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(54) **Title**: ENHANCED CHANNEL STATE INFORMATION REPORTING FOR DOWNLINK CONTROL CHANNEL

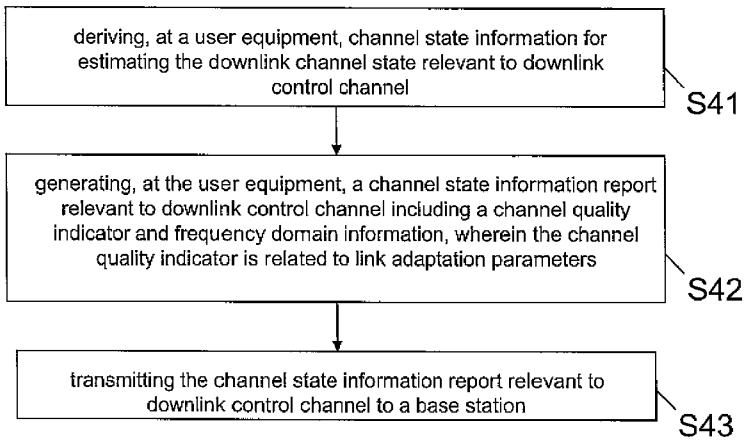


Fig. 4

(57) **Abstract**: The present invention provides methods, apparatuses and a computer program product for enhanced CSI reporting for ePDCCH. The present invention includes deriving, at a user equipment, channel state information for estimating the downlink channel state relevant to downlink control channel, generating, at the user equipment, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters, and transmitting the channel state information report relevant to downlink control channel to a base station.

WO 2013/107053 A1

ENHANCED CHANNEL STATE INFORMATION REPORTING FOR DOWNLINK CONTROL CHANNEL

Field of the invention

The present invention relates to methods, apparatuses and a program for enhanced CSI (Channel State Information) reporting for downlink control channel, e.g. ePDCCH (enhanced Physical Downlink Control Channel). In particular, the present invention relates to CSI signalling in uplink (UL) in the case ePDCCH is used. One focus of the present invention is on providing an optimized support for ePDCCH link adaptation.

The introduction of ePDCCH sets new requirements to the CSI reporting. Therefore, the present invention presents new solutions allowing for efficient ePDCCH link adaptation.

Background of the invention

The standardization of ePDCCH will be one of the main areas for improvement in LTE (Long Term Evolution) Release 11. While the conventional PDCCH relies on frequency distributed transmission and transmit diversity providing robust system operation in the absence of accurate CSI (consisting of one or more of CQI (Channel Quality Indicator), PMI (Precoder Matrix Indicator), RI (Rank Indicator), or PTI (Precoder Type Indicator)), the aim of ePDCCH is to benefit from elaborate CSI when that happens to be available. The basic properties of ePDCCH were agreed in 3GPP RAN1#67 meeting, November 14 – 18, 2011:

- Both localized and distributed transmission of the enhanced control channel are supported

- DM RS (Demodulation Reference Signal) are used for demodulation of ePDCCH (support for CRS (Common Reference Signal) in some cases is still to be evaluated in further studies)

In order to be able to make use of localized transmission and precoding (which the usage of DM RS enables), the eNodeB needs to have available elaborate CSI, preferably both in time and frequency.

The impact of CSI reporting on the overall system performance is two-fold. Purely from the DL (downlink) point of view, the more accurate and elaborate CSI there is available, the better. From the UL (uplink) point of view, on the other hand, the CSI provides significant overhead by reserving bandwidth that could otherwise be used for data transmission. The efficiency of CSI transmission is expected to become even more critical along with the upcoming DL features and system deployments. In particular with carrier aggregation, it is expected that asymmetrical DL-UL combinations are rather dominant, hence stretching the UL capacity required for increased CSI feedback (FB).

Periodic CSI reporting on PUCCH has often been assumed to be the fundamental mode of providing the eNodeB with information on the UEs' channel conditions. Based on the rather frequent periodic CSI reports, the eNodeB can make the decision on which UEs to schedule, how to perform PDCCH and PDSCH link adaptation and, if needed, request the UE to provide more elaborate aperiodic CSI reports on a per need basis. However, the drawback of the current periodic (PUCCH) CSI reporting modes is that they do not suit well the purpose of ePDCCH link adaptation. The reasons for it are as follows.

For example, the definition of CQI matches poorly the probable ePDCCH link adaptation parameters (aggregation level, modulation). The current 4-bit table as defined in 3GPP TS 36.213, section 7.2.3 (shown in Table 1) includes a large number of redundant MCS (Modulation and Coding Scheme), and it is also not clear how the entries could be mapped to ePDCCH parameters in an efficient way.

Further, the periodic CSI provides only little or no information about the frequency domain behavior of the channel. Furthermore, the granularity of the feedback does not necessarily match well the ePDCCH resource allocation frequency domain granularity.

CQI index	modulation	coding rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

Table 1: CQI table according to LTE Release 8

From the above considerations, it becomes apparent that there is a need for an elaborate yet compact periodic CSI feedback reporting mode, capable of serving ePDCCH UEs. The present invention presents a novel CSI reporting mechanism to enable (UL) resource efficient CSI feedback to support especially ePDCCH.

Currently, there are no proposals for CSI feedback schemes tailored to support ePDCCH in 3GPP. For LTE Release 8, different modes of periodic CSI reporting schemes have been described (cf. 3GPP TS 36.213, section 7.2.2). A short overview of these modes is given below:

Mode 1-0

- For Single Tx and Open Loop MIMO

- A single wideband CQI (4 bits)
- RI is reported in a separate subframe (1-2 bits, OL spatial multiplexing only)

Mode 1-1

- For Closed Loop MIMO
- A wideband CQI (4 bits)
- A Delta-CQI for the 2nd Codeword (3-bits)
- A PMI (2 bits for 2*2 MIMO, 4 bits for 4*4 MIMO)
- RI is reported in a separate subframe (1-2 bits, OL spatial multiplexing only)

Mode 2-0

- For Single Tx and Open Loop MIMO
- RI is reported in a separate subframe (1-2 bits, OL spatial multiplexing only)
- System band is divided into J bandwidth parts
- Consists of a series of reports:
    - A wideband CQI (see Mode 1-0), followed by:
    - The CQI and the subband index for the best subband within the first bandwidth part, followed by:
    - The CQI and the subband index for the best subband within the second bandwidth part etc...

Mode 2-1

- For Closed Loop MIMO
- RI is reported in a separate subframe (1-2 bits, OL spatial multiplexing only)
- Similar to Mode 2-0 except that the wideband report correspond to the format of Mode 1-1
- The wideband PMI is used for the frequency selective reports.

Summary of the Invention

According to the present invention, there are provided methods, apparatuses and a computer program product for enhanced CSI reporting for downlink control channel.

According to an aspect of the invention there is provided a method, comprising:

deriving, at a user equipment, channel state information for estimating the downlink channel state relevant to downlink control channel,

generating, at the user equipment, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

transmitting the channel state information report relevant to downlink control channel to a base station.

According to another aspect of the invention there is provided a method, comprising:

receiving, at a base station, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

scheduling a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

According to further refinements as defined under the above aspect

- the channel quality indicator indicates the required amount of physical resources for the downlink control channel to ensure reliable detection;
- the channel quality indicator indicates the supported aggregation level for the downlink control channel;
- the channel quality indicator indicates the supported modulation scheme for the downlink control channel;
- the channel quality indicator indicates the supported SU-MIMO rank for the downlink control channel;
- the frequency domain information includes an index of a preferred downlink control channel candidate and the related channel quality indicator;

- the frequency domain information includes channel quality indicators for multiple downlink control channel candidates with an indication of associated resources;
- the downlink control channel is an enhanced downlink control channel.

According to another aspect of the invention there is provided an apparatus, comprising:

a deriving unit configured to derive channel state information for estimating the downlink channel state relevant to downlink control channel,

a generating unit configured to generate a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

a transmitter configured to transmit the channel state information report relevant to downlink control channel to a base station.

According to another aspect of the invention there is provided an apparatus, comprising:

a receiver configured to receive a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

a scheduling unit configured to schedule a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

According to further refinements as defined under the above aspect

- the channel quality indicator indicates the required amount of physical resources for the downlink control channel to ensure reliable detection;
- the channel quality indicator indicates the supported aggregation level for the downlink control channel;

- the channel quality indicator indicates the supported modulation scheme for the downlink control channel;
- the channel quality indicator indicates the supported SU-MIMO rank for the downlink control channel;
- the frequency domain information includes an index of a preferred downlink control channel candidate and the related channel quality indicator;
- the frequency domain information includes channel quality indicators for multiple downlink control channel candidates with an indication of associated resources;
- the downlink control channel is an enhanced downlink control channel.

According to another aspect of the present invention there is provided a computer program product comprising code means adapted to produce steps of any of the methods as described above when loaded into the memory of a computer.

According to a still further aspect of the invention there is provided a computer program product as defined above, wherein the computer program product comprises a computer-readable medium on which the software code portions are stored.

According to a still further aspect of the invention there is provided a computer program product as defined above, wherein the program is directly loadable into an internal memory of the processing device.

According to another aspect of the invention there is provided an apparatus, comprising:

means for deriving channel state information for estimating the downlink channel state relevant to downlink control channel,

means for generating a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

means for transmitting the channel state information report relevant to downlink control channel to a base station.

According to another aspect of the invention there is provided an apparatus, comprising:

means for receiving a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

means for scheduling a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

Brief Description of the Drawings

These and other objects, features, details and advantages will become more apparent from the following detailed description of embodiments of the present invention which is to be taken in conjunction with the appended drawings, in which:

Fig. 1 is a diagram showing an example of ePDCCH candidate positions in the frequency domain.

Fig. 2 is a diagram showing another example of ePDCCH candidate positions in the frequency domain.

Fig. 3 is a block diagram showing an example of a user equipment according to certain embodiments of the present invention

Fig. 4 is a flowchart illustrating processing of the user equipment according to certain embodiments of the present invention.

Fig. 5 is a block diagram showing an example of a base station according to certain embodiments of the present invention.

Fig. 6 is a flowchart illustrating processing of the base station according to certain embodiments of the present invention.

Detailed Description

In the following, embodiments of the present invention are described by referring to general and specific examples of the embodiments, wherein the features of the embodiments can be freely combined with each other unless otherwise described. It is to be understood, however, that the description is given by way of example only, and that the described embodiments are by no means to be understood as limiting the present invention thereto.

The basic idea of the present invention is to provide an optimized, enhanced periodic PUCCH CSI (eCSI_Ctrl) reporting scheme capable of supporting ePDCCH. The main point is that the reports should be usable for eNodeB as such for scheduling ePDCCH, i.e. should contain the necessary link adaptation parameters for ePDCCH scheduling. It is noted that the eCSI_Ctrl transmission could be also bundled with the aperiodic CSI reporting on PUSCH.

According to an exemplary embodiment of the present invention, a new kind of CQI is defined, denoted here as enhanced CQI for control information (eCQI_Ctrl). In order to be able to make efficient use of the CSI report for ePDCCH scheduling, the eCQI_Ctrl needs to directly relate to the link adaptation parameters relevant to ePDCCH instead of the MCS/TBS, to which the conventional CQI for *PDSCH* transmission relates. The eCQI_Ctrl has the following characteristics:

- the eCQI_Ctrl may indicate the supported aggregation level for ePDCCH;
- the eCQI_Ctrl may indicate the supported modulation scheme for the ePDCCH;
- the eCQI_Ctrl may indicate the supported SU-MIMO rank for the ePDCCH.

Examples on how to define and signal these properties are described later.

Further, the eCSI should also provide frequency domain information. That is, in frequency domain the eCSI report should provide the eNodeB with information directly applicable for the scheduling decision of the ePDCCH.

The basic setting is, that the eNodeB has configured the UE to monitor a few ePDCCH candidates, characterized by, e.g., certain PRB allocation (this can be thought of as the ePDCCH search space).

As shown in the exemplary Figure 1, the candidates may be either localized or distributed. Now the eCSI report should be able to indicate either:

- the (index of) preferred ePDCCH candidate and the related eCQI_Ctrl, or
- eCQI_Ctrl for multiple ePDCCH candidates with indication of the associated resources.

The estimation of eCSI is based on reference signals transmitted from the eNB. In one embodiment the eCSI will be estimated using multiple reference signal ports. In this embodiment the UE needs to make an assumption about the relation between the used antenna ports and the transmission of E-PDCCH. In one embodiment, the UE autonomously selects a precoding matrix indicator (PMI) and includes selected PMI in the eCSI report. It is noted that the UE could potentially select different PMI for different ePDCCH candidate. Reusing PMI(s) selected for the estimation of PDSCH CQI is another option. The UE may also assume open loop transmit diversity for E-PDCCH in which case no additional information related to the spatial transmission parameters is needed.

In the following, detailed implementation and signalling alternatives are described. However, it is noted that these alternatives are described for illustration purposes only and that the present invention is not limited to the described alternatives.

According to an exemplary embodiment of the present invention, an example of a definition of eCQI_Ctrl is described.

The eCQI_Ctrl can be understood to be the UE's recommendation for the link adaptation parameters to be used when scheduling ePDCCH. The definition (from UE testing point of view) may be, for example, that a given ePDCCH target block error rate (e.g. 1%) shall not be exceeded when the ePDCCH is scheduled as indicated by the eCQI_Ctrl.

The table 2 shows an example of an eCQI_Ctrl table design. It should be noted that this is just a generic example indicating the different possibilities and is not to be understood as limiting the present invention. There may be, as a non-limiting example, the case that rank adaptation/ SU-MIMO of ePDCCH is not supported and hence example index#1 becomes redundant or that 16QAM/any higher-order modulation is not going to be supported, making the example index #2 & #3 redundant.

eCQI_Ctrl index	interpretation
#0	out-of-range
#1	rank = 2, 16-QAM, Agg 1/2
#2	16-QAM, Agg 1/2
#3	16 QAM, Agg 1
#4	QPSK, Agg 1
#5	QPSK, Agg 2
#6	QPSK, Agg 4
#7	QPSK, Agg 8

Table 1. An exemplary eCQI_Ctrl Table.

In table 2 shown above, the eCQI_Ctrl index indicates, e.g. rank of the transmission, modulation order, and/or aggregation level.

In this regard, it is noted that aggregation levels as a way of link adaptation used already in LTE Rel. 8 for PDCCH in the exemplary eCQI_Ctrl Table 1 are only to be understood as an exemplary way to perform link adaptation on ePDCCH. One differentiating element in this context is in the way that the aggregation levels are used. In LTE Rel. 8, the aggregation levels are created by concatenating

resources that are scattered in the frequency domain, while in this specific context, the concatenated resources are characterized by being resources that are located within a limited set of physical resources (for instance being neighbors in the frequency domain). In previous LTE Rel. 8 specifications, there is no relation between the CQI information and the expected performance on the control channel. Other link adaptation methods indicating the supported data rate or spectral efficiency on ePDCCH can be envisioned as well and are in the same way applicable with respect to Table 1.

According to another exemplary embodiment of the present invention, an example of a definition of frequency domain operation of eCQI_Ctrl is described in the following.

As mentioned above, another main characteristic of the eCSI is the ability to inform the eNodeB about the frequency domain characteristics for the propagation channel to assist the eNodeB in scheduling the ePDCCH in an optimal way. Again, some alternatives can be envisioned:

According to a first exemplary example, the UE points out the best ePDCCH candidate and signals that to the eNodeB. In this case the eCSI report consists of:

- the index of the preferred ePDCCH candidate (#1 ... # 6 in Figure 1), and
- the related eCQI_Ctrl for that.

As already previously mentioned, in here, the UE assumes either the same precoder to be applied as indicated in CSI for PDSCH or some ePDCCH specific diversity operation. Alternatively, an ePDCCH specific precoder recommendation (ePMI) might be included in addition to the eCSI report.

Assuming the exemplary values in Figure 1 and Table 2, this information can be signalled using:

3 bits (eCQI_Ctrl) + 3 bits (index to the ePDCCH candidates) = 6 bits.

According to a second exemplary example, the UE signals to the eNodeB the eCQI_Ctrl for each ePDCCH candidate (either localized, distributed or both). Now the number of bits is:

3 bits (eCQI_Ctrl) * number of ePDCCH candidates = 12 bits (localized only), or 18 bits (localized & distributed).

In this case, a signaling format larger than the current periodic PUCCH format 2 would be required, such as PUCCH format 3.

A third exemplary example is a combination of the first and second exemplary examples described above. That is, the UE indicates the eCQI_Ctrl for the best localized ePDCCH candidate (#1... #4, 2 bits needed) and the related eCQI_Ctrl + an eCQI_Ctrl for the distributed candidates. As the eCQI_Ctrl of the distributed candidates can be assumed to be somewhat similar, it may not be necessary to select one of them. Now, the size of the eSCI report becomes:

2 bits (selecting one of the localized ePDCCH candidates) + 3 bits (eCQI_Ctrl for the selected localized ePDCCH candidate) + 3 bits (eCQI_Ctrl for the distributed candidate(s)) = 8 bits.

As an alternative for the arrangement depicted in Figure 1, the frequency distributed ePDCCH candidates may also be arranged so that they occupy the same PRBs as the localized ePDCCH candidates as shown in Figure 2. In this case, there is only a single distributed candidate existing. Thus, there is no need to distinguish between different distributed ePDCCH candidates, which simplifies the signaling slightly.

Based on the examples given in Figures 1 and 2 related to the ePDCCH arrangement, the following alternatives overall can be considered:

In a first option, according to Fig. 1, there is a separate PRB allocation for the localized and distributed candidates. Hence, more than one candidate (for example, candidates #5 and #6) may exist for the distributed ePDCCH

transmission. The detailed signaling examples in this regard are as set out in the first to third exemplary example described above.

In a second option, according to Figure 2, localized and distributed candidates share the same PRBs. In such a case, a single candidate may exist for the distributed ePDCCH transmission (candidate #5 in Figure 2). Related to the signaling examples described above, 15 bits will be sufficient for signaling according to the second exemplary example described above for the localized and distributed transmission (12 bits localized + 3 bits distributed). For the first and third exemplary example, the detailed signaling examples are as described above.

A third option is a hybrid mode 1 combining the above described first and second options. In such a case, localized and distributed candidates have a separate PRBs allocation (as in the first option of Figure 1), but there may be just a single distributed ePDCCH candidate over 4 PRBs existing (as in the second option of Figure 2). The related signaling examples are the same as for the second option described above.

A fourth option is a hybrid mode 2 combing the first and second options, where localized and distributed candidates share the same PRB allocations (as in the second option of Figure 2), but there may exist more than one distributed candidates (e.g. candidates #5 and #6 with 2 PRBs each, as in the first option of Figure 1). The related signaling examples for this hybrid allocation mode are the same as for the first option described above.

Fig. 3 is a block diagram showing an example of a user equipment according to certain embodiments of the present invention.

As shown in Fig. 3, according to an embodiment of the present invention, the user equipment 30 comprises a transmitter/receiver 31, a deriving unit 32 and a generating unit 33. The deriving unit 32 derives channel state information for estimating the downlink channel state relevant to downlink control channel and then, the generating unit generates a channel state information report relevant

to downlink control channel including a channel quality indicator and frequency domain information. Then the user equipment transmits the channel state information report relevant to downlink control channel to a base station via the transmitter/receiver 31.

Fig. 4 is a flowchart illustrating processing of the user equipment according to certain embodiments of the present invention.

According to an embodiment of the present invention, first, in a step S41, the user equipment derives channel state information for estimating the downlink channel state relevant to downlink control channel, and then, in a step S42, generates a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters. In a step S43, the user equipment transmits the channel state information report relevant to downlink control channel to a base station.

Fig. 5 is a block diagram showing an example of a base station according to certain embodiments of the present invention.

As shown in Fig. 5, according to an embodiment of the present invention, the base station 50 comprises a receiver/transmitter 51 and a scheduling unit 52.

The transmitter/receiver 51 receives a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters, and the scheduling unit 52 schedules a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

Fig. 6 is a flowchart illustrating processing of the base station according to certain embodiments of the present invention.

According to an embodiment of the present invention, first, in a step S61, the base station receives a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters. Then, in as step S62, the base station schedules a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

According to certain embodiment of the present invention, the channel quality indicator is related to link adaptation parameters relevant to downlink control channel, and the channel quality indicator may indicate the supported data rate or spectral efficiency for downlink control channel, the supported amount of physical resources for the downlink control channel, e.g. aggregation level, the supported modulation scheme for the downlink control channel, and/or the supported SU-MIMO rank for the downlink control channel. However, it is noted that the present invention is not limited to the above mentioned channel quality indicator and that the supported data rate, required amount of physical resources to ensure reliable detection or spectral efficiency for downlink control channel, e.g. aggregation level, the supported modulation scheme for the downlink control channel, and/or the supported SU-MIMO rank for the downlink control channel are merely examples of the indications of the channel quality indicator. Other link adaptation parameters reflecting the required amount of physical resources to ensure reliable control channel detection than the aggregation level applicable for ePDCCH may be of course envisioned and are to be considered as part of the embodiment.

Further, according to certain embodiment of the present invention, the frequency domain information may include an index of a preferred downlink control channel candidate and the related channel quality indicator or channel quality indicators for multiple downlink control channel candidates with an indication of associated resources.

According to certain embodiment of the present invention, the downlink control channel is an enhanced downlink control channel, for example, an enhanced

physical downlink control channel ePDCCH conforming to long term evolution advanced, LTE-A, Release 11.

In the foregoing exemplary description of the user equipment and the base station, only the units that are relevant for understanding the principles of the invention have been described using functional blocks. The user equipment and the base station may comprise further units that are necessary for its respective operation. However, a description of these units is omitted in this specification. The arrangement of the functional blocks of the devices is not construed to limit the invention, and the functions may be performed by one block or further split into sub-blocks.

When in the foregoing description it is stated that the apparatus, i.e. the user equipment or the base station (or some other means) is configured to perform some function, this is to be construed to be equivalent to a description stating that a (i.e. at least one) processor or corresponding circuitry, potentially in cooperation with computer program code stored in the memory of the respective apparatus, is configured to cause the apparatus to perform at least the thus mentioned function. Also, such function is to be construed to be equivalently implementable by specifically configured circuitry or means for performing the respective function (i.e. the expression "unit configured to" is construed to be equivalent to an expression such as "means for").

In view of the above, it is an advantage of the present invention that it allows optimized link adaptation for ePDCCH. It is hard to make use to e.g. the frequency-localized properties of the ePDCCH unless timely frequency domain information is available. This cannot be easily enabled with the existing CSI reporting modes. The eCSI payload remains also on a reasonably low level, allowing for reporting over PUCCH.

With the proposed eCQI_Ctrl it is also possible to support UE recommended frequency distributed transmission. This means that a UE can estimate that channel is changing very fast and then can give feedback that frequency distributed transmission is preferred.

For the purpose of the present invention as described herein above, it should be noted that

- method steps likely to be implemented as software code portions and being run using a processor at a user equipment, base station or network entity (as examples of devices, apparatuses and/or modules thereof, or as examples of entities including apparatuses and/or modules therefore), are software code independent and can be specified using any known or future developed programming language as long as the functionality defined by the method steps is preserved;

- generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the embodiments and its modification in terms of the functionality implemented;

- method steps and/or devices, units or means likely to be implemented as hardware components at the above-defined apparatuses, or any module(s) thereof, (e.g., devices carrying out the functions of the apparatuses according to the embodiments as described above) are hardware independent and can be implemented using any known or future developed hardware technology or any hybrids of these, such as MOS (Metal Oxide Semiconductor), CMOS (Complementary MOS), BiMOS (Bipolar MOS), BiCMOS (Bipolar CMOS), ECL (Emitter Coupled Logic), TTL (Transistor-Transistor Logic), etc., using for example ASIC (Application Specific IC (Integrated Circuit)) components, FPGA (Field-programmable Gate Arrays) components, CPLD (Complex Programmable Logic Device) components or DSP (Digital Signal Processor) components;

- devices, units or means (e.g. the above-defined base station, or any one of their respective units/means) can be implemented as individual devices, units or means, but this does not exclude that they are implemented in a distributed fashion throughout the system, as long as the functionality of the device, unit or means is preserved;

- an apparatus like the user equipment and the base station may be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of an apparatus or module, instead of being hardware implemented, be implemented as software in a (software) module such as a computer program or

a computer program product comprising executable software code portions for execution/being run on a processor;
- a device may be regarded as an apparatus or as an assembly of more than one apparatus, whether functionally in cooperation with each other or functionally independently of each other but in a same device housing, for example.

In general, it is to be noted that respective functional blocks or elements according to above-described aspects can be implemented by any known means, either in hardware and/or software, respectively, if it is only adapted to perform the described functions of the respective parts. The mentioned method steps can be realized in individual functional blocks or by individual devices, or one or more of the method steps can be realized in a single functional block or by a single device.

Generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the present invention. Devices and means can be implemented as individual devices, but this does not exclude that they are implemented in a distributed fashion throughout the system, as long as the functionality of the device is preserved. Such and similar principles are to be considered as known to a skilled person.

Software in the sense of the present description comprises software code as such comprising code means or portions or a computer program or a computer program product for performing the respective functions, as well as software (or a computer program or a computer program product) embodied on a tangible medium such as a computer-readable (storage) medium having stored thereon a respective data structure or code means/portions or embodied in a signal or in a chip, potentially during processing thereof.

The present invention also covers any conceivable combination of method steps and operations described above, and any conceivable combination of nodes, apparatuses, modules or elements described above, as long as the above-described concepts of methodology and structural arrangement are applicable.

It is noted that the embodiments and general and specific examples described above are provided for illustrative purposes only and are in no way intended that the present invention is restricted thereto. Rather, it is the intention that all variations and modifications which fall within the scope of the appended claims are covered.

Abbreviations:

CQI	Channel Quality Indicator
CRS	Common Reference Signal
CSI	Channel State Information
DL	Downlink
DM RS	Demodulation Reference Signal
eNB	LTE Base Station, evolved Node B
ePDCCH	Enhanced Physical Downlink Control Channel
HARQ	Hybrid Automatic Repeat Request
LTE	Long Term Evolution
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PMI	Precoder Matrix Indicator
PRB	Physical Resource Block
PTI	Precoder Type Indicator
PUCCH	Physical Uplink Control Channel
QPSK	Quadrature Phase Shift Keying
RI	Rank Indicator
SCell	Secondary Cell
TBS	Transport Block Size
UE	User Equipment
UL	Uplink

What is Claimed is:

1. A method, comprising:

deriving, at a user equipment, channel state information for estimating the downlink channel state relevant to downlink control channel,

generating, at the user equipment, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

transmitting the channel state information report relevant to downlink control channel to a base station.

2. A method, comprising:

receiving, at a base station, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

scheduling a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

3. The method according to claim 1 or 2, wherein

the channel quality indicator indicates the required amount of physical resources for the downlink control channel to ensure reliable detection.

4. The method according to claim 3, wherein

the channel quality indicator indicates the supported aggregation level for the downlink control channel.

5. The method according to any one of claims 1 to 4, wherein

the channel quality indicator indicates the supported modulation scheme for the downlink control channel.

6. The method according to any one of claims 1 to 5, wherein

the channel quality indicator indicates the supported SU-MIMO rank for the downlink control channel.

7. The method according to any one of claims 1 to 6, wherein

the frequency domain information includes an index of a preferred downlink control channel candidate and the related channel quality indicator.

8. The method according to any one of claims 1 to 6, wherein

the frequency domain information includes channel quality indicators for multiple downlink control channel candidates with an indication of associated resources.

9. The method according to any one of claims 1 to 8, wherein the downlink control channel is an enhanced downlink control channel.

10. An apparatus, comprising:

a deriving unit configured to derive channel state information for estimating the downlink channel state relevant to downlink control channel,

a generating unit configured to generate a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

a transmitter configured to transmit the channel state information report relevant to downlink control channel to a base station.

11. An apparatus, comprising:

a receiver configured to receive a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

a scheduling unit configured to schedule a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

12. The apparatus according to claim 1 or 2, wherein

the channel quality indicator indicates the required amount of physical resources for the downlink control channel to ensure reliable detection.

13. The apparatus according to claim 12, wherein

the channel quality indicator indicates the supported aggregation level for the downlink control channel.

14. The apparatus according to any one of claims 10 to 13, wherein

the channel quality indicator indicates the supported modulation scheme for the downlink control channel.

15. The apparatus according to any one of claims 10 to 14, wherein

the channel quality indicator indicates the supported SU-MIMO rank for the downlink control channel.

16. The apparatus according to any one of claims 10 to 15, wherein

the frequency domain information includes an index of a preferred downlink control channel candidate and the related channel quality indicator.

17. The apparatus according to any one of claims 10 to 15, wherein

the frequency domain information includes channel quality indicators for multiple downlink control channel candidates with an indication of associated resources.

18. The apparatus according to any one of claims 10 to 17, wherein the downlink control channel is an enhanced downlink control channel.

19. A computer program product including a program for a processing device, comprising software code portions for performing the steps of any one of claims 1 to 9 when the program is run on the processing device.

20. The computer program product according to claim 19, wherein the computer program product comprises a computer-readable medium on which the software code portions are stored.

21. The computer program product according to claim 19, wherein the program is directly loadable into an internal memory of the processing device.

22. An apparatus, comprising:

means for deriving channel state information for estimating the downlink channel state relevant to downlink control channel,

means for generating a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

means for transmitting the channel state information report relevant to downlink control channel to a base station.

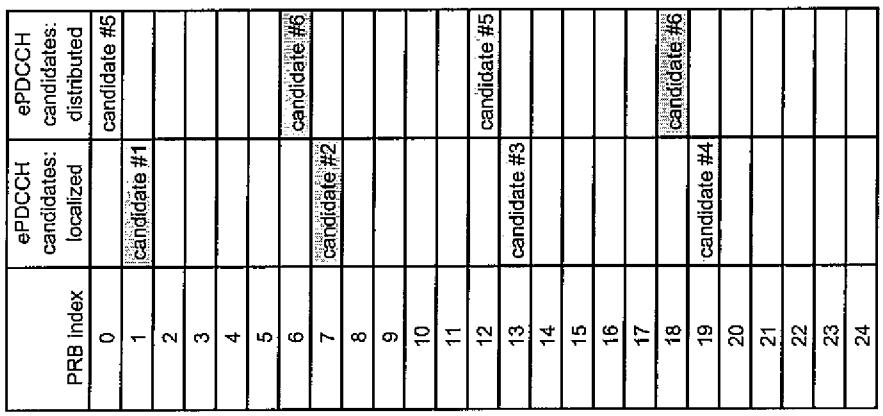
23. An apparatus, comprising:

means for receiving a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information,

wherein the channel quality indicator is related to link adaptation parameters, and

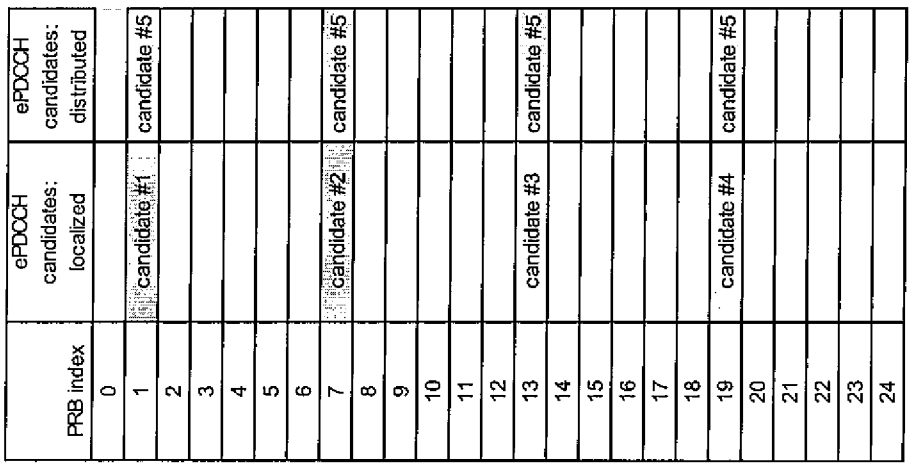
means for scheduling a downlink control channel based on information in the received channel state information report relevant to downlink control channel.

Fig. 1



PRB index	ePDCCH candidates: localized	ePDCCH candidates: distributed
0		candidate #5
1	candidate #1	
2		
3		
4		
5		
6		candidate #6
7	candidate #2	
8		
9		
10		
11		
12		candidate #5
13	candidate #3	
14		
15		
16		
17		
18		candidate #6
19	candidate #4	
20		
21		
22		
23		
24		

Fig. 2



PRB index	ePDCCH candidates: localized	ePDCCH candidates: distributed
0		
1	candidate #1	candidate #5
2		
3		
4		
5		
6		
7	candidate #2	candidate #5
8		
9		
10		
11		
12		
13	candidate #3	candidate #5
14		
15		
16		
17		
18		
19	candidate #4	candidate #5
20		
21		
22		
23		
24		

Fig. 3

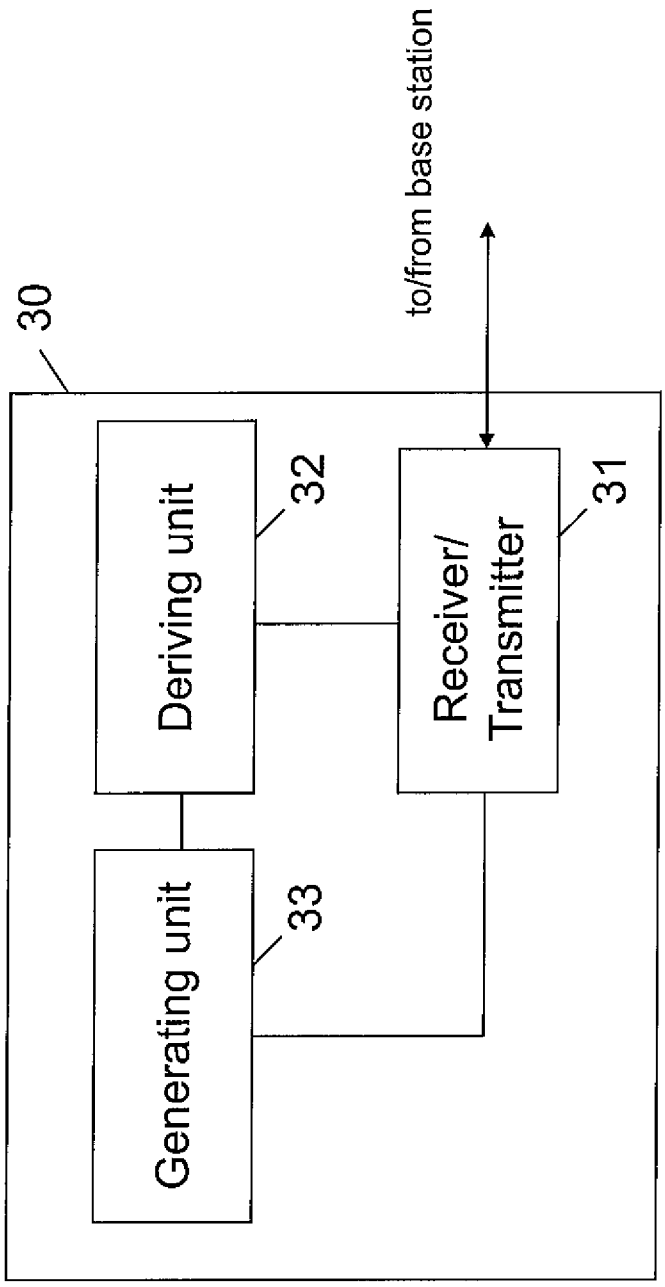

30
to/from base station
Deriving unit
32
Receiver/
Transmitter
31
Generating unit
33

Fig. 4

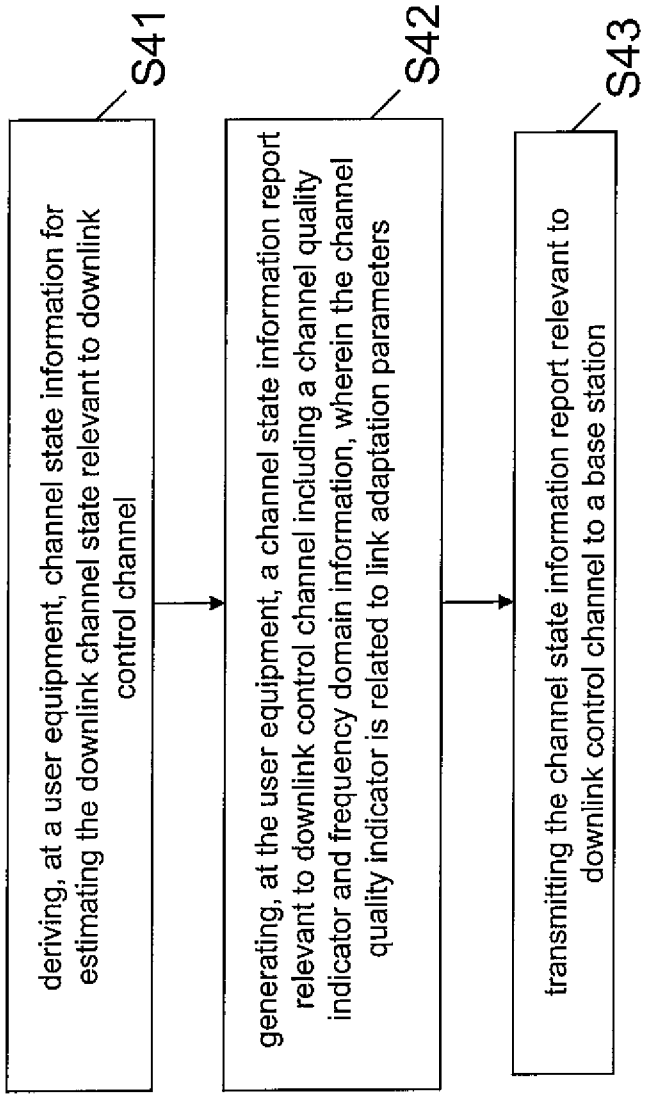

S41
deriving, at a user equipment, channel state information for estimating the downlink channel state relevant to downlink control channel
S42
generating, at the user equipment, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters
S43
transmitting the channel state information report relevant to downlink control channel to a base station

Fig. 5

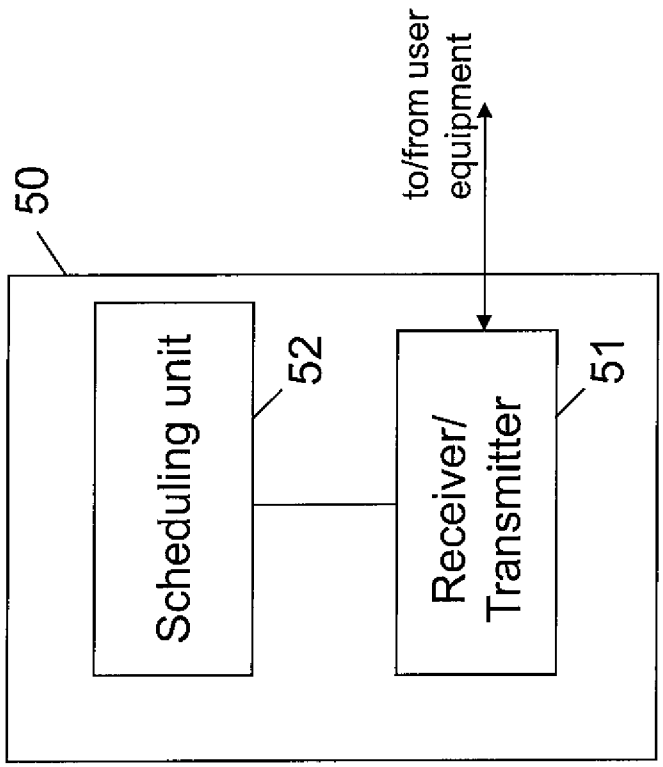
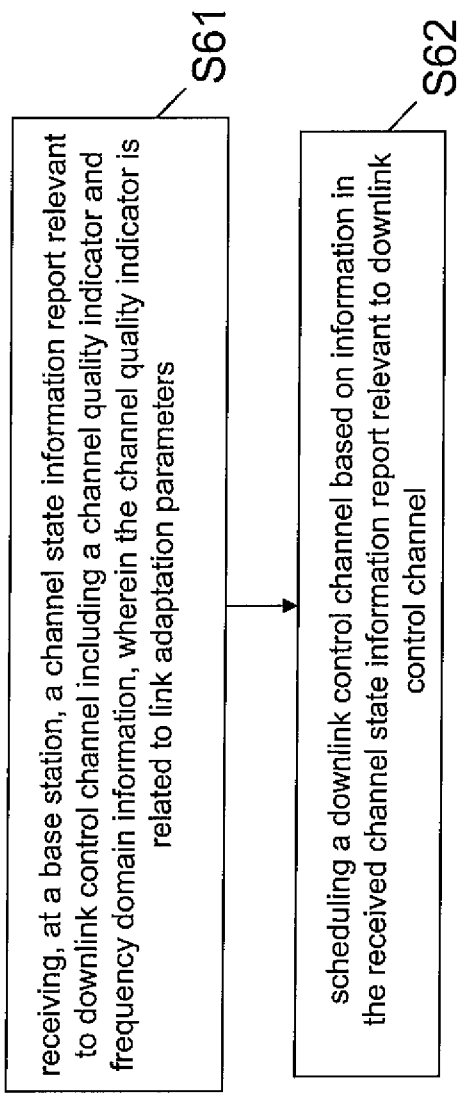

50
to/from user equipment
Scheduling unit
52
Receiver/ Transmitter
51

Fig. 6


S61
receiving, at a base station, a channel state information report relevant to downlink control channel including a channel quality indicator and frequency domain information, wherein the channel quality indicator is related to link adaptation parameters
S62
scheduling a downlink control channel based on information in the received channel state information report relevant to downlink control channel

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/070689

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04 (2009.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H04W;H04Q;H04B

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)

WPI,EPODOC,CNPAT: CSI, channel state information, report, link adaptation, CA, carrier aggregation, frequency domain

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO2009/118707A1 (NOKIA CORP. et al.) 01 Oct. 2009(01.10.2009) see paragraphs 0024,0027 in the description	1-23
A	CN102291752A (INST. TELECOM. SCI&TECHNOLOGY) 21 Dec. 2011(21.12.2011) see the whole document	1-23
A	CN102307083A (INST. TELECOM. SCI&TECHNOLOGY) 04 Jan. 2012 (04.01.2012) see the whole document	1-23
A	ERICSSON et al., Periodic CSI reporting for CA, 3GPP TSG RAN WG1 Meeting #63 R1-105858, 19 Nov. 2010(19.11.2010) see the whole document	1-23

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

* Special categories of cited documents:

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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 Sep. 2012(06.09.2012)	**15 Nov. 2012 (15.11.2012)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer HE,Xiulian Telephone No. (86-10)62413426

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/070689

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
WO 2009118707 A1	01.10.2009	EP 2266358 A1	29.12.2010
		US 2011019637 A1	27.01.2011
CN102291752A	21.12.2011	NONE	
CN102307083A	04.01.2012	NONE	