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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 June 2017 (29.06.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/111807 A1

(51) International Patent Classification:
H04W 52/24 (2009.01)

(21) International Application Number:
PCT/US2015/000353

(22) International Filing Date:
24 December 2015 (24.12.2015)

(25) Filing Language: English

(26) Publication Language: English

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

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

[Continued on next page]

(54) Title: UPLINK POWER CONTROL FOR INTERFERENCE MITIGATION IN FULL- DUPLEX CELLULAR NETWORKS

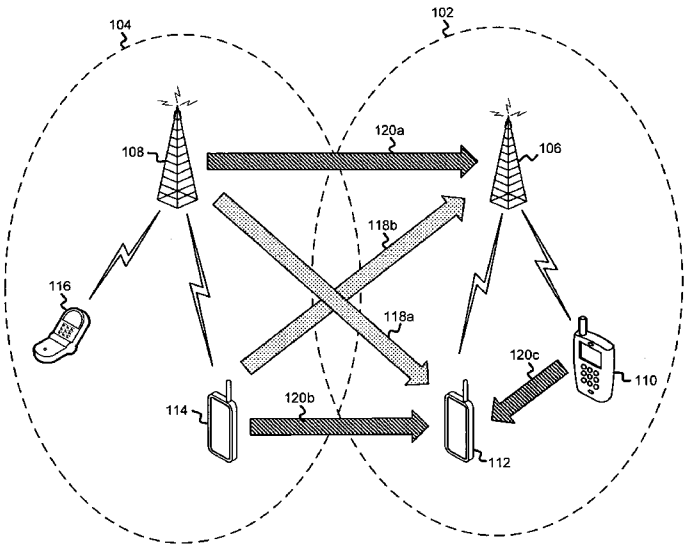


FIG. 1

(57) Abstract: Technology described herein relates to technologies for open-loop power control (OLPC) for Full-Duplex (FD) systems that takes UE-to-UE interference and eNB-to-eNB interference into account. Technology is provided whereby a trade-off between UL and DL performance is characterized as a function of a transmit power setting. Technology is provided to mitigate UE-to-UE interference and eNB-to-eNB interference in FD systems. In addition, technology is provided to identify a power setting that will substantially maximize a sum spectral efficiency (SE). In addition, different neighboring cells can set different target power levels based on current interference conditions and current uplink/downlink conditions in each cell.

WO 2017/111807 A1

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

Published:

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

UPLINK POWER CONTROL FOR INTERFERENCE MITIGATION IN FULL-DUPLEX CELLULAR NETWORKS

BACKGROUND

[0001] Wireless mobile communication technology uses various standards and protocols to transmit data between a node (e.g., a transmission station) and a wireless device (e.g., a mobile device). Some wireless devices communicate using orthogonal frequency-division multiple access (OFDMA) in a downlink (DL) transmission and single carrier frequency division multiple access (SC-FDMA) in an uplink (UL) transmission. Standards and protocols that use orthogonal frequency-division multiplexing (OFDM) for signal transmission include the third generation partnership project (3GPP) long term evolution (LTE), the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard (e.g., 802.16e, 802.16m), which is commonly known to industry groups as WiMAX (Worldwide interoperability for Microwave Access), and the IEEE 802.11 standard, which is commonly known to industry groups as WiFi.

[0002] In 3GPP radio access network (RAN) LTE systems, the node in an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) system is referred to as an eNode B (also commonly denoted as evolved Node Bs, enhanced Node Bs, eNodeBs, or eNBs), which communicates with the wireless device, known as a user equipment (UE). The downlink (DL) transmission can be a communication from the node (e.g., eNodeB) to the wireless device (e.g., UE), and the uplink (UL) transmission can be a communication from the wireless device to the node.

[0003] In LTE, data can be transmitted from the eNodeB to the UE via a physical downlink shared channel (PDSCH). A physical uplink control channel (PUCCH) can be used to acknowledge that data was received. Downlink and uplink channels or transmissions can use time-division duplexing (TDD) or frequency-division duplexing (FDD).

[0004] In many current LTE cellular systems, a Half-Duplex (HD) scheme is used such that so that transceivers do not simultaneously receive and transmit radio transmissions on the same frequency at the same time. By contrast, in Full-Duplex (FD) systems, transceivers can simultaneously transmit and receive radio transmissions on the same frequency at the same time. Thus, the spectral efficiency of FD systems can

therefore exceed the spectral efficiency of HD systems by a factor of 2 because UL and DL transmissions can occur in parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

[0006] FIG. 1 is a diagram that illustrates several types of interference that can occur between two full-duplex (FD) cells in accordance with an example;

[0007] FIG. 2 illustrates functionality of an apparatus of an enhanced small-cell evolved Node B (eNB) in a Full-Duplex (FD) cellular system in accordance with an example;

[0008] FIG. 3 illustrates functionality of an apparatus of a user equipment (UE) compatible with a Full-Duplex (FD) cellular network in accordance with an example;

[0009] FIG. 4 provides an example illustration of a wireless device in accordance with an example;

[0010] FIG. 5 provides an example illustration of a user equipment (UE) device, such as a wireless device, a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device; And

[0011] FIG. 6 illustrates a diagram of a node (e.g., eNB and/or a Serving GPRS Support Node) and a wireless device (e.g., UE) in accordance with an example.

[0012] Reference will now be made to the exemplary embodiments illustrated and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of is thereby intended.

DETAILED DESCRIPTION

[0013] Before some embodiments are disclosed and described, it is to be understood that the claimed subject matter is not limited to the particular structures, process operations, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals

in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating operations and do not necessarily indicate a particular order or sequence.

[0014] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly, but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0015] Full-Duplex (FD) cellular systems offer greater spectral efficiency than Half-Duplex (HD) cellular systems. However, since Uplink (UL) and Downlink (DL) transmissions can occur at the same time on the same frequency in FD systems, additional types of interference that do not generally occur in HD systems can occur in FD systems.

[0016] FIG. 1 is a diagram that illustrates an example of several types of interference that can occur in an FD cell 102 and an FD cell 104. A cellular base station 106 can serve the FD cell 102 and a cellular base station 108 can serve the FD cell 104. At a given time, the cellular base station can be receiving a UL transmission from a User Equipment (UE) 110 and sending a DL transmission to a UE 112. At the same time, the cellular base station 108 can be receiving a UL transmission from a UE 114 and sending a DL transmission to a UE 116.

[0017] Conventional interferences that occur in HD systems are represented by the arrows 118a–b. Arrow 118a represents conventional interference between the DL transmission from the cellular base station 108 and the DL transmission from the cellular base station 106. Arrow 118a points to the UE 112 because the quality of reception at the UE 112 of the DL transmission from the cellular base station 106 will be affected by the interference represented by the arrow 118a. Arrow 118a originates at the cellular base station 108 because the DL transmission that interferes with reception at the UE 112 is being sent from the cellular base station 108.

[0018] Arrow 118b represents conventional interference between the UL transmission from the UE 114 and the UL transmission from the UE 110. Arrow 118b points to the cellular base station 106 because the quality of reception at the cellular base station 106 of the UL transmission from the UE 110 will be affected by the interference represented by the arrow 118b. Arrow 118b originates at the UE 114 because the UL transmission that interferes with reception at the cellular base station 106 is being sent

from the UE 114. Hence, conventional interference of HD systems tends to be either between DL transmissions of two neighboring cells or between UL transmissions of two neighboring cells (though other types of interference can occur in neighboring HD cells that are asynchronously deployed).

[0019] In FD systems, additional types of interference can occur. Some of these FD types of interference (FD-interferences) are represented by the arrows 120a–c. Arrow 120a represents FD-interference between the DL transmission sent by the cellular base station 108 and the UL transmission sent by the UE 110. Arrow 120a points to the cellular base station 106 because the quality of reception at the cellular base station 106 of the UL transmission from the UE 110 will be affected by the interference represented by the arrow 120a. Arrow 120a originates at the cellular base station 108 because the DL transmission that interferes with reception at the cellular base station 106 is being sent from the cellular base station 108.

[0020] Arrow 120b represents FD-interference between the UL transmission sent by the UE 114 and the DL transmission sent by the cellular base station 106. Arrow 120b points to the UE 112 because the quality of reception at the UE 112 of the DL transmission from the cellular base station 106 will be affected by the interference represented by the arrow 120b. Arrow 120b originates at the UE 114 because the UL transmission that interferes with reception at the UE 112 is being sent from the UE 114.

[0021] Arrow 120b represents FD-interference between the UL transmission sent by the UE 114 and the DL transmission sent by the cellular base station 106. Arrow 120b points to the UE 112 because the quality of reception at the UE 112 of the DL transmission from the cellular base station 106 will be affected by the interference represented by the arrow 120b. Arrow 120b originates at the UE 114 because a UL transmission that interferes with reception at the UE 112 is being sent from the UE 114.

[0022] Arrow 120c represents FD-interference between the UL transmission sent by the UE 110 and the DL transmission sent by the cellular base station 106. Arrow 120c points to the UE 112 because the quality of reception at the UE 112 of the DL transmission from the cellular base station 106 will be affected by the interference represented by the arrow 120c. Arrow 120c originates at the UE 110 because a UL transmission that interferes with reception at the UE 112 is being sent from the UE 110.

[0023] Hence, as shown in the example of FIG. 1, FD systems can experience interference between DL and UL transmissions in addition to interference between DL

and DL transmissions and interference between UL and UL transmissions. For the purposes of this disclosure, the terms "BS-to-BS interference" and "eNB-to-eNB interference" (I_{eNB}) will be used to refer to interference between DL traffic sent from one or more cellular base stations (e.g., eNBs) and UL traffic sent to a cellular base station (whose reception of the UL traffic is affected by the eNB-to-eNB interference). In addition, the term "UE-to-UE interference" (I_{UE}) will be used to refer to interference between UL traffic sent to one or cellular base stations and DL traffic sent from a cellular base station to a UE (whose reception of the DL traffic is affected by the UE-to-UE interference).

[0024] UE-to-UE interference and eNB-to-eNB interference can be controlled by adjusting UE transmission power for the UL traffic. However, there is a trade-off: while increasing UE transmission power can improve the Signal-to-Interference Noise Ratio (SINR) for UL transmissions, it can also degrade the SINR for DL transmissions and Spectral Efficiency (SE) by increasing UE-to-UE interference.

[0025] Examples of the present disclosure provide technology for open-loop power control (OLPC) that takes UE-to-UE interference and eNB-to-eNB interference into account for FD systems. Technology is provided whereby the trade-off between UL and DL performance is characterized as a function of a transmit power setting. Technology is provided to mitigate UE-to-UE interference and eNB-to-eNB interference. In addition, technology is provided to identify a power setting that will substantially maximize a sum SE. These technologies allow different cellular base stations to set different target power levels; this can help conserve UE battery power.

[0026] In FDD LTE systems and TDD LTE systems with OLPC for UL, each eNB sets a target received power level P_0 and a fractional power control (FPC) parameter α. These parameters control the distribution of the UL Signal-to-Noise Ratio (SNR) experienced by the serving UEs in the cell. P_0 and α are typically set based on the noise power at the eNB. Each serving UE can then adjust its transmit power P_{tx} according to the following equation:

$$P_{tx} = min\{P_{max}, P_0 + 10 \cdot \log(M) + \alpha \cdot PL\},$$

where P_{max} is the maximum transmit power limit of the UE, M is the number of Physical resource Blocks (PRBs) allocated to the UE, PL is the pathloss between the UE and the eNB, and *min* indicates that the lesser of the two quantities enclosed in braces is selected. P_0 and α are typically broadcast to UEs from each eNB.

[0027] In FD systems, in addition to conventional uplink interference, each eNB experiences an additional eNB-to-eNB interference (I_{eNB}) which is relatively static. Hence, P_0 has to be increased to overcome the eNB-to-eNB interference. Moreover, I_{eNB} is different for different eNBs. Each eNB can therefore utilize and set its OLPC parameters differently based on its respective I_{eNB}. For example, an eNB with a large I_{eNB} can set a large P_0, while an eNB with a small I_{eNB} can set a small P_0.

[0028] On the other hand, in order to mitigate UE-to-UE interference (I_{UE}) in the downlink, P_0 can be decreased. Thus there is a trade-off in UL and DL performance in FD systems depending on how P_0 is set. P_0 can also be set in order to substantially maximize a sum of DL SE and UL SE, thereby taking both UE-to-UE interference and eNB-to-eNB interference into account.

Substantially Optimal Uniform Power Setting from the UL Perspective (Option 1)

[0029] For FD systems, the uplink performance degrades mainly because of eNB-to-eNB interference (which is typically stronger than the conventional uplink interference from the adjacent cells). This interference can be overcome by increasing the target power level to $B \cdot P_0$ uniformly for all eNBs, where B is a boosting factor. B can be chosen such that the UL SINR with eNB-to-NB interference is roughly same as the conventional LTE UL SINR. In order to accomplish this, B can be chosen so that the left-hand term of the following equation and the right-hand term of the following equation are approximately equal:

[0030] $\frac{P_{rx}}{I_{UL}+N_0} \approx \frac{BP_{rx}}{BI_{UL}+I_{eNB}+N_0}$, for all UL UEs in the network.

[0031] The left-hand term is the UL SINR experienced by a UE in a half-duplex system when the eNB target power level is set to P_0. The right-hand term is the UL SINR experienced by the same UE in a FD system (with added eNB-to-eNB interference) when all the eNBs set their target power level to $B \cdot P_0$. P_{Rx} is the received signal power from the UE at the serving eNB and I_{UL} is the conventional UL interference from adjacent cells (averaged over the UL users in each of the neighboring cells). If the noise term N_0 is ignored (in most deployments, uplink is interference limited), B can be set to be much greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ (e.g., by at least one decimal order of magnitude). In other words, $B \approx max_{UE}\left\{\frac{I_{eNB}}{I_{UL}}\right\}$, where max_{UE} indicates the maximum ratio over all uplink UEs in the network.

[0032] In real network, $\frac{I_{eNB}}{I_{UL}}$ for every individual UE may not be known. However, the statistics of the ratio $\frac{I_{eNB}}{I_{UL}}$ over all the UEs can be calculated from, for example, network key performance indicator (KPI) statistics. Hence, B can be set based on the statistics of the interference ratio between BS-to-BS interference and conventional UL interference. For instance, B can be set approximately equal to a value B_{UL}, where B_{UL} is a 95th percentile value based the cumulative distribution function (CDF) of the interference ratio $\frac{I_{eNB}}{I_{UL}}$. Other percentiles can be used for this same purpose, though gains in the UL performance of FD systems are marginal once B is set to a value greater than the 95th percentile.

Optimal uniform power setting from the downlink perspective (Option 2)

[0033] For FD systems, the downlink performance degrades because of the UE-to-UE interference (I_{UE}). One way to overcome this interference is to decrease the target power level to $B \cdot P_0$ uniformly for all eNBs, wherein the boosting factor B is less than 1. B can be chosen such that the DL SINR with UE-to-UE interference is roughly same as the conventional LTE DL SINR. In order to accomplish this, B can be chosen so that the left-hand term of the following equation and the right-hand term of the following equation are approximately equal:

[0034] $\frac{P_{rx}}{I_{DL}+N_0} \approx \frac{P_{rx}}{I_{DL}+BI_{UE}+N_0}$, for all DL UEs in the network.

[0035] The left-hand term is the DL SINR experienced by a UE in a half-duplex system when the eNB target power level is set to P_0. The right-hand term is the DL SINR experienced by the same UE in an FD system (with added UE-to-UE interference) when the eNBs in the FD system set their target power level as $B \cdot P_0$. P_{rx} is the received signal power from the eNB at the serving UE and I_{DL} is the conventional DL interference from adjacent cells' eNBs. Ignoring the noise term N_0 (in most deployments, downlink is interference limited), B can be set to be much less than $\frac{I_{DL}}{I_{UE}}$. In other words, $B \approx \min_{UE}\left\{\frac{I_{DL}}{I_{UE}}\right\}$, where $\min_{UE}$ indicates the minimum ratio over all downlink UEs in the network.

[0036] In a practical network, $\frac{I_{DL}}{I_{UE}}$ may not be known for all UEs. However, the statistics of the ratio $\frac{I_{DL}}{I_{UE}}$ over all the UEs can be calculated from, for example, network

KPI statistics. Hence, B can be set based on the statistics of the interference ratio conventional DL interference and UE-to-UE interference. For instance, B can be set approximately equal to a value B_{DL}, where B_{DL} is a 5th percentile value based the cumulative distribution function (CDF) of the interference ratio $\frac{I_{DL}}{I_{UE}}$. Other percentiles can be used for this same purpose, though gains in the DL performance of FD systems are marginal once B is set to a value less than the 5th percentile.

[0037] For both option 1 and option 2, the setting of B_{DL} and B_{UL} can rely on applicable desired results for UL performance and DL performance. Specifically, for $B_{DL} < B < B_{UL}$, there is a trade-off between the UL and DL performance. If $B_{DL} > B_{UL}$, there is a substantially optimal power setting of $B = 0.5(B_{DL} + B_{UL})$ for which both the UE-to-UE interference and the eNB-to-eNB interference are almost completely mitigated.

[0038] Although the notation used to describe option 1 and option 2 suggests that all eNbs in the FD network are set to the same initial target power before adjustments are made using the boosting factor, options 1 and 2 are not limited to scenarios where all eNbs have the same original target receive power. The initial target powers of different eNBs can be set differently, though the criterion of the adjustment based on new BS-to-BS interference can still be applied. In addition, options 1 and 2 do not necessitate additional signaling. The resulting target power can be broadcast to the UE.

[0039] **Adaptive power setting from the uplink perspective (Option 3a)**

[0040] Since the eNB-to-eNB interference (I_{eNB}) is different for different eNBs, the boosting factor B can be set differently for different eNB based on each UEs respective I_{eNB} level. I_{eNB} can be treated as noise and each eNB can set B so as to retain the respective eNB's uplink SNR. In order to accomplish this, B can be chosen to be a value B_{eNB} so that the left-hand term of the following equation and the right-hand term of the following equation are approximately equal:

[0041] $$\frac{P_{rx}}{N_0} = \frac{B_{eNB}P_{rx}}{I_{eNB}+N_0}$$

[0042] P_{Rx} is the received signal power from the UE at the serving eNB, while N_0 is the noise term. The left-hand term is the UL SNR experienced by UE in an HD system when the eNB sets a target received power level P_0. The right-hand term is the UL SNR of the same UE in an FD system with eNB-to-eNB interference when the eNB sets a target received power level of $B_{eNB}P_0$. Thus, $B_{eNB} = 1 + \frac{I_{eNB}}{N_0}$. Since the maximum B of

B_{UL} is generally sufficient to get close to the desired UL performance, each eNB can use an adaptive power control setting such that the respective eNB's target power level is set to $B_{eNB}P_0$, where $B_{eNB} = \max\left\{1 + \frac{I_{eNB}}{N_0}, B_{UL}\right\}$ and *max* indicates that the maximum of the two terms in braces is selected.

[0043] For this setting to be applied, I_{eNB} can be measured at each eNB using an eNB-eNB reference signal. One advantage of option 3a compared to option 1 is that eNBs with smaller I_{eNB} values will set a smaller target received power level. Hence the corresponding serving UL UEs can transmit with lower power and UE battery power can be saved.

Adaptive power setting from the uplink perspective (Option 3b)

[0044] In option 3b, each eNB in an FD system can adjust its respective B such that the UL SINR (as opposed to the UL SNR) is retained. In order to accomplish this, B can be chosen to be a value B_{eNB} so that the left-hand term of the following equation and the right-hand term of the following equation are approximately equal:

$$\frac{P_{rx}}{I_{UL}+N_0} = \frac{B_{eNB}P_{rx}}{I_{UL}+I_{eNB}+N_0}$$

[0045] The left-hand term is the UL SINR experienced by a UE in the HD system, when the eNB sets a target received power level P_0. The right-hand term is the UL SINR of the same UE in an FD system with eNB-to-eNB interference when the eNB sets a target received power level of $B_{eNB}P_0$. For simplicity in this example, it is assumed that all other eNBs use the same target power level of P_0. Thus, $B_{eNB} = 1 + \frac{I_{eNB}}{I_{UL}+N_0}$. Taking the maximum B of B_{UL}into account, each eNB can use an adaptive power control setting such that the respective eNB's target power level is set to $B_{eNB}P_0$, where $B_{eNB} = \max\left\{1 + \frac{I_{eNB}}{I_{UL}+N_0}, B_{UL}\right\}$ and *max* indicates that the maximum of the two terms in braces is selected. To apply this adaptive power control setting, I_{eNB} and I_{UL} should be known at each eNB. As in option 3a, this adaptive target power level setting saves UE battery power.

Adaptive power setting maximizing the uplink and downlink sum performance (Option 4)

[0046] In option 4, the receive target power level can be set to substantially maximize the sum spectrum efficiency (SE) in the downlink and uplink. The sum of

downlink SE and uplink SE in an LTE system (with one DL and UL UE associated with each eNB) can be represented as

$$\log\left(1+\frac{P_{UL}}{I_{UL}+N_0}\right)+\log\left(1+\frac{P_{DL}}{I_{DL}+N_0}\right).$$

P_{DL} is the received signal power in the downlink. P_{UL} is the received signal power in the uplink when the target received signal power is set to P_0 by the eNB.

The sum of the downlink SE and the uplink SE in an FD system in the presence of eNB-to-eNB interference (I_{eNB}) and UE-to-UE interference (I_{UE}), with the eNB target received power level set as $B \cdot P_0$, is given by

$$\log\left(1+\frac{P_{UL}}{BI_{UL}+I_{eNB}+N_0}\right)+\log\left(1+\frac{P_{DL}}{I_{DL}+BI_{UE}+N_0}\right).$$

B can be chosen so to substantially maximize this expression. Ignoring the noise terms and assuming the SINR is greater than -1decibels (dB), this expression reduces to

$$\log\left(\frac{P_{UL}}{BI_{UL}+I_{eNB}}\right)+\log\left(\frac{P_{DL}}{I_{DL}+BI_{UE}}\right).$$

When this reduced expression is differentiated with respect to B and set equal to zero, the get the solution to maximize the sum SE is

$$B=\sqrt{\frac{I_{eNB}}{I_{UL}}\frac{I_{DL}}{I_{UE}}}.$$

For option 4 to be applied, all interference terms should be known, including the BS-to-BS interference, the UE-to-UE interference, the conventional DL interference, and the conventional UL interference. An appropriate option can be chosen from the options 1–4 based on the deployment scenario, the availability of the interference terms, and desired system resultsfor uplink and downlink performance.

[0047] FIG. 2 illustrates functionality 200 of an apparatus of an enhanced small-cell evolved Node B (eNB) in a Full-Duplex (FD) cellular system in accordance with an example. The functionality 200 can be implemented as a method or the functionality can be executed as instructions on a machine (e.g., by one or more processors), where the instructions are included on at least one non-transitory computer-readable storage medium.

[0048] As in block 210, circuitry at the eNB (e.g., comprising one or more processors and memory) can be configured to identify an initial target power level P_0.

[0049] As in block 220, the circuitry at the eNB can be further configured to send the initial target power level P_0 to one or more user equipments (UEs) in a cell of the eNB.

[0050] As in block 230, the circuitry at the eNB can be further configured to identify one or more FD-interference values including one or more of: an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, or a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources.

[0051] If the circuitry at the eNB is configured to determine the eNB-to-eNB interference value I_{eNB}, the circuitry can be further configured to identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; and determine the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

[0052] Alternatively, the circuitry at the eNB can be configured to set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[0053] Alternatively, the circuitry at the eNB can be configured to set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and

determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[0054] The circuitry at the eNB can also be configured to identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between the DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and the second interference value quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE; determine a 95th-percentile ratio for the plurality of ratios; and determine the boosting factor B by setting the boosting factor to the 95th-percentile ratio.

[0055] If the circuitry at the eNB is configured to identify the UE-to-UE interference value I_{UE}, the circuitry can be further configured to identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determine the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

[0056] The circuitry at the eNB can be further configured to identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and the second interference value quantifies an interference between additional UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the additional UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources; determine a 5th-

percentile ratio for the plurality of ratios; and determine the boosting factor B by setting the boosting factor to the 5th-percentile ratio.

[0057] If the circuitry at the UE is configured to identify both the eNB-to-eNB interference value I_{eNB} and the UE-to-UE interference value I_{UE}, then the circuitry can be further configured to identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determine the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

[0058] As in block 240, the circuitry at the eNB can be further configured to determine a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values that are identified.

[0059] As in block 250, the circuitry at the eNB can be further configured to determine an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0.

[0060] As in block 260, the circuitry at the eNB can be further configured to

[0061] The circuitry at the eNB can be further configured to send the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

[0062] FIG. 3 illustrates functionality 300 of an apparatus of a user equipment (UE) compatible with a Full-Duplex (FD) cellular network in accordance with an example. The functionality 300 can be implemented as a method or the functionality can be executed as instructions on a machine (e.g., by one or more processors), where the instructions are included on at least one non-transitory computer-readable storage medium.

[0063] As in block 310, circuitry at the UE (e.g., comprising one or more processors and memory) can be configured to measure a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between uplink (UL) traffic sent from other UEs and downlink (DL) traffic sent to the UE from an evolved Node B (eNB), wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources.

[0064] As in block 320, the circuitry at the UE can be further configured to send the UE-to-UE interference value to the eNB.

[0065] As in block 330, the circuitry at the UE can be further configured to receive, from the eNB, a target power level P_0.

[0066] The circuitry at the UE can be further configured to receive a fractional power control (FPC) parameter α from the eNB.

[0067] The circuitry at the UE can be further configured to set a transmit power P_{tx} of the UE to either an upper transmit power limit P_{max} of the UE or $P_0 + 10 \cdot \log(M) + \alpha \cdot PL$, whichever is greater, wherein M is a number of Physical Resource Blocks (PRBs) allocated to the UE by the eNB and PL is a path loss between the UE and the eNB. The base of the logarithm can be 2, 10, or e, for example.

[0068] The circuitry at the UE can be further configured to measure a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from one more neighboring eNBs and the DL traffic sent to the UE from the eNB; and send the conventional DL interference value I_{DL} to the eNB.

[0069] FIG. 4 provides an example illustration of a mobile device, such as a user equipment (UE), a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. The mobile device can include one or more antennas configured to communicate with a node, macro node, low power node (LPN), or, transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband processing unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), or other type of wireless wide area network (WWAN) access point. The mobile device can be configured to communicate using at least one wireless communication standard such as, but not limited to, 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The mobile device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The mobile device can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN.

[0070] The mobile device can also comprise a wireless modem. The wireless modem can comprise, for example, a wireless radio transceiver and baseband circuitry (e.g., a baseband processor). The wireless modem can, in one example, modulate signals

that the mobile device transmits via the one or more antennas and demodulate signals that the mobile device receives via the one or more antennas.

[0071] The mobile device can include a storage medium. In one aspect, the storage medium can be associated with and/or communication with the application processor, the graphics processor, the display, the non-volatile memory port, and/or internal memory. In one aspect, the application processor and graphics processor are storage mediums.

[0072] FIG. 4 also provides an illustration of a microphone and one or more speakers that can be used for audio input and output from the mobile device. The display screen can be a liquid crystal display (LCD) screen, or other type of display screen such as an organic light emitting diode (OLED) display. The display screen can be configured as a touch screen. The touch screen can use capacitive, resistive, or another type of touch screen technology. An application processor and a graphics processor can be coupled to internal memory to provide processing and display capabilities. A non-volatile memory port can also be used to provide data input/output options to a user. The non-volatile memory port can also be used to expand the memory capabilities of the mobile device. A keyboard can be integrated with the mobile device or wirelessly connected to the wireless device to provide additional user input. A virtual keyboard can also be provided using the touch screen.

[0073] FIG. 5 provides an example illustration of a user equipment (UE) device 500, such as a wireless device, a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. The UE device 500 can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access point. The UE device 500 can be configured to communicate using at least one wireless communication standard such as, but not limited to, 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The UE device 500 can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The UE device 500 can communicate in a wireless

local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN.

[0074] In some embodiments, the UE device 500 may include application circuitry 502, baseband circuitry 504, Radio Frequency (RF) circuitry 506, front-end module (FEM) circuitry 508 and one or more antennas 510, coupled together at least as shown.

[0075] The application circuitry 502 may include one or more application processors. For example, the application circuitry 502 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 (e.g., storage medium 512) and may be configured to execute instructions stored in the memory/storage (e.g., storage medium 512) to enable various applications and/or operating systems to run on the system.

[0076] The baseband circuitry 504 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 504 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 506 and to generate baseband signals for a transmit signal path of the RF circuitry 506. Baseband processing circuity 504 may interface with the application circuitry 502 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 506. For example, in some embodiments, the baseband circuitry 504 may include a second generation (2G) baseband processor 504a, third generation (3G) baseband processor 504b, fourth generation (4G) baseband processor 504c, and/or other baseband processor(s) 504d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 504 (e.g., one or more of baseband processors 504a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 506. 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 504 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of

the baseband circuitry 504 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.

[0077] In some embodiments, the baseband circuitry 504 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) 504e of the baseband circuitry 504 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 may include one or more audio digital signal processor(s) (DSP) 504f. The audio DSP(s) 504f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 504 and the application circuitry 502 may be implemented together such as, for example, on a system on a chip (SOC).

[0078] In some embodiments, the baseband circuitry 504 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 504 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), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 504 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0079] The RF circuitry 506 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 506 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 506 may include a receive signal path which may include circuitry to down-convert RF signals received

from the FEM circuitry 508 and provide baseband signals to the baseband circuitry 504. RF circuitry 506 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 504 and provide RF output signals to the FEM circuitry 508 for transmission.

[0080] In some embodiments, the RF circuitry 506 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 506 may include mixer circuitry 506a, amplifier circuitry 506b and filter circuitry 506c. The transmit signal path of the RF circuitry 506 may include filter circuitry 506c and mixer circuitry 506a. RF circuitry 506 may also include synthesizer circuitry 506d for synthesizing a frequency for use by the mixer circuitry 506a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 506a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 508 based on the synthesized frequency provided by synthesizer circuitry 506d. The amplifier circuitry 506b may be configured to amplify the down-converted signals and the filter circuitry 506c 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 504 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although other types of baseband signals may be used . In some embodiments, mixer circuitry 506a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0081] In some embodiments, the mixer circuitry 506a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 506d to generate RF output signals for the FEM circuitry 508. The baseband signals may be provided by the baseband circuitry 504 and may be filtered by filter circuitry 506c. The filter circuitry 506c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0082] In some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may include two or more mixers and may be arranged for quadrature down-conversion and/or up-conversion respectively. In some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a 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 506a of the receive signal path and the mixer circuitry 506a may be arranged for direct down-conversion and/or direct up-conversion, respectively. In some embodiments, the mixer circuitry 506a of the receive signal path and the mixer circuitry 506a of the transmit signal path may be configured for super-heterodyne operation.

[0083] 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 alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 506 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 504 may include a digital baseband interface to communicate with the RF circuitry 506.

[0084] 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.

[0085] In some embodiments, the synthesizer circuitry 506d may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 506d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0086] The synthesizer circuitry 506d may be configured to synthesize an output frequency for use by the mixer circuitry 506a of the RF circuitry 506 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 506d may be a fractional N/N+1 synthesizer.

[0087] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although the frequency input may also be provided by another type of device. Divider control input may be provided by either the baseband circuitry 504 or the applications processor 502 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 502.

[0088] Synthesizer circuitry 506d of the RF circuitry 506 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 Nd equal packets of phase, where Nd 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.

[0089] In some embodiments, synthesizer circuitry 506d 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 LO frequency (fLO). In some embodiments, the RF circuitry 506 may include an IQ/polar converter.

[0090] FEM circuitry 508 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 510, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 506 for further processing. FEM circuitry 508 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 506 for transmission by one or more of the one or more antennas 510.

[0091] In some embodiments, the FEM circuitry 508 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 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 506). The transmit signal path of the FEM circuitry 508 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 506), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 510.

[0092] In some embodiments, the UE device 500 may include additional elements such as, for example, memory/storage, display (e.g., touch screen), camera, antennas, keyboard, microphone, speakers, sensor, and/or input/output (I/O) interface.

[0093] FIG. 6 illustrates a diagram 600 of a node 610 (e.g., eNB and/or a Serving GPRS Support Node) and a wireless device 620 (e.g., UE) in accordance with an example. The node can include a base station (BS), a Node B (NB), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a remote radio unit (RRU), or a central processing module (CPM). In one aspect, the node can be a Serving GPRS Support Node. The node 610 can include a node device 612. The node device 612 or the node 610 can be configured to communicate with the wireless device 620. The node device 612 can be configured to implement technologies described herein. The node device 612 can include a processing module 614 and a transceiver module 616. In one aspect, the node device 612 can include the transceiver module 616 and the processing module 614 forming a circuitry for the node 610. In one aspect, the transceiver module 616 and the processing module 614 can form a circuitry of the node device 612. The processing module 614 can include one or more processors and memory. In one embodiment, the processing module 622 can include one or more application processors. The transceiver module 616 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 616 can include a baseband processor.

[0094] The wireless device 620 can include a transceiver module 624 and a processing module 622. The processing module 622 can include one or more processors and memory. In one embodiment, the processing module 622 can include one or more application processors. The transceiver module 624 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 624 can include a baseband processor. The wireless device 620 can be configured to implement technologies described herein. The node 610 and the wireless devices 620 can also include one or more storage mediums, such as the transceiver module 616, 624 and/or the processing module 614, 622.

Examples

[0095] The following examples pertain to specific embodiments and point out specific features, elements, or steps that can be used or otherwise combined in achieving such embodiments.

[0096] Example 1 includes an apparatus of an evolved Node B (eNB) in a Full-Duplex (FD) cellular system, the apparatus comprising one or more processors and memory configured to: identify an initial target power level P_0; signal transceiver circuitry at the eNB to send the initial target power level P_0 to one or more user equipments (UEs) in a cell of the eNB; identify one or more FD-interference values including one or more of: an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, or a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources; determine a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values that are identified; determine an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0; and signal the transceiver circuitry at the eNB to send the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

[0097] Example 2 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify the eNB-to-eNB interference value I_{eNB}; identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; determine the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

[0098] Example 3 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between the DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and the second interference value quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE; determine a 95th-percentile ratio for the plurality of ratios; and determine the boosting factor B by setting the boosting factor to the 95th-percentile ratio.

[0099] Example 4 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify the UE-to-UE interference value I_{UE}; identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determine the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

[00100] Example 5 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and the second interference value quantifies an interference between additional UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the additional UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources; determine a 5th-

percentile ratio for the plurality of ratios; and determine the boosting factor B by setting the boosting factor to the 5th-percentile ratio.

[00101] Example 6 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify the eNB-to-eNB interference value I_{eNB}; identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00102] Example 7 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify the eNB-to-eNB interference value I_{eNB}; identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00103] Example 8 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to: identify the eNB-to-eNB interference value I_{eNB}; identify the UE-to-UE interference value I_{UE}; identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determine the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

[00104] Example 9 includes an apparatus of a user equipment (UE) compatible with a Full-Duplex (FD) cellular network, the apparatus comprising one or more processors and memory configured to: measure a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between uplink (UL) traffic sent from other UEs and downlink (DL) traffic sent to the UE from an evolved Node B (eNB), wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources; signal transceiver circuitry at the UE to send the UE-to-UE interference value to the eNB; and identify a target power level P_0 received from the eNB.

[00105] Example 10 includes the apparatus of example 9, wherein the one or more processors and memory are further configured to identify a fractional power control (FPC) parameter α received from the eNB,.

[00106] Example 11 includes the apparatus of example 10, wherein the one or more processors and memory are further configured to set a transmit power P_{tx} of the UE to either an upper transmit power limit P_{max} of the UE or $P_0 + 10 \cdot \log(M) + \alpha \cdot PL$, whichever is greater, wherein M is a number of Physical Resource Blocks (PRBs) allocated to the UE by the eNB and PL is a path loss between the UE and the eNB.

[00107] Example 12 includes the apparatus of example 9, 10, or 11, wherein the one or more processors and memory are further configured to: measure a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from one more neighboring eNBs and the DL traffic sent to the UE from the eNB; and signal the transceiver circuitry at the UE to send the conventional DL interference value I_{DL} to the eNB.

[00108] Example 13 includes a non-transitory or transitory computer-readable storage medium containing instructions thereon which, when executed by one or more processors, perform the following: identifying an initial target power level P_0; signaling transceiver circuitry at an eNB to send the initial target power level P_0 to one or more user equipments (UEs) in a cell of an evolved Node B (eNB) of a Full-Duplex (FD) cellular network; identifying one or more FD-interference values; determining a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values; determining an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0; and signaling transceiver circuitry at the eNB to send the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

[00109] Example 14 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; determining the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

[00110] Example 15 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and the second interference value quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE; determining a 95^{th}-percentile ratio for the plurality of ratios; and determining the boosting factor B by setting the boosting factor to the 95^{th}-percentile ratio.

[00111] Example 16 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from

the eNB use overlapping time resources and overlapping frequency resources ,and wherein the FD-interference values comprise the UE-to-UE interference value I_{UE}; identifying a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determining the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

[00112] Example 17 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between DL traffic sent from one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and the second interference value quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources; determining a 5^{th}-percentile ratio for the plurality of ratios; and determining the boosting factor B by setting the boosting factor to the 5^{th}-percentile ratio.

[00113] Example 18 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; setting a UL boost factor B_{UL} to a value that is greater

than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00114] Example 19 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; setting a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00115] Example 20 includes the computer-readable medium of example 13, further containing instructions thereon which, when executed by one or more processors, perform the following: identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources ,and wherein the FD-interference values comprise the UE-to-UE interference

value I_{UE}; identifying a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; identifying a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and determining the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

[00116] Example 21 includes a means for setting a power level in a Full-Duplex (FD) cellular system, the means comprising: a means for identifying an initial target power level P_0; a means for sending the initial target power level P_0 to one or more user equipments (UEs) in a cell of an evolved Node B (eNB) of a Full-Duplex (FD) cellular network; a means for identifying one or more FD-interference values; a means for determining a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values; a means for determining an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0; and a means for sending the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

[00117] Example 22 includes the means of example 21, further comprising: a means for identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; a means for identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; a means for determining the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

[00118] Example 23 includes the means of example 21, further comprising: a means for identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference

value for the respective UE; the first interference value quantifies an interference between DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and the second interference value quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE; a means for determining a 95^{th}-percentile ratio for the plurality of ratios; and a means for determining the boosting factor B by setting the boosting factor to the 95^{th}-percentile ratio.

[00119] Example 24 includes the means of example 21, further comprising: a means for identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources ,and wherein the FD-interference values comprise the UE-to-UE interference value I_{UE}; a means for identifying a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and a means for determining the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

[00120] Example 25 includes the means of example 21, further comprising: a means for identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein: each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE; the first interference value quantifies an interference between DL traffic sent from one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and the second interference value quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources; a means for determining

a 5th-percentile ratio for the plurality of ratios; and a means for determining the boosting factor B by setting the boosting factor to the 5th-percentile ratio.

[00121] Example 26 includes the means of example 21, further comprising: a means for identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; a means for identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; a means for setting a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; a means for setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and a means for determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00122] Example 27 includes the means of example 21, further comprising: a means for identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; a means for identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; a means for setting a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude; a means for setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and a means for determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

[00123] Example 28 includes the means of example 21, further comprising: a means for identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB}; a means for identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources ,and wherein the FD-interference values comprise the UE-to-UE interference value I_{UE}; a means for identifying a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; a means for identifying a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and a means for determining the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

[00124] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. A non-transitory computer readable storage medium can be a computer readable storage medium that does not include signal. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive,

magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

[00125] 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.

[00126] While the flowcharts presented for this technology may imply a specific order of execution, the order of execution may differ from what is illustrated. For example, the order of two more blocks may be rearranged relative to the order shown. Further, two or more blocks shown in succession may be executed in parallel or with partial parallelization. In some configurations, one or more blocks shown in the flow chart may be omitted or skipped. Any number of counters, state variables, warning semaphores, or messages may be added to the logical flow for enhanced utility, accounting, performance, measurement, troubleshooting, or other purposes.

[00127] As used herein, the word "or" indicates an inclusive disjunction. For example, as used herein, the phrase "A or B" represents an inclusive disjunction of exemplary conditions A and B. Hence, "A or B" is false only if both condition A is false and condition B is false. When condition A is true and condition B is also true, "A or B" is also true. When condition A is true and condition B is false, "A or B" is true. When condition B is true and condition A is false, "A or B" is true. In other words, the term

"or," as used herein, should not be construed as an exclusive disjunction. The term "xor" is used where an exclusive disjunction is intended.

[00128] As used herein, the term processor can include general-purpose processors, specialized processors such as VLSI, FPGAs, and other types of specialized processors, as well as base-band processors used in transceivers to send, receive, and process wireless communications.

[00129] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module can be implemented as a hardware circuit (e.g., an application-specific integrated circuit (ASIC)) comprising custom VLSI circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module can also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00130] Modules can also be implemented in software for execution by various types of processors. An identified module of executable code can, for instance, comprise one or more physical or logical blocks of computer instructions, which can, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module does not have to be physically located together, but can comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00131] Indeed, a module of executable code can be a single instruction, or many instructions, and can even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data can be identified and illustrated herein within modules, and can be embodied in any suitable form and organized within any suitable type of data structure. The operational data can be collected as a single data set, or can be distributed over different locations including over different storage devices, and can exist, at least partially, merely as electronic signals on a system or network. The modules can be passive or active, including agents operable to perform desired functions.

[00132] As used herein, the term "processor" can include general purpose processors, specialized processors such as VLSI, FPGAs, and other types of specialized

processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00133] Reference throughout this specification to "an example" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment. Thus, appearances of the phrases "in an example" in various places throughout this specification are not necessarily all referring to the same embodiment.

[00134] As used herein, a plurality of items, structural elements, compositional elements, and/or materials can be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and examples can be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous.

[00135] Furthermore, the described features, structures, or characteristics can be combined in any suitable manner in one or more embodiments. In the foregoing description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of some embodiments. One skilled in the relevant art will recognize, however, that the some embodiments can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of different embodiments.

[00136] While the forgoing examples are illustrative of the principles used in various embodiments in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the embodiments. Accordingly, it is not intended that the claimed matter be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of an evolved Node B (eNB) in a Full-Duplex (FD) cellular system, the apparatus comprising one or more processors and memory configured to:

identify an initial target power level P_0;

signal transceiver circuitry at the eNB to send the initial target power level P_0 to one or more user equipments (UEs) in a cell of the eNB;

identify one or more FD-interference values including one or more of:

an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, or

a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources;

determine a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values that are identified;

determine an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0; and

signal the transceiver circuitry at the eNB to send the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

2. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify the eNB-to-eNB interference value I_{eNB};

identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB; and

determine the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

3. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein:

each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE;

the first interference value quantifies an interference between the DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and

the second interference value quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE;

determine a 95th-percentile ratio for the plurality of ratios; and

determine the boosting factor B by setting the boosting factor B to the 95th-percentile ratio.

4. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify the UE-to-UE interference value I_{UE};

identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and

determine the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

5. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein:

each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE;

the first interference value quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and

the second interference value quantifies an interference between additional UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the additional UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources;

determine a 5^{th}-percentile ratio for the plurality of ratios; and

determine the boosting factor B by setting the boosting factor B to the 5^{th}-percentile ratio.

6. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify the eNB-to-eNB interference value I_{eNB};

identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude;

set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and

determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

7. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify the eNB-to-eNB interference value I_{eNB};

identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

set a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude;

set an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and

determine the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

8. The apparatus of claim 1, wherein the one or more processors and memory are further configured to:

identify the eNB-to-eNB interference value I_{eNB};

identify the UE-to-UE interference value I_{UE};

identify a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

identify a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and

determine the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

9. An apparatus of a user equipment (UE) compatible with a Full-Duplex (FD) cellular network, the apparatus comprising one or more processors and memory configured to:

measure a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between uplink (UL) traffic sent from other UEs and downlink (DL) traffic sent to the UE from an evolved Node B (eNB), wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources;

signal transceiver circuitry at the UE to send the UE-to-UE interference value to the eNB; and

identify a target power level P_0 received from the eNB.

10. The apparatus of claim 9, wherein the one or more processors and memory are further configured to identify a fractional power control (FPC) parameter α received from the eNB.

11. The apparatus of claim 10, wherein the one or more processors and memory are further configured to set a transmit power P_{tx} of the UE to either an upper transmit power limit P_{max} of the UE or $P_0 + 10 \cdot \log(M) + \alpha \cdot PL$, whichever is greater, wherein M is a number of Physical Resource Blocks (PRBs) allocated to the UE by the eNB and PL is a path loss between the UE and the eNB.

12. The apparatus of claim 9, 10, or 11, wherein the one or more processors and memory are further configured to:

measure a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from one more neighboring eNBs and the DL traffic sent to the UE from the eNB; and

signal the transceiver circuitry at the UE to send the conventional DL interference value I_{DL} to the eNB.

13. A computer-readable storage medium containing instructions thereon which, when executed by one or more processors, perform the following:

identifying an initial target power level P_0;

signaling transceiver circuitry at the eNB to send the initial target power level P_0 to one or more user equipments (UEs) in a cell of an evolved Node B (eNB) of a Full-Duplex (FD) cellular network;

identifying one or more FD-interference values;

determining a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values;

determining an adjusted target power level $B \cdot P_0$ that equals the boosting factor B multiplied by the initial target power level P_0; and

signaling the transceiver circuitry at the eNB to send the adjusted target power level $B \cdot P_0$ to the one or more UEs in the cell.

14. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB};

identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

determining the boosting factor B by calculating a quotient $\frac{I_{eNB}}{I_{UL}}$ and setting the boosting factor B to a value that is greater than the quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude.

15. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the UE, wherein:

each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE;

the first interference value quantifies an interference between DL traffic sent from one or more neighboring eNBs and UL traffic sent to the eNB from the respective UE, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB from the respective UE use overlapping time resources and overlapping frequency resources; and

the second interference value quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB from the respective UE;

determining a 95th-percentile ratio for the plurality of ratios; and

determining the boosting factor B by setting the boosting factor to the 95th-percentile ratio.

16. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency

resources ,and wherein the FD-interference values comprise the UE-to-UE interference value I_{UE};

identifying a conventional DL interference value I_{DL} that quantifies an interference between DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and

determining the boosting factor B by calculating a quotient $\frac{I_{DL}}{I_{UE}}$ and setting the boosting factor B to a value that is less than the quotient $\frac{I_{DL}}{I_{UE}}$ by at least one decimal order of magnitude.

17. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying a plurality of ratios for a plurality of user equipments (UEs) in the cell of the eNB, wherein:

each ratio in the plurality of ratios is a quotient of a first interference value for a respective UE in the plurality of UEs and a second interference value for the respective UE;

the first interference value quantifies an interference between DL traffic sent from one more neighboring eNBs and DL traffic sent from the eNB to the respective UE; and

the second interference value quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE, wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB to the respective UE use overlapping time resources and overlapping frequency resources;

determining a 5^{th}-percentile ratio for the plurality of ratios; and

determining the boosting factor B by setting the boosting factor to the 5^{th}-percentile ratio.

18. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB};

identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

setting a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude;

setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and

determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

19. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB};

identifying a conventional UL interference value I_{UL} that quantifies an interference between UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

setting a UL boost factor B_{UL} to a value that is greater than a quotient $\frac{I_{eNB}}{I_{UL}}$ by at least one decimal order of magnitude;

setting an eNB boost factor B_{eNB} to a value equal to an expression $1 + \frac{I_{eNB}}{I_{UL}+N_0}$, wherein N_0 quantifies a level of signal noise of the UL traffic sent to the eNB; and

determining the boosting factor B by setting the boosting factor B to either B_{UL} or B_{eNB}, whichever is greater.

20. The computer-readable medium of claim 13, further containing instructions thereon which, when executed by one or more processors, perform the following:

identifying an eNB-to-eNB interference value I_{eNB} that quantifies an interference between downlink (DL) traffic sent from one or more neighboring eNBs and uplink (UL) traffic sent to the eNB, wherein the DL traffic sent from the one or more neighboring eNBs and the UL traffic sent to the eNB use overlapping time resources and overlapping frequency resources, and wherein the FD-interference values comprise the eNB-to-eNB interference value I_{eNB};

identifying a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between UL traffic sent to the eNB or the one or more neighboring eNBs and DL traffic sent from the eNB, wherein the UL traffic sent to the eNB or the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources ,and wherein the FD-interference values comprise the UE-to-UE interference value I_{UE};

identifying a conventional UL interference value I_{UL} that quantifies an interference between additional UL traffic sent to the one more neighboring eNBs and the UL traffic sent to the eNB;

identifying a conventional DL interference value I_{DL} that quantifies an interference between additional DL traffic sent from the one more neighboring eNBs and the DL traffic sent from the eNB; and

determining the boosting factor B by setting the boosting factor B equal to an expression $\sqrt{\frac{I_{eNB} \cdot I_{DL}}{I_{UL} \cdot I_{UE}}}$.

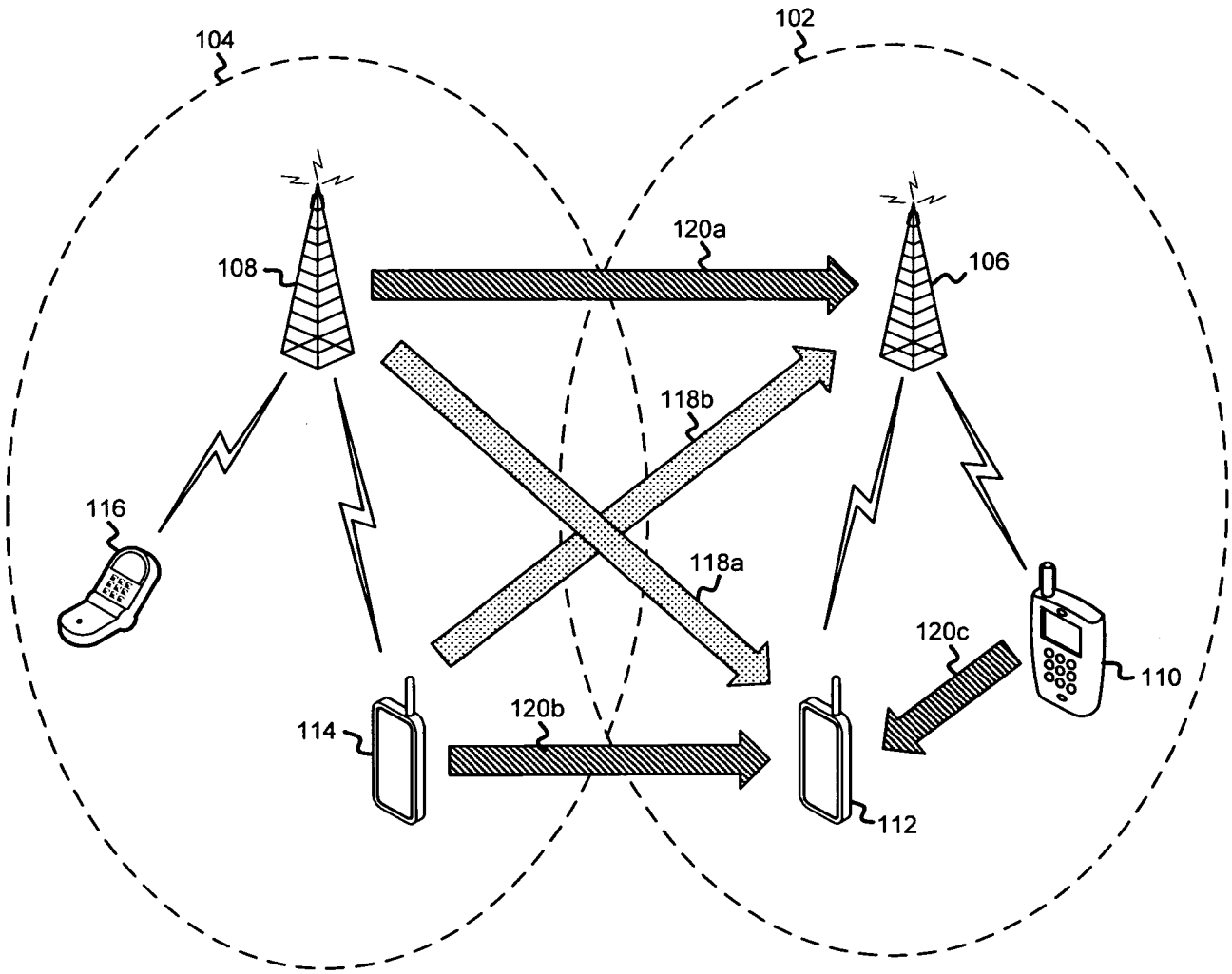


FIG. 1

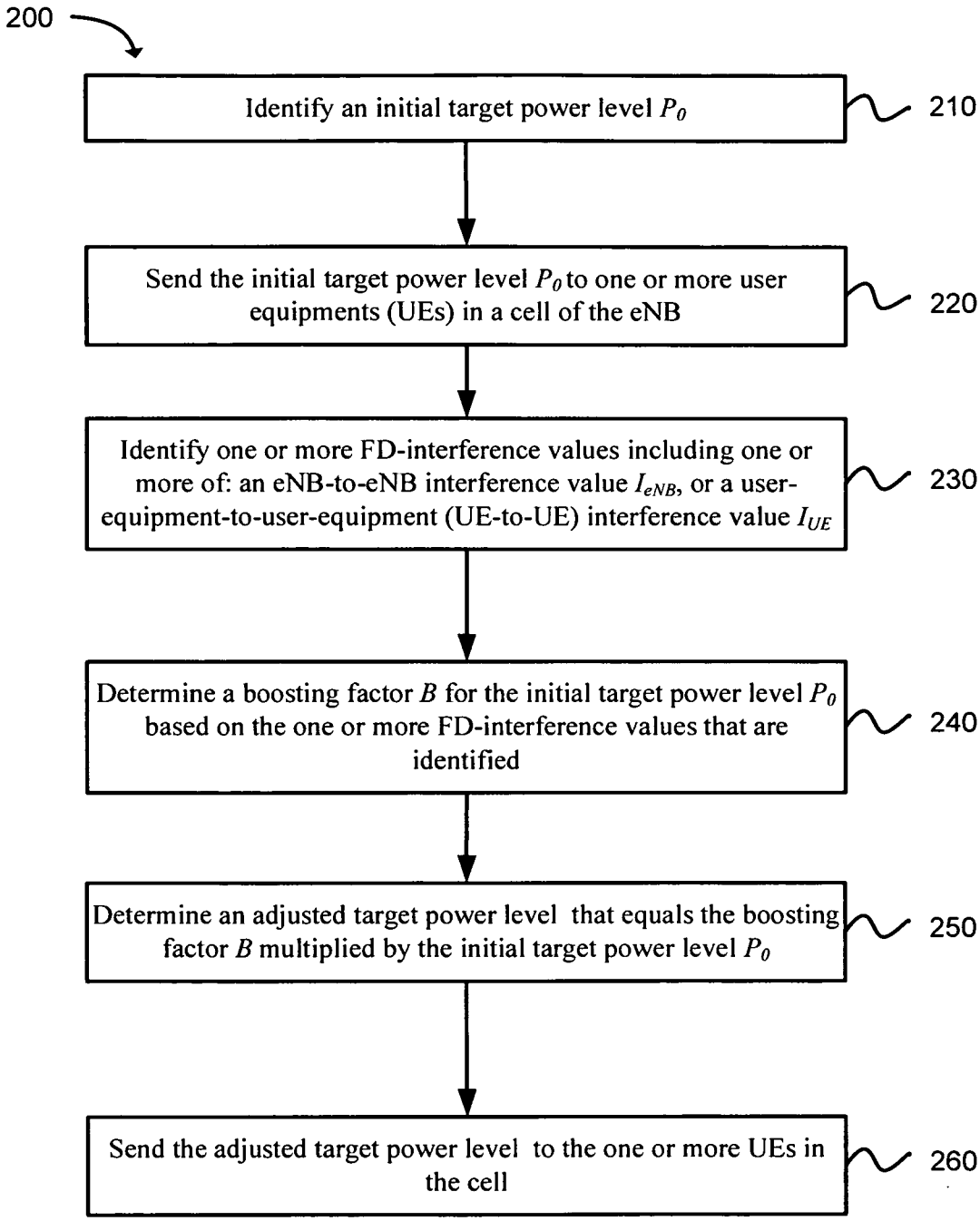

200
Identify an initial target power level P_0
210
Send the initial target power level P_0 to one or more user equipments (UEs) in a cell of the eNB
220
Identify one or more FD-interference values including one or more of: an eNB-to-eNB interference value I_{eNB}, or a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE}
230
Determine a boosting factor B for the initial target power level P_0 based on the one or more FD-interference values that are identified
240
Determine an adjusted target power level that equals the boosting factor B multiplied by the initial target power level P_0
250
Send the adjusted target power level to the one or more UEs in the cell
260

FIG. 2

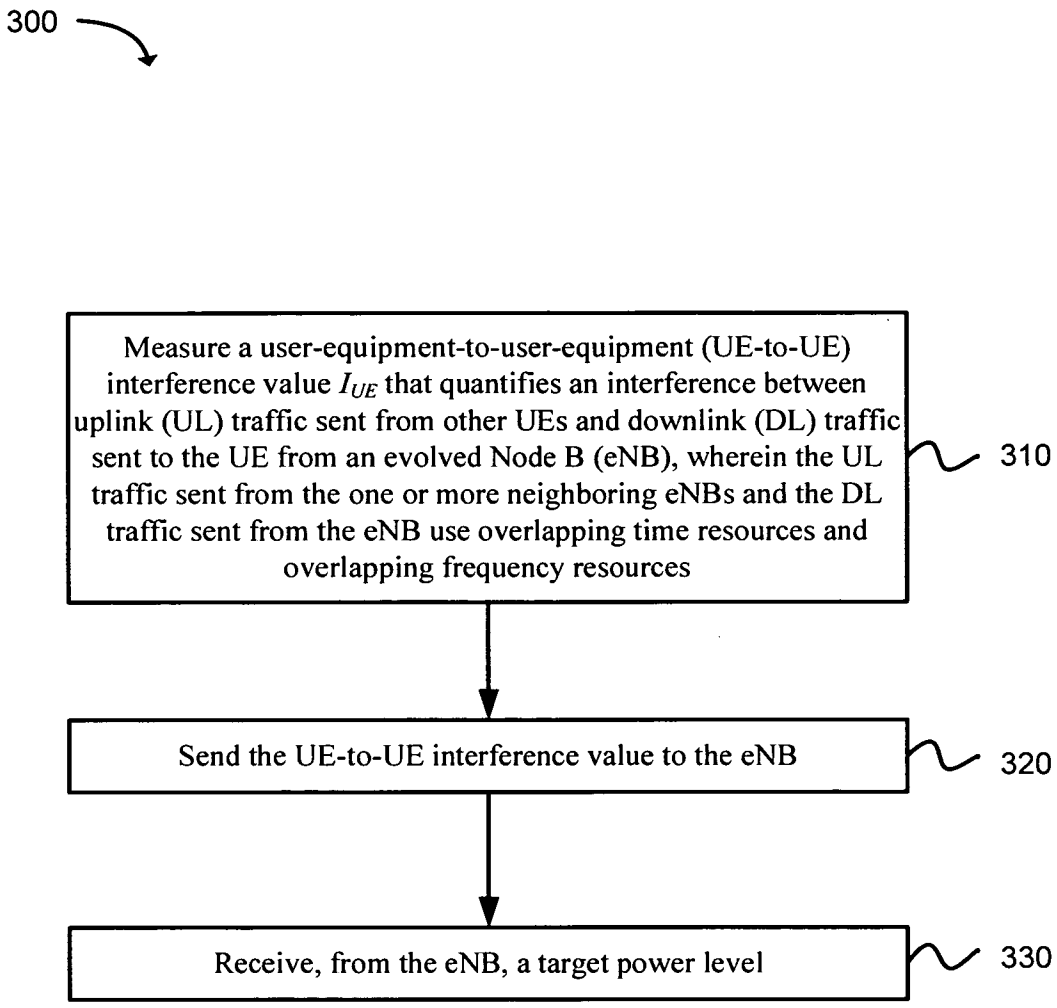

300
Measure a user-equipment-to-user-equipment (UE-to-UE) interference value I_{UE} that quantifies an interference between uplink (UL) traffic sent from other UEs and downlink (DL) traffic sent to the UE from an evolved Node B (eNB), wherein the UL traffic sent from the one or more neighboring eNBs and the DL traffic sent from the eNB use overlapping time resources and overlapping frequency resources
310
Send the UE-to-UE interference value to the eNB
320
Receive, from the eNB, a target power level
330

FIG. 3

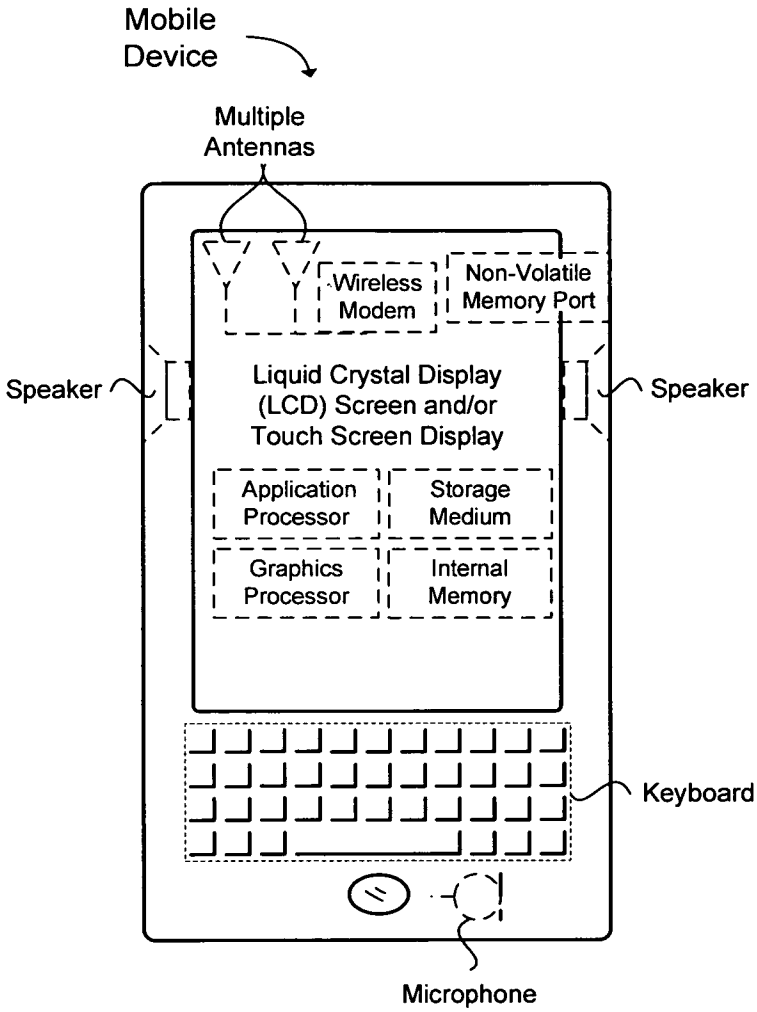

Mobile Device
Multiple Antennas
Wireless Modem
Non-Volatile Memory Port
Speaker
Liquid Crystal Display (LCD) Screen and/or Touch Screen Display
Speaker
Application Processor
Storage Medium
Graphics Processor
Internal Memory
Keyboard
Microphone

FIG. 4

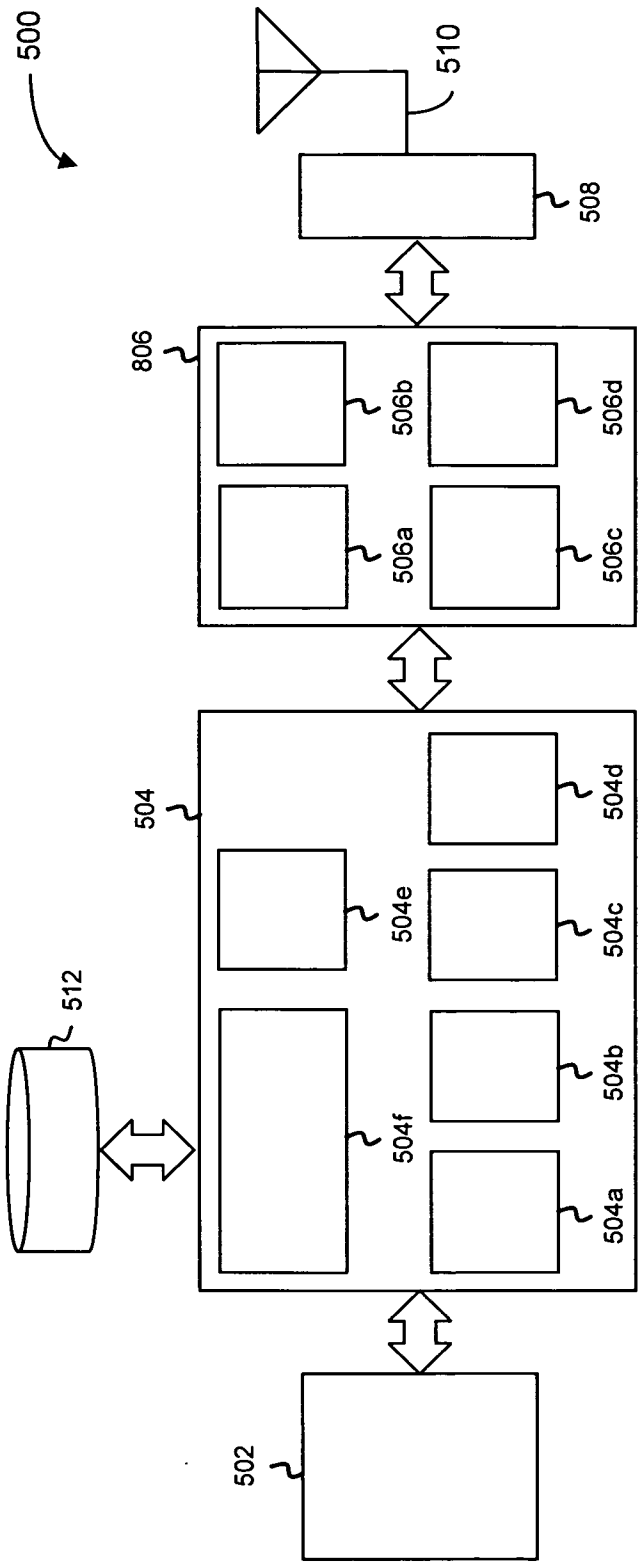

500
510
508
806
506b
506d
506a
506c
504
504d
504e
504c
512
504f
504b
504a
502

FIG. 5

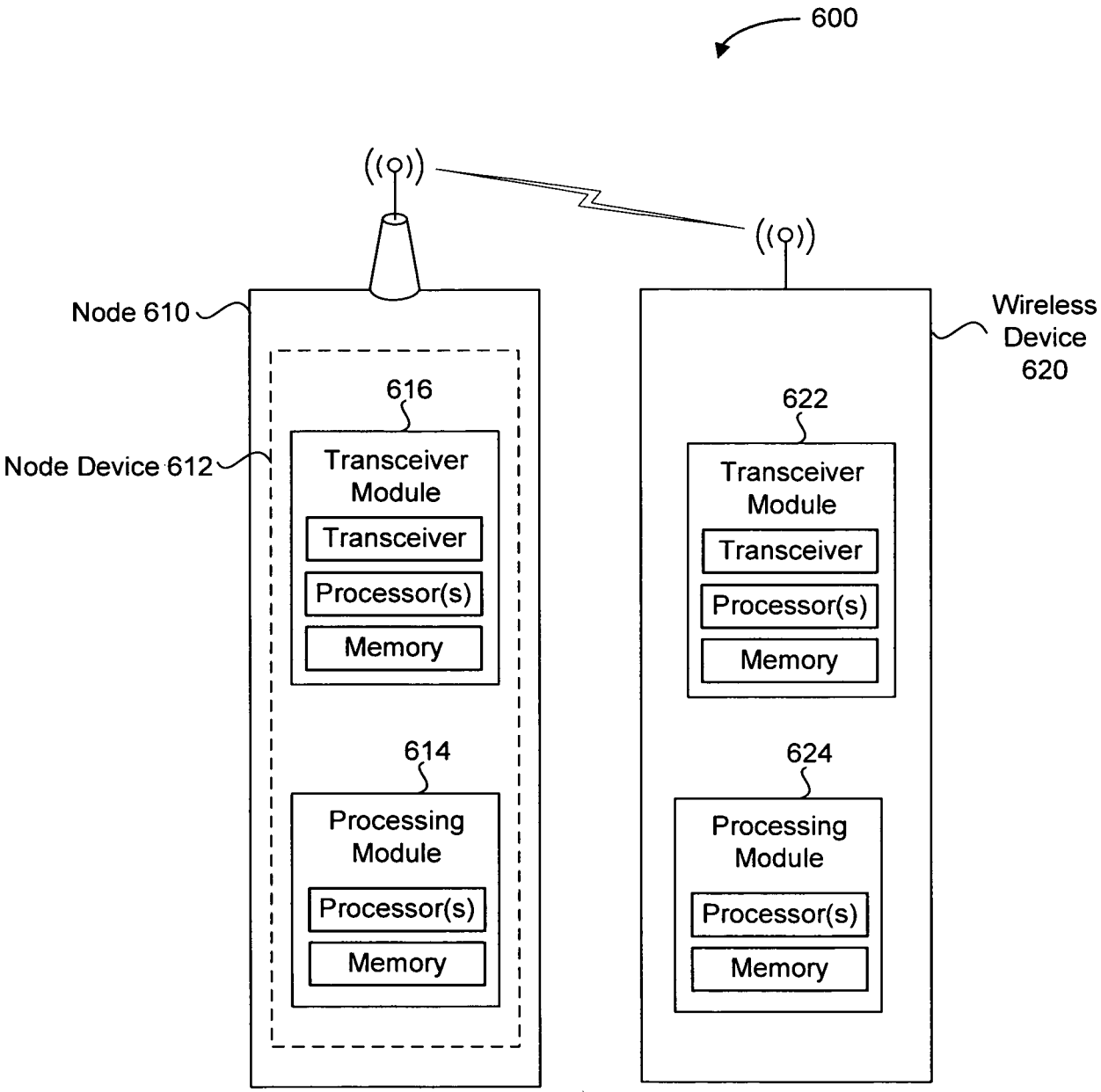

600
Node 610
Node Device 612
616
Transceiver Module
Transceiver
Processor(s)
Memory
614
Processing Module
Processor(s)
Memory
Wireless Device 620
622
Transceiver Module
Transceiver
Processor(s)
Memory
624
Processing Module
Processor(s)
Memory

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/000353

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W52/24
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/179979 A1 (QUALCOMM INC [US]; FENG MINGHAI [CN]; WANG NENG [CN]; HOU JILEI [CN];) 13 November 2014 (2014-11-13)	1,13
A	paragraph [0056]	2-12,
	paragraph [0064] - paragraph [0068]	14-20

X	US 2014/177486 A1 (WANG YIPING [US] ET AL) 26 June 2014 (2014-06-26)	9-12
	paragraph [0055] - paragraph [0063]	
	paragraph [0074]	
	paragraph [0101] - paragraph [0102]	
	paragraph [0120] - paragraph [0145]	

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 September 2016	12/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Baas, Gert-Jan

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/000353

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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A	WO 2014/056137 A1 (QUALCOMM INC [US]; FENG MINGHAI [CN]; GUO JIMING [CN]; WANG NENG [CN];) 17 April 2014 (2014-04-17) paragraph [0059] - paragraph [0068]	1-20
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/000353

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