-carrier scheduling the primary cell by the secondary cell; and

the secondary cell is configured with a first BWP to support the cross-carrier scheduling primary cell and the secondary cell is configured with a second BWP not to support the cross-carrier scheduling primary cell.

4. The method according to claim 1, wherein:

the DCI comprises a bandwidth part indicator including a cross-carrier scheduling primary cell indicator; and

the method further comprises:

in response to the bandwidth part indicator indicating a BWP being active and the cross-carrier scheduling primary cell indicator indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the bandwidth part indicator indicating a BWP being active and the cross-carrier scheduling primary cell indicator indicating a release of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

5. The method according to claim 1, wherein:

the DCI comprises a SCell dormancy indicator;

the method further comprises:

in response to the SCell dormancy indicator indicating to use a first non-dormant BWP being active, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the SCell dormancy indicator indicating to use a second non-dormant BWP being active, switching off the cross-carrier scheduling the primary cell by the secondary cell; and the secondary cell is configured with the first non-dormant BWP to support the cross-carrier scheduling primary cell and the secondary cell is configured with the second non-dormant BWP not to support the cross-carrier scheduling primary cell.

6. The method according to claim 1, wherein:

the DCI comprises a SCell dormancy indicator including a cross-carrier scheduling primary cell indicator; and

the method further comprises:

in response to the SCell dormancy indicator indicating to use a non-dormant BWP and the cross-carrier scheduling primary cell indicator indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the SCell dormancy indicator indicating to use a non-dormant BWP and the cross-carrier scheduling primary cell indicator indicating a release of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

7. The method according to claim 1, wherein:

the DCI comprises a non-fallback DCI comprising a field indicating the cross-carrier scheduling primary cell; and

the method further comprises:

in response to the field in the non-fallback DCI indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the field in the non-fallback DCI indicating a release of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

8. The method according to claim 1, wherein:

the DCI comprises a fallback DCI comprising an indicator indicating the cross-carrier scheduling primary cell; and

the method further comprises:

in response to the indicator in the fallback DCI indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the indicator in the fallback DCI indicating a release of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

9. The method according to any of claims 3-8, wherein:

an effective time point for switching on or off the cross-carrier scheduling primary cell by the secondary cell comprises at least one of the following:

a first time based on a time of receiving the DCI and an offset value; and

a second time based on a time of the physical shared channel scheduled by the DCI and the offset value.

10. The method according to claim 9, wherein:

the offset value is an integer being equal to or greater than zero; and

the offset value indicates an offset period determined by multiplying the integer with at least one of the following: an absolute time interval, an orthogonal frequency-division multiplexing (OFDM) symbol, or a slot.

11. The method according to claim 8, wherein:

the indicator in the fallback DCI comprises at least one of the following:

a cyclic redundancy check (CRC) scrambled by a specific radio network temporary identifier (RNTI);

at least one reserved bit in the fallback DCI; and

a short message in the fallback DCI.

12. The method according to claim 1, wherein:

the DCI comprises a factor indicating the cross-carrier scheduling primary cell; and

the method further comprises:

in response to the factor in the DCI indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the factor in the DCI indicating a release of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

13. The method according to claim 12, wherein:

the factor in the DCI comprises :

a blind decoding/control channel element (BD/CCE) scaling factor, or

a cell weight factor; and

when the factor in the DCI equals to (1, 0) for PCell and SCell respectively, the factor indicates the release of the cross-carrier scheduling primary cell.

14. A method for wireless communication, comprising:

switching cross-carrier scheduling primary cell for a user equipment (UE), wherein a secondary cell is configured to schedule the primary cell, by:

receiving, by the UE, a medium access control (MAC) control element (CE) from a network base station, the MAC CE used to switch the cross-carrier scheduling primary cell.

15. The method according to claim 14, wherein:

the cross-carrier scheduling primary cell comprises PDCCH of a secondary cell (SCell) scheduling a physical shared channel on the primary cell;

the primary cell comprises at least one of a primary cell in a master cell group (PCell), or a primary secondary cell (PSCell); and

the physical shared channel on the primary cell comprises at least one of a physical downlink shared channel (PDSCH), or a physical uplink shared channel (PUSCH) on the primary cell.

16. The method according to claim 14, wherein:

the MAC CE comprises a specific MAC CE comprising a MAC subheader with a specific logic channel identification (LCID) indicating the cross-carrier scheduling primary cell; and

the method further comprises:

in response to a field in the MAC CE indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and in response to the field in the MAC CE indicating a release of the activation of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell by the secondary cell.

17. The method according to claim 14, wherein:

the MAC CE comprises a joint MAC CE comprising a reserved bit indicating the cross-carrier scheduling primary cell; and

the method further comprises:

in response to the reserved bit indicating an activation of the cross-carrier scheduling primary cell, switching on the cross-carrier scheduling the primary cell by the secondary cell, and

in response to the reserved bit indicating a release of the activation of the cross-carrier scheduling primary cell, switching off the cross-carrier scheduling the primary cell of the secondary cell.

18. The method according to claim 17, wherein:

the joint MAC CE comprises a SCell activation/deactivation MAC CE.

19. A method for wireless communication, comprising:

switching cross-carrier scheduling primary cell for a user equipment (UE) by a timer, wherein a secondary cell is configured or activated to schedule the primary cell, comprising:

in response to, within a time period of the timer, receiving a DCI on the secondary cell to cross-carrier scheduling the primary cell, resetting, by the UE, the timer; and

in response to passing the time period of the timer without receiving at least one

DCI on the secondary cell to cross-carrier scheduling the primary cell, releasing, by the UE, the cross-carrier scheduling the primary cell by the secondary cell.

20. A method for wireless communication, comprising:

performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and

restoring, by the UE, a factor in the primary cell for scheduling the primary cell.

21. The method according to claim 20, wherein:

the factor in the primary cell comprises at least one of the following:

a blind decoding/control channel element (BD/CCE) scaling factor; or

a cell weight factor.

22. The method according to claim 20, wherein:

the UE switches off the cross-carrier scheduling primary cell by the secondary cell in response to the factor is configured to (1, 0) for PCell and SCell respectively, indicating that the BD/CCE scaling factor is restored.

23. The method according to claim 20, wherein:

the UE switches off the cross-carrier scheduling primary cell by the secondary cell , indicating that the BD/CCE scaling factor is restored to (1, 0) for PCell and SCell respectively.

24. A method for wireless communication, comprising:

performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE); and

restoring, by the UE, a non-fallback downlink control information (DCI) in the primary cell for scheduling the primary cell.

25. The method according to claim 24, wherein:

in response to the UE switching off the cross-carrier scheduling primary cell by the secondary cell, the UE switches from a second BWP configured with a fallback DCI to a first BWP configured with the non-fallback DCI, restoring the non-fallback DCI in the primary cell for scheduling the primary cell; and

wherein:

the primary cell is configured with the first BWP having a first search space index, the first BWP configured with the non-fallback DCI, and

the primary cell is configured with the second BWP having a second search space index, the second BWP configured with a fallback DCI.

26. The method according to claim 24, wherein:

in response to the UE switching off the cross-carrier scheduling primary cell by the secondary cell, the UE enables the non-fallback DCI in a BWP, restoring the non-fallback DCI in the primary cell for scheduling the primary cell; and

wherein:

the primary cell is configured with the BWP having a first search space index, the BWP configured with non-fallback DCI, and the non-fallback DCI is disabled when the UE switches on the cross-carrier scheduling primary cell by the secondary cell.

27. A wireless communications apparatus comprising a processor and a memory, wherein the processor is configured to read code from the memory and implement a method recited in any of claims 1 to 26.

28. A computer program product comprising a computer-readable program medium code stored thereupon, the code, when executed by a processor, causing the processor to implement a method recited in any of claims 1 to 26.

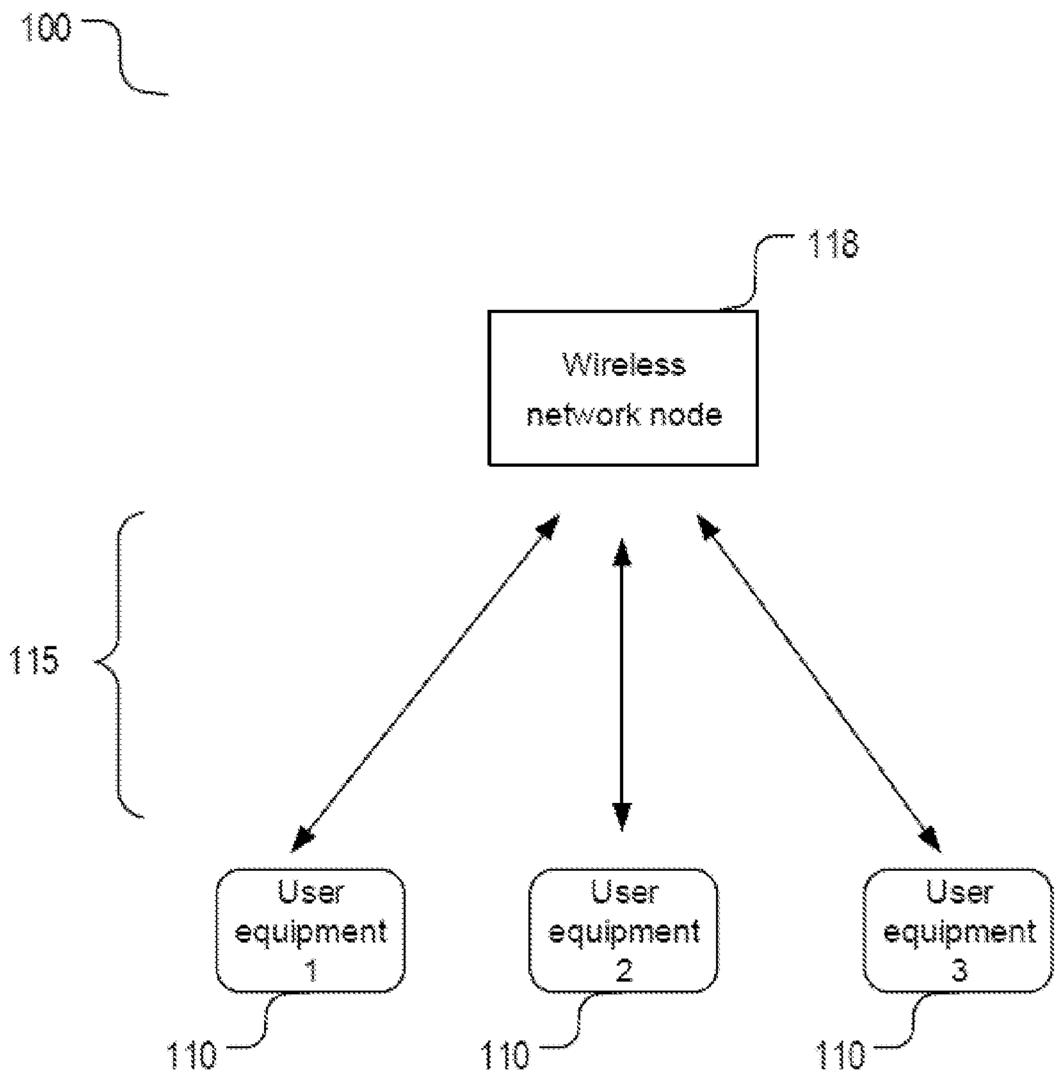
100
118
Wireless
network node
115
User
equipment
1
User
equipment
2
User
equipment
3
110
110
110

FIG. 1

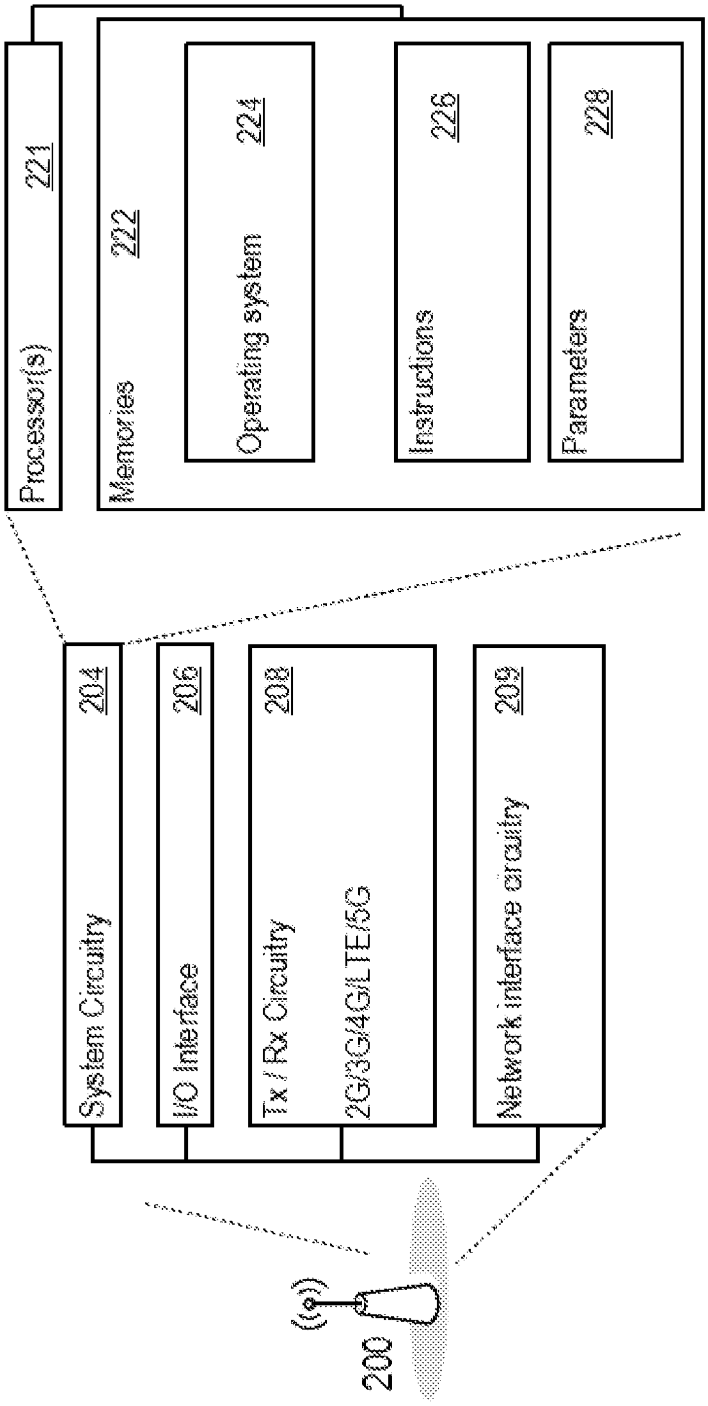
Processor(s) 221
Memories 222
Operating system 224
Instructions 226
Parameters 228
System Circuitry 204
I/O Interface 206
Tx / Rx Circuitry 208
2G/3G/4G/LTE/5G
Network interface circuitry 209
200

FIG. 2

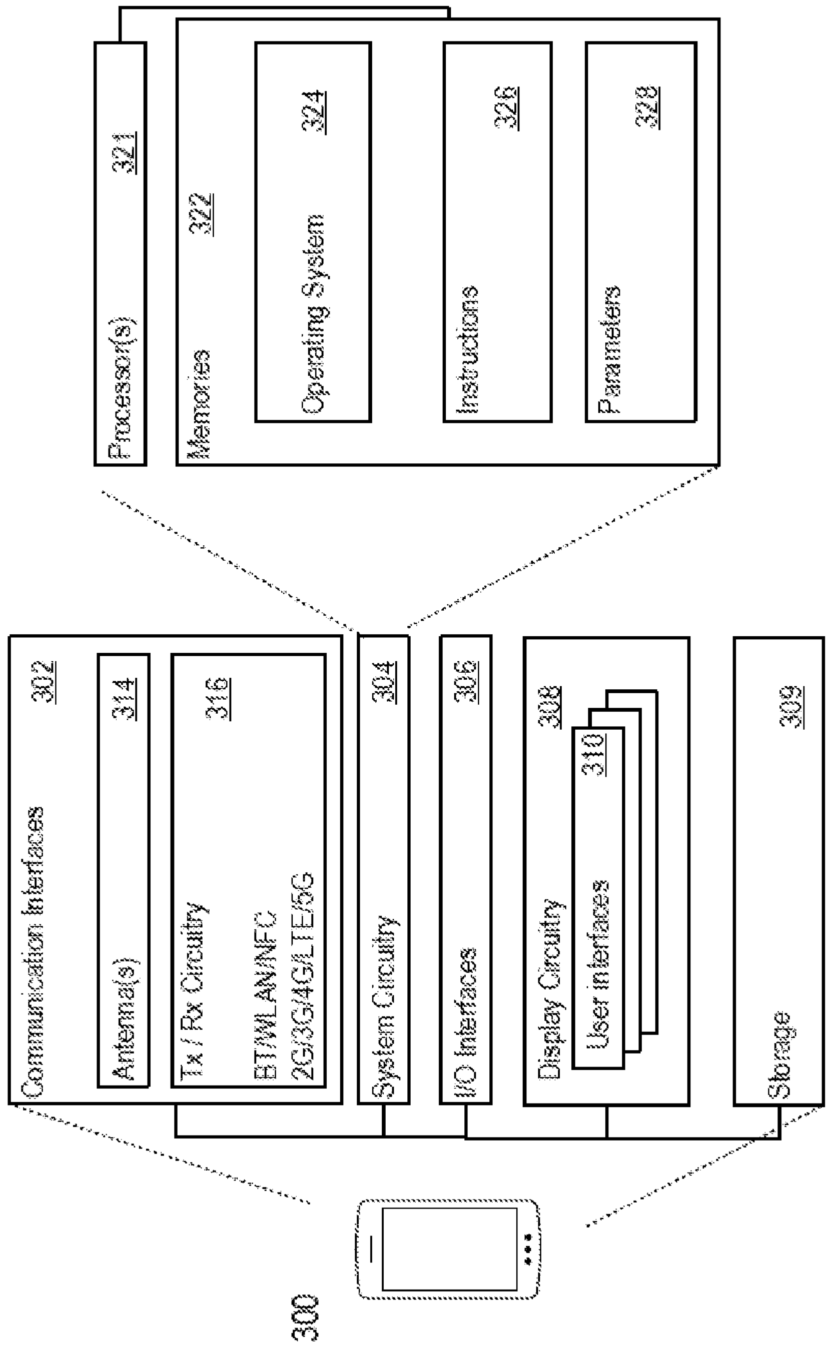
300
Communication Interfaces 302
Antenna(s) 314
Tx / Rx Circuitry 316
BT/WLAN/NFC
2G/3G/4G/LTE/5G
System Circuitry 304
I/O Interfaces 306
Display Circuitry 308
User interfaces 310
Storage 309
Processor(s) 321
Memories 322
Operating System 324
Instructions 326
Parameters 328

FIG. 3

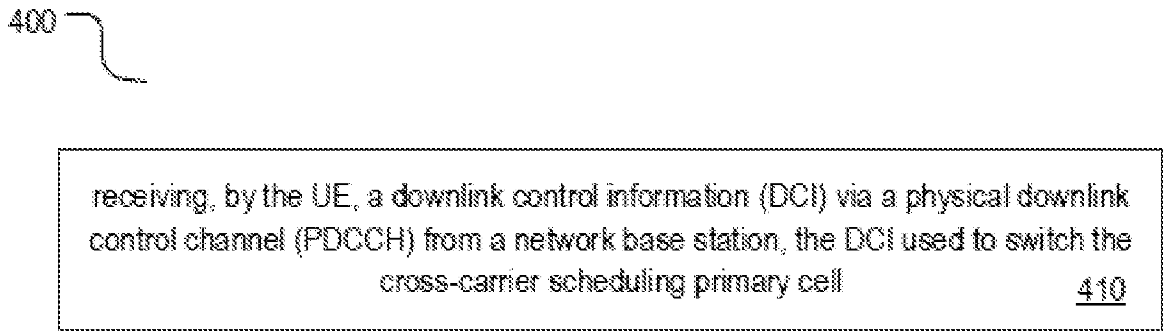
400
receiving, by the UE, a downlink control information (DCI) via a physical downlink control channel (PDCCH) from a network base station, the DCI used to switch the cross-carrier scheduling primary cell
410

FIG. 4

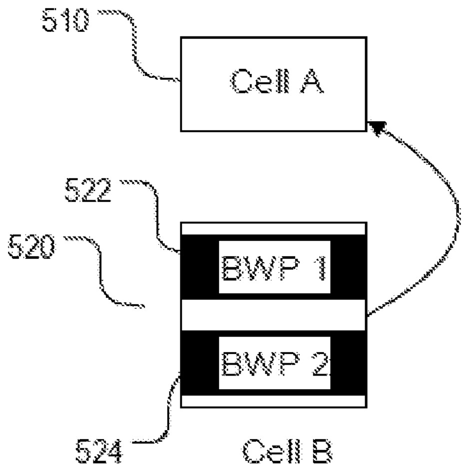
510
Cell A
522
520
BWP 1
BWP 2
524
Cell B

FIG. 5

2bits value	BD/CCE scaling factor Between PCell and the SCell
00	(0.33,0.66)
01	(0.5,0.5)
10	(0.66,0.33)
11	(1,0)

FIG. 6

receiving, by the UE, a medium access control (MAC) control element (CE) from a network base station, the MAC CE used to switch the cross-carrier scheduling primary cell 710

FIG. 7

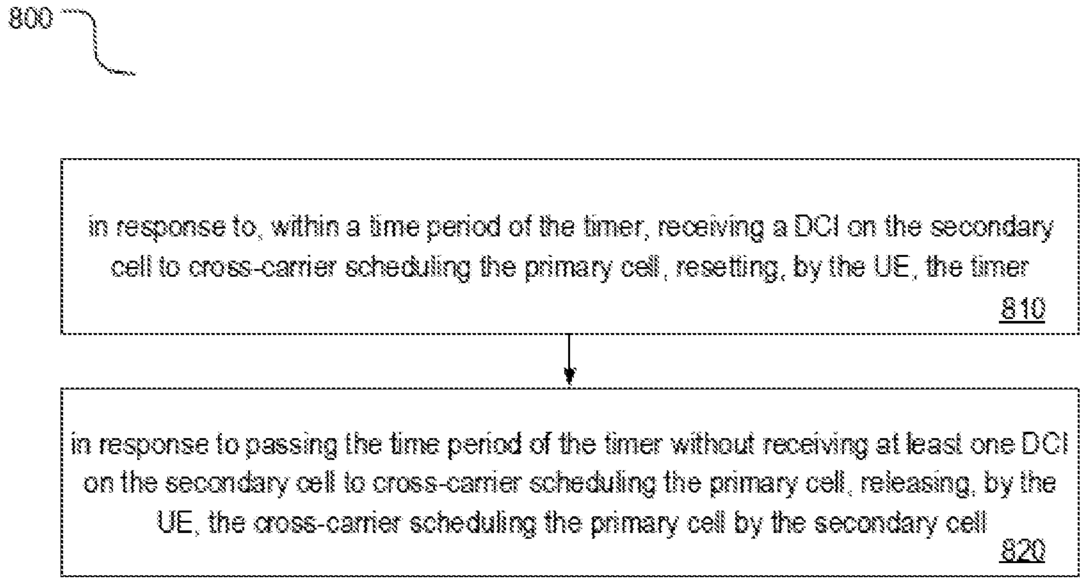
800
in response to, within a time period of the timer, receiving a DCI on the secondary cell to cross-carrier scheduling the primary cell, resetting, by the UE, the timer
810
in response to passing the time period of the timer without receiving at least one DCI on the secondary cell to cross-carrier scheduling the primary cell, releasing, by the UE, the cross-carrier scheduling the primary cell by the secondary cell
820

FIG. 8

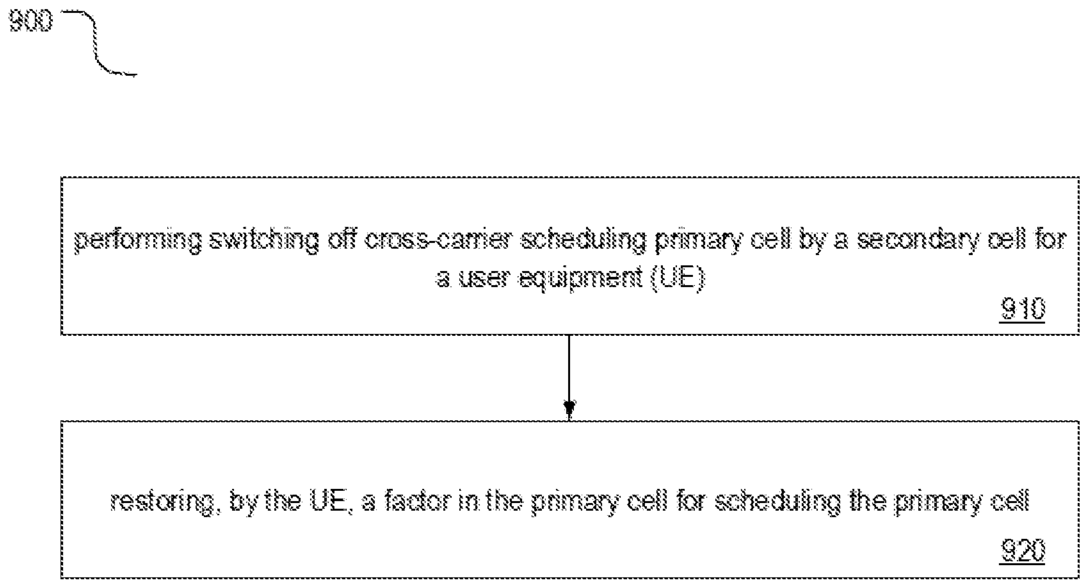
900
performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE)
910
restoring, by the UE, a factor in the primary cell for scheduling the primary cell
920

FIG. 9

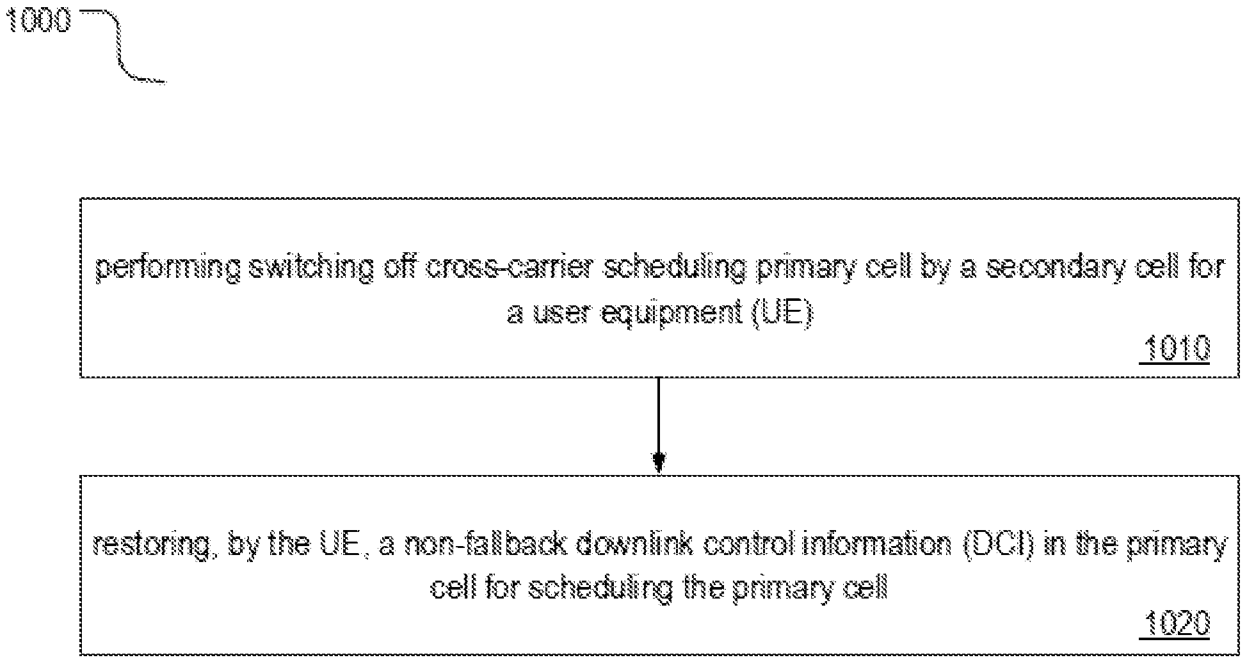
1000
performing switching off cross-carrier scheduling primary cell by a secondary cell for a user equipment (UE)
1010
restoring, by the UE, a non-fallback downlink control information (DCI) in the primary cell for scheduling the primary cell
1020

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/121142

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(2009.01)i

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; H04Q; H04L

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)

CNPAT, CNKI, EPODOC, WPI, 3GPP: cross-carrier, scheduling, primary, PCELL, secondary, SCELL, DCI, PDCCH, switch on, switch off, restore

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 111132359 A (BEIJING SPREADTRUM HI-TECH COMMUNICATIONS TECHNOLOGY CO.， LTD.) 08 May 2020 (2020-05-08) description， paragraphs 72， 78-110， 148， 149	1-19， 27， 28
A	MODERATORERICSSON. "Summary of NR Dynamic spectrum sharing (DSS) in Email discussion [102-e-NR-DSS-DC_enh2-01]" *3GPP TSG-RAN WG1 #102-e eMeeting R1-2007442,* 28 August 2020 (2020-08-28), section 2.1.2	20-26， 27， 28
A	US 2019281585 A1 (COMCAST CABLE COMMUNICATIONS， LLC) 12 September 2019 (2019-09-12) the whole document	1-28

☐ Further documents are listed in the continuation of Box C.　　☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "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	Date of mailing of the international search report
18 June 2021	**15 July 2021**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**TIAN,Tao**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961637**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/121142

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN	111132359	A	08 May 2020	None	
US	2019281585	A1	12 September 2019	None	