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(54) Title: VERY FAST JOINT BASE STATION (BS) AND USER EQUIPMENT (UE) BEAM ADAPTATION IN MILLIMETER WAVE (MMWAVE) CELLULAR SYSTEMS

(57) Abstract: Techniques for very fast joint UE (user equipment) and BS (base station) beam adaptation are discussed. One example embodiment comprises one or more processors of a UE configured to: process a physical downlink control channel (PDCCH) received by transceiver circuitry from an Evolved NodeB (eNB) via one or more of a tier-1 UE sector with broad beams and low gains or a plurality of tier-2 UE sectors with narrow beams and high gains; measure, based on the processed PDCCH, an associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors, wherein the plurality of tier-2 UE sectors comprises a primary tier-2 UE sector; determine to replace the primary tier-2 UE sector with a distinct tier-2 UE sector of the plurality of tier-2 UE sectors; generate a message requesting the eNB to update a tier-2 eNB sector associated with the primary tier-2 UE sector; and output the message to the transceiver circuitry for transmission to the eNB.

FIG. 9

[Continued on next page]

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VERY FAST JOINT BASE STATION (BS) AND USER EQUIPMENT (UE) BEAM ADAPTATION IN MILLIMETER WAVE (MMWAVE) CELLULAR SYSTEMS

FIELD

[0001] The present disclosure relates to wireless technology, and more specifically to techniques for rapid joint beam adaptation.

BACKGROUND

[0002] In order to satisfy the ever-increasing demand for data, 5G radio access technologies (RATs) will involve communication at very high carrier frequencies such as the millimeter Wave (mmWave) spectrum, where bandwidth is plentiful. However, the cost to moving to such high frequencies is that electromagnetic wave propagation is poor. To address this, highly directional antenna arrays can be employed at both the base station (e.g., Evolved NodeB (eNB), etc.) and user equipment (UE), in order to generate transmit and/or receive beams to provide a higher gain, but narrower beamwidth than non-directional antenna arrays. However, because of the narrower beamwidth, these beams can be more easily obscured by obstacles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is a block diagram illustrating an example user equipment (UE) useable in connection with various aspects described herein.

[0004] FIG. 2 is a diagram illustrating an example scenario involving beam adaptation in a millimeter wave (mmWave) wireless system, according to various aspects described herein.

[0005] FIG. 3 is a diagram illustrating an example of a two-tier RF (radio frequency) beamforming architecture that can be employed by a BS (base station) and/or UE (user equipment) in connection with various aspects described herein.

[0006] FIG. 4 is a diagram illustrating an example sub-frame structure that can be employed in connection with various aspects described herein.

[0007] FIG. 5 is a diagram illustrating an example scenario involving a joint BS and UE beam adaptation procedure according to various aspects described herein.

[0008] FIG. 6 is a diagram illustrating an example m-part PDCCH (physical downlink control channel) that can be employed in connection with various aspects described herein.
[0009] FIG. 7 is a block diagram illustrating a system that facilitates rapid joint beam adaptation at a UE, according to various aspects described herein.

[0010] FIG. 8 is a block diagram illustrating a system that facilitates very fast joint beam adaptation at a base station according to various aspects described herein.

[0011] FIG. 9 is a flow diagram illustrating a method that facilitates very fast joint beam adaptation by a UE according to various aspects described herein.

[0012] FIG. 10 is a flow diagram illustrating a method that facilitates very fast joint UE and BS beam adaptation by a base station according to various aspects described herein.

**DETAILED DESCRIPTION**

[0013] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0014] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0015] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in
which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0016] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

[0017] 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.

[0018] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 1 illustrates, for one embodiment, example components of a User Equipment (UE) device 100. In some embodiments, the UE device 100 may include application circuitry 102, baseband circuitry 104, Radio Frequency (RF) circuitry 106, front-end module (FEM) circuitry 108 and one or more antennas 110, coupled together at least as shown.
[0019] The application circuitry 102 may include one or more application processors. For example, the application circuitry 102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0020] The baseband circuitry 104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 104 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 106 and to generate baseband signals for a transmit signal path of the RF circuitry 106. Baseband processing circuitry 104 may interface with the application circuitry 102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 106. For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s) 104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 104 (e.g., one or more of baseband processors 104a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 106. 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 104 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 104 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.

[0021] In some embodiments, the baseband circuitry 104 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) 104e of the baseband circuitry 104 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) 104f. The audio DSP(s) 104f may be 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 104 and the application circuitry 102 may be implemented together such as, for example, on a system on a chip (SOC).

[0022] In some embodiments, the baseband circuitry 104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 104 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 104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0023] RF circuitry 106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 108 and provide baseband signals to the baseband circuitry 104. RF circuitry 106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 104 and provide RF output signals to the FEM circuitry 108 for transmission.

[0024] In some embodiments, the RF circuitry 106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 106 may include mixer circuitry 106a, amplifier circuitry 106b and filter circuitry 106c. The transmit signal path of the RF circuitry 106 may include filter circuitry 106c and mixer circuitry 106a. RF
circuitry 106 may also include synthesizer circuitry 106d for synthesizing a frequency for use by the mixer circuitry 106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 108 based on the synthesized frequency provided by synthesizer circuitry 106d. The amplifier circuitry 106b may be configured to amplify the down-converted signals and the filter circuitry 106c 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 104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0025] In some embodiments, the mixer circuitry 106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 106d to generate RF output signals for the FEM circuitry 108. The baseband signals may be provided by the baseband circuitry 104 and may be filtered by filter circuitry 106c. The filter circuitry 106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0026] In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a 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 106a of the receive signal path and the mixer circuitry 106a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may be configured for super-heterodyne operation.

[0027] 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 106 may include analog-to-digital converter (ADC) and
digital-to-analog converter (DAC) circuitry and the baseband circuitry 104 may include a
digital baseband interface to communicate with the RF circuitry 106.

[0028] 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.

[0029] In some embodiments, the synthesizer circuitry 106d 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 106d may be a delta-sigma synthesizer, a frequency
multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0030] The synthesizer circuitry 106d may be configured to synthesize an output
frequency for use by the mixer circuitry 106a of the RF circuitry 106 based on a
frequency input and a divider control input. In some embodiments, the synthesizer
circuitry 106d may be a fractional N/N+1 synthesizer.

[0031] In some embodiments, frequency input may be provided by a voltage
controlled oscillator (VCO), although that is not a requirement. Divider control input may
be provided by either the baseband circuitry 104 or the applications processor 102
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 102.

[0032] Synthesizer circuitry 106d of the RF circuitry 106 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.

[0033] In some embodiments, synthesizer circuitry 106d 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 (ILO). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0034] FEM circuitry 108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 106 for further processing. FEM circuitry 108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 106 for transmission by one or more of the one or more antennas 110.

[0035] In some embodiments, the FEM circuitry 108 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 106). The transmit signal path of the FEM circuitry 108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 110.

[0036] In some embodiments, the UE device 100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0037] Additionally, although the above example discussion of device 100 is in the context of a UE device, in various aspects, a similar device can be employed in connection with a base station (BS) such as an Evolved NodeB (eNB), etc.

[0038] Various aspects discussed herein facilitate very fast joint BS and UE beam adaptation in 5G mmWave cellular systems. In contrast to conventional beam adaptation techniques, techniques employed in various embodiments can provide for beam adaptation within a single transmission time interval (TTI).

[0039] Referring to FIG. 2, illustrated is an example scenario involving beam adaptation in a millimeter wave (mmWave) wireless system, according to various
aspects described herein. In the example of FIG. 2, the mmWave channel between the base station (BS) and user equipment (UE) comprises two paths, 202 and 204, with the active path for communications in 210-230 indicated via arrows. At 210, the BS and UE have focused their beams on a reflection path, 202, for very high data rate communication, with the respective beams indicated as b1 and u1. At 220, reflection path 202 gets blocked (e.g., due to human blockage as shown at 220, or due to reflector movement, etc.), significant reducing the quality of path 202. Thus, the BS and UE can fall back on using the second best path, 204, as shown at 230. In various aspects described herein, techniques can be employed such that, within a single TTI, the BS and UE can detect the variation in link quality (with a link comprising a pair of a BS beam and a UE beam), and adapt their beams accordingly, to the link associated with path 204 in the example of FIG. 2, indicated by the beams b2 and u2, for the BS and UE respectively.

[0040] Conventional techniques for joint BS and UE beam adaptation rely on the BS and UE repeating a sector sweep procedures. As a result, there is a considerable delay (e.g., around 40-200 ms) before the BS and the UE can adapt due to channel/link (selected beam pair) quality variation, or re-establish the communication link in case of blockage. This not only degrades throughput and increases delay, but also increases the power consumption of the mobile device, due to the additional energy spent on the sector sweep procedure.

[0041] However, in various aspects described herein, a UE can intelligently identify the quality of different paths during PDCCH (physical downlink control channel) reception. Upon detection of blockage in the best path or variation in the quality of the paths, the UE can instruct the BS to take appropriate measures and switch the BS beam, and the UE can change the UE beam accordingly. Various techniques are discussed herein that can facilitate very fast joint beam adaptation. Embodiments employing such techniques can facilitate joint beam adaptation by a BS and UE within a single TTI (e.g., 0.4 ms, etc.) without performing a new sector sweep procedure. Very fast joint beam adaptation based on techniques described herein can significantly improve the throughput, delay, and power consumption characteristics of a UE.

[0042] Referring to FIG. 3, illustrated is an example diagram of a two-tier RF (radio frequency) beamforming architecture that can be employed by a BS and/or UE in connection with various aspects described herein. This two-tier RF beamforming architecture can comprise: (i) a first plurality (a relatively smaller number) of Tier-1
sectors with broad beams and low gains, which are better for low data-rate control
information communication (e.g., PDCCH transmission, BCH (broadcast channel)
transmission, ACK (Hybrid Automatic Repeat Request (HARQ) Acknowledgement)
reception, etc.) and/or communications having a lower modulation order; and (ii) a
second plurality (a relatively larger number) of Tier-2 sectors with narrow beams and
high gains, which are better for high data-rate data communications (e.g., having a
higher modulation order, etc.). In various aspects, the numbers of tier-1 sectors and tier-
2 sectors can vary (and, in particular, need not match the numbers depicted for the
purposes of illustration in the example of FIG. 3), although in general there can be a
plurality (e.g., tens, or more of less, etc.) of tier-2 sectors for each tier-1 sector.
[0043] In various aspects, techniques discussed herein can facilitate rapid joint beam
adaptation in either of two scenarios.
[0044] In the first scenario, during the initial sector sweep procedure BS and UE
identify two or more Tier-2 sector pairs (e.g., a tier-2 UE sector and an associated tier-2
BS sector, etc.) corresponding to different reflection paths. For example, in FIG. 2, the
BS and the UE can identify the Tier-2 sector pairs (b1, u1) and (b2, u2) corresponding
to the paths 202 and 204, respectively.
[0045] In the second scenario, the UE can identify two or more Tier-2 UE sectors
corresponding to different paths (for example, during the initial acquisition or sector
sweep procedure), but the corresponding Tier-2 BS sectors need not be identified. For
example, in FIG. 2, only u1 and u2 are identified at the UE.
[0046] In some aspects, at a high level, fast joint BS and UE beam adaptation can
be performed as follows. A UE can use a Tier-1 UE sector for reception of the PDCCH
from the BS. The UE can estimate the quality of the reflection paths for its Tier-2 UE
sectors. If there is a change in the quality of the reflection paths (e.g., for the Tier-2 UE
sectors, etc.), the UE can initiate beam adaptation according to techniques described
herein, which can depend on the specific scenario.
[0047] In the first scenario (e.g., wherein both the BS and UE have identified a
plurality of associated pairs of tier-2 sectors, etc.), the UE can inform the BS to use the
Tier-2 BS sector corresponding to the current best reflection path (i.e., as determined
from Tier-2 UE sectors, etc.) and the UE can update the Tier-2 UE sector accordingly.
[0048] In the second scenario (e.g., wherein the UE but not necessarily the BS has
identified a plurality of tier-2 sectors, etc.) the UE can inform the BS that the Tier-2 UE
sector is changed, and can request the BS to initiate a Tier-1 specific Tier-2 BS sector
sweep procedure in order for the BS to identify the best Tier-2 BS sector corresponding to the updated Tier-2 UE sector.

[0049] Referring to FIG. 4, illustrated is an example sub-frame structure that can be employed in connection with various aspects described herein. The subframe of FIG. 4 can have a TTI (e.g., 0.4 ms, 0.8 ms, etc.) that is shortened relative to a TTI of conventional systems (e.g., 1 ms). The example subframe can comprise a PDCCH (e.g., comprising n symbols) at the beginning of the subframe, a PDSCH (physical downlink shared channel) for sending DL (downlink) data to one or more UEs, a GP (guard period) or gap between DL and UL (uplink) transmissions, and a portion for UL transmissions, which can comprise ACK(s) and/or NACK(s) (HARQ Negative Acknowledgement(s)) in response to the DL data sent via the PDSCH. In various aspects, determination of quality associated with tier-2 UE sectors can be based on PDCCH received via a subframe such as the example subframe of FIG. 4, and when the UE determines that a tier-2 UE sector should be updated, a UE request for the BS to update the tier-2 BS sector (e.g., via the techniques for the first scenario or the second scenario, etc.) can be sent by the UE as an UL transmission (e.g., in connection with ACK/NACK, etc.) in the same subframe.

[0050] Referring to FIG. 5, illustrated is one example scenario involving a joint BS and UE beam adaptation procedure according to various aspects described herein. The example of FIG. 5 depicts joint BS and UE beam adaptation in connection with the first scenario (e.g., wherein both the BS and UE have identified a plurality of associated pairs of tier-2 sectors, etc.) in response to a path blockage or other circumstances causing quality degradation on a current communication path associated with a primary tier-2 UE sector and a primary tier-2 BS sector (the upper path in each of 500-530 in the example of FIG. 5). However, as described in greater detail below, similar techniques can be employed in connection with the second scenario (e.g., wherein the UE but not necessarily the BS has identified a plurality of tier-2 sectors, etc.).

[0051] At 500, the BS can use a tier-1 BS sector for transmission of the PDCCH, and the UE can use a Tier-1 UE sector for reception of the PDCCH. Since both the BS and the UE use Tier-1 sectors, control information can be received by the UE even when the best path is blocked. While receiving PDCCH, the UE can estimate the quality of a plurality of paths (and hence the corresponding Tier-2 UE sectors) comprising a current communication path and one or more other paths (two paths are shown in the example
of FIG. 5). In various aspects, path quality estimation can be performed using AoA (angle of arrival) estimation algorithms or other techniques discussed herein.

[0052] At 510, since the previous best path (the upper path in the example of FIG. 5) is blocked and the BS is not yet aware of its blockage, the BS uses its prior (e.g., current primary) Tier-2 BS sector for sending the DL signal to the UE. This can result in a loss of information at the UE irrespective of its sector (Tier-1 or Tier-2).

[0053] At 520, in the first scenario, the UE can send the DL NACK and can also inform the BS regarding the updated Tier-2 BS sector to use when communicating with the UE. BS reception can happen on the Tier-1 BS sector and the UE transmission can happen on the new primary Tier-2 UE sector.

[0054] At 530, the BS can schedule an immediate re-transmission (or re-schedule the UE in another sub-frame) and can send the data to the UE with the updated (new primary) Tier-2 BS sector.

[0055] As discussed above, in some aspects, the UE can use a Tier-1 UE sector for PDCCH reception. By using a broad Tier-1 UE sector for PDCCH reception, the UE is able to receive signals from different paths. Hence, control information can still be received (note that control information is typically sent at the lowest MCS (modulation and coding scheme)), even if one path is blocked.

[0056] However, some UEs (for example, UEs at cell edge) may not be able to use a broad Tier-1 UE sector for control information reception, since the link budget may not close. As described in greater detail below, in various aspects, alternative techniques for fast joint BS and UE adaptation can be employed that do not rely on the UE using a Tier-1 UE sector for PDCCH reception.

[0057] In some aspects, the UE can use an AoA estimation algorithm to evaluate the quality of its incoming paths (and hence Tier-2 UE sectors) while receiving PDCCH.

[0058] In other aspects, the PDCCH data which is transmitted by the BS can be divided into multiple parts, for example, m parts. Referring to FIG. 6, illustrated is an example m-part PDCCH that can be employed in connection with various aspects described herein. In the first part, the BS can announce the UEs that are scheduled in the current sub-frame, and can also identify in which of the following m-1 parts each scheduled UE’s exact schedule is declared. The UEs can use their Tier-1 UE sectors to decode the first part (which is common across all UEs) as well as the part belonging to them, and can use the redundant parts (the other m-2 parts) to perform a UE receive sector sweep across a set of pre-determined Tier-2 UE sectors. This procedure can
allow the UEs to obtain up-to-date information regarding the quality of the paths (and thus, about the corresponding Tier-2 UE sectors), such as via SNR (signal to noise ratio) or SINR (signal to interference plus noise ratio) measurements, etc.

[0059] In various aspects, the UE can evaluate the quality of different paths (and hence the corresponding Tier-2 sector pairs). If there is a change in the quality of paths (e.g., a current primary tier-2 UE sector no longer has a best quality among tier-2 UE sectors, etc.), the UE can proceed as follows.

[0060] In the first scenario (e.g., in which the Tier-2 BS sectors corresponding to tier-2 UE sectors are known at the BS), the UE can instruct the BS to update its Tier-2 BS sector during an UL Data and/or Control transmission and the can update its Tier-2 UE sector accordingly.

[0061] In the second scenario (e.g., in which the Tier-2 BS sector(s) corresponding to tier-2 UE sectors are not known at the BS, etc.), the UE can inform the BS that its Tier-2 UE sector has changed and can ask the BS to initiate a Tier-1 specific Tier-2 transmit sector sweep. This information can be sent to the BS during UL Data/Control transmission.

[0062] Additionally, in some aspects, techniques can be employed that do not require beam broadening (i.e., using a Tier-1 UE sector) at the UE for PDCCH reception. In order to allow the UE to obtain information regarding the quality of the different paths without using a Tier-1 UE sector, the BS can transmit a Secondary Synchronization Signal (SSS), etc. on its Tier-1 BS sector at the beginning of PDCCH. The duration of this SSS (etc.) transmission can be such that it allows UE(s) to perform a sector sweep on one or more of their pre-determined Tier-2 UE sectors. The duration of this SSS transmission or the number of symbols that it takes can be declared during the initial UE attachment, or can be part of the BCH, can be predefined, etc. Each UE can then perform a sector sweep on its pre-determined set of Tier-2 UE sectors in order to obtain information regarding the quality of these Tier-2 UE sectors. If there is a change in a UE’s Tier-2 UE sector quality, the UE can follow the same techniques discussed above to inform the BS of the change in the tier-2 UE sector and request the BS to update its Tier-2 sector in the first scenario or initiate a Tier-1 specific Tier-2 transmit sector sweep in the second scenario.

[0063] Referring to FIG. 7, illustrated is a block diagram of a system 700 that facilitates rapid joint beam adaptation at a UE, according to various aspects described herein. System 700 can include one or more processors 710 (e.g., one or more
baseband processors such as one or more of the baseband processors discussed in connection with FIG. 1), transceiver circuitry 720 (e.g., comprising one or more of transmitter circuitry or receiver circuitry, which can employ common circuit elements, distinct circuit elements, or a combination thereof), and a memory 730 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor(s) 710 or transceiver circuitry 720). In various aspects, system 700 can be included within a user equipment (UE). As described in greater detail below, system 700 can facilitate determination of a best tier-2 sector pair for communication with a BS within a single TTI.

[0064] Transceiver circuitry 720 can receive, and processor(s) 710 can process, a PDCCH transmitted by a BS (e.g., Evolved NodeB (eNB), etc.). Depending on the type of received signal or message, processing (e.g., by processor(s) 710, processor(s) 810, etc.) can comprise one or more of: identifying physical resources associated with the signal/message, detecting the signal/message, resource element group deinterleaving, demodulation, descrambling, and/or decoding.

[0065] Depending on the embodiment, the PDCCH can be received by transceiver circuitry 720 via a tier-1 UE sector, a plurality of tier-2 UE sectors (e.g., a primary tier-2 UE sector and one or more other tier-2 UE sectors, etc.), or a combination. Processor(s) 710 can measure a path quality for each of the plurality of tier-2 UE sectors, which can be a predetermined set of n tier-2 UE sectors (e.g., based on a previously performed sector sweep procedure, etc.). The number of tier-2 UE sectors, n, can be one of set during an initial UE attachment, indicated via a broadcast channel, predefined, etc.

[0066] Processor 720 can measure the path quality for each tier-2 UE sector based on any of a variety of techniques, which can depend on how the PDCCH is received.

[0067] In one example, transceiver circuitry 720 can receive the entire PDCCH via the tier-1 UE sector, and processor 720 can measure path quality associated with the plurality of tier-2 sectors based on an angle of arrival estimation algorithm.

[0068] In another example, distinct portions of the PDCCH can be received by transceiver circuitry 720 via distinct tier-2 UE sectors of the plurality of tier-2 UE sectors, and processor(s) 710 can measure path quality for each distinct tier-2 UE sector based on signals received over that tier-2 UE sector (e.g., based on a SNR or SINR, etc.). In some aspects, the eNB can transmit a SSS (e.g., at the beginning of the PDCC, etc.), and transceiver circuitry 720 can perform a sector sweep over the plurality of tier-2 UE sectors during the SSS transmission. In other aspects, the PDCCH can comprise m
parts as discussed herein, with the first part indicating another part (of the m-1 parts after the first part) that is associated with the UE, and wherein the remaining m-2 parts are associated with other UEs. In such aspects, transceiver circuitry 720 can receive the first part and the part associated with the UE via the tier-1 UE sector, and can receive the remaining m-2 parts via a sector sweep over the plurality of tier-2 UE sectors.

[0069] Additionally, processor 720 can determine to replace the primary tier-2 UE sector with a distinct tier-2 UE sector (e.g., to be a new primary tier-2 UE sector). In various aspects, the determination by processor(s) 710 can be based on the measured path qualities associated with the primary tier-2 UE sector and the distinct tier-2 UE sector, or with the plurality of tier-2 UE sectors, etc. Additionally or alternatively, the determination by processor(s) 710 can be based on a failure to receive a PDSCH transmission indicated via a DL assignment for the UE in the received PDCCH.

[0070] Processor(s) 710 can generate a message requesting the eNB to update a tier-2 eNB sector associated with the primary tier-2 UE sector, and can output the message to transceiver circuitry 720 for transmission to the eNB (e.g., via the distinct tier-2 UE sector). Depending on the embodiment, the nature of the message can vary. In various aspects (e.g., when the determination to replace the primary tier-2 UE sector is based at least in part on a failed PDSCH reception, etc.), the message can comprise a NACK (a Hybrid Automatic Repeat Request (HARQ) Negative Acknowledgement (NACK)).

[0071] In various aspects associated with the first scenario discussed herein (e.g., wherein the eNB has a predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector, etc.), the message can comprise a request to the eNB to update the primary tier-2 eNB sector (e.g., the sector used by the eNB for the PDSCH transmission to the UE indicated via the PDCCH) to the predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector.

[0072] In various aspects associated with the second scenario discussed herein (e.g., wherein the eNB does not have a predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector, etc.), the message can comprise a request to the eNB to perform a sector sweep of tier-2 eNB sectors (e.g., tier-2 eNB sectors associated with the tier-1 eNB sector used to transmit the PDCCH, etc.) to determine a distinct tier-2 eNB sector to replace a current primary tier-2 eNB sector that is associated with the primary tier-2 UE sector.
[0073] Referring to FIG. 8, illustrated is a block diagram of a system 800 that facilitates very fast joint beam adaptation at a base station according to various aspects described herein. System 800 can include one or more processors 810 (e.g., one or more baseband processors such as one or more of the baseband processors discussed in connection with FIG. 1), transceiver circuitry 820 (e.g., which can comprise one or more of transmitter circuitry (e.g., associated with one or more transmit chains) or receiver circuitry (e.g., associated with one or more receive chains), wherein the transmitter circuitry and receiver circuitry can employ common circuit elements, distinct circuit elements, or a combination thereof), and memory 830 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor(s) 810 or transceiver circuitry 820). In various aspects, system 800 can be included within an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (Evolved Node B, eNodeB, or eNB) or other base station in a wireless communications network. In some aspects, the processor(s) 810, transceiver circuitry 820, and the memory 830 can be included in a single device, while in other aspects, they can be included in different devices, such as part of a distributed architecture. As described in greater detail below, system 800 can facilitate joint beam adaptation by the BS and a UE within a single TTI.

[0074] Processor(s) 810 can generate a PDCCH that comprises a DL assignment for the UE, and can output the PDCCH to transceiver circuitry 820 for transmission to one or more UEs (which can comprise the UE) via a tier-1 eNB sector. Depending on the type of signal or message generated, outputting for transmission (e.g., by processor(s) 710, processor(s) 810, etc.) can comprise one or more of the following: generating a set of associated bits that indicate the content of the signal or message, coding (e.g., which can include adding a cyclic redundancy check (CRC) and/or coding via one or more of turbo code, low density parity-check (LDPC) code, tailbiting convolution code (TBCC), etc.), scrambling (e.g., based on a scrambling seed), modulating (e.g., via one of binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), or some form of quadrature amplitude modulation (QAM), etc.), and/or resource mapping (e.g., to a scheduled set of resources, to a set of time and frequency resources granted for uplink transmission, etc.).

[0075] Depending on the embodiment, the nature of the PDCCH may vary.

[0076] For example, in some aspects, processor(s) 810 can generate a SSS and can output the SSS to transceiver circuitry 820 for transmission at the beginning of the
PDCCH. The SSS can be transmitted for a predetermined duration or a predetermined number of symbols, which can be of a sufficient duration or number of symbols for the UE to perform a sector sweep over a predetermined number of tier-2 UE sectors (e.g., where the number of tier-2 UE sectors can be set at initial UE attachment, via a BCH that processor(s) 810 can generate and output to transceiver circuitry 820 for transmission, predefined, etc.).

[0077] As another example, in various aspects, processor(s) 810 can generate (and transceiver circuitry 820 can transmit) a PDCCH that comprises m parts. Each of the final m-1 parts can be associated with a distinct UE, and the first part can indicate which of the final m-1 parts is associated with which of the distinct UEs. As described herein, this can facilitate reception by each UE of the first part and the part of the PDCCH for that UE via a tier-1 UE sector, and that UE can perform a sector sweep of its tier-2 UE sectors during the other m-2 parts.

[0078] Processor(s) 810 can generate a set of DL data and can output the set of DL data to transceiver circuitry 820 for transmission to the UE in a PDSCH via a current primary tier-2 eNB sector. The current primary tier-2 eNB sector can be associated with a current primary tier-2 UE sector for communication along a current communication path.

[0079] In aspects, as described herein, the UE can determine to replace the current primary tier-2 UE sector. Accordingly, transceiver circuitry 820 can receive (and processor(s) 810 can process a message transmitted by the UE comprising a request for the eNB to update or replace its current primary tier-2 eNB sector. In some aspects, the message can comprise a NACK in response to the set of DL data transmitted to the UE in the PDSCH. In aspects, as described herein, transceiver circuitry 820 can receive the message during the same subframe that transceiver circuitry 820 transmits the PDCCH and the set of DL data via the PDSCH.

[0080] Processor(s) 810 can select a new primary tier-2 eNB sector in different manners depending on the embodiment and scenario.

[0081] For example, in the first scenario (e.g., wherein the eNB has a predetermined tier-2 eNB sector associated with a new primary tier-2 UE sector selected by the UE, etc.), the message can indicate one or more of the new primary tier-2 UE sector or the predetermined tier-2 eNB sector associated with the new primary tier-2 UE sector, and processor(s) 810 can select the predetermined tier-2 eNB sector as the new primary tier-2 eNB sector based on the message.
As another example, in the second scenario (e.g., wherein the eNB does not have a predetermined tier-2 eNB sector associated with a new primary tier-2 UE sector selected by the UE, etc.), the message can request that the UE has selected a new primary tier-2 UE sector but need not indicate the new primary tier-2 UE sector and/or the message can request that the eNB perform a tier-2 sector sweep. In the second scenario, transceiver circuitry 820 can perform a sector sweep of a plurality of tier-2 eNB sectors, and processor(s) 810 can select a new primary tier-2 eNB sector based on the sector sweep (e.g., by measuring a quality metric (e.g., SNR, SINR, etc.) associated with each tier-2 eNB sector of the plurality of tier-2 eNB sectors, and selecting a best tier-2 eNB sector based on the measured quality metric).

In aspects wherein the message indicates a NACK, processor(s) 810 can re-output the set of DL data to transceiver circuitry 820 for re-transmission to the UE via the new primary tier-2 eNB sector selected by processor(s) 810.

Referring to FIG. 9, illustrated is a flow diagram of a method 900 that facilitates very fast joint beam adaptation by a UE according to various aspects described herein. In some aspects, method 900 can be performed at a UE. In other aspects, a machine readable medium can store instructions associated with method 900 that, when executed, can cause a UE to perform the acts of method 900.

At 910, a PDCCH can be received from an eNB. Depending on the embodiment, the PDCCH can be received via a tier-1 UE sector, via a plurality of tier-2 UE sectors, or a combination.

At 920, based at least in part on the received PDCCH, a signal quality or path quality can be evaluated for each of the plurality of tier-2 UE sectors (e.g., based on AoA estimation algorithm, SNR/SINR measurements, etc.).

At 930, based at least in part on the evaluated signal qualities, a determination can be made to replace a current primary tier-2 UE sector. In aspects, this determination can also be made based at least in part on a failure to receive a PDSCH transmission (e.g., indicated via the PDCCH) via the current primary tier-2 UE sector.

At 940, a new primary tier-2 UE sector can be selected from the plurality of tier-2 UE sectors, which can be based at least in part on the evaluated signal qualities of the plurality of tier-2 UE sectors.

At 950, a message can be generated comprising a request for the eNB to replace a current primary tier-2 eNB sector with an updated tier-2 eNB sector. In some
aspects, the message can also comprise HARQ feedback associated with a PDSCH transmission to the UE indicated via the PDCCH, such as a NACK. In various embodiments related to the first scenario, the message can comprise a request for the eNB to replace the current primary tier-2 eNB sector with a predetermined sector associated with the new primary tier-2 UE sector. In various embodiments related to the second scenario, the message can comprise a request to the eNB to perform a sector sweep of tier-2 eNB sectors to determine a new primary tier-2 eNB sector, or can otherwise trigger such action at the eNB (e.g., via an indication that the UE has selected a new primary tier-2 UE sector, etc.).

[0090] Referring to FIG. 10, illustrated is a flow diagram of a method 1000 that facilitates very fast joint UE and BS beam adaptation by a base station according to various aspects described herein. In some aspects, method 1000 can be performed at an eNB. In other aspects, a machine readable medium can store instructions associated with method 1000 that, when executed, can cause an eNB to perform the acts of method 1000.

[0091] At 1010, a PDCCH can be generated which can comprise a first downlink control information (DCI) message that indicates a first downlink (DL) assignment for a first UE.

[0092] At 1020, the PDCCH can be transmitted to the first UE via a tier-1 eNB sector.

[0093] At 1030, a set of DL data can be transmitted to the first UE via a current primary tier-2 eNB sector. The set of DL data can be transmitted via PDSCH and based at least in part on the first DL assignment.

[0094] At 1040, a message can be received that comprises a request to replace the current primary tier-2 eNB sector with a new primary tier-2 eNB sector. In some aspects, the message can also comprise HARQ feedback in response to the set of DL data, such as a HARQ NACK.

[0095] At 1050, a new tier-2 eNB sector can be selected. Depending on the embodiment, the nature of the selection can vary. For example, in the first scenario, the request can indicate a new primary tier-2 eNB sector, which can be selected, or can indicate a new primary tier-2 UE sector, and a tier-2 eNB sector predetermined to be associated with the new primary tier-2 UE sector can be selected. As another example, in the second scenario, a sector sweep of tier-2 eNB sectors associated with the tier-1
eNB sector can be performed, and the new tier-2 eNB sector can be selected based on the sector sweep (e.g., as a sector associated with a best path quality, etc.).

[0096] At 1060, in aspects wherein the message indicated a HARQ NACK or a NACK was otherwise received in connection with the set of DL data, the set of DL data can be re-transmitted via the new primary tier-2 eNB sector.

[0097] Examples herein can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including executable instructions that, when performed by a machine (e.g., a processor with memory, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like) cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described.

[0098] Example 1 is an apparatus configured to be employed within a User Equipment (UE), comprising one or more processors configured to: decode physical downlink control channel (PDCCH) data received by transceiver circuitry from an Evolved NodeB (eNB) via one or more of a tier-1 UE sector or a plurality of tier-2 UE sectors; measure, based on the decoded PDCCH data, an associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors, wherein the plurality of tier-2 UE sectors comprises a primary tier-2 UE sector; determine to replace the primary tier-2 UE sector with a distinct tier-2 UE sector of the plurality of tier-2 UE sectors; and generate an uplink (UL) message requesting the eNB to update a tier-2 eNB sector associated with the primary tier-2 UE sector.

[0099] Example 2 comprises the subject matter of any variation of example 1, wherein the PDCCH data is received via the tier-1 UE sector.

[0100] Example 3 comprises the subject matter of any variation of example 1, wherein a first portion of the PDCCH data is received via the tier-1 UE sector, and wherein a second portion of the PDCCH data is received via a sector sweep over the plurality of tier-2 UE sector.

[0101] Example 4 comprises the subject matter of any variation of example 1, wherein the PDCCH data comprises a secondary synchronization signal (SSS), and wherein the SSS is received via a sector sweep over the plurality of tier-2 UE sectors.

[0102] Example 5 comprises the subject matter of any variation of any of examples 1-4, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is indicated via a broadcast channel (BCH).
Example 6 comprises the subject matter of any variation of any of examples 1-4, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is configured via an initial UE attachment.

Example 7 comprises the subject matter of any variation of any of examples 1-4, wherein the one or more processors are configured to measure the associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors via an angle of arrival (AoA) estimation algorithm.

Example 8 comprises the subject matter of any variation of any of examples 1-4, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request to update the tier-2 eNB sector to a predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector.

Example 9 comprises the subject matter of any variation of any of examples 1-4, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request for the eNB to perform a sector sweep of tier-2 eNB sectors to update the tier-2 eNB sector associated with the primary tier-2 UE sector.

Example 10 comprises the subject matter of any variation of any of examples 1-4, wherein the one or more processors are configured to determine to replace the primary tier-2 UE sector based on a failed reception of physical downlink shared channel (PDSCH) data scheduled via the decoded PDCCH data.

Example 11 comprises the subject matter of any variation of example 10, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the PDSCH.

Example 12 comprises the subject matter of any variation of any of examples 1-11, wherein the one or more processors are configured to determine to replace the primary tier-2 UE sector based on a failed reception of physical downlink shared channel (PDSCH) data scheduled via the decoded PDCCH data.

Example 13 comprises the subject matter of any variation of example 12, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the PDSCH.

Example 14 comprises the subject matter of any variation of example 1, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is indicated via a broadcast channel (BCH).
[00112] Example 15 comprises the subject matter of any variation of example 1, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is configured via an initial UE attachment.

[00113] Example 16 comprises the subject matter of any variation of example 1, wherein the one or more processors are configured to measure the associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors via an angle of arrival (AoA) estimation algorithm.

[00114] Example 17 comprises the subject matter of any variation of example 1, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request to update the tier-2 eNB sector to a predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector.

[00115] Example 18 comprises the subject matter of any variation of example 1, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request for the eNB to perform a sector sweep of tier-2 eNB sectors to update the tier-2 eNB sector associated with the primary tier-2 UE sector.

[00116] Example 19 comprises the subject matter of any variation of example 1, wherein the one or more processors are configured to determine to replace the primary tier-2 UE sector based on a failed reception of physical downlink shared channel (PDSCH) data scheduled via the decoded PDCCH data.

[00117] Example 20 comprises the subject matter of any variation of example 19, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the PDSCH.

[00118] Example 21 is a machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to: receive, from an Evolved NodeB (eNB), a physical downlink control channel (PDCCH) via one or more of a tier-1 UE sector or a plurality of tier-2 UE sectors; evaluate a signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based on the received PDCCH; determine to replace a current primary tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on a signal quality associated with the current primary tier-2 UE sector; select a new primary tier-2 UE sector of the plurality of tier-2 UE sectors; generate a message requesting the eNB to replace a current primary tier-2 eNB sector with a new primary tier-2 eNB sector; and transmit the message to the eNB via the new primary tier-2 UE sector.
[00119] Example 22 comprises the subject matter of any variation of example 21, wherein the instructions, when executed, cause the UE to determine to replace the current primary tier-2 UE sector based at least in part on a failed reception of a data set from a physical downlink shared channel (PDSCH), wherein the data set is indicated via a downlink (DL) assignment of the PDCCH.

[00120] Example 23 comprises the subject matter of any variation of example 21, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK).

[00121] Example 24 comprises the subject matter of any variation of any of examples 21-23, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a tier-2 eNB sector associated with the new primary tier-2 UE sector.

[00122] Example 25 comprises the subject matter of any variation of any of examples 21-23, wherein the message requests that the eNB select the new tier-2 eNB sector selected via a sector sweep of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector.

[00123] Example 26 comprises the subject matter of any variation of any of examples 21-23, wherein the PDCCH comprises m parts, and wherein the instructions, when executed, further cause the UE to: receive a first part of the PDCCH and a UE-specific part of the PDCCH via the tier-1 UE sector, wherein the first part indicates the UE-specific part; and perform a sector sweep of the plurality of tier-2 UE sectors during the m-2 parts of the PDCCH other than the first part and the UE-specific part.

[00124] Example 27 comprises the subject matter of any variation of any of examples 21-23, wherein the instructions, when executed, cause the UE to evaluate the signal quality associated with each tier-2 UE sector based on an angle of arrival (AoA) estimation algorithm.

[00125] Example 28 comprises the subject matter of any variation of any of examples 21-23, wherein the PDCCH comprises a secondary synchronization signal (SSS), and wherein the instructions, when executed, further cause the UE to: perform a sector sweep of the plurality of tier-2 UE sectors during the SSS; and evaluate the signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on the SSS.

[00126] Example 29 comprises the subject matter of any variation of any of examples 21-23, wherein the plurality of tier-2 UE sectors comprises n UE sectors, wherein n is configured via one of a broadcast channel (BCH) or an initial attachment of the UE.
Example 30 comprises the subject matter of any variation of any of examples 21-29, wherein the plurality of tier-2 UE sectors comprises n UE sectors, wherein n is configured via one of a broadcast channel (BCH) or an initial attachment of the UE.

Example 31 comprises the subject matter of any variation of example 21, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a tier-2 eNB sector associated with the new primary tier-2 UE sector.

Example 32 comprises the subject matter of any variation of example 21, wherein the message requests that the eNB select the new tier-2 eNB sector selected via a sector sweep of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector.

Example 33 comprises the subject matter of any variation of example 21, wherein the PDCCH comprises m parts, and wherein the instructions, when executed, further cause the UE to: receive a first part of the PDCCH and a UE-specific part of the PDCCH via the tier-1 UE sector, wherein the first part indicates the UE-specific part; and perform a sector sweep of the plurality of tier-2 UE sectors during the m-2 parts of the PDCCH other than the first part and the UE-specific part.

Example 34 comprises the subject matter of any variation of example 21, wherein the instructions, when executed, cause the UE to evaluate the signal quality associated with each tier-2 UE sector based on an angle of arrival (AoA) estimation algorithm.

Example 35 comprises the subject matter of any variation of example 21, wherein the PDCCH comprises a secondary synchronization signal (SSS), and wherein the instructions, when executed, further cause the UE to: perform a sector sweep of the plurality of tier-2 UE sectors during the SSS; and evaluate the signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on the SSS.

Example 36 comprises the subject matter of any variation of example 21, wherein the plurality of tier-2 UE sectors comprises n UE sectors, wherein n is configured via one of a broadcast channel (BCH) or an initial attachment of the UE.

Example 37 is an apparatus configured to be employed within an Evolved NodeB (eNB), comprising one or more processors configured to: generate physical downlink control channel (PDCCH) data, wherein the PDCCH data indicates a downlink (DL) assignment associated with a first User Equipment (UE); encode the PDCCH data for transmission to the first UE; modulate a set of DL data for transmission to the first
UE via a current primary tier-2 eNB sector of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector, wherein the primary tier-2 eNB sector is associated with a current primary tier-2 UE sector; map the modulated set of DL data to a physical downlink shared channel (PDSCH) based on the DL assignment; process a message received by the transceiver circuitry from the first UE via the tier-1 eNB sector, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a new primary tier-2 eNB sector; and select, in response to the message, the new primary tier-2 eNB sector from the plurality of tier-2 eNB sectors.

[00135] Example 38 comprises the subject matter of any variation of example 37, wherein the one or more processors are configured to output the PDCCH data to the transceiver circuitry for transmission to the first UE via the tier-1 sector of the eNB.

[00136] Example 39 comprises the subject matter of any variation of example 37, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the set of DL data.

[00137] Example 40 comprises the subject matter of any variation of example 39, wherein the one or more processors are further configured to map the set of DL data to the PDSCH for retransmission to the first UE via the new primary tier-2 eNB sector.

[00138] Example 41 comprises the subject matter of any variation of any of examples 37-40, wherein the PDCCH data comprises a secondary synchronization signal (SSS) for a predetermined time or a predetermined number of symbols.

[00139] Example 42 comprises the subject matter of any variation of any of examples 37-40, wherein the PDCCH data comprises m parts, wherein each of the final m-1 parts of the PDCCH data is associated with one or more distinct UEs of a set of UEs comprising the first UE, and wherein the first part of the PDCCH data indicates with which distinct UE each of the final m-1 parts is associated.

[00140] Example 43 comprises the subject matter of any variation of any of examples 37-40, wherein the message indicates a new primary tier-2 UE sector, and wherein the one or more processors are configured to select a tier-2 eNB sector associated with the new primary tier-2 UE sector as the new primary tier-2 eNB sector.

[00141] Example 44 comprises the subject matter of any variation of any of examples 37-40, wherein the one or more processors are configured to select the new primary tier-2 eNB sector based at least in part on a sector sweep of the plurality of tier-2 eNB sectors.
[00142] Example 45 comprises the subject matter of any variation of any of examples 37-40, wherein the one or more processors are configured to encode the PDCCH and map the set of DL data for transmission during a subframe, and wherein the message is received during the subframe.

[00143] Example 46 comprises the subject matter of any variation of example 37, wherein the PDCCH data comprises a secondary synchronization signal (SSS) for a predetermined time or a predetermined number of symbols.

[00144] Example 47 comprises the subject matter of any variation of example 37, wherein the PDCCH data comprises m parts, wherein each of the final m-1 parts of the PDCCH data is associated with one or more distinct UEs of a set of UEs comprising the first UE, and wherein the first part of the PDCCH indicates with which distinct UE each of the final m-1 parts is associated.

[00145] Example 48 comprises the subject matter of any variation of example 37, wherein the message indicates a new primary tier-2 UE sector, and wherein the one or more processors are configured to select a tier-2 eNB sector associated with the new primary tier-2 UE sector as the new primary tier-2 eNB sector.

[00146] Example 49 comprises the subject matter of any variation of example 37, wherein the one or more processors are configured to select the new primary tier-2 eNB sector based at least in part on a sector sweep of the plurality of tier-2 eNB sectors.

[00147] Example 50 comprises the subject matter of any variation of example 37, wherein the one or more processors are configured to encode the PDCCH and map the set of DL data for transmission during a subframe, and wherein the message is received during the subframe.

[00148] Example 51 is an apparatus configured to be employed within a User Equipment (UE), comprising means for communication and means for processing. The means for communication is configured to receive, from an Evolved NodeB (eNB), a physical downlink control channel (PDCCH) via one or more of a tier-1 UE sector or a plurality of tier-2 UE sectors. The means for processing is configured to: evaluate a signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based on the received PDCCH; determine to replace a current primary tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on a signal quality associated with the current primary tier-2 UE sector; select a new primary tier-2 UE sector of the plurality of tier-2 UE sectors; and generate a message requesting the eNB to replace a current primary tier-2 eNB sector with a new primary tier-2 eNB sector. The means for
communication is further configured to transmit the message to the eNB via the new primary tier-2 UE sector.

[00149] Example 52 comprises the subject matter of any variation of example 51, wherein the means for processing is further configured to determine to replace the current primary tier-2 UE sector based at least in part on a failed reception of a data set from a physical downlink shared channel (PDSCH), wherein the data set is indicated via a downlink (DL) assignment of the PDCCH.

[00150] Example 53 comprises the subject matter of any variation of example 51, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK).

[00151] Example 54 comprises the subject matter of any variation of any of examples 51-53, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a tier-2 eNB sector associated with the new primary tier-2 UE sector.

[00152] Example 55 comprises the subject matter of any variation of any of examples 51-53, wherein the message requests that the eNB select the new tier-2 eNB sector selected via a sector sweep of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector.

[00153] Example 56 comprises the subject matter of any variation of any of examples 51-53, wherein the PDCCH comprises m parts, and wherein the means for communication are further configured to: receive a first part of the PDCCH and a UE-specific part of the PDCCH via the tier-1 UE sector, wherein the first part indicates the UE-specific part; and perform a sector sweep of the plurality of tier-2 UE sectors during the m-2 parts of the PDCCH other than the first part and the UE-specific part.

[00154] Example 57 comprises the subject matter of any variation of any of examples 51-53, wherein the means for processing are further configured to evaluate the signal quality associated with each tier-2 UE sector based on an angle of arrival (AoA) estimation algorithm.

[00155] Example 58 comprises the subject matter of any variation of any of examples 51-53, wherein the PDCCH comprises a secondary synchronization signal (SSS), wherein the means for communication are further configured to perform a sector sweep of the plurality of tier-2 UE sectors during the SSS, and wherein the means for processing are further configured to evaluate the signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on the SSS.
[00156] Example 59 comprises the subject matter of any variation of any of examples 51-53, wherein the plurality of tier-2 UE sectors comprises n UE sectors, wherein n is configured via one of a broadcast channel (BCH) or an initial attachment of the UE.

[00157] Example 60 comprises the subject matter of any variation of any of examples 1-20, further comprising the transceiver circuitry.

[00158] Example 61 comprises the subject matter of any variation of any of examples 37-50, further comprising the transceiver circuitry.

[00159] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00160] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00161] In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a “means”) used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.
CLAIMS

What is claimed is:

1. An apparatus configured to be employed within a User Equipment (UE), comprising one or more processors configured to:
   decode physical downlink control channel (PDCCH) data received by transceiver circuitry from an Evolved NodeB (eNB) via one or more of a tier-1 UE sector or a plurality of tier-2 UE sectors;
   measure, based on the decoded PDCCH data, an associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors, wherein the plurality of tier-2 UE sectors comprises a primary tier-2 UE sector;
   determine to replace the primary tier-2 UE sector with a distinct tier-2 UE sector of the plurality of tier-2 UE sectors; and
   generate an uplink (UL) message requesting the eNB to update a tier-2 eNB sector associated with the primary tier-2 UE sector.

2. The apparatus of claim 1, wherein the PDCCH data is received via the tier-1 UE sector.

3. The apparatus of claim 1, wherein a first portion of the PDCCH data is received via the tier-1 UE sector, and wherein a second portion of the PDCCH data is received via a sector sweep over the plurality of tier-2 UE sector.

4. The apparatus of claim 1, wherein the PDCCH data comprises a secondary synchronization signal (SSS), and wherein the SSS is received via a sector sweep over the plurality of tier-2 UE sectors.

5. The apparatus of any of claims 1-4, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is indicated via a broadcast channel (BCH).

6. The apparatus of any of claims 1-4, wherein the plurality of tier-2 UE sectors comprises n tier-2 UE sectors, wherein n is configured via an initial UE attachment.
7. The apparatus of any of claims 1-4, wherein the one or more processors are configured to measure the associated path quality for each tier-2 UE sector of the plurality of tier-2 UE sectors via an angle of arrival (AoA) estimation algorithm.

8. The apparatus of any of claims 1-4, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request to update the tier-2 eNB sector to a predetermined tier-2 eNB sector associated with the distinct tier-2 UE sector.

9. The apparatus of any of claims 1-4, wherein the message requesting the eNB to update the tier-2 eNB sector associated with the primary tier-2 UE sector comprises a request for the eNB to perform a sector sweep of tier-2 eNB sectors to update the tier-2 eNB sector associated with the primary tier-2 UE sector.

10. The apparatus of any of claims 1-4, wherein the one or more processors are configured to determine to replace the primary tier-2 UE sector based on a failed reception of physical downlink shared channel (PDSCH) data scheduled via the decoded PDCCH data.

11. The apparatus of claim 10, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the PDSCH.

12. A machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to:
   receive, from an Evolved NodeB (eNB), a physical downlink control channel (PDCCH) via one or more of a tier-1 UE sector or a plurality of tier-2 UE sectors;
   evaluate a signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based on the received PDCCH;
   determine to replace a current primary tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on a signal quality associated with the current primary tier-2 UE sector;
   select a new primary tier-2 UE sector of the plurality of tier-2 UE sectors;
   generate a message requesting the eNB to replace a current primary tier-2 eNB sector with a new primary tier-2 eNB sector; and
transmit the message to the eNB via the new primary tier-2 UE sector.

13. The machine readable medium of claim 12, wherein the instructions, when executed, cause the UE to determine to replace the current primary tier-2 UE sector based at least in part on a failed reception of a data set from a physical downlink shared channel (PDSCH), wherein the data set is indicated via a downlink (DL) assignment of the PDCCH.

14. The machine readable medium of claim 12, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK).

15. The machine readable medium of any of claims 12-14, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a tier-2 eNB sector associated with the new primary tier-2 UE sector.

16. The machine readable medium of any of claims 12-14, wherein the message requests that the eNB select the new tier-2 eNB sector selected via a sector sweep of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector.

17. The machine readable medium of any of claims 12-14, wherein the PDCCH comprises m parts, and wherein the instructions, when executed, further cause the UE to:
   receive a first part of the PDCCH and a UE-specific part of the PDCCH via the tier-1 UE sector, wherein the first part indicates the UE-specific part; and
   perform a sector sweep of the plurality of tier-2 UE sectors during the m-2 parts of the PDCCH other than the first part and the UE-specific part.

18. The machine readable medium of any of claims 12-14, wherein the instructions, when executed, cause the UE to evaluate the signal quality associated with each tier-2 UE sector based on an angle of arrival (AoA) estimation algorithm.

19. The machine readable medium of any of claims 12-14, wherein the PDCCH comprises a secondary synchronization signal (SSS), and wherein the instructions, when executed, further cause the UE to:
perform a sector sweep of the plurality of tier-2 UE sectors during the SSS; and evaluate the signal quality associated with each tier-2 UE sector of the plurality of tier-2 UE sectors based at least in part on the SSS.

20. The machine readable medium of any of claims 12-14, wherein the plurality of tier-2 UE sectors comprises n UE sectors, wherein n is configured via one of a broadcast channel (BCH) or an initial attachment of the UE.

21. An apparatus configured to be employed within an Evolved NodeB (eNB), comprising one or more processors configured to:
   generate physical downlink control channel (PDCCH) data, wherein the PDCCH data indicates a downlink (DL) assignment associated with a first User Equipment (UE);
   encode the PDCCH data for transmission to the first UE;
   modulate a set of DL data for transmission to the first UE via a current primary tier-2 eNB sector of a plurality of tier-2 eNB sectors associated with a tier-1 eNB sector, wherein the primary tier-2 eNB sector is associated with a current primary tier-2 UE sector;
   map the modulated set of DL data to a physical downlink shared channel (PDSCH) based on the DL assignment;
   process a message received by the transceiver circuitry from the first UE via the tier-1 eNB sector, wherein the message requests that the eNB replace the current primary tier-2 eNB sector with a new primary tier-2 eNB sector; and
   select, in response to the message, the new primary tier-2 eNB sector from the plurality of tier-2 eNB sectors.

22. The apparatus of claim 21, wherein the one or more processors are configured to output the PDCCH data to the transceiver circuitry for transmission to the first UE via the tier-1 sector of the eNB.

23. The apparatus of claim 21, wherein the message comprises a hybrid automatic repeat request (HARQ) negative acknowledgement (NACK) in response to the set of DL data.
24. The apparatus of claim 23, wherein the one or more processors are further configured to map the set of DL data to the PDSCH for retransmission to the first UE via the new primary tier-2 eNB sector.

25. The apparatus of any of claims 21-24, wherein the PDCCH data comprises a secondary synchronization signal (SSS) for a predetermined time or a predetermined number of symbols.

26. The apparatus of any of claims 21-24, wherein the PDCCH data comprises m parts, wherein each of the final m-1 parts of the PDCCH data is associated with one or more distinct UEs of a set of UEs comprising the first UE, and wherein the first part of the PDCCH data indicates with which distinct UE each of the final m-1 parts is associated.

27. The apparatus of any of claims 21-24, wherein the message indicates a new primary tier-2 UE sector, and wherein the one or more processors are configured to select a tier-2 eNB sector associated with the new primary tier-2 UE sector as the new primary tier-2 eNB sector.

28. The apparatus of any of claims 21-24, wherein the one or more processors are configured to select the new primary tier-2 eNB sector based at least in part on a sector sweep of the plurality of tier-2 eNB sectors.

29. The apparatus of any of claims 21-24, wherein the one or more processors are configured to encode the PDCCH data and map the set of DL data for transmission during a subframe, and wherein the message is received during the subframe.
FIG. 4

PDCCH

ACK/NACK

PDSCH (DL data)

TTI (e.g., 0.4 or 0.8ms, etc.)

PDCCH
910 RECEIVE PDCCH FROM eNB VIA TIER-1 UE SECTOR AND/OR PLURALITY OF TIER-2 UE SECTORS

920 EVALUATE SIGNAL QUALITY ASSOCIATED WITH EACH TIER-2 UE SECTOR BASED ON RECEIVED PDCCH

930 MAKE DETERMINATION TO REPLACE CURRENT PRIMARY TIER-2 UE SECTOR BASED ON SIGNAL QUALITIES

940 SELECT NEW PRIMARY TIER-2 UE SECTOR FROM PLURALITY OF TIER-2 UE SECTORS

950 GENERATE MESSAGE REQUESTING eNB TO REPLACE CURRENT PRIMARY eNB TIER-2 SECTOR

960 TRANSMIT MESSAGE TO eNB VIA NEW PRIMARY TIER-2 UE SECTOR

FIG. 9
1010 GENERATE PDCCH COMPRISING DCI INDICATING DL ASSIGNMENT TO FIRST UE

1020 TRANSMIT PDCCH TO FIRST UE

1030 TRANSMIT DL DATA ASSOCIATED WITH DL ASSIGNMENT TO FIRST UE IN PDSCH VIA CURRENT PRIMARY TIER-2 eNB SECTOR

1040 RECEIVE MESSAGE REQUESTING eNB TO REPLACE CURRENT TIER-2 eNB SECTOR WITH NEW TIER-2 eNB SECTOR

1050 SELECT NEW TIER-2 eNB SECTOR

1060 OPTIONALLY RETRANSMIT DL DATA TO FIRST UE IN PDSCH VIA NEW TIER-2 eNB SECTOR

FIG. 10
### A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/06  H04B7/08  H04W2/04  
ADD. H04B7/0408

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)

H04B  
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

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* Further documents are listed in the continuation of Box C.*  

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Date of the actual completion of the international search: 15 February 2017

Date of mailing of the international search report: 24/02/2017

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Authorized officer: Toumpakaris, D
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<td>WO 2014178656 A1</td>
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<td>14-02-2013</td>
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