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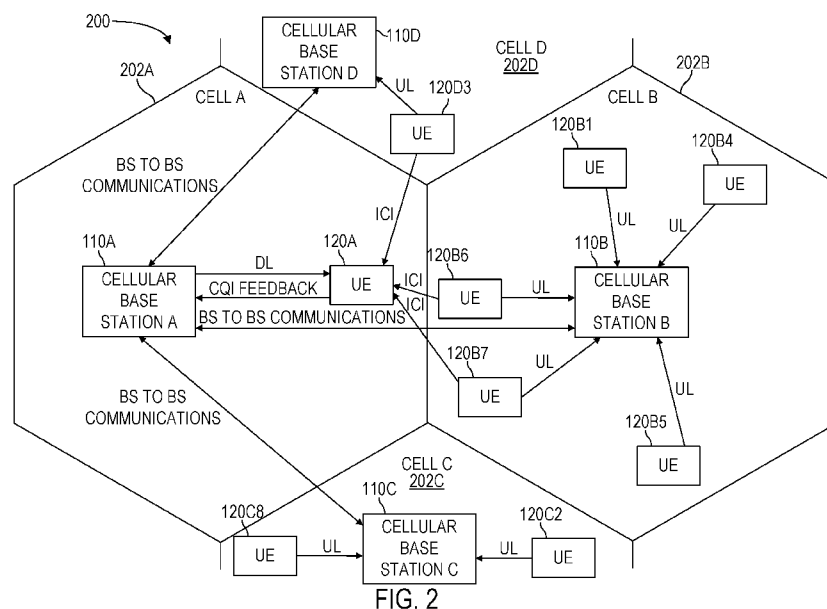


FIG. 2

(57) Abstract: Disclosed are apparatuses for a cellular base station, computer-readable storage media, and cellular base stations. An apparatus for a cellular base station is configured to support full-duplex communication, process downlink User Equipment (UE) channel quality feedback (CQI feedback) data received from a UE, identify uplink interference to the downlink channels based on the CQI feedback data, assemble an uplink interference candidate aggressor list, and determine which UEs are uplink interference aggressors based at least on the CQI feedback data and the uplink interference candidate aggressor list. A computer-readable storage medium includes computer-readable instructions configured to instruct a processor to identify downlink resource units that experienced at least a threshold level of uplink inter-cell interference, and determine that at least one other UE is an inter-cell interference aggressor by correlating the identified resource units with corresponding resource units of uplink communications received by at least one other



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**METHOD TO IDENTIFY AGGRESSOR OF UE-TO-UE INTERFERENCE IN FULL  
DUPLEX SYSTEM USING BS-TO-BS  
COMMUNICATIONS**

Technical Field

**[0001]** This disclosure relates generally to the field of wireless communications, and more specifically to user equipment and base stations configured to identify User Equipment (UEs) that interfere with downlink communications between a cellular base station and a UE.

Background

**[0002]** In recent years, demand for access to fast mobile wireless data for mobile electronic devices has fueled the development of the 3rd Generation Partnership Project (3GPP) long term evolution (LTE) communication system (hereinafter "LTE system"). End users access the LTE system using mobile electronic devices (known as "user equipment," or equivalently "UE") including appropriate electronics and software modules to communicate according to standards set forth by 3GPP. Discussions and research are currently directed toward a next generation communication protocol (e.g., 5G).

Brief Description of the Drawings

**[0003]** FIG. 1 is a simplified illustration of a system showing a severe UE-to-UE interference scenario.

**[0004]** FIG. 2 is a simplified block diagram of a full-duplex cellular system according to some embodiments.

**[0005]** FIG. 3 is a simplified signal flow diagram illustrating signals exchanged within the full-duplex cellular system of FIG. 2.

**[0006]** FIG. 4 is a table of indexed data.

**[0007]** FIG. 5A is a table illustrating indexed logic levels indicating resource units that are determined to be affected by inter-cell interference.

**[0008]** FIG. 5B is a table illustrating indexed Identifiers of candidate aggressor UEs.

**[0009]** FIG. 6 is a block diagram illustrating components, according to some example embodiments.

**[0010]** FIG. 7 illustrates, for some embodiments, example components of an electronic device.

### Detailed Description of Preferred Embodiments

**[0011]** In the following detailed description, reference is made to the accompanying drawings, which form a part hereof, and in which are shown by way of illustration specific embodiments in which the present disclosure may be practiced. These embodiments are described in sufficient detail to enable those of ordinary skill in the art to practice the disclosure made herein. It should be understood, however, that the detailed description and the specific examples, while indicating examples of embodiments of the disclosure, are given by way of illustration only, and not by way of limitation. From the disclosure, various substitutions, modifications, additions, rearrangements, or combinations thereof within the scope of the disclosure may be made and will become apparent to those of ordinary skill in the art.

**[0012]** In accordance with common practice, the various features illustrated in the drawings may not be drawn to scale. The illustrations presented herein are not meant to be actual views of any particular apparatus (e.g., device, system, etc.) or method, but are merely idealized representations that are employed to describe various embodiments of the disclosure. Accordingly, the dimensions of the various features may be arbitrarily expanded or reduced for clarity. In addition, some of the drawings may be simplified for clarity. Thus, the drawings may not depict all of the components of a given apparatus or all operations of a particular method.

**[0013]** Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof. Some drawings may illustrate signals as a single signal for clarity of presentation and description. It should be understood by a person of ordinary skill in the art that the signal may represent a bus of signals, wherein the bus may have a variety of bit widths, and the present disclosure may be implemented on any number of data signals including a single data signal.

**[0014]** The various illustrative logical blocks, modules, circuits, and algorithm acts described in connection with embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and acts are described generally in terms of

their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the embodiments of the disclosure described herein.

**[0015]** In addition, it is noted that the embodiments may be described in terms of a process that is depicted as a flowchart, a flow diagram, a structure diagram, a signaling diagram, or a block diagram. Although a flowchart or signaling diagram may describe operational acts as a sequential process, many of these acts can be performed in another sequence, in parallel, or substantially concurrently. In addition, the order of the acts may be rearranged. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. Furthermore, the methods disclosed herein may be implemented in hardware, software, or both. If implemented in software, the functions may be stored or transmitted as one or more computer-readable instructions (e.g., software code) on a computer-readable medium. Computer-readable media includes both computer storage media (i.e., non-transitory media) and communication media including any medium that facilitates transfer of a computer program from one place to another.

**[0016]** Full duplex (FD) techniques, which support simultaneous transmit and receive communications in the same frequency at the same time, can potentially double a spectrum efficiency. Compared to half-duplex (HD), an FD system is associated with significant interference between its transmission and receiver chain. Recent techniques from industry and academics demonstrate more than 120 decibels (dB) of interference cancellation for FD systems, thus enabling potential applications of full-duplex operation in real wireless cellular systems. Unlike point-to-point FD systems, FD cellular networks have more complicated interference environments, including base station to base station (BS-to-BS) interference in an uplink (UL), and UE-to-UE interference in a downlink (DL).

**[0017]** For cellular systems, such as Long Term Evolution (LTE), UEs transmitting signals in the UL create conventional co-channel interference to other UL signals in other cells. For full-duplex cellular systems, signals transmitted in the UL may also create interference to signals in the DL, especially signals transmitted in the DL

nearby (i.e., UE-to-UE interference). Such interference may corrupt the victim signal transmitted in the DL.

**[0018]** FIG. 1 is a simplified illustration of a system 100 showing a severe UE-to-UE interference scenario. Such a scenario occurs when UEs 120-1, 120-2, and 120-3 are close to each other, and located near an edge of cells (UE 120-1 is located near an edge of a cell serviced by base station 110-1, and UEs 120-2 and 120-3 are located near an edge of a cell serviced by base station 110-2) where the interference problem between UEs is exacerbated. In this scenario, the signals received in the downlink DL by UEs 120-1 and 120-3 (the victim UEs) are typically quite weak (e.g., because the victim UEs 120-1 and 120-3 are at the edge of the cell serviced by their base stations 110-1 and 110-2, respectively) while the interfering uplink UE 120-2 transmits, typically at the level close to a maximum output power (e.g., because UE 120-2 is at the edge of the cell serviced by its base station 110-2). Accordingly, the interference received by UE 120-1 is inter-cell interference, and the interference received by UE 120-3 is intra-cell interference.

**[0019]** From a perspective of user-perceived service quality, cell edge UEs in high-density indoor environments (e.g., cafeterias, airports, etc.) are particularly vulnerable to severe performance degradation caused by UE-to-UE interference. This is because stationary UEs in such environments are likely to transmit/receive persistently for long periods of time, resulting in prolonged service disruption due to strong interference. Such service disruption caused by UE-to-UE interference should be properly handled to truly utilize the benefits of full-duplex capability.

**[0020]** Recently, researchers have proposed approaches to handle the UE-to-UE interference, including both non-coordinative schemes and coordinative joint schedulers to intelligently schedule UEs with little UE-to-UE interference for simultaneous transmission and reception. For example, a distributive joint UL-DL scheduler can find an acceptable intra-cell uplink and downlink pair to schedule in order to address the intra-cell UE-to-UE interference. This solution is well-suited for small cell access systems since UE transmission power is low and intra-cell UE-UE interference dominates compared to inter-cell UE-to-UE interference. When inter-cell interference, however, is high, such as when there is a macrostation (HETNET) with nearby UEs transmitting with high power, or when the victim UE is at cell edge and vulnerable to the uplink UEs from neighbor cells, a scheduler just for intra-cell

UE-to-UE interference may not be sufficient. Some level of inter-cell coordination would be used.

**[0021]** Identifying inter-cell aggressors is challenging because information sharing and signaling exchanges are made between base stations. In addition, for systems like LTE systems, with a frequency reuse factor of 1, even if uplink intra-cell UEs are orthogonal, there can be multiple inter-cell uplink UEs using the same resource. So even the scheduler record is shared among base stations, and the aggressor(s) could come from one or more uplink UEs sharing the same resource. Mechanisms are known that identify a downlink UE as a victim of UE-to-UE interference. Also, mechanisms are known that identify the uplink aggressor UEs from uplink UE aggressor candidates. These mechanisms for identifying the uplink aggressor UE are based on known resource block (PRB) information and power head room (PHR) information. The aggressor can come from intra-cell or inter-cell. If the aggressor is possibly from some of the neighboring cells, the PRB and/or PHR information is shared across base stations, and the base station of the serving cell identifies which base station serves the aggressor (e.g., based on the serving base station's knowledge on the correlation of the interference pattern and the PRB pattern of its neighbor cells). The serving base station notifies the base station that is identified as serving the aggressor about the interference patterns. The base station serving the aggressor can then identify the aggressor UE(s) within the cell corresponding to the base station serving the aggressor.

**[0022]** Disclosed herein are systems, apparatuses, and methods for identifying the aggressor of UE-to-UE interference, given that multiple uplink UEs from different cells may overlap in the same resource. Instead of notifying possible neighbor base stations containing the aggressor of the interference pattern, the serving base station itself intelligently identifies the aggressor UEs directly, and if the aggressor is served by neighbor base stations, the serving base station only shares the aggressor UE identifier with its neighbors, which eases the signaling requirement and reduces burdens on the neighbor base stations to identify the aggressor, compared to prior known solutions.

**[0023]** When the base station knows the interference pattern from the downlink UE channel quality feedback (CQI), and scheduled resource block information of itself and of the possible aggressor base stations during the observation window, it can map digitally indexed data (which may be discussed herein as table) to indicate

possible uplink UE IDs in each downlink victim's resource block (PRB) location in the observation window. A specific UE-to-UE interference on one resource element could come from aggregation of multiple UL UEs, or just one specific UE among all, which makes it challenging to identify which uplink UE is the contributor to the interference. Proposed herein are methods for identifying specific aggressor(s) from the aggregated interference pattern, since a given candidate aggressor UL UE has relatively similar interference impacts on DL UE (in terms of reference signal interference power) during the observation period. Accordingly, a contribution of the interferences may be determined by looking at its occurrence in the whole observation window, instead of each interfered resource element only. In other words, information of the occurrence of the candidate aggressor UL UEs at the non-interfered resource element is relied upon to help make decisions (e.g., determinations of whether a given candidate aggressor UL UE is a contributor to the interference) on the interfered resource elements.

**[0024]** Without properly addressing UE-to-UE interference, full-duplex spectrum efficiency gain in cellular systems can be diminished. UE-to-UE interference can be intra-cell interference or inter-cell interference. Previous solutions to address inter-cell UE-to-UE interference either use complicated central schedulers where global information, such as channel state information, is known, or simplified distributive methods, such as geometry location based approaches, satisfying some uplink-downlink-UE-pair scheduler opportunities.

**[0025]** Embodiments disclosed herein are configured to mitigate the inter-cell UE-to-UE interference problem by identifying the inter-cell aggressors from the serving base station. The schedule loosely coordinates between base stations and employs low signaling exchange between base stations. The signaling exchange can be done via an X2 interface or a C-RAN structure.

**[0026]** In some embodiments, disclosed herein is an apparatus for a cellular base station including one or more processors, and one or more computer-readable storage media operably coupled to the one or more processors and including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct the one or more processors to perform operations. The operations include supporting full-duplex communication of User Equipment (UEs) within a cell corresponding to the base station, processing downlink UE channel quality feedback (CQI feedback) data received from a UE, the CQI feedback data

indicating channel quality of downlink channels between the cellular base station and the UE, identifying uplink interference to the downlink channels based, at least in part, on the CQI feedback data, assembling an uplink interference candidate aggressor list including uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data indicating channel usage of at least a portion of UEs within the adjacent cells, and determining which of the UEs within the adjacent cells are uplink interference aggressors based at least on the CQI feedback data and the uplink interference candidate aggressor list.

**[0027]** In some embodiments, disclosed herein is a computer-readable storage medium including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct one or more processors of a cellular base station to identify resource units, used in a downlink between the cellular base station and a User Equipment (UE) in a full-duplex communication system, that experienced at least a threshold level of inter-cell interference from at least one other UE transmitting in an uplink to at least one other cellular base station, and determine that the at least one other UE is an inter-cell interference aggressor by correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station.

**[0028]** In some embodiments, disclosed herein is a cellular base station including one or more communication elements, and control circuitry operably coupled to the one or more communication elements. The control circuitry is configured to participate in full-duplex communications with User Equipment (UEs) within a cell corresponding to the cellular base station, transmit, with the one or more communication elements, data to the UEs in a downlink, and receive, with the one or more communication elements, CQI feedback from each of the UEs, the CQI feedback indicating a channel quality of the downlink. The control circuitry is also configured to receive, with the one or more communication elements, uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data identifying other UEs in the one or more adjacent cells and uplink resource units used by the other UEs. The control circuitry is further configured to identify downlink resource units that were affected by at least a threshold level of inter-cell interference that were used to transmit the data to the UEs in the downlink, and correlate the identified downlink resource units with the identified uplink resource

units to determine which of the other UEs interfered with the downlink communications.

**[0029]** FIG. 2 is a simplified block diagram of a full-duplex cellular system 200 according to some embodiments.

**[0030]** FIG. 3 is a simplified signal flow diagram 300 illustrating signals exchanged within the full-duplex cellular system 200 of FIG. 2.

**[0031]** Referring to FIGS. 2 and 3 together, the cellular system 200 includes several cells (cell A 202A, cell B 202B, cell C 202C, and cell D 202D, sometimes referred to together herein as “cells” 202). Each cell 202 includes a cellular base station (cellular base station A 110A, cellular base station B 110B, cellular base station C 110C, and cellular base station D 110D, corresponding to cells 202A, 202B, 202C, and 202D, respectively). The cellular base stations 110A, 110B, 110C, and 110D are sometimes referred to herein simply as “base station” 110 individually, and “base stations” 110 together.

**[0032]** Each base station 110 is configured to support full-duplex communication of UEs 120 within the cell 202 corresponding thereto. For example, FIG. 2 shows base station 110A serving UE 120A, base station 110B serving UEs 120B1, 120B4, 120B5, 120B6, and 120B7, base station 110D serving UE 120D3, and base station 110C serving UEs 120C2 and 120C8. The UEs 120 are sometimes referred to herein simply together as “UEs” 120 and separately as “UE” 120.

**[0033]** As shown in FIG. 2, UE 120A is located near the edge of cell 202A. Accordingly, downlink communications DL 310 transmitted from the base station 110A to the UE 120A in the downlink DL may be of relatively low receiver power. At the same time, UEs 120 that are located near the UE 120A in adjacent cells 202 may transmit data to their serving base stations 110 in the uplink UL with relatively high power because they are located relatively far from their serving base stations 110. When communication resources used in the downlink between the base station 110A and the UE 120A overlap communication resources used in the uplink UL by the UEs 120D3, 120B6, and 120B7 and their serving base stations 110, a relatively large amount of inter-cell interference may result. As shown in FIG. 2, inter-cell interference ICI from UEs 120D3, 120B6, and 120B7 is received by UE 120A.

**[0034]** Each of the UEs 120 in each of the cells 202 is configured to transmit channel quality feedback (CQI) including data indicating channel quality of downlink communications DL between the UE 120 and the cellular base station 110 serving

the UE 120. For example, the UE 120A is configured to transmit CQI feedback 320 including data indicating channel quality of the downlink communications DL 320 between the cellular base station 110A and the UE 120A. Each of the base stations 110 is configured to receive and process the CQI feedback, and identify uplink UL interference to the downlink channels based, at least in part, on the CQI feedback.

**[0035]** Using the CQI feedback, each of the base stations 110 is configured to identify, for each UE 120 served thereby, DL communication resource units (e.g., resource blocks (RBs), PRBs, PRB subgroups, etc.) used by the UE 120 over a number of time subframes (e.g., transmission time intervals (TTIs)). In some embodiments, the base stations 110 are configured to determine, for each identified resource unit at each identified time subframe, whether at least a threshold level (e.g., measured in signal to interference ratio (SIR)) of inter-cell interference was present. By way of non-limiting example, different logic levels (e.g., a logic level “1” and a logic level “0”) may be stored and indexed by resource units and time units such that a logic level indicating whether the threshold level of inter-cell interference was detected is assigned to each identified resource unit for each identified time unit. FIG. 4 illustrates one way this information may be indexed.

**[0036]** FIG. 4 is a table 400 of indexed data. The table includes indexed resource units 402 indexed by resource unit and time unit (with indices shown as “resource unit, time unit”). The table 400 is of size  $N_R$  resource units by  $N_T$  time units. Referring to FIGS. 2-4 together, the different logic levels indicating whether or not each of the indexed resource units 402 was affected by inter-cell interference may be assigned to each of the indexed resource units 402. The logic levels may be merely binary in some instances. In some instances, more than two logic levels may be used to indicate various levels of inter-cell interference. A simple binary example involving the base station 110A and the UE 120A is discussed below with reference to FIG. 5A.

**[0037]** Referring once again to FIGS. 2 and 3, each of the base stations 110 is also configured to communicate with the base stations 110 in adjacent cells 202 via BS-to-BS communications (e.g., using an X2 interface, a cloud radio access network (C-RAN) structure, other communication protocol, or combinations thereof). In some embodiments, the BS-to-BS communications may be administered by a central scheduler configured to communicate with each of the base stations 110. In some embodiments, the BS-to-BS communications may be administrated through a

distributed scheduler (e.g., by the base stations 110 working together as a distributed scheduler).

**[0038]** Using the BS-to-BS communications, the base stations 110 are configured to receive UL channel data 340 indicating UL channel usage of the UEs 120 serviced by the other base stations 110. By way of non-limiting example, the UL channel data 340 may include data identifying at least a portion of UEs 120 that communicated in the UL, specific communication resource units used by the identified UEs 120, and time subframes that the identified UEs 120 used for each identified communication resource. In some embodiments, the base stations 110 are configured to provide the UL channel data 340 to the other base stations 110 on a request basis (e.g., responsive to a request for information 330). In such embodiments, the requesting base station 110 may request only UL channel data 340 that overlaps the identified resource units and the identified time subframes that the requesting base station 110 is monitoring for the UEs 120 serviced thereby. Accordingly, relatively little data may be transmitted in the UL channel data 340. In some embodiments, UL channel data 340 may be periodically transmitted via the BS-to-BS communications. In such embodiments, relatively larger amounts of data may be transmitted between the base stations 110 because the data is transmitted whether or not it overlaps the identified resource units and the identified time subframes that the requesting base station 110 is monitoring.

**[0039]** Each of the base stations 110 may be configured to assemble an uplink interference candidate aggressor list including uplink channel data received from the other cellular base stations 110. For example, identifiers (IDs) identifying UEs in adjacent cells may be indexed by resource units and time units, similarly to the logic levels indicating whether identified resource elements were affected by inter-cell interference, as discussed above with reference to FIG. 4. The base stations 110 are configured to compare indices of the IDs to the indices of the logic levels to determine whether the UEs 120 corresponding to the IDs are inter-cell interference aggressors. The cellular base stations 110 are configured to transmit identified aggressor IDs 350 to the other cellular base stations 110.

**[0040]** FIGS. 5A and 5B illustrate an example of indexed data that may be used by the cellular base station 110A of FIG. 2 to determine inter-cell interference aggressors affecting UE 120A. The tables illustrated in FIGS. 5A and 5B are for illustration only, and do not necessarily indicate that one unit = (1PRB/TTI) as the

actual unit depends on the resource unit of the CQI feedback methods (CQI feedback could be sent every multiple TTIs and quantized to one value and represent quality over multiple PRBs).

**[0041]** FIG. 5A is a table 400A illustrating indexed logic levels indicating resource units that are determined to be affected by inter-cell interference. In the example of FIG. 5A, logic level “1” indicates that at least a threshold level of inter-cell interference was detected. Logic level “0” indicates that less than the threshold level of inter-cell interference was detected. As shown in FIG. 5A, five of the resource elements used by UE 120A in the downlink were affected by inter-cell interference.

**[0042]** The table 400A has  $N_R \times N_T = 3 \times 4$  elements, where  $N_R$  indicates the number of PRBs or the number of PRB subgroups, and  $N_T$  is the number of time subframes used in the evaluation.

**[0043]** FIG. 5B is a table 400B illustrating indexed IDs of candidate aggressor UEs. In the example of FIG. 5B, the number “1” identifies UE 120B1, “2” identifies UE 120C2, “3” identifies UE 120D3, “4” identifies UE 120B4, “5” identifies UE 120B5, “6” identifies UE 120B6, “7” identifies UE 120B7, and “8” identifies UE 120C8, as shown in FIG. 2.

**[0044]** Similar to table 400A, table 400B has  $N_R \times N_T = 3 \times 4$  elements, where  $N_R$  indicates the number of PRBs or the number of PRB subgroups, and  $N_T$  is the number of time subframes used in the evaluation. Each element corresponds to a list of IDs of uplink UEs 120 that were assigned uplink transmission in the given element.

**[0045]** Referring to FIGS. 2, 5A, and 5B together, the base station 110A is configured to determine which of the UEs 120 in the neighboring cells 202 are inter-cell interference aggressors against UE 120A. To address the intra-cell and inter-cell UE-to-UE interference introduced by full-duplex in cellular systems, possible aggressors are categorized into four categories based on their occurrence in interfered or non-interfered resource units. Mechanisms are proposed herein to identify the intra-cell and inter-cell aggressors from the serving cell for each category.

**[0046]** With CQI feedback from the downlink UE 120A, the base station 110A knows if the downlink UE 120A at the specific evaluation timeframe (e.g., observation interval) is a victim of UE-to-UE inter-cell interference or not. If it is, the base station 110A knows at which resource block or resource block subgroup/sub-

band resource location the victim UE 120A encountered the UE-to-UE interference. Therefore, the base station 110A has the information illustrated in table 400A.

**[0047]** In addition, it is assumed that serving base station 110A has information of the scheduled uplink resource block allocation mapping from itself 110A and neighboring base stations 110. Therefore, base station 110A can obtain a table as 400B for each downlink UE 120 it serves.

**[0048]** Each element in table 400B may contain zero, one, or multiple UL UE IDs. Zero IDs means that at this PRB location and this TTI, there was no UL UE 120 scheduled. Multiple UL UE IDs mean that there were multiple uplink UEs 120 (from multiple cells 202) scheduled in the same resource as the downlink victim UE 120A at this resource unit.

**[0049]** The objective is to find out which uplink UEs 120 cause the UE-to-UE inter-cell interference to the downlink UE 120A, based at least in part on information in table 400A and table 400B. By way of non-limiting example, the objective may be to fill a determination table corresponding to data indicating whether candidate aggressor UEs 120 are determined to be inter-cell interference aggressors for the victim downlink UE 120A, where M is a total number of uplink UEs under consideration. An example of a determination table is:

| Uplink UE Index                    | 1       | 2       | 3       | ... | M       |
|------------------------------------|---------|---------|---------|-----|---------|
| Aggressor (1) or Not Aggressor (0) | 1 or 0? | 1 or 0? | 1 or 0? |     | 1 or 0? |

**[0050]** In the example illustrated in FIGS. 5A and 5B, the UE-to-UE interference for the downlink victim UE 120A occurs at (PRB, TTI) location (1,1), (1,3), (2,4), (3,2), and (3,3). The corresponding scheduled uplink UEs 120 are listed in table 400B of FIG. 5B. By way of non-limiting example, at (PRB, TTI) location (1,1) of table 400B, uplink UE IDs 1, 2, and 3 are listed, and at (PRB, TTI) location (3,3), uplink UE ID 7 is listed.

**[0051]** As illustrated in the example of FIGS. 5A and 5B, based on the occurrences in the interfered resource units, the uplink UEs 120 may be categorized in four types, as follows:

**[0052]** Type 1 (which appeared in only the non-interfered units): UEs 120 having IDs 4 and 5 in table 400B.

**[0053]** Type 2 (which appeared in only the interfered units): UEs 120 having IDs 3, 6, and 7 in table 400B.

**[0054]** Type 3 (which appeared in both the interfered units and non-interfered units): UEs 120 having IDs 1, 2, and 8.

**[0055]** Type 4 (which did not appear in either the interfered units or the non-interfered units): these are the uplink UEs 120 about to be scheduled, without prior information from DL UE CQI feedback.

**[0056]** For type 1 UEs 120, the value in the corresponding determination table should be 0 as a non-aggressor. For type 2 and type 3 UEs 120, there is a possibility that each can be an aggressor or non-aggressor. This scheme is proposed based on the fact that each candidate uplink UE 120 has a similar impact on the DL victim UE 120A during the observation period (based on the reference interference power). Accordingly, if the uplink UE 120 appears in the non-interfered slot, even if it is also shown in the interfered slot, we treat it as a non-aggressor. Otherwise, if it is an aggressor, it should impact the non-interfered resource unit similarly as it impacts the interfered resource unit. Accordingly, the non-interfered resource should have appeared as interfered instead in table 400A. In some embodiments, Type 2 UEs 110 are determined to be aggressors. In some embodiments, Type 1 and Type 3 UEs 120 are determined to be non-aggressors. Type 4 UEs show no history of being aggressors in the data available to the cellular base station 110, but may or may not become aggressors in future communications.

**[0057]** Under these rules, the determination table for the examples shown in FIGS. 5A and 5B would be as follows:

| Uplink UE Index                    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------------------------------|---|---|---|---|---|---|---|---|
| Aggressor (1) or Not Aggressor (0) | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |

In effect, in some embodiments, only those of the UEs 120 within the adjacent cells 202 that only used resource units that the CQI feedback data indicates were interfered with are determined to be uplink interference aggressors.

**[0058]** An algorithm that may be used to identify aggressor UL UEs 120 using the CQI information and the candidate aggressor list is as follows:

- Assume the number of occurrences of UL UE  $j$  during  $N$   $t_{ti}$  is  $\alpha_j$ . The value of  $j$ -th element of the determination table, Alpha, can be obtained as:

- If occurrence  $\mathbf{o}=1$ ,
- Find out (row, column) index in table 400B  $(m,n)$ ,
- Where  $(m,n)$  element of table 400B =  $\mathbf{j}$ ;
- Alpha = value of  $(m,n)$  element in table 400A;
- Else if occurrence  $\mathbf{o}>1$ ,
- Find out the list of (row,column) index in table 400B  $(m_1,n_1), \dots (m_{\mathbf{o}},n_{\mathbf{o}})$ ,  
where  $(m_1,n_1), \dots (m_{\mathbf{o}},n_{\mathbf{o}})$  elements of table 400B =  $\mathbf{j}$ ,
- Alpha=value of minimum of  $(m_1,n_1), (m_2,n_2)\dots(m_{\mathbf{o}},n_{\mathbf{o}})$  elements in table 400A.

For initialization of new UL UE 120 to be scheduled (type 4), since there is no view of it from CQI feedback, the corresponding element of the determination table can be set as infinity.

**[0059]** Using this algorithm for the example of FIGS. 5A and 5B results in the determination table discussed above.

**[0060]** As a specific, non-limiting example of an application of this algorithm, a plurality of resource units used in a downlink between the cellular base station 110A and the UE 120A may be indexed and stored by the cellular base station 110A. A first logic value (e.g., logic value "1") may be assigned to each of the indexed resource units used in the downlink that are identified as having experienced at least a threshold level of inter-cell interference. A second logic value (e.g., logic value "0") that is less than the first logic value may be assigned to each of the indexed resource units used in the downlink that are not identified as having experienced at least the threshold level of inter-cell interference. Only two logic values, the first logic value and the second logic value, are used in this non-limiting example. One of the first logic value or the second logic value may be assigned to UE identifiers corresponding to UEs 120 identified by the other cellular base stations 110 as having used resource units for uplink communications with the other cellular base stations 110 while the UE 120A used the resource units for downlink communications from the cellular base station 110A. This assignment may be made by assigning, to a UE identifier, a one of the first logic value or the second logic value that is assigned to a resource unit that was identified by another cellular base station 110 as having been used by one of the UEs 120 corresponding to the UE identifier if the resource unit was the only one of the resource units identified by the other cellular base station

110 as having been used by the one of the UEs corresponding to the UE identifier. Also, the first logic value may be assigned to a UE identifier if more than one of the resource units was identified by the other cellular base station 110 as having been used by the one of the UEs corresponding to the UE identifier, and each of the more than one resource units have the first logic value assigned thereto. Furthermore, the second logic value may be assigned to the UE identifier if more than one of the resource units were identified by the other cellular base station 110 as having been used by the one of the UEs corresponding to the UE identifier, and at least one of the more than one of the resource units have the second logic value assigned thereto.

**[0061]** After the determination table is obtained, if a distributed scheduler is used in the system 200, the serving base station 110A notifies its neighbor base stations 110 of the UE IDs shown as aggressors in the determination table. The UE IDs are not necessarily actual UE IDs used by the base stations 110 to identify the UEs 120. Rather, the IDs used can be shortened versions that contain enough bits for the corresponding neighboring base station 110 to identify it among its own UL UEs 120. If a centralized scheduler is used, the determination table is available to the central scheduler and can be used as one input for better scheduler performance.

**[0062]** FIG. 6 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 6 shows a diagrammatic representation of hardware resources 600 including one or more processors (or processor cores) 610, one or more memory/storage devices 620, and one or more communication resources 630, each of which is communicatively coupled via a bus 640.

**[0063]** The processors 610 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 612 and a processor 614. The memory/storage devices 620 may include main memory, disk storage, or any suitable combination thereof.

**[0064]** The communication resources 630 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 604 and/or one or more databases 606 via a network 608. For example, the communication resources 630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

**[0065]** Instructions 650 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 610 to perform any one or more of the methodologies discussed herein. The instructions 650 may reside, completely or partially, within at least one of the processors 610 (e.g., within the processor's cache memory), the memory/storage devices 620, or any suitable combination thereof. Furthermore, any portion of the instructions 650 may be transferred to the hardware resources 600 from any combination of the peripheral devices 604 and/or the databases 606. Accordingly, the memory of processors 610, the memory/storage devices 620, the peripheral devices 604, and the databases 606 are examples of computer-readable and machine-readable media. By way of non-limiting example, the instructions 650 may be configured to instruct any of the processors 610 to perform any of the operations or functions discussed herein.

**[0066]** 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.

**[0067]** Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 7 illustrates, for some embodiments, example components of an electronic device 700. In some embodiments, the electronic device 700 may be, may implement, may be

incorporated into, or otherwise may be a part of a user equipment (UE) (e.g., the UEs 120 of FIG. 1), a cellular base station (e.g., the base stations 110 of FIG. 1), or some other suitable electronic device. In some embodiments, the electronic device 700 may include application circuitry 702, baseband circuitry 704, Radio Frequency (RF) circuitry 706, front-end module (FEM) circuitry 708 and one or more antennas 710, coupled together at least as shown in FIG. 7.

**[0068]** The application circuitry 702 may include one or more application processors. For example, the application circuitry 702 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

**[0069]** The baseband circuitry 704 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 704 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 706 and to generate baseband signals for a transmit signal path of the RF circuitry 706. Baseband processing circuitry 704 may interface with the application circuitry 702 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 706. For example, in some embodiments, the baseband circuitry 704 may include a second generation (2G) baseband processor 704A, third generation (3G) baseband processor 704B, fourth generation (4G) baseband processor 704C, and/or other baseband processor(s) 704D for other existing generations, generations in development, or generations to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 704 (e.g., one or more of baseband processors 704A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 706. The radio control functions may 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 704 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding

circuitry of the baseband circuitry 704 may 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 may include other suitable functionality in other embodiments.

**[0070]** In some embodiments, the baseband circuitry 704 may 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) 704E of the baseband circuitry 704 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry 704 may include one or more audio digital signal processor(s) (DSP) 704F. The audio DSP(s) 704F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments.

**[0071]** The baseband circuitry 704 may further include memory/storage 704G. The memory/storage 704G may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 704. Memory/storage 704G for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 704G may include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 704G may be shared among the various processors or dedicated to particular processors.

**[0072]** Components of the baseband circuitry 704 may be suitably combined in a single chip, combined in 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 704 and the application circuitry 702 may be implemented together, such as, for example, on a system on a chip (SOC).

**[0073]** In some embodiments, the baseband circuitry 704 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 704 may 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), or a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 704 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

**[0074]** RF circuitry 706 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 706 may include switches, filters, amplifiers, etc., to facilitate the communication with the wireless network. RF circuitry 706 may include a receive signal path, which may include circuitry to down-convert RF signals received from the FEM circuitry 708 and provide baseband signals to the baseband circuitry 704. RF circuitry 706 may also include a transmit signal path, which may include circuitry to up-convert baseband signals provided by the baseband circuitry 704 and provide RF output signals to the FEM circuitry 708 for transmission.

**[0075]** In some embodiments, the RF circuitry 706 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 706 may include mixer circuitry 706A, amplifier circuitry 706B, and filter circuitry 706C. The transmit signal path of the RF circuitry 706 may include filter circuitry 706C and mixer circuitry 706A. RF circuitry 706 may also include synthesizer circuitry 706D for synthesizing a frequency for use by the mixer circuitry 706A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 706A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 708 based on the synthesized frequency provided by synthesizer circuitry 706D. The amplifier circuitry 706B may be configured to amplify the down-converted signals, and the filter circuitry 706C may 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 may be provided to the baseband circuitry 704 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 706A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

**[0076]** In some embodiments, the mixer circuitry 706A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized

frequency provided by the synthesizer circuitry 706D to generate RF output signals for the FEM circuitry 708. The baseband signals may be provided by the baseband circuitry 704 and may be filtered by filter circuitry 706C. The filter circuitry 706C may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

**[0077]** In some embodiments, the mixer circuitry 706A of the receive signal path and the mixer circuitry 706A of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 706A of the receive signal path and the mixer circuitry 706A of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 706A of the receive signal path and the mixer circuitry 706A of the transmit signal path may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 706A of the receive signal path and the mixer circuitry 706A of the transmit signal path may be configured for super-heterodyne operation.

**[0078]** In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these embodiments, the RF circuitry 706 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 704 may include a digital baseband interface to communicate with the RF circuitry 706.

**[0079]** In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

**[0080]** In some embodiments, the synthesizer circuitry 706D may be a fractional-M 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 may be suitable. For example, synthesizer circuitry 706D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

**[0081]** The synthesizer circuitry 706D may be configured to synthesize an output frequency for use by the mixer circuitry 706A of the RF circuitry 706 based on a

frequency input and a divider control input. In some embodiments, the synthesizer circuitry 706D may be a fractional  $N/N+1$  synthesizer.

**[0082]** In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 704 or the application circuitry 702 depending on the desired output frequency. In some embodiments, a divider control input (e.g., M) may be determined from a look-up table based on a channel indicated by the application circuitry 702.

**[0083]** Synthesizer circuitry 706D of the RF circuitry 706 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may 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 may 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 may 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.

**[0084]** In some embodiments, synthesizer circuitry 706D may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may 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 may be a local oscillator (LO) frequency (fLO). In some embodiments, the RF circuitry 706 may include an IQ/polar converter.

**[0085]** FEM circuitry 708 may include a receive signal path, which may include circuitry configured to operate on RF signals received from one or more antennas 710, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 706 for further processing. FEM circuitry 708 may also include a transmit signal path, which may include circuitry configured to amplify

signals for transmission provided by the RF circuitry 706 for transmission by one or more of the one or more antennas 710.

**[0086]** In some embodiments, the FEM circuitry 708 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry 708 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 708 may 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 706). The transmit signal path of the FEM circuitry 708 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 706), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 710).

**[0087]** In some embodiments, the electronic device 700 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

**[0088]** In embodiments where the electronic device 700 is, implements, is incorporated into, or is otherwise part of a base station or a UE, the RF circuitry 706 may be configured to receive and to send a signal. The baseband circuitry 704 may be configured to implement the cellular base station 110 (FIG. 2), the UE 120 (FIG. 2), some other embodiment or example disclosed herein, or combinations thereof.

**[0089]** In some embodiments, the electronic device 700 of FIG. 7 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. For example, the electronic device 700 of FIG. 7 may be configured to implement the cellular base station 110 (FIG. 2), the UE 120 (FIG. 2), some other embodiment or example disclosed herein, or combinations thereof.

### EXAMPLES

**[0090]** The following is a list of example embodiments that fall within the scope of the disclosure. In order to avoid complexity in providing the disclosure, not all of the examples listed below are separately and explicitly disclosed as having been contemplated herein as combinable with all of the others of the examples listed below and other embodiments disclosed hereinabove. Unless one of ordinary skill in the art would understand that these examples listed below, and the above disclosed embodiments, are not combinable, it is contemplated within the scope of the disclosure that such examples and embodiments are combinable.

**[0091]** Example 1: An apparatus for a cellular base station, including: one or more processors; and one or more computer-readable storage media operably coupled to the one or more processors and including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct the one or more processors to: support full-duplex communication of User Equipment (UEs) within a cell corresponding to the cellular base station; process downlink UE channel quality feedback (CQI feedback) data received from a UE, the CQI feedback data indicating channel quality of downlink channels between the cellular base station and the UE; identify uplink interference to the downlink channels based, at least in part, on the CQI feedback data; assemble an uplink interference candidate aggressor list including uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data indicating channel usage of at least a portion of UEs within the adjacent cells; and determine which of the UEs within the adjacent cells are uplink interference aggressors based at least on the CQI feedback data and the uplink interference candidate aggressor list.

**[0092]** Example 2: The apparatus of Example 1, wherein the computer-readable instructions are configured to instruct the one or more processors to determine which of the UEs within the adjacent cells are uplink interference aggressors by determining that uplink interference aggressors are only those of the UEs that the uplink interference candidate aggressor list indicates used only resource units that the CQI feedback data indicates were interfered with.

**[0093]** Example 3: The apparatus according to any one of Examples 1-2, wherein the channel quality of the downlink channels indicated by the CQI feedback data includes a signal-to-interference ratio of downlink communication signals from the cellular base station to uplink interference.

**[0094]** Example 4: The apparatus of Example 3, wherein the computer readable instructions are configured to instruct the one or more processors to identify the uplink interference to the downlink channels by determining that a channel is interfered with if the signal-to-interference ratio of the channel is less than a predetermined threshold signal-to-interference ratio.

**[0095]** Example 5: The apparatus according to any one of Examples 1-4, wherein the computer-readable instructions are configured to instruct the one or more processors to cause requests to be transmitted to the cellular base stations in the one or more adjacent cells, the requests requesting the uplink channel data.

**[0096]** Example 6: The apparatus of Example 5, wherein: the computer-readable instructions are further configured to instruct the one or more processors to transmit the requests responsive to identifying the uplink interference to the downlink channels; and the requests are configured to request identifiers of those of the UEs within the adjacent cells that were transmitting data using resource units used by the UE and for which the CQI feedback data indicates the channel quality of the downlink channels was less than a predetermined threshold.

**[0097]** Example 7: The apparatus according to any one of Examples 1-4, wherein the computer-readable instructions are configured to instruct the one or more processors to cause the cellular base station to periodically receive the uplink channel data.

**[0098]** Example 8: The apparatus according to any one of Examples 1-7, wherein the uplink channel data is received through one of an X2 interface or a cloud radio access network (C-RAN) structure.

**[0099]** Example 9: The apparatus according to any one of Examples 1-8, wherein the computer-readable instructions are further configured to cause identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to the cellular base stations in the one or more adjacent cells.

**[00100]** Example 10: The apparatus according to any one of Examples 1-8, wherein the computer-readable instructions are further configured to cause identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to a centralized scheduler.

**[00101]** Example 11: The apparatus according to any one of Examples 1-9, wherein the computer-readable instructions are further configured to instruct the one or more processors to cause uplink channel data of its own cell to be transmitted to the cellular base stations in the one or more adjacent cells.

**[00102]** Example 12: The apparatus of Example 11, wherein the computer-readable instructions are further configured to instruct the one or more processors to cause UEs within its own cell that are identified to be interference aggressors by the cellular base stations in the one or more adjacent cells to communicate in the uplink using different resource units than those previously determined to be causing inter-cell interference.

**[00103]** Example 13: A computer-readable storage medium including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct one or more processors of a cellular base station to: identify resource units, used in a downlink between the cellular base station and a User Equipment (UE) in a full-duplex communication system, that experienced at least a threshold level of inter-cell interference from at least one other UE transmitting in an uplink to at least one other cellular base station; and determine that the at least one other UE is an inter-cell interference aggressor by correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station.

**[00104]** Example 14: The computer-readable storage medium of Example 13, wherein the computer-readable instructions are configured to instruct the one or more processors to identify the at least one other UE as an inter-cell interference aggressor by: digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE; assigning a first logic value to each of the plurality of resource units used in the downlink that are identified as having experienced at least the threshold level of inter-cell interference; assigning a second logic value to each of the plurality of resource units used in the downlink that are not identified as having experienced at least the threshold level of inter-cell interference; assigning one of the first logic value or the second logic value to UE identifiers corresponding to UEs identified by the at least one other cellular base station as having used resource units for uplink communications with the at least one other cellular base station while the UE used the resource units for downlink communications from the cellular base station; determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the first logic value assigned thereto are inter-cell interference aggressors; and determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the second logic value assigned thereto are not inter-cell interference aggressors.

**[00105]** Example 15: The computer-readable storage medium of Example 14, wherein the computer-readable instructions are configured to assign the one of the first logic value or the second logic value to the UE identifiers by: assigning, to a UE identifier, a one of the first logic value or the second logic value that is assigned to a resource unit that was identified by the at least one other cellular base station as

having been used by one of the UEs corresponding to the UE identifier if the resource unit was the only one of the resource units identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier; assigning, to the UE identifier, the first logic value if more than one of the resource units was identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and each of the more than one of the resource units have the first logic value assigned thereto; and assigning, to the UE identifier, the second logic value if more than one of the resource units were identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and at least one of the more than one of the resource units have the second logic value assigned thereto.

**[00106]** Example 16: The computer-readable storage medium of Example 13, wherein the computer-readable instructions are further configured to instruct the one or more processors to: assign a UE identifier corresponding to an other UE operating in another cell to a first group if the other UE used at least some of the same resource units in an uplink as the UE used in the downlink, but none of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference; assign the UE identifier to a second group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and all of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference; assign the UE identifier to a third group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and some of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference, and some of the at least some of the same resource units were identified as not having experienced at least the threshold level of inter-cell interference; and assign the UE identifier to a fourth group if the other UE did not use any of the same resource units in the uplink as the UE used in the downlink.

**[00107]** Example 17: The computer-readable storage medium of Example 16, wherein the computer-readable instructions are further configured to determine that the other UE is an inter-cell interference aggressor if the UE is assigned to the second group.

**[00108]** Example 18: The computer-readable storage medium according to any one of Examples 16 and 17, wherein the computer-readable instructions are further configured to determine that the other UE is not an inter-cell interference aggressor if the UE is assigned to any one of the first group, the third group, or the fourth group.

**[00109]** Example 19: The computer-readable storage medium of Example 13, wherein correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station includes: digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE; assigning a first logic value to each of the plurality of indexed resource units identified as having experienced at least the threshold level of inter-cell interference; assigning a second logic value to each of the plurality of resource units used in the indexed resource units that are not identified as having experienced at least threshold level of inter-cell interference; assigning UE identifiers of other UEs that transmitted communications in an uplink to the at least one other cellular base station using the indexed resource elements to those of the indexed resource elements that the other UEs used to transmit the communications in the uplink; assigning the one of the first logic value or the second logic value that was assigned to a one of the resource elements that is assigned to a first UE identifier if there is only one occurrence of the first UE identifier assigned to one of the indexed resource elements; and assigning a minimum one of the first logic value or the second logic value assigned to each resource unit that is assigned to each occurrence of the first UE identifier if there are more than one occurrences of the first UE identifier assigned to the indexed resource elements.

**[00110]** Example 20: The computer-readable storage medium of Example 19, wherein the computer-readable instructions are further configured to instruct the one or more processors to determine that the first UE identifier corresponds to an inter-cell interference aggressor if the first logic value is assigned thereto, and that the first UE identifier corresponds to a non-aggressor if the second logic value is assigned thereto.

**[00111]** Example 21: A cellular base station, including: one or more communication elements; control circuitry operably coupled to the one or more communication elements and configured to: participate in full-duplex communications with User Equipment (UEs) within a cell corresponding to the cellular base station; transmit, with the one or more communication elements, data to the UEs in a downlink;

receive, with the one or more communication elements, CQI feedback from each of the UEs, the CQI feedback indicating a channel quality of the downlink; receive, with the one or more communication elements, uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data identifying other UEs in the one or more adjacent cells and uplink resource units used by the other UEs; identify downlink resource units that were affected by at least a threshold level of inter-cell interference that were used to transmit the data to the UEs in the downlink; correlate the identified downlink resource units with the identified uplink resource units to determine which of the other UEs interfered with the downlink communications.

**[00112]** Example 22: The cellular base station of Example 21, wherein the control circuitry is configured to determine that those of the other UEs that are associated with only those of the downlink resource units that were affected by at least the threshold level of inter-cell interference are inter-cell interference aggressors.

**[00113]** Example 23: A method of operating a cellular base station, the method including: supporting full-duplex communication of User Equipment (UEs) within a cell corresponding to the cellular base station; processing downlink UE channel quality feedback (CQI feedback) data received from a UE, the CQI feedback data indicating channel quality of downlink channels between the cellular base station and the UE; identifying uplink interference to the downlink channels based, at least in part, on the CQI feedback data; assembling an uplink interference candidate aggressor list including uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data indicating channel usage of at least a portion of UEs within the adjacent cells; and determining which of the UEs within the adjacent cells are uplink interference aggressors based at least on the CQI feedback data and the uplink interference candidate aggressor list.

**[00114]** Example 24: The method of Example 23, wherein determining which of the UEs within the adjacent cells are uplink interference aggressors includes determining that uplink interference aggressors are only those of the UEs that the uplink interference candidate aggressor list indicates used only resource units that the CQI feedback data indicates were interfered with.

**[00115]** Example 25: The method according to any one of Examples 23 and 24, wherein processing CQI feedback data includes processing a signal-to-interference

ratio of downlink communication signals from the cellular base station to uplink interference.

**[00116]** Example 26: The method of Example 25, wherein identify uplink interference to the downlink channels includes determining that a channel is interfered with if the signal-to-interference ratio of the channel is less than a predetermined threshold signal-to-interference ratio

**[00117]** Example 27: The method according to any one of Examples 23-26, further including causing requests to be transmitted to the cellular base stations in the one or more adjacent cells, the requests requesting the uplink channel data.

**[00118]** Example 28: The method of Example 27, wherein: causing requests to be transmitted includes transmitting the requests responsive to identifying the uplink interference to the downlink channels; and the requests are configured to request identifiers of those of the UEs within the adjacent cells that were transmitting data using resource units used by the UE and for which the CQI feedback data indicates the channel quality of the downlink channels was less than a predetermined threshold.

**[00119]** Example 29: The method according to any one of Examples 23-26, further including causing the cellular base station to periodically receive the uplink channel data.

**[00120]** Example 30: The method according to any one of Examples 23-29, further including causing the cellular base station to receive the uplink channel data through one of an X2 interface or a cloud radio access network (C-RAN) structure.

**[00121]** Example 31: The method according to any one of Example 23-30, further including causing identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to the cellular base stations in the one or more adjacent cells.

**[00122]** Example 32: The method according to any one of Examples 23-30, further including causing identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to a centralized scheduler.

**[00123]** Example 33: The method of Example 23, further including causing uplink channel data of the cell to be transmitted to the cellular base stations in the one or more adjacent cells.

**[00124]** Example 34: The method of Example 33, further including causing UEs within the cell that are identified to be interference aggressors by the cellular base stations in the one or more adjacent cells to communicate in the uplink using different resource units than those previously determined to be causing inter-cell interference.

**[00125]** Example 35: A method of operating a cellular base station, the method including: identify resource units, used in a downlink between the cellular base station and a User Equipment (UE) in a full-duplex communication system, that experienced at least a threshold level of inter-cell interference from at least one other UE transmitting in an uplink to at least one other cellular base station; and determining that the at least one other UE is an inter-cell interference aggressor by correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station.

**[00126]** Example 36: The method of Example 35, wherein identifying the at least one other UE as an inter-cell interference aggressor includes: digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE; assigning a first logic value to each of the plurality of resource units used in the downlink that are identified as having experienced at least the threshold level of inter-cell interference; assigning a second logic value to each of the plurality of resource units used in the downlink that are not identified as having experienced at least the threshold level of inter-cell interference; assigning one of the first logic value or the second logic value to UE identifiers corresponding to UEs identified by the at least one other cellular base station as having used resource units for uplink communications with the at least one other cellular base station while the UE used the resource units for downlink communications from the cellular base station; determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the first logic value assigned thereto are inter-cell interference aggressors; and determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the second logic value assigned thereto are not inter-cell interference aggressors.

**[00127]** Example 37: The method of Example 36, wherein assigning the one of the first logic value or the second logic value to the UE identifiers includes: assigning, to a UE identifier, a one of the first logic value or the second logic value that is assigned

to a resource unit that was identified by the at least one other cellular base station as having been used by one of the UEs corresponding to the UE identifier if the resource unit was the only one of the resource units identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier; assigning, to the UE identifier, the first logic value if more than one of the resource units was identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and each of the more than one of the resource units have the first logic value assigned thereto; and assigning, to the UE identifier, the second logic value if more than one of the resource units were identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and at least one of the more than one of the resource units have the second logic value assigned thereto.

**[00128]** Example 38: The method of Example 35, wherein determining that the at least one other UE is an inter-cell interference aggressor includes: assigning a UE identifier corresponding to an other UE operating in another cell to a first group if the other UE used at least some of the same resource units in an uplink as the UE used in the downlink, but none of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference; assigning the UE identifier to a second group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and all of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference; assigning the UE identifier to a third group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and some of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference, and some of the at least some of the same resource units were identified as not having experienced at least the threshold level of inter-cell interference; and assigning the UE identifier to a fourth group if the other UE did not use any of the same resource units in the uplink as the UE used in the downlink.

**[00129]** Example 39: The method of Example 38, wherein determining that the at least one other UE is an inter-cell interference aggressor includes determining that the other UE is an inter-cell interference aggressor if the UE is assigned to the second group.

**[00130]** Example 40: The method according to any one of Examples 38 and 39, further including determining that the other UE is not an inter-cell interference aggressor if the UE is assigned to any one of the first group, the third group, or the fourth group.

**[00131]** Example 41: The method of Example 35, wherein correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station includes: digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE;

**[00132]** assigning a first logic value to each of the plurality of indexed resource units identified as having experienced at least the threshold level of inter-cell interference; assigning a second logic value to each of the plurality of resource units used in the indexed resource units that are not identified as having experienced at least threshold level of inter-cell interference; assigning UE identifiers of other UEs that transmitted communications in an uplink to the at least one other cellular base station using the indexed resource elements to those of the indexed resource elements that the other UEs used to transmit the communications in the uplink; assigning the one of the first logic value or the second logic value that was assigned to a one of the resource elements that is assigned to a first UE identifier if there is only one occurrence of the first UE identifier assigned to one of the indexed resource elements; and assigning a minimum one of the first logic value or the second logic value assigned to each resource unit that is assigned to each occurrence of the first UE identifier if there are more than one occurrences of the first UE identifier assigned to the indexed resource elements.

**[00133]** Example 42: The method of Example 41, wherein determining that the at least one other UE is an inter-cell interference aggressor includes determining that the first UE identifier corresponds to an inter-cell interference aggressor if the first logic value is assigned thereto, and that the first UE identifier corresponds to a non-aggressor if the second logic value is assigned thereto.

**[00134]** Example 43: A method of operating a cellular base station, the method including: participating in full-duplex communications with User Equipment (UEs) within a cell corresponding to the cellular base station; transmitting, with one or more communication elements, data to the UEs in a downlink; receiving, with the one or more communication elements, CQI feedback from each of the UEs, the CQI feedback indicating a channel quality of the downlink; receiving, with the one or more

communication elements, uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data identifying other UEs in the one or more adjacent cells and uplink resource units used by the other UEs; identifying downlink resource units that were affected by at least a threshold level of inter-cell interference that were used to transmit the data to the UEs in the downlink; and correlating the identified downlink resource units with the identified uplink resource units to determine which of the other UEs interfered with the downlink communications.

**[00135]** Example 44: The method of Example 43, further including determining that those of the other UEs that are associated with only those of the downlink resource units that were affected by at least the threshold level of inter-cell interference are inter-cell interference aggressors.

**[00136]** Example 45: At least one computer-readable storage medium including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct one or more processors to perform any one of the methods of Examples 23-44.

**[00137]** Example 46: A means for performing any one of the methods of Examples 23-44.

**[00138]** While certain illustrative embodiments have been described in connection with the figures, those of ordinary skill in the art will recognize and appreciate that embodiments encompassed by the disclosure are not limited to those embodiments explicitly shown and described herein. Rather, many additions, deletions, and modifications to the embodiments described herein may be made without departing from the scope of embodiments encompassed by the disclosure, such as those hereinafter claimed, including legal equivalents. In addition, features from one disclosed embodiment may be combined with features of another disclosed embodiment while still being encompassed within the scope of embodiments encompassed by the disclosure, as contemplated by the inventors.

Claims

1. An apparatus for a cellular base station, comprising:  
one or more processors; and  
one or more computer-readable storage media operably coupled to the one or more processors and including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct the one or more processors to:  
support full-duplex communication of User Equipment (UEs) within a cell corresponding to the cellular base station;  
process downlink UE channel quality feedback (CQI feedback) data received from a UE, the CQI feedback data indicating channel quality of downlink channels between the cellular base station and the UE;  
identify uplink interference to the downlink channels based, at least in part, on the CQI feedback data;  
assemble an uplink interference candidate aggressor list including uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data indicating channel usage of at least a portion of UEs within the adjacent cells; and  
determine which of the UEs within the adjacent cells are uplink interference aggressors based at least on the CQI feedback data and the uplink interference candidate aggressor list.
2. The apparatus of claim 1, wherein the computer-readable instructions are configured to instruct the one or more processors to determine which of the UEs within the adjacent cells are uplink interference aggressors by determining that uplink interference aggressors are only those of the UEs that the uplink interference candidate aggressor list indicates used only resource units that the CQI feedback data indicates were interfered with.
3. The apparatus of claim 1, wherein the channel quality of the downlink channels indicated by the CQI feedback data includes a signal-to-interference ratio of downlink communication signals from the cellular base station to uplink interference.

4. The apparatus of claim 3, wherein the computer readable instructions are configured to instruct the one or more processors to identify the uplink interference to the downlink channels by determining that a channel is interfered with if the signal-to-interference ratio of the channel is less than a predetermined threshold signal-to-interference ratio.

5. The apparatus according to any one of claims 1-4, wherein the computer-readable instructions are configured to instruct the one or more processors to cause requests to be transmitted to the cellular base stations in the one or more adjacent cells, the requests requesting the uplink channel data.

6. The apparatus of claim 5, wherein:  
the computer-readable instructions are further configured to instruct the one or more processors to transmit the requests responsive to identifying the uplink interference to the downlink channels; and  
the requests are configured to request identifiers of those of the UEs within the adjacent cells that were transmitting data using resource units used by the UE and for which the CQI feedback data indicates the channel quality of the downlink channels was less than a predetermined threshold.

7. The apparatus according to any one of claims 1-4, wherein the computer-readable instructions are configured to instruct the one or more processors to cause the cellular base station to periodically receive the uplink channel data.

8. The apparatus according to any one of claims 1-4, wherein the uplink channel data is received through one of an X2 interface or a cloud radio access network (C-RAN) structure.

9. The apparatus according to any one of claims 1-4, wherein the computer-readable instructions are further configured to cause identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to the cellular base stations in the one or more adjacent cells.

10. The apparatus according to any one of claims 1-4, wherein the computer-readable instructions are further configured to cause identification data identifying the UEs within the adjacent cells that are determined to be uplink interference aggressors to be transmitted to a centralized scheduler.

11. The apparatus according to any one of claims 1-4, wherein the computer-readable instructions are further configured to instruct the one or more processors to cause uplink channel data of its own cell to be transmitted to the cellular base stations in the one or more adjacent cells.

12. The apparatus of claim 11, wherein the computer-readable instructions are further configured to instruct the one or more processors to cause UEs within its own cell that are identified to be interference aggressors by the cellular base stations in the one or more adjacent cells to communicate in the uplink using different resource units than those previously determined to be causing inter-cell interference.

13. A computer-readable storage medium including computer-readable instructions stored thereon, the computer-readable instructions configured to instruct one or more processors of a cellular base station to:

identify resource units, used in a downlink between the cellular base station and a User Equipment (UE) in a full-duplex communication system, that experienced at least a threshold level of inter-cell interference from at least one other UE transmitting in an uplink to at least one other cellular base station; and  
determine that the at least one other UE is an inter-cell interference aggressor by correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station.

14. The computer-readable storage medium of claim 13, wherein the computer-readable instructions are configured to instruct the one or more processors to identify the at least one other UE as an inter-cell interference aggressor by:  
digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE;

assigning a first logic value to each of the plurality of resource units used in the downlink that are identified as having experienced at least the threshold level of inter-cell interference;

assigning a second logic value to each of the plurality of resource units used in the downlink that are not identified as having experienced at least the threshold level of inter-cell interference;

assigning one of the first logic value or the second logic value to UE identifiers corresponding to UEs identified by the at least one other cellular base station as having used resource units for uplink communications with the at least one

other cellular base station while the UE used the resource units for downlink communications from the cellular base station;  
determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the first logic value assigned thereto are inter-cell interference aggressors; and  
determining that those of the UEs identified by the at least one other cellular base station that correspond to the UE identifiers having the second logic value assigned thereto are not inter-cell interference aggressors.

15. The computer-readable storage medium of claim 14, wherein the computer-readable instructions are configured to assign the one of the first logic value or the second logic value to the UE identifiers by:

assigning, to a UE identifier, a one of the first logic value or the second logic value that is assigned to a resource unit that was identified by the at least one other cellular base station as having been used by one of the UEs corresponding to the UE identifier if the resource unit was the only one of the resource units identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier;  
assigning, to the UE identifier, the first logic value if more than one of the resource units was identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and each of the more than one of the resource units have the first logic value assigned thereto; and  
assigning, to the UE identifier, the second logic value if more than one of the resource units were identified by the at least one other cellular base station as having been used by the one of the UEs corresponding to the UE identifier, and at least one of the more than one of the resource units have the second logic value assigned thereto.

16. The computer-readable storage medium of claim 13, wherein the computer-readable instructions are further configured to instruct the one or more processors to:

assign a UE identifier corresponding to an other UE operating in another cell to a first group if the other UE used at least some of the same resource units in an uplink as the UE used in the downlink, but none of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference;

assign the UE identifier to a second group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and all of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference;

assign the UE identifier to a third group if the other UE used at least some of the same resource units in the uplink as the UE used in the downlink, and some of the at least some of the same resource units were identified as having experienced at least the threshold level of inter-cell interference, and some of the at least some of the same resource units were identified as not having experienced at least the threshold level of inter-cell interference; and

assign the UE identifier to a fourth group if the other UE did not use any of the same resource units in the uplink as the UE used in the downlink.

17. The computer-readable storage medium of claim 16, wherein the computer-readable instructions are further configured to determine that the other UE is an inter-cell interference aggressor if the UE is assigned to the second group.

18. The computer-readable storage medium of claim 16, wherein the computer-readable instructions are further configured to determine that the other UE is not an inter-cell interference aggressor if the UE is assigned to any one of the first group, the third group, or the fourth group.

19. The computer-readable storage medium of claim 13, wherein correlating the identified resource units with corresponding resource units of uplink communications received by the at least one other cellular base station comprises: digitally indexing a plurality of resource units used in the downlink between the cellular base station and the UE;

assigning a first logic value to each of the plurality of indexed resource units identified as having experienced at least the threshold level of inter-cell interference;

assigning a second logic value to each of the plurality of resource units used in the indexed resource units that are not identified as having experienced at least threshold level of inter-cell interference;

assigning UE identifiers of other UEs that transmitted communications in an uplink to the at least one other cellular base station using the indexed resource elements to those of the indexed resource elements that the other UEs used to transmit the communications in the uplink;

assigning the one of the first logic value or the second logic value that was assigned to a one of the resource elements that is assigned to a first UE identifier if there is only one occurrence of the first UE identifier assigned to one of the indexed resource elements; and

assigning a minimum one of the first logic value or the second logic value assigned to each resource unit that is assigned to each occurrence of the first UE identifier if there are more than one occurrences of the first UE identifier assigned to the indexed resource elements.

20. The computer-readable storage medium of claim 19, wherein the computer-readable instructions are further configured to instruct the one or more processors to determine that the first UE identifier corresponds to an inter-cell interference aggressor if the first logic value is assigned thereto, and that the first UE identifier corresponds to a non-aggressor if the second logic value is assigned thereto.

21. A cellular base station, comprising:  
one or more communication elements;  
control circuitry operably coupled to the one or more communication elements and configured to:  
participate in full-duplex communications with User Equipment (UEs) within a cell corresponding to the cellular base station;  
transmit, with the one or more communication elements, data to the UEs in a downlink;  
receive, with the one or more communication elements, CQI feedback from each of the UEs, the CQI feedback indicating a channel quality of the downlink;  
receive, with the one or more communication elements, uplink channel data received from cellular base stations in one or more adjacent cells, the uplink channel data identifying other UEs in the one or more adjacent cells and uplink resource units used by the other UEs;  
identify downlink resource units that were affected by at least a threshold level of inter-cell interference that were used to transmit the data to the UEs in the downlink;  
correlate the identified downlink resource units with the identified uplink resource units to determine which of the other UEs interfered with the downlink communications.
22. The cellular base station of claim 21, wherein the control circuitry is configured to determine that those of the other UEs that are associated with only those of the downlink resource units that were affected by at least the threshold level of inter-cell interference are inter-cell interference aggressors.

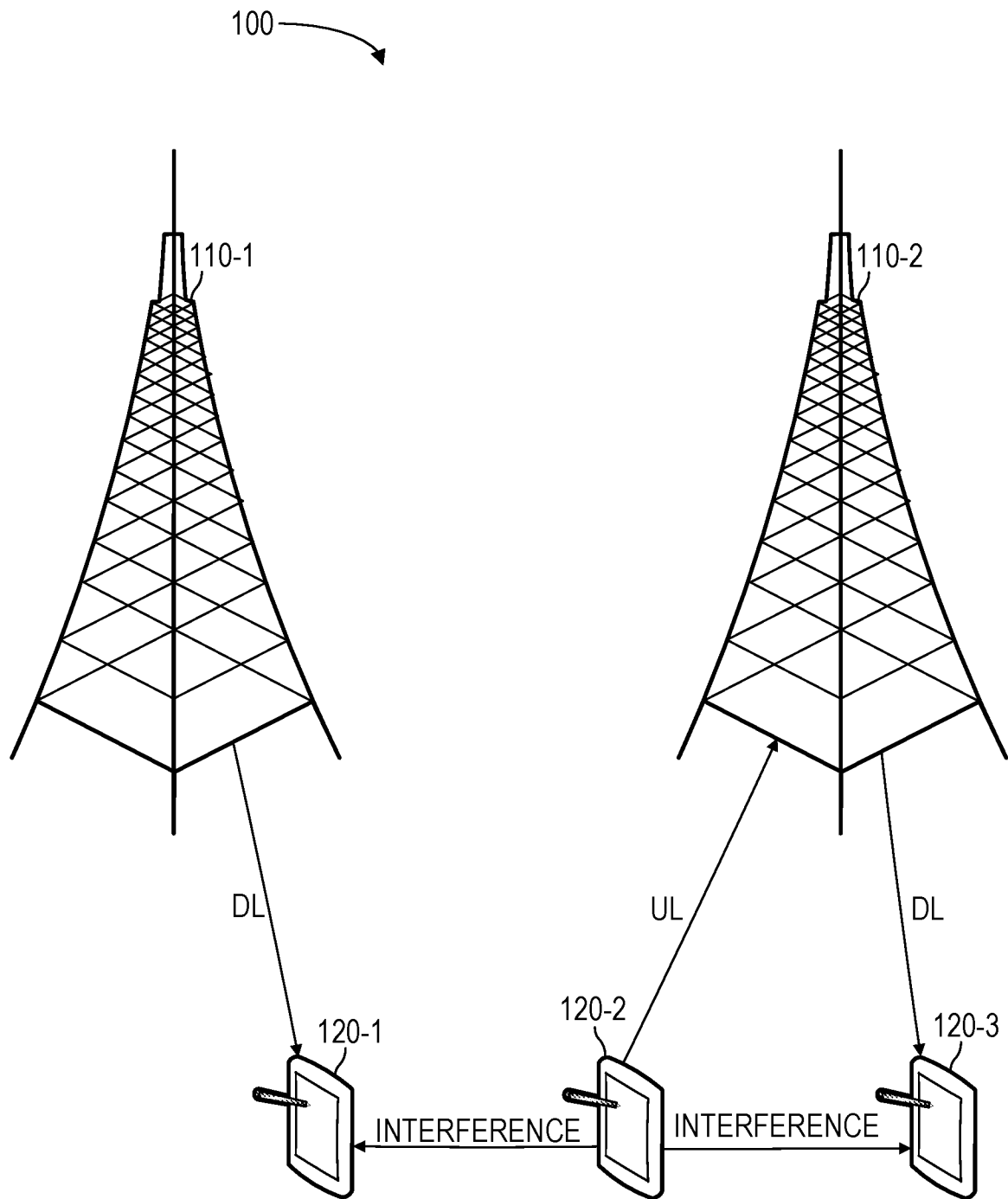


FIG. 1

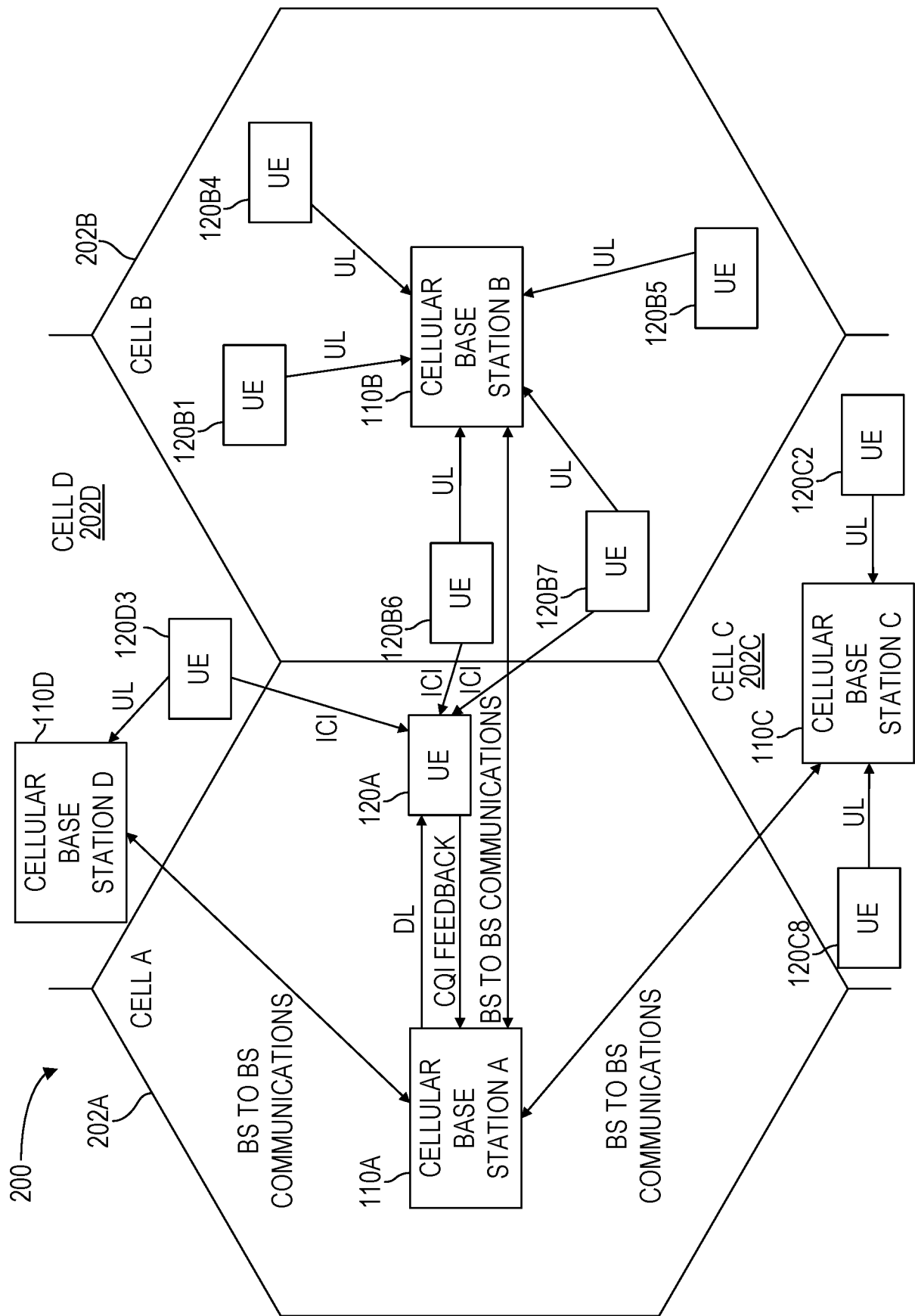


FIG. 2

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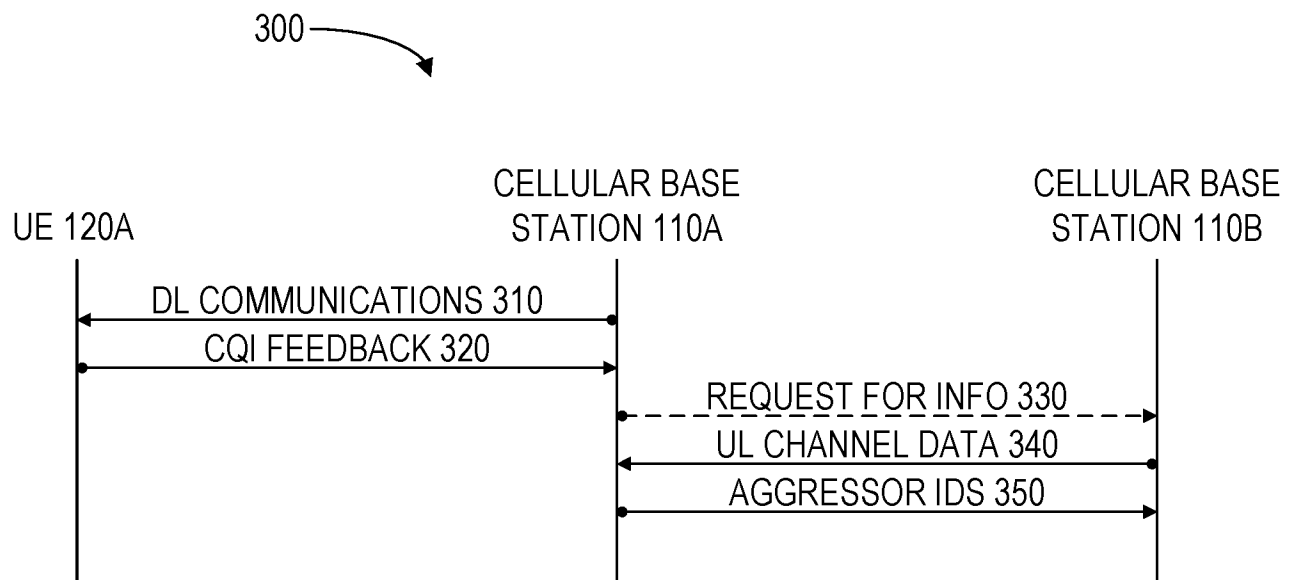


FIG. 3

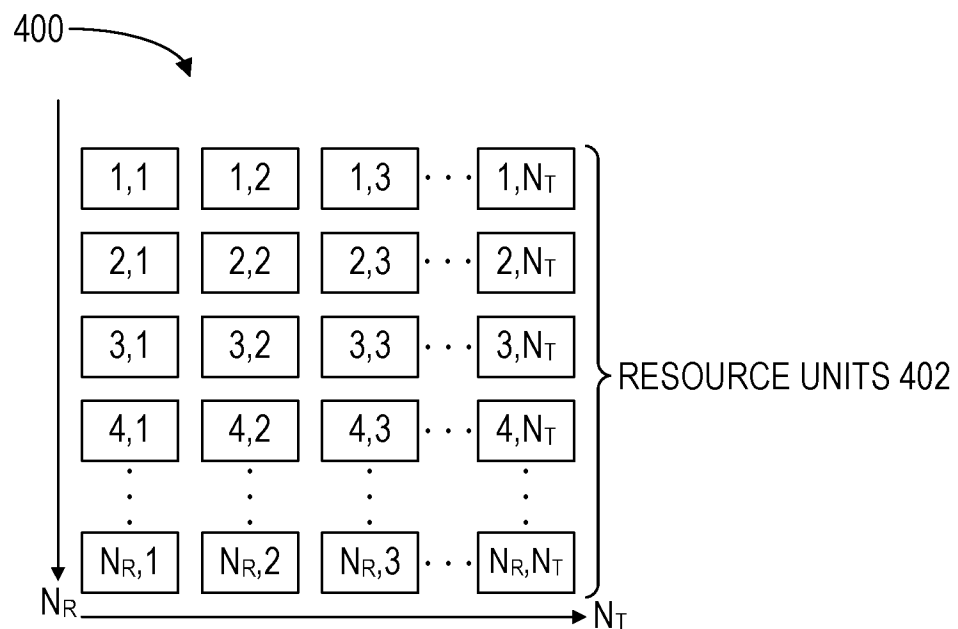


FIG. 4

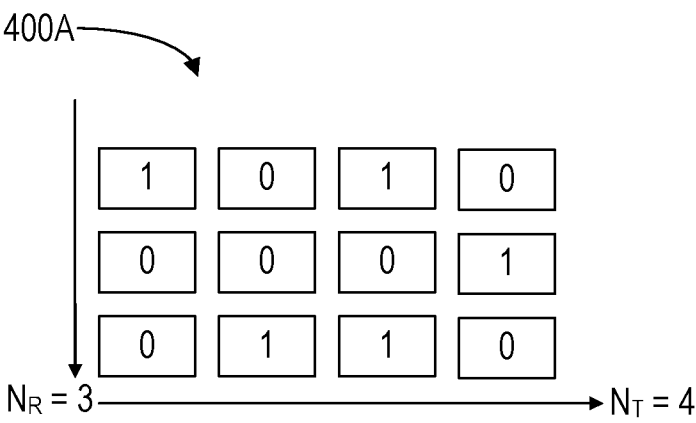


FIG. 5A

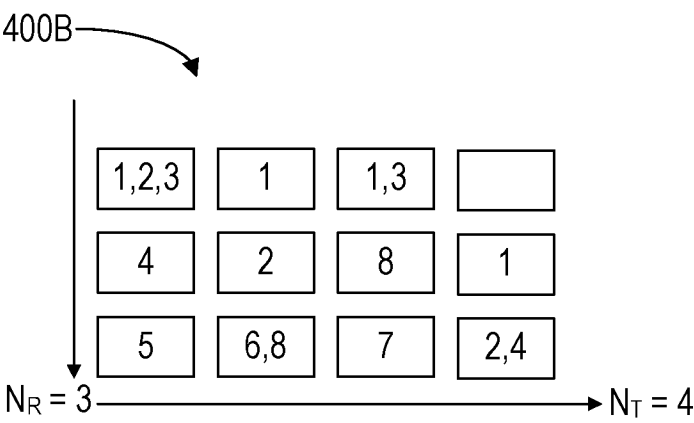


FIG. 5B

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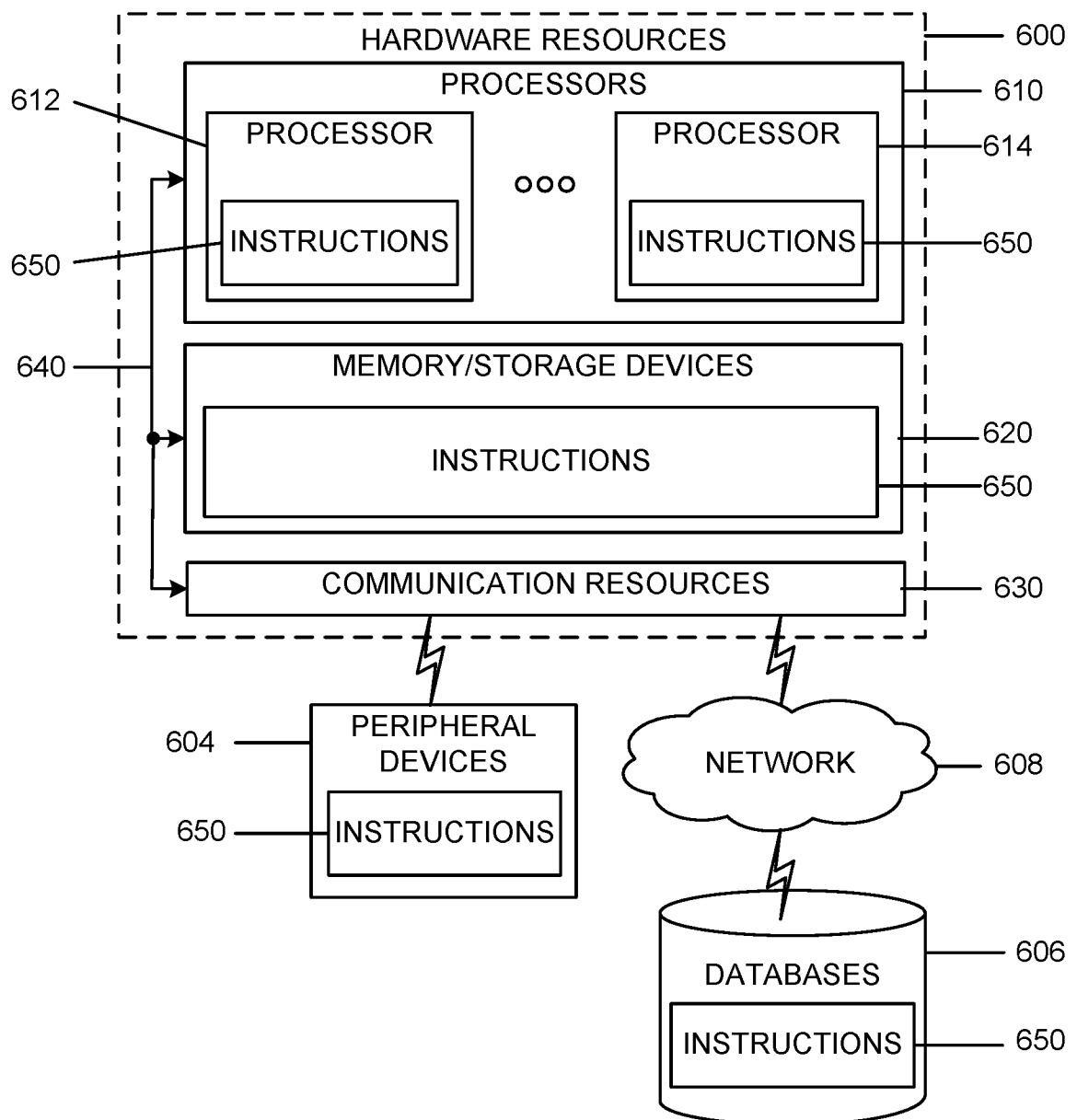


FIG. 6

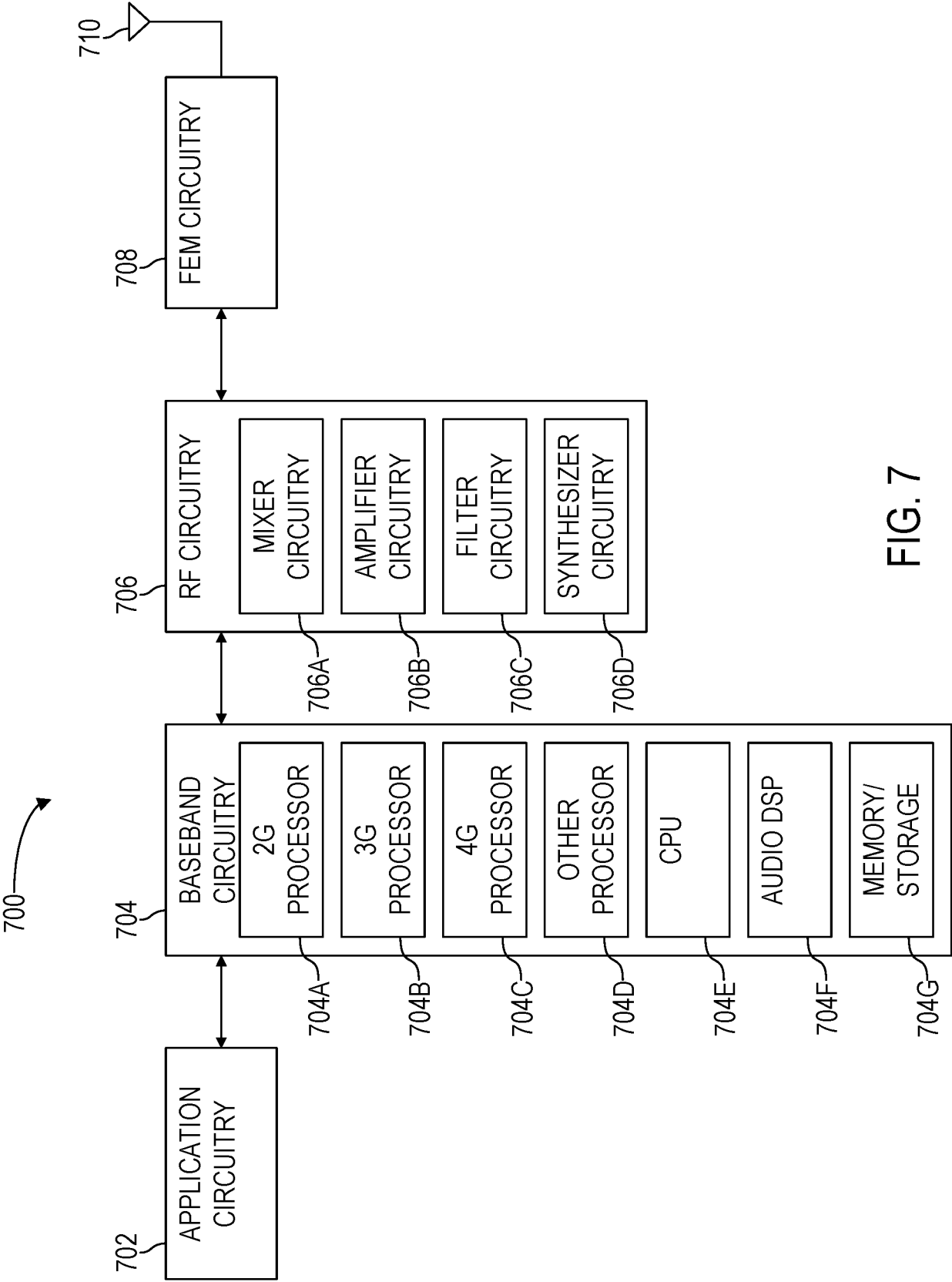


FIG. 7

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/037142

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W72/08

ADD. H04W72/04 H04W92/20

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         | EP 1 182 902 A1 (LUCENT TECHNOLOGIES INC [US]) 27 February 2002 (2002-02-27)                                                                                                                                   | 13-15                 |
| A         | paragraph [0002] - paragraph [0024]                                                                                                                                                                            | 1-12,<br>16-22        |
| A         | -----<br>EP 2 120 475 A1 (SHARP KK [JP])<br>18 November 2009 (2009-11-18)<br>figures 3-5<br>paragraph [0068] - paragraph [0083];<br>figures 3-5<br>paragraph [0098] - paragraph [0113];<br>figures 13, 14A-14C | 1-22                  |
| A         | -----<br>US 2014/177485 A1 (WANG YIPING [US] ET AL)<br>26 June 2014 (2014-06-26)<br>paragraph [0140] - paragraph [0158]<br>-----<br>-/-                                                                        | 1-22                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

"&amp;" document member of the same patent family

Date of the actual completion of the international search

21 February 2017

Date of mailing of the international search report

01/03/2017

Name and mailing address of the ISA/

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Fax: (+31-70) 340-3016

Authorized officer

Martos Riaño, Demian

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/037142

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                       |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Relevant to claim No. |
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