(54) Title: DOWNLINK CONTROL TRANSMISSION IN MULTICARRIER OPERATION

(57) Abstract: A wireless communication network distributes resources for a Physical Downlink Control Channel (PDCCH) over multiple carriers in accordance with a constraint that limits a number of blind decoding actions required by user equipment (UE). Distribution can entail segregating UE-specific and common search spaces to different monitored carriers. Distribution can entail segregating aggregation levels to different monitored carriers. Distribution can entail segregating a number of decoding candidates for a given aggregation level to different monitored carriers. The distribution can be orthogonal or non-orthogonal, and can be UE-based or per cell-based. The distribution can be static, semi-static or hop with time.

FIG. 1
as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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DOWNLINK CONTROL TRANSMISSION IN MULTICARRIER OPERATION

CLAIM OF PRIORITY UNDER 35 U.S.C. §119

[0001] The present Application for Patent claims priority to Provisional Application No. 61/175,411 entitled "DOWNLINK CONTROL TRANSMISSION IN MULTICARRIER OPERATION" filed May 4, 2009, and assigned to the assignee hereof and hereby expressly incorporated by reference herein.

BACKGROUND

Field

[0002] The present disclosure relates generally to communication, and more specifically to techniques for transmitting information in a wireless communication network.

Background

[0003] The present disclosure relates generally to communication, and more specifically to techniques for transmitting information in a wireless communication network.

[0004] The 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) represents a major advance in cellular technology and is the next step forward in cellular 3G services as a natural evolution of Global system for mobile communications (GSM) and Universal Mobile Telecommunications System (UMTS). LTE provides for an uplink speed of up to 75 megabits per second (Mbps) and a downlink speed of up to 300 Mbps and brings many technical benefits to cellular networks. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade. Bandwidth is scalable from 1.25 MHz to 20 MHz. This suits the needs of different network operators that have different bandwidth allocations, and also allows operators to provide different services based on spectrum. LTE is also expected to improve spectral efficiency in 3G networks, allowing carriers to
provide more data and voice services over a given bandwidth. LTE encompasses high-speed data, multimedia unicast and multimedia broadcast services.

[0005] The LTE physical layer (PHY) is a highly efficient means of conveying both data and control information between an enhanced base station (eNodeB) and mobile user equipment (UE). The LTE PHY employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier - Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of symbol periods.

[0006] Recently, LTE Advanced is an evolving mobile communication standard for providing 4G services. Being defined as 3G technology, LTE does not meet the requirements for 4G also called IMT Advanced as defined by the International Telecommunication Union such as peak data rates up to 1 Gbit/s. Besides the peak data rate, LTE Advanced also targets faster switching between power states and improved performance at the cell edge.

SUMMARY

[0007] The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosed aspects. This summary is not an extensive overview and is intended to neither identify key or critical elements nor delineate the scope of such aspects. Its purpose is to present some concepts of the described features in a simplified form as a prelude to the more detailed description that is presented later.

[0008] In one aspect, a method is provided for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information by employing a processor executing computer executable instructions stored on a computer readable storage medium to implement the following acts: A constraint is accessed for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. A reduced set of the plurality of decoding candidates is monitored in
accordance with the constraint. The reduced set of decoding candidates is blind decoded.

[0009] In another aspect, a computer program product is provided for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. At least one computer readable storage medium stores computer executable instructions that, when executed by the at least one processor, implement components: A first set of instructions causes a computer to access a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. A second set of instructions causes the computer to monitor a reduced set of decoding candidates in accordance with the constraint. A third set of instructions causes the computer to blind decode the reduced set of decoding candidates.

[0010] In an additional aspect, an apparatus is provided for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. At least one computer readable storage medium stores computer executable instructions that when executed by the at least one processor implement components: Means is provided for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. Means are provided for monitoring a reduced set of decoding candidates in accordance with the constraint. Means are provided for blind decoding the reduced set of decoding candidates.

[0011] In a further aspect, an apparatus is provided for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. A computing platform accesses a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distribution on a plurality of carriers. A receiver monitors a reduced set of decoding candidates in accordance with the constraint. A decoder blind decodes the reduced set of decoding candidates.

[0012] In yet one aspect, a method is provided for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information by employing a processor executing computer executable instructions stored on a computer readable storage medium to implement the following acts: A constraint is accessed for a Physical Downlink Control CHannel
(PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. The Physical Downlink Control CHannel (PDCCH) is mapped on the plurality of carriers in accordance with the constraint. The PDCCH is encoded and transmitted the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

[0013] In yet another aspect, a computer program product is provided for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. At least one computer readable storage medium stores computer executable instructions that, when executed by at least one processor, implement components: A first set of instructions causes a computer to access a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. A second set of instructions causes the computer to map the Physical Downlink Control CHannel (PDCCH) on the plurality of carriers in accordance with the constraint. A third set of instructions causes the computer to encode and transmit the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

[0014] In yet an additional aspect, an apparatus is provided for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. At least one computer readable storage medium stores computer executable instructions that, when executed by the at least one processor, implement components comprising: Means are provided for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. Means are provided for mapping the Physical Downlink Control CHannel (PDCCH) on the plurality of carriers in accordance with the constraint. Means are provided for encoding and transmitting the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

[0015] In yet a further aspect, an apparatus is provided for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. A computing platform accesses a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. A mapping/encoder maps and encodes
the Physical Downlink Control CHannel (PDCCH) on the plurality of carriers in accordance with the constraint. A transmitter transmits the PDCCH as mapped and encoded for user equipment (UE) to blind decode using a reduced set of decoding candidates.

[0016] To the accomplishment of the foregoing and related ends, one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects and are indicative of but a few of the various ways in which the principles of the aspects may be employed. Other advantages and novel features will become apparent from the following detailed description when considered in conjunction with the drawings and the disclosed aspects are intended to include all such aspects and their equivalents.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0017] The features, nature, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[0018] FIG. 1 depicts a block diagram of a communication system in which user equipment blind decodes candidate Downlink Control Information (DCI) on Physical Downlink Control Channels (PDCCH) using multicarrier operations.

[0019] FIG. 2 depicts a flow diagram of a methodology or sequence of operations for transmitting and monitoring candidates distributed on PDCCH on multiple monitored carriers.

[0020] FIG. 3 depicts a heterogeneous wireless communication network for constraining multicarrier control channel blind decoding.

[0021] FIG. 4 depicts a macro base station for communication with UE that constrains multicarrier control channel blind decoding.

[0022] FIG. 5 depicts a block diagram of a communication system that constrains multicarrier control channel blind decoding.

[0023] FIG. 6 depicts a block diagram of a logical grouping of electrical components for monitoring a physical downlink control channel (PDCCH) in a wireless communication system.
[0024] FIG. 7 depicts a block diagram of a logical grouping of electrical components for transmitting a physical downlink control channel (PDCCH) in a wireless communication system.

[0025] FIG. 8 depicts a block diagram of an apparatus having means for monitoring a physical downlink control channel (PDCCH) in a wireless communication system.

[0026] FIG. 9 depicts a block diagram of an apparatus having means for transmitting a physical downlink control channel (PDCCH) in a wireless communication system.

[0027] FIGS. 10A-10B depict a flow diagram of a methodology or sequence of operations for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information.

[0028] FIGS. 11A-11B depict a flow diagram of a methodology or sequence of operations for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information.

**DETAILED DESCRIPTION**

[0029] Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It may be evident, however, that the various aspects may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate describing these aspects.

[0030] With reference to FIG. 1, a communication system 100 has a node depicted as an evolved Base Node (eNB) 102 that constrains distribution of Downlink Control Information (DCI) 104a-104z on Aggregations Levels 1, 2, 4 and 8 depicted at 106a-106d of a Physical Downlink Control Channel (PDCCH) 108, respectively in a manner that enables user equipment (UE) 110 to successfully perform blind decoding using dual receivers 112a, 112b on two monitored carriers without overlap. In particular, the eNB 102 accesses a stored constraint 114, such as by a computing platform (not shown), used to limit how the PDCCH 108 is distributed by a mapping / encoder 116 for transmitting by antennas 118a, 118b. UE 110 accesses a stored constraint 120, such as by a
computing platform (not shown), in order to determine how the distribution is limited, and thus the number of decoding candidates that have to be processed by a demapping / decoder 122.

[0031] Currently, in LTE release 8, downlink control (PDCCH) is transmitted for a UE using either a common search space or UE-specific search space. Each search space is further classified into PDCCH aggregation levels for different protection of the control channel transmission. In the common search space, two levels are defined: 4 CCEs or 8 CCEs, where each CCE consists of 36 resource elements (REs). In the UE-specific search space, four levels are defined: 1, 2, 4 and 8. For each aggregation level, each UE has to try to decode more than one possible candidate. To be more specific, for common search space level 4 (CCEs), up to 4 candidates, while for level 8, up to 2 candidates. For UE-specific search space, up to 6, 6, 2, and 2 candidates for levels 1, 2, 4 and 8, respectively. Each candidate may carry up to two downlink control information (DCI) formats. As a result, the total number of blind decodes for a UE is up to \((r+2)*2 + (6+6+2+2)*2 = 44\) in any subframe. Note that the search spaces among common and UE-specific, and for different aggregation levels might overlap. This overlap, if such occurs, limits the possibility of scheduling a UE due to potential collision with other UEs. LTE-A offers the opportunity for a UE to monitor multiple carriers at the same time. In this case, it is desirable to limit the total number of blind decodes, e.g., still 44 (or higher but limited) comparing to the single-carrier operation. If a UE is required to monitor more than one carrier, but the PDDCH search space is limited by one carrier, and the number of the blind decodes is kept at 44, the limitation due to overlapping as indicated will still exist.

[0032] In order to improve the scheduling restriction/limitation discussed above, the innovation provides the following:

Distribute search space (UE-specific and common) to different monitored carriers, and/or

Distribute the aggregation levels to different monitored carriers, and/or

Distribute the number of decoding candidates for a given aggregation level to different monitored carriers.

The distribution can be orthogonal (still keeping 44 blind decodes), or non-orthogonal (>44 blind decodes). For instance, with 2 carriers, a UE may only monitor aggregation
levels 1 and 4 in carrier 1, and 2 and 8 in carrier 2 (orthogonal distribution). Another
example is to monitor levels 1, 4 and 8 in carrier 1 and 2 and 8 in carrier 2 (non-
orthogonal distribution), the total number of blind decodes in this example is 48 > 44).
The distribution can be done on a UE basis (or per cell basis), such as by referencing a
user equipment identifier or cell identifier. To compute the actual distribution, one may
utilize time information (e.g., SFN or subframe index, UE ID, cell ID, etc.) The
distribution may hop with time.

[0033] The distribution can be uniformly or non-uniformly distributed across
carriers. In particular, the distribution can be such that two carriers have the same
number of decoding candidates (uniform) or different number (non-uniform) of
decoding candidates. Further, the distribution can limit a total number of decoding
candidates across a plurality of carriers to be the same as possible for a single carrier
communication approach. For example, UE can be configured for monitoring three (3)
downlink carriers. A single carrier configuration case would provide for a defined
number of control symbols configured, a size of PHICH (e.g., DL ACK/NAK
transmission (Tx) to support UL H-ARQ, etc.), a number of transmit antennas, the
carrier bandwidth(s), etc. This single carrier configuration results in a maximum
number of blind decoding candidates such as up to 44. Rather than utilizing 44 on each
of the three downlink carriers, a constraint can limit the total amount of blind decoding
to lesser number, such as 96. In one aspect, each of the carriers can be constrained to
have a uniform number. For example, for a 96 decoding candidate constraint, each of
the three carriers can have a limit of 32 decoding candidates. In another aspect, a subset
of the carriers can have a uniform amount. For example, given a constraint of 96 and a
single carrier number of 44, a first carrier can have 44, a second carrier can have 26 and
a third carrier can have 26. In an additional aspect, the distribution imposed by a
constraint can be non-uniform. For example, given a constraint of 96 and a single
carrier number of 44, a first carrier can have 44, a second carrier can have 31, and a
third carrier can have 21. For a further aspect, the constraint can impose a distribution
that is both uniform and non-uniform. For example, given a constraint of 96 and a
single carrier number of 44, a first carrier can have 44, a second carrier can have 44, and
a third carrier can have 8. Yet another example is Carrier 1: 96, carrier 2: 0, and carrier
3: 0 - that is, two carriers with 0 decoding candidates, while the first carrier has it all.
In all the examples listed earlier (how to distribute 96 candidates), the reduced set of
decoding candidates may come from limiting the search space (e.g., only supporting UE-specific search space), limiting the number of aggregation levels (e.g., only support levels 4 and 8), limiting the number of candidates per aggregation level, or a combination thereof. For instance, one carrier may have a full set of decoding candidates as in the single carrier case, while another carrier only supports UE-specific search space with limited aggregation levels and/or limited candidates per aggregation level.

[0034] In the extreme case, a carrier may not have any PDCCH decoding candidates, such that a UE will not monitor this carrier to decode PDCCH. In one example, given a constraint of 96 and a single carrier number of 44, a first carrier can have 48, a second carrier can have 48, and a third carrier can have 0 (no PDCCH decoding candidates). In yet another example, given a constraint of 96 and a single carrier number of 44, a first carrier can have 52, a second carrier can have 44, and a third carrier can have 0 (no PDCCH decoding candidates). It should be noted that typically a carrier with a large number of decoding candidates has more reliable PDCCH transmission, less loaded, less scheduling restrictions/collisions, etc. Such carrier(s) can be called primary carriers or anchor carriers. A UE can be semi-statically configured with such primary carriers. On the other hand, a carrier with small or zero number of decoding candidates is often interference limited or loaded.

[0035] In FIG. 2, a methodology or sequence of operations 200 is provided for a physical downlink control channel (PDCCH) transmitted by a node and received by user equipment in a wireless communication system. A set of PDCCH candidates for a search space in a subframe are for monitoring two carriers at a time, wherein the subframe comprises a control region for transmitting control information, the control region comprising a plurality of resource elements mapped to a plurality of control channel elements (CCEs), a CCE corresponds to a set of resource elements, and the search space that comprises a contiguous set of CCEs is classified into a common search space and a UE-specific search space, wherein the common search space is monitored by all user equipments (UEs) in a cell and the UE-specific search space is monitored by at least one UE in the cell (block 200). A constraint is accessed for a Physical Downlink Control Channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers (block 202).
One or more techniques can be employed for the constraining distribution. In block 204, UE-specific search space and common search space are distributed to different monitored carriers. In block 206, aggregation levels are distributed to different monitored carriers. In block 208, a number of decoding candidates for a selected aggregation level are distributed to different monitored carriers. In block 210, candidates for blind decoding are distributed in an orthogonal manner with regard to monitored carriers. In block 212, aggregation levels 1 and 4 are distributed in a first carrier and aggregation levels 2 and 8 are distributed in a second carrier. In block 214, candidates for blind decoding are distributed in a nonorthogonal manner with regard to monitored carriers. In block 216, aggregation levels 1, 4 and 8 are distributed in a first carrier and aggregation levels 2 and 8 are distributed in a second carrier. In block 218, the candidates for blind decoding are distributed on a UE-basis. In block 220, the candidates for blind decoding are distributed on a per cell basis. In block 222, the candidates for blind decoding are distributed with frequency hopping over time.

FIG. 3 shows a wireless communication network 300, which may include a number of base stations 310 and other network entities. A base station may be a station that communicates with the terminals and may also be referred to as an access point, a Node B, an evolved Node B, etc. Each base station 310 may provide communication coverage for a particular geographic area. The term "cell" can refer to a coverage area of a base station and/or a base station subsystem serving this coverage area, depending on the context in which the term is used.

A base station may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cell. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by terminals with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by terminals with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by terminals having association with the femto cell, e.g., terminals belonging to a closed subscriber group (CSG). The CSG may include terminals for users in a home, terminals for users subscribing to a special service plan, etc. A base station for a macro cell may be referred to as a macro base station. A base
station for a pico cell may be referred to as a pico base station. A base station for a femto cell may be referred to as a femto base station or a home base station.

In the example shown in FIG. 3, base stations 310a, 310b and 310c may be macro base stations for macro cells 302a, 302b and 302c, respectively. Base station 310x may be a pico base station for a pico cell 302x. Base station 310y may be a femto base station for a femto cell 302y. Although not shown in FIG. 3 for simplicity, the macro cells may overlap at the edges. The pico and femto cells may be located within the macro cells (as shown in FIG. 3) or may overlap with macro cells and/or other cells.

Wireless network 300 may also include relay stations, e.g., a relay station 310z. A relay station is a station that receives a transmission of data and/or other information from an upstream station and sends a transmission of the data and/or other information to a downstream station. The upstream station may be a base station, another relay station, or a terminal. The downstream station may be a terminal, another relay station, or a base station. A relay station may also be a terminal that relays transmissions for other terminals. A relay station may transmit and/or receive low reuse preambles. For example, a relay station may transmit a low reuse preamble in similar manner as a pico base station and may receive low reuse preambles in similar manner as a terminal.

A network controller 330 may couple to a set of base stations and provide coordination and control for these base stations. Network controller 330 may be a single network entity or a collection of network entities. Network controller 330 may communicate with base stations 310 via a backhaul. Backhaul network communication 334 can facilitate point-to-point communication between base stations 310a-310c employing such a distributed architecture. Base stations 310a-310c may also communicate with one another, e.g., directly or indirectly via wireless or wireline backhaul.

Wireless network 300 may be a homogeneous network that includes only macro base stations (not shown in FIG. 3). Wireless network 300 may also be a heterogeneous network that includes base stations of different types, e.g., macro base stations, pico base stations, home base stations, relay stations, etc. These different types of base stations may have different transmit power levels, different coverage areas, and different impact on interference in wireless network 300. For example, macro base stations may have a high transmit power level (e.g., 20 Watts) whereas pico and femto
base stations may have a low transmit power level (e.g., 3 Watt). The techniques described herein may be used for homogeneous and heterogeneous networks.

Terminals 320 may be dispersed throughout wireless network 300, and each terminal may be stationary or mobile. A terminal may also be referred to as an access terminal (AT), a mobile station (MS), user equipment (UE), a subscriber unit, a station, etc. A terminal may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, etc. A terminal may communicate with a base station via the downlink and uplink. The downlink (or forward link) refers to the communication link from the base station to the terminal, and the uplink (or reverse link) refers to the communication link from the terminal to the base station.

A terminal may be able to communicate with macro base stations, pico base stations, femto base stations, and/or other types of base stations. In FIG. 3, a solid line with double arrows indicates desired transmissions between a terminal and a serving base station, which is a base station designated to serve the terminal on the downlink and/or uplink. A dashed line with double arrows indicates interfering transmissions between a terminal and a base station. An interfering base station is a base station causing interference to a terminal on the downlink and/or observing interference from the terminal on the uplink.

Wireless network 300 may support synchronous or asynchronous operation. For synchronous operation, the base stations may have the same frame timing, and transmissions from different base stations may be aligned in time. For asynchronous operation, the base stations may have different frame timing, and transmissions from different base stations may not be aligned in time. Asynchronous operation may be more common for pico and femto base stations, which may be deployed indoors and may not have access to a synchronizing source such as Global Positioning System (GPS).

In one aspect, to improve system capacity, the coverage area 302a, 302b, or 302c corresponding to a respective base station 310a-310c can be partitioned into multiple smaller areas (e.g., areas 304a, 304b, and 304c). Each of the smaller areas 304a, 304b, and 304c can be served by a respective base transceiver subsystem (BTS, not shown). As used herein and generally in the art, the term "sector" can refer to a BTS and/or its coverage area depending on the context in which the term is used. In one
example, sectors 304a, 304b, 304c in a cell 302a, 302b, 302c can be formed by groups of antennas (not shown) at base station 410, where each group of antennas is responsible for communication with terminals 420 in a portion of the cell 302a, 302b, or 302c. For example, a base station 410 serving cell 302a can have a first antenna group corresponding to sector 304a, a second antenna group corresponding to sector 304b, and a third antenna group corresponding to sector 304c. However, it should be appreciated that the various aspects disclosed herein can be used in a system having sectorized and/or unsectorized cells. Further, it should be appreciated that all suitable wireless communication networks having any number of sectorized and/or unsectorized cells are intended to fall within the scope of the hereto appended claims. For simplicity, the term "base station" as used herein can refer both to a station that serves a sector as well as a station that serves a cell. It should be appreciated that as used herein, a downlink sector in a disjoint link scenario is a neighbor sector. While the following description generally relates to a system in which each terminal communicates with one serving access point for simplicity, it should be appreciated that terminals can communicate with any number of serving access points.

[0047] Referring to FIG. 4, a multiple access wireless communication system according to one aspect is illustrated. An access point (AP) 400 includes multiple antenna groups, one including 404 and 406, another including 408 and 410, and an additional including 412 and 414. In FIG. 4, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Access terminal (AT) 416 is in communication with antennas 412 and 414, where antennas 412 and 414 transmit information to access terminal 416 over forward link 420 and receive information from access terminal 416 over reverse link 418. Access terminal 422 is in communication with antennas 406 and 408, where antennas 406 and 408 transmit information to access terminal 422 over forward link 426 and receive information from access terminal 422 over reverse link 424. In a FDD system, communication links 418, 420, 424 and 426 may use different frequency for communication. For example, forward link 420 may use a different frequency then that used by reverse link 418.

[0048] Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the access point. In the aspect, antenna
groups each are designed to communicate to access terminals in a sector, of the areas covered by access point 400.

In communication over forward links 420 and 426, the transmitting antennas of access point 400 utilize beamforming in order to improve the signal-to-noise ratio of forward links for the different access terminals 416 and 424. Also, an access point using beamforming to transmit to access terminals scattered randomly through its coverage causes less interference to access terminals in neighboring cells than an access point transmitting through a single antenna to all its access terminals.

An access point may be a fixed station used for communicating with the terminals and may also be referred to as an access point, a Node B, or some other terminology. An access terminal may also be called an access terminal, user equipment (UE), a wireless communication device, terminal, access terminal or some other terminology.

FIG. 5 shows a block diagram of a design of communication system 500 between a base station 502 and a terminal 504, which may be one of the base stations and one of the terminals in FIG. 1. Base station 502 may be equipped with TX antennas 534a through 534t, and terminal 504 may be equipped with RX antennas 552a through 552r, where in general T ≥ 1 and R ≥ 1.

At base station 502, a transmit processor 520 may receive traffic data from a data source 512 and messages from a controller/processor 540. Transmit processor 520 may process (e.g., encode, interleave, and modulate) the traffic data and messages and provide data symbols and control symbols, respectively. Transmit processor 520 may also generate pilot symbols and data symbols for a low reuse preamble and pilot symbols for other pilots and/or reference signals. A transmit (TX) multiple-input multiple-output (MIMO) processor 530 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the pilot symbols, if applicable, and may provide T output symbol streams to T modulators (MODs) 532a through 532t. Each modulator 532 may process a respective output symbol stream (e.g., for OFDM, SC-FDM, etc.) to obtain an output sample stream. Each modulator 532 may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. T downlink signals from modulators 532a through 532t may be transmitted via T antennas 534a through 534t, respectively.
At terminal 504, antennas 552a through 552r may receive the downlink signals from base station 502 and may provide received signals to demodulators (DEMODs) 554a through 554r, respectively. Each demodulator 554 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each demodulator 554 may further process the input samples (e.g., for OFDM, SC-FDM, etc.) to obtain received symbols. A MIMO detector 556 may obtain received symbols from all R demodulators 554a through 554r, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A receive processor 558 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded traffic data for terminal 504 to a data sink 560, and provide decoded messages to a controller/processor 580. A low reuse preamble (LRP) processor 584 may detect for low reuse preambles from base stations and provide information for detected base stations or cells to controller/processor 580.

On the uplink, at terminal 504, a transmit processor 564 may receive and process traffic data from a data source 562 and messages from controller/processor 580. The symbols from transmit processor 564 may be precoded by a TX MIMO processor 566 if applicable, further processed by modulators 554a through 554r, and transmitted to base station 502. At base station 502, the uplink signals from terminal 504 may be received by antennas 534, processed by demodulators 532, detected by a MIMO detector 536 if applicable, and further processed by a receive processor 538 to obtain the decoded packets and messages transmitted by terminal 504.

Controllers/processors 540 and 580 may direct the operation at base station 502 and terminal 504, respectively. Processor 540 and/or other processors and modules at base station 502 may perform or direct processes for the techniques described herein. Processor 584 and/or other processors and modules at terminal 504 may perform or direct processes for the techniques described herein. Memories 542 and 582 may store data and program codes for base station 502 and terminal 504, respectively, or dynamically perform storing. A scheduler 544 may schedule terminals for data transmission on the downlink and/or uplink and may provide resource grants for the scheduled terminals.

Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips
that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0057] With reference to FIG. 6, illustrated is a system 600 for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. For example, system 600 can reside at least partially in user equipment (UE). It is to be appreciated that system 600 is represented as including functional blocks, which can be functional blocks that represent functions implemented by a computing platform, processor, software, or combination thereof (e.g., firmware). System 600 includes a logical grouping 602 of electrical components that can act in conjunction. For instance, logical grouping 602 can include an electrical component for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers 604. Moreover, logical grouping 602 can include an electrical component for monitoring a reduced set of decoding candidates in accordance with the constraint 606. In addition, logical grouping 602 can include an electrical component for blind decoding the reduced set of decoding candidates 608. Additionally, system 600 can include a memory 620 that retains instructions for executing functions associated with electrical components 604-608. While shown as being external to memory 620, it is to be understood that one or more of electrical components 604-608 can exist within memory 620.

[0058] With reference to FIG. 7, illustrated is a system 700 for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. For example, system 700 can reside at least partially within a network entity (e.g., evolved base node). It is to be appreciated that system 700 is represented as including functional blocks, which can be functional blocks that represent functions implemented by a computing platform, processor, software, or combination thereof (e.g., firmware). System 700 includes a logical grouping 702 of electrical components that can act in conjunction. For instance, logical grouping 702 can include an electrical component for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers 704. Moreover, logical grouping 702
can include an electrical component for mapping the Physical Downlink Control CHannel (PDCCH) on the plurality of carriers in accordance with the constraint 706. In addition, logical grouping 702 can include an electrical component for encoding and transmitting the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates 708. Additionally, system 700 can include a memory 720 that retains instructions for executing functions associated with electrical components 704-708. While shown as being external to memory 720, it is to be understood that one or more of electrical components 704-708 can exist within memory 720.

[0059] In FIG. 8, an apparatus 802 is depicted for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. Means 804 are provided for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. Means 806 are provided for monitoring a reduced set of decoding candidates in accordance with the constraint. Means 808 are provided for blind decoding the reduced set of decoding candidates.

[0060] In FIG. 9, an apparatus 902 is depicted for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. Means 904 are provided for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers. Means 906 are provided for mapping the Physical Downlink Control CHannel (PDCCH) on the plurality of carriers in accordance with the constraint. Means 908 are provided for encoding and transmitting the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

[0061] In FIGS. 10A-10B, a methodology or sequence of operations 1000 is provided for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information. A processor is employed for executing computer executable instructions stored on a computer readable storage medium to implement the methodology (block 1002). A constraint is accessed for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers (block 1004). A
reduced set of the plurality of decoding candidates is monitored in accordance with the
constraint (block 1006). The reduced set of decoding candidates is blind decoded
(block 1008). In one aspect, the constraint limits distribution of the PDCCH such that
the UE avoids needing to monitor more than two carriers at a time (block 1009). In
particular, the constraint can limit the number of decoding candidates to approximately
the same as those possible for a single carrier implementation (block 1010).
Alternatively, the constraint limits the decoding candidates to a total number N within a
range of a lower number L of decoding candidates possible for a single carrier and an
upper number U equal to a product of the single carrier lower number L and a number
of monitored multiple carriers M, i.e., $L \leq N \leq L^*M$ (block 1012).

The constraint accessed in block 1002 can entail one or more characteristics
for limiting the number of blind decoding that has to be accomplished to successfully
receive PDCCH sent via multiple carriers. In one aspect, the constraint distributes a
common search space to a selected one of the plurality of carriers and distributes user
equipment specific search space to another selected one of the plurality of carriers
(block 1014). In another aspect, the constraint distributes a first aggregation level to a
selected one of the plurality of carriers and distributes a second aggregation level to
another selected one of the plurality of carriers (block 1016). In an additional aspect,
the constraint distributes a first subset of decoding candidates for a selected aggregation
level to a selected one of the plurality of carriers and distributes a second subset of
decoding candidates for the selected aggregation level to another selected one of the
plurality of carriers (block 1018). In another additional aspect, the constraint distributes
decoding candidates on user equipment basis (block 1019). In a further aspect, the
constraint distributes decoding candidates on a per cell basis (block 1020). In yet one
aspect, the constraint is for deriving a distribution based upon a subframe index (block
1022). In yet another aspect, the constraint is for deriving a distribution based upon a
random seed or a plurality of random seeds (block 1024).

A determination can be made whether the distribution of the PDCCH occurs
semi-statically (block 1026), and if so an updated determination of distribution is
scheduled (block 1028).
[0064] A determination can be made whether the distribution of the PDCCH hops with time (block 1030), and if so an updated determination of distribution is scheduled (block 1032).

[0065] In FIGS. 11A-IIB, a methodology or sequence of operations 1100 is provided for transmitting a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information. A processor is employed for executing computer executable instructions stored on a computer readable storage medium to implement the methodology (block 1102). A constraint is accessed for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers (block 1104). The Physical Downlink Control CHannel (PDCCH) is mapped on the plurality of carriers in accordance with the constraint (block 1106). The PDCCH is encoded and transmitted as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates (block 1108). In one aspect, the constraint limits distribution of the PDCCH such that the UE avoids needing to monitor more than two carriers at a time (block 1109). In particular, the constraint can limit the number of decoding candidates to approximately the same as those possible for a single carrier implementation (block 1110). Alternatively, the constraint limits the decoding candidates to a total number N within a range of a lower number L of decoding candidates possible for a single carrier and an upper number U equal to a product of the single carrier lower number L and a number of monitored multiple carriers M, i.e., \( L \leq N \leq L \times M \) (block 1112).

[0066] The constraint accessed in block 1102 can entail one or more characteristics for limiting the number of blind decoding that has to be accomplished to successfully receive PDCCH sent via multiple carriers. In one aspect, the constraint distributes a common search space to a selected one of the plurality of carriers and distributes user equipment specific search space to another selected one of the plurality of carriers (block 1114). In another aspect, the constraint distributes a first aggregation level to a selected one of the plurality of carriers and distributes a second aggregation level to another selected one of the plurality of carriers (block 1116). In an additional aspect, the constraint distributes a first subset of decoding candidates for a selected aggregation level to a selected one of the plurality of carriers and distributes a second subset of decoding candidates for the selected aggregation level to another selected one of the
plurality of carriers (block 1118). In another additional aspect, the constraint distributes decoding candidates on user equipment basis. In a further aspect, the constraint distributes decoding candidates on a per cell basis (block 1120). In yet one aspect, the constraint is for deriving a distribution based upon a subframe index (block 1122). In yet another aspect, the constraint is for deriving a distribution based upon one or more random seeds (block 1124).

[0067] A determination can be made whether the distribution of the PDCCH occurs semi-statically (block 1126), and if so an updated determination of distribution is scheduled (block 1128).

[0068] A determination can be made whether the distribution of the PDCCH hops with time (block 1130), and if so an updated determination of distribution is scheduled (block 1132).

[0069] Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the aspects disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

[0070] As used in this application, the terms "component", "module", "system", and the like are intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components may reside within a process
and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers.

[0071] The word "exemplary" is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0072] Various aspects will be presented in terms of systems that may include a number of components, modules, and the like. It is to be understood and appreciated that the various systems may include additional components, modules, etc. and/or may not include all of the components, modules, etc. discussed in connection with the figures. A combination of these approaches may also be used. The various aspects disclosed herein can be performed on electrical devices including devices that utilize touch screen display technologies and/or mouse-and-keyboard type interfaces. Examples of such devices include computers (desktop and mobile), smart phones, personal digital assistants (PDAs), and other electronic devices both wired and wireless.

[0073] In addition, the various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0074] Furthermore, the one or more versions may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques to produce software, firmware, hardware, or any combination thereof to control a computer to implement the disclosed aspects. The term "article of manufacture" (or alternatively, "computer program product") as used herein is intended
to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips...), optical disks (e.g., compact disk (CD), digital versatile disk (DVD)...), smart cards, and flash memory devices (e.g., card, stick). Additionally it should be appreciated that a carrier wave can be employed to carry computer-readable electronic data such as those used in transmitting and receiving electronic mail or in accessing a network such as the Internet or a local area network (LAN). Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope of the disclosed aspects.

[0075] The steps of a method or algorithm described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[0076] The previous description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[0077] In view of the exemplary systems described supra, methodologies that may be implemented in accordance with the disclosed subject matter have been described with reference to several flow diagrams. While for purposes of simplicity of explanation, the methodologies are shown and described as a series of blocks, it is to be
understood and appreciated that the claimed subject matter is not limited by the *order of* the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Moreover, not all illustrated blocks may be required to implement the methodologies described herein. Additionally, it should be further appreciated that the methodologies disclosed herein are capable of being stored on an article of manufacture to facilitate transporting and transferring such methodologies to computers. The term article of manufacture, as used herein, is intended to encompass a computer program accessible from any computer-readable device, carrier, or media.

[0078] It should be appreciated that any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein, will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

[0079] WHAT IS CLAIMED IS:
CLAIMS

1. A method for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information, comprising:

   employing a processor executing computer executable instructions stored on a computer readable storage medium to implement following acts:

   accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;

   monitoring a reduced set of decoding candidates in accordance with the constraint; and

   blind decoding the reduced set of decoding candidates.

2. The method of claim 1, further comprising accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected one of a common search space and a user equipment specific search space.

3. The method of claim 1, further comprising accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected subset of aggregation levels for a search space.

4. The method of claim 1, further comprising accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected subset of decoding candidates for an aggregation levels and a search space.

5. The method of claim 1, further comprising accessing the constraint that distributes decoding candidates on a user equipment basis.

6. The method of claim 1, further comprising accessing the constraint that distributes decoding candidates on a per cell basis.

7. The method of claim 1, further comprising accessing the constraint by deriving a distribution based upon a subframe index.

8. The method of claim 1, further comprising accessing the constraint by deriving a distribution based upon a random seed.

9. The method of claim 1, further comprising accessing the constraint that distributes decoding candidates based a user equipment identifier, a cell identifier, a subframe index, or a random seed.
10. The method of claim 1, further comprising accessing the constraint that distributes decoding candidates by at least two characteristics selected from a group consisting of a user equipment identifier, a cell identifier, a subframe index, a first random seed, and a second random seed.

11. The method of claim 1, wherein distribution of the Physical Downlink Control CHannel (PDCCH) occurs semi-statically.

12. The method of claim 1, wherein distribution of the Physical Downlink Control CHannel (PDCCH) occurs with hops with time.

13. The method of claim 1, further comprising accessing the constraint that avoids having to monitor more than two carriers at a time.

14. The method of claim 1, further comprising accessing the constraint that limits the decoding candidates to a number corresponding to a number of possible decoding candidates for a single carrier.

15. The method of claim 1, further comprising accessing the constraint that limits the decoding candidates to a total number N within a range of a single carrier lower number L of decoding candidates and an upper number U equal to a product of the single carrier lower number L and a number of monitored multiple carriers M.

16. The method of claim 1, further comprising monitoring the reduced set of decoding candidates that are uniformly distributed across carriers.

17. The method of claim 1, further comprising monitoring the reduced set of decoding candidates that are non-uniformly distributed across carriers.

18. The method of claim 1, further comprising accessing the constraint that limits the plurality of carriers to have a total number of decoding candidates that corresponds to a single carrier.

19. A computer program product for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information, comprising:

- at least one computer readable storage medium storing computer executable instructions that, when executed by the at least one processor, implement components comprising:
  
- a first set of instructions for causing a computer to access a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;
a second set of instructions for causing the computer to monitor a reduced set of decoding candidates in accordance with the constraint; and

a third set of instructions for causing the computer to blind decode the reduced set of decoding candidates.

20. An apparatus for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information, comprising:

at least one processor;

at least one computer readable storage medium storing computer executable instructions that, when executed by the at least one processor, implement components comprising:

means for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;

means for monitoring a reduced set of decoding candidates in accordance with the constraint; and

means for blind decoding the reduced set of decoding candidates.

21. An apparatus for monitoring a Physical Downlink Control CHannel (PDCCH) in a wireless communication system for receiving broadcast, multicast or unicast information, comprising:

a computing platform for accessing a constraint for a Physical Downlink Control CHannel (PDCCH) that limits mapping of decoding candidates distribution on a plurality of carriers;

a receiver for monitoring a reduced set of decoding candidates in accordance with the constraint; and

a decoder for blind decoding the reduced set of decoding candidates.

22. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected one of a common search space and a user equipment specific search space.

23. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected subset of aggregation levels for a search space.
24. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected subset of decoding candidates for an aggregation levels and a search space.

25. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that distributes decoding candidates on user equipment basis.

26. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that distributes decoding candidates on a per cell basis.

27. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint by deriving a distribution based upon a subframe index.

28. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint by deriving a distribution based upon a random seed.

29. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that distributes decoding candidates based a user equipment identifier, a cell identifier, a subframe index, or a random seed.

30. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that distributes decoding candidates by at least two characteristics selected from a group consisting of a user equipment identifier, a cell identifier, a subframe index, a first random seed, and a second random seed.

31. The apparatus of claim 21, wherein distribution of the Physical Downlink Control CHannel (PDCCH) occurs semi-statically.

32. The apparatus of claim 21, wherein distribution of the Physical downlink control channel (pdcch) occurs with hops with time.

33. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that avoids having to monitor more than two carriers at a time.

34. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that limits the decoding candidates to a number corresponding to a number of possible decoding candidates for a single carrier.

35. The apparatus of claim 21, wherein the computing platform is further for accessing the constraint that limits the decoding candidates to a total number N within a range of a single carrier lower number L of decoding candidates and an upper number U equal to a product of the single carrier lower number L and a number of monitored multiple carriers M.
36. The apparatus of claim 21, wherein the receiver is further for monitoring the reduced set of decoding candidates that are uniformly distributed across carriers.

37. The apparatus of claim 21, wherein the receiver is further for monitoring the reduced set of decoding candidates that are non-uniformly distributed across carriers.

38. The method of claim 21, wherein the computing platform is further for accessing the constraint that limits the plurality of carriers to have a total number of decoding candidates that corresponds to a single carrier.

39. A method for transmitting a Physical Downlink Control Channel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information, comprising:

   employing a processor executing computer executable instructions stored on a computer readable storage medium to implement following acts:
   accessing a constraint for a Physical Downlink Control Channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;
   mapping the Physical Downlink Control Channel (PDCCH) on the plurality of carriers in accordance with the constraint; and
   encoding and transmitting the Physical Downlink Control Channel (PDCCH) as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

40. A computer program product for transmitting a Physical Downlink Control Channel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information, comprising:

   at least one computer readable storage medium storing computer executable instructions that, when executed by at least one processor, implement components comprising:
   a first set of instructions for causing a computer to access a constraint for a Physical Downlink Control Channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;
   a second set of instructions for causing the computer to map the Physical Downlink Control Channel (PDCCH) on the plurality of carriers in accordance with the constraint; and
a third set of instructions for causing the computer to encode and transmit the Physical Downlink Control Channel (PDCCH) as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

41. An apparatus for transmitting a Physical Downlink Control Channel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information, comprising:

at least one processor;

at least one computer readable storage medium storing computer executable instructions that, when executed by the at least one processor, implement components comprising:

means for accessing a constraint for a Physical Downlink Control Channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;

means for mapping the Physical Downlink Control Channel (PDCCH) on the plurality of carriers in accordance with the constraint; and

means for encoding and transmitting the Physical Downlink Control Channel (PDCCH) as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates.

42. An apparatus for transmitting a Physical Downlink Control Channel (PDCCH) in a wireless communication system for sending broadcast, multicast or unicast information, comprising:

a computing platform for accessing a constraint for a Physical Downlink Control Channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers;

a mapping/encoder for mapping and encoding the Physical Downlink Control Channel (PDCCH) on the plurality of carriers in accordance with the constraint; and

a transmitter for transmitting the Physical Downlink Control Channel (PDCCH) as mapped and encoded for user equipment (UE) to blind decode using a reduced set of decoding candidates.

43. The apparatus of claim 42, wherein the computing platform is further for accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected one of a common search space and a user equipment specific search space.
44. The apparatus of claim 42, wherein the computing platform is further for accessing the constraint that limits distribution for a selected at least one of the plurality of carriers to a selected subset of aggregation levels for a search space.
METHODOLOGY FOR MONITORING A PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) IN A WIRELESS COMMUNICATION SYSTEM

MONITORING A SET OF PDCCH CANDIDATES FOR A SEARCH SPACE IN A SUBFRAME BY MONITORING TWO CARRIERS AT A TIME, WHEREIN THE SUBFRAME COMPRISSES A CONTROL REGION FOR TRANSMITTING CONTROL INFORMATION, THE CONTROL REGION COMPRISSES A PLURALITY OF RESOURCE ELEMENTS MAPPED TO A PLURALITY OF CONTROL CHANNEL ELEMENTS (CCES), A CCE CORRESPONDS TO A SET OF RESOURCE ELEMENTS, AND THE SEARCH SPACE THAT COMPRISSES A CONTIGUOUS SET OF CCES IS CLASSIFIED INTO A COMMON SEARCH SPACE AND A UE-SPECIFIC SEARCH SPACE, WHEREIN THE COMMON SEARCH SPACE IS MONITORED BY ALL USER EQUIPMENTS (UEs) IN A CELL AND THE UE-SPECIFIC SEARCH SPACE IS MONITORED BY AT LEAST ONE UE IN THE CELL.

BLIND DECODING CANDIDATES ON BOTH MONITORED CARRIERS, WHEREIN THE CANDIDATES ARE CONSTRAINED TO AVOID HAVING A SELECTED THIRD OF THE SET OF PDCCH CANDIDATES ON A AN UNMONITORED CARRIER OVERLAPPING ANY TWO SIMULTANEOUS DECODED CANDIDATES.

UE-SPECIFIC SEARCH SPACE AND COMMON SEARCH SPACE ARE DISTRIBUTED TO DIFFERENT MONITORED CARRIERS.

AGGREGATION LEVELS ARE DISTRIBUTED TO DIFFERENT MONITORED CARRIERS.

A NUMBER OF DECODING CANDIDATES FOR A SELECTED AGGREGATION LEVEL ARE DISTRIBUTED TO DIFFERENT MONITORED CARRIERS.

CANDIDATES FOR BLIND DECODING ARE DISTRIBUTED IN AN ORTHOGONAL MANNER WITH REGARD TO MONITORED CARRIERS.

CANDIDATES FOR BLIND DECODING ARE DISTRIBUTED IN A NONORTHOGONAL MANNER WITH REGARD TO MONITORED CARRIERS.

AGGREGATION LEVELS 1, 4 AND 8 ARE DISTRIBUTED IN A FIRST CARRIER AND AGGREGATION LEVELS 2 AND 8 ARE DISTRIBUTED IN A SECOND CARRIER.

THE CANDIDATES FOR BLIND DECODING ARE DISTRIBUTED ON A UE-BASIS.

THE CANDIDATES FOR BLIND DECODING ARE DISTRIBUTED ON A PER CELL BASIS.

THE CANDIDATES FOR BLIND DECODING ARE DISTRIBUTED WITH FREQUENCY HOPPING OVER TIME.

FIG. 2
600

Logical Grouping 602

ELECTRICAL COMPONENTS FOR ACCESSING A CONSTRAINT FOR A PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) THAT LIMITS MAPPING OF DECODING CANDIDATES DISTRIBUTED ON A PLURALITY OF CARRIERS 604

ELECTRICAL COMPONENTS FOR MONITORING A REDUCED SET OF THE PLURALITY OF DECODING CANDIDATES IN ACCORDANCE WITH THE CONSTRAINT 606

ELECTRICAL COMPONENTS FOR BLIND DECODING THE REDUCED SET OF THE PLURALITY OF DECODING CANDIDATES 608

Memory 620

FIG. 6
Logical Grouping 702

Electrical components for accessing a constraint for a physical downlink control channel (PDCCH) that limits mapping of decoding candidates distributed on a plurality of carriers 704

Electrical components for mapping the physical downlink control channel (PDCCH) on the plurality of carriers in accordance with the constraint 706

Electrical components for encoding and transmitting the PDCCH as mapped for user equipment (UE) to blind decode using a reduced set of decoding candidates 708

Memory 720

FIG. 7
APPARATUS 802

MEANS FOR ACCESSING A CONSTRAINT FOR A PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) THAT LIMITS MAPPING OF DECODING CANDIDATES DISTRIBUTED ON A PLURALITY OF CARRIERS 804

MEANS FOR MONITORING A REDUCED SET OF THE PLURALITY OF DECODING CANDIDATES IN ACCORDANCE WITH THE CONSTRAINT 806

MEANS FOR BLIND DECODING THE REDUCED SET OF THE PLURALITY OF DECODING CANDIDATES 808

FIG. 8
FIG. 9

APPARATUS 902

MEANS FOR ACCESSING A CONSTRAINT FOR A PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) THAT LIMITS MAPPING OF DECODING CANDIDATES DISTRIBUTED ON A PLURality OF CARRIERS 904

MEANS FOR MAPPING THE PHYSICAL DOWNLINK CONTROL CHANNEL (PDCCH) ON THE PLURality OF CARRIERS IN ACCORDANCE WITH THE CONSTRAINT 906

MEANS FOR ENCODING AND TRANSMITTING THE PDCCH AS MAPPED FOR USER EQUIPMENT (UE) TO BLIND DECODE USING A REDUCED SET OF DECODING CANDIDATES 908
METHODOLOGY FOR MONITORING PDCCH IN A WIRELESS COMMUNICATION SYSTEM FOR RECEIVING BROADCAST, MULTICAST OR UNICAST INFORMATION

PROCESSOR EMPLOYED FOR EXECUTING COMPUTER EXECUTABLE INSTRUCTIONS STORED ON COMPUTER READABLE STORAGE MEDIUM

CONSTRAINT IS ACCESSED FOR PDCCH THAT LIMITS MAPPING OF DECODING CANDIDATES DISTRIBUTED ON PLURALITY OF CARRIERS

CONSTRAINT DISTRIBUTES COMMON SEARCH SPACE TO SELECTED ONE OF PLURALITY OF CARRIERS AND DISTRIBUTES UE-SPECIFIC SEARCH SPACE TO ANOTHER SELECTED ONE OF PLURALITY OF CARRIERS

CONSTRAINT DISTRIBUTES FIRST AGGREGATION LEVEL TO SELECTED ONE OF PLURALITY OF CARRIERS AND DISTRIBUTES SECOND AGGREGATION LEVEL TO ANOTHER SELECTED ONE OF PLURALITY OF CARRIERS

CONSTRAINT DISTRIBUTES FIRST SUBSET OF DECODING CANDIDATES FOR SELECTED AGGREGATION LEVEL TO SELECTED ONE OF PLURALITY OF CARRIERS AND DISTRIBUTES SECOND SUBSET OF DECODING CANDIDATES FOR SELECTED AGGREGATION LEVEL TO ANOTHER SELECTED ONE OF PLURALITY OF CARRIERS

CONSTRAINT DISTRIBUTES DECODING CANDIDATES ON UE BASIS

CONSTRAINT DISTRIBUTES DECODING CANDIDATES ON PER CELL BASIS

CONSTRAINT IS FOR DERIVING DISTRIBUTION BASED UPON SUBFRAME INDEX

CONSTRAINT IS FOR DERIVING DISTRIBUTION BASED UPON ONE OR MORE RANDOM SEEDS

REDUCED SET OF PLURALITY OF DECODING CANDIDATES IS MONITORED IN ACCORDANCE WITH CONSTRAINT

FIG. 10A
REDUCED SET OF PLURALITY OF DECODING CANDIDATES IS BLIND DECODED \textit{1008}

CONSTRAINT LIMITS NUMBER OF DECODING CANDIDATES SO THAT UE NEED NOT MONITOR MORE THAN TWO CARRIERS AT A TIME \textit{1009}

CONSTRAINT LIMITS NUMBER OF DECODING CANDIDATES TO APPROXIMATELY SAME AS THOSE POSSIBLE FOR SINGLE CARRIER IMPLEMENTATION \textit{1010}

CONSTRAINT LIMITS DECODING CANDIDATES TO TOTAL NUMBER \(N\) WITHIN RANGE OF LOWER NUMBER \(L\) OF DECODING CANDIDATES POSSIBLE FOR SINGLE CARRIER AND AN UPPER NUMBER \(U\) EQUAL TO PRODUCT OF SINGLE CARRIER NUMBER \(L\) AND NUMBER OF MONITORED MULTIPLE CARRIERS \(M\), I.E., \(L \leq N \leq L^*M\) \textit{1012}

\begin{algorithm}
\textbf{SEMI-STATIC?} \textit{1026}
\begin{cases}
\text{No} & \text{HOP IN TIME?} \textit{1030} \\
\text{Yes} & \text{UPDATED DETERMINATION OF DISTRIBUTION IS SCHEDULED} \textit{1028}
\end{cases}
\end{algorithm}

\textbf{EXIT}

\textbf{UPDATED DETERMINATION OF DISTRIBUTION IS SCHEDULED} \textit{1032}

\textbf{FIG. 10B}
METHODOLOGY FOR TRANSMITTING PDCCH IN WIRELESS COMMUNICATION SYSTEM FOR SENDING BROADCAST, MULTICAST OR UNICAST INFORMATION

PROCESSOR EMPLOYED FOR EXECUTING COMPUTER EXECUTABLE INSTRUCTIONS STORED ON COMPUTER READABLE STORAGE MEDIUM

CONSTRAINT IS ACCESSED FOR PDCCH THAT LIMITS MAPPING OF DECODING CANDIDATES DISTRIBUTED ON PLURality OF CARRIERS

CONSTRAINT DISTriBUtES COMMON SEARCH SPACE TO SELECTED ONE OF PLURality OF CARRIERS AND DISTriBUtES UE-SPECIFIC SEARCH SPACE TO ANOTHER SELECTED ONE OF PLURality OF CARRIERS

CONSTRAINT DISTriBUtES FIRST AGGREGATION LEVEL TO SELECTED ONE OF PLURality OF CARRIERS AND DISTriBUtES SECOND AGGREGATION LEVEL TO ANOTHER SELECTED ONE OF PLURality OF CARRIERS

CONSTRAINT DISTriBUtES FIRST SUBSET OF DECODING CANDIDATES FOR SELECTED AGGREGATION LEVEL TO SELECTED ONE OF PLURality OF CARRIERS AND DISTriBUtES SECOND SUBSET OF DECODING CANDIDATES FOR SELECTED AGGREGATION LEVEL TO ANOTHER SELECTED ONE OF PLURality OF CARRIERS

CONSTRAINT DISTriBUtES DECODING CANDIDATES ON UE BASIS

CONSTRAINT DISTriBUtES DECODING CANDIDATES ON PER CELL BASIS

CONSTRAINT IS FOR DERIVING DISTRIBUTION BASED UPON SUBFRAME INDEX

CONSTRAINT IS FOR DERIVING DISTRIBUTION BASED UPON ONE OR MORE RANDOM SEEDS

PDCCH IS MAPPED ON PLURality OF CARRIERS IN ACCORDANCE WITH CONSTRAINT

FIG. 11A
A FIG. 11A

PDCCH IS ENCODED AND TRANSMITTED AS MAPPED FOR UE (UE) TO BLIND DECODE USING REDUCED SET OF DECODING CANDIDATES 1108

CONSTRAINT LIMITS NUMBER OF DECODING CANDIDATES SO THAT UE NEED NOT MONITOR MORE THAN TWO CARRIERS AT A TIME 1109

CONSTRAINT LIMITS NUMBER OF DECODING CANDIDATES TO APPROXIMATELY SAME AS THOSE POSSIBLE FOR SINGLE CARRIER IMPLEMENTATION 1110

CONSTRAINT LIMITS DECODING CANDIDATES TO TOTAL NUMBER N WITHIN RANGE OF LOWER NUMBER L OF DECODING CANDIDATES POSSIBLE FOR SINGLE CARRIER AND AN UPPER NUMBER U EQUAL TO PRODUCT OF SINGLE CARRIER NUMBER L AND NUMBER OF MONITORED MULTIPLE CARRIERS M, I.E., L ≤ N ≤ L * M 1112

SEMI-STATIC? 1126

NO

HOP IN TIME? 1130

NO

EXIT

UPDATE DETERMINATION OF DISTRIBUTION IS SCHEDULED 1132

YES

YES

UPDATE DETERMINATION OF DISTRIBUTION IS SCHEDULED 1128

FIG. 11B
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L5/00 H04W72/04

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

ADD.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L 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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Relevant to claim No</th>
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<td>X</td>
<td>WO 2009/041779 A1 (LG ELECTRONICS INC [KR]; CHUNG JAE HOON [KR]; KIM SO YEON [KR]; LEE EU) 2 April 2009 (2009-04-02) paragraphs [0004], [0078] - [0085], [0094], [0096], [0106], [0108], [0116] figure 17</td>
<td>1-44</td>
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Further documents are listed in the continuation of Box C

See patent family annex

Date of the actual completion of the international search

4 August 2010

Name and mailing address of the ISA/

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Date of mailing of the international search report

11/08/2010

Authorized officer

Ferrari , Jeannot

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<td>X</td>
<td>SAMSUNG: &quot;Configuration of PDCCH Monitoring Set&quot; 3GPP DRAFT; R1-080028 PDCCH RESTRICTION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WGl, no. Sevilla, Spain; 20080108, 8 January 2008 (2008-01-08), XP050108571 [retrieved on 2008-01-08] the whole document</td>
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<td>X</td>
<td>NOKIA ET AL: &quot;Handling DCI formats and blind decoding in LTE-Advanced&quot; 3GPP DRAFT; R1-091768, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. San Francisco, USA; 20090428, 28 April 2009 (2009-04-28), XP050339291 [retrieved on 2009-04-28] chapter 2</td>
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