

CHANNEL QUALITY REPORTING METHOD AND ARRANGEMENT IN A TELECOMMUNICATION SYSTEM

FIELD OF THE INVENTION

- 5 The present invention relates to reporting of Channel Quality Indicator (CQI) in a packet-based wireless telecommunication network.

BACKGROUND

- 10 In 3GPP Release 5, High-Speed Downlink Packet Access (HSDPA) is introduced, where a new modulation scheme (16 QAM) is introduced in addition to the existing QPSK (Quadrature Phase Shift Keying) modulation scheme in Release 99.

- In HSDPA systems, the UE (User Equipment) reports the Channel Quality Indicator (CQI) through uplink HS-DPCCH (High Speed Downlink Physical Control Channel) to the RBS (Radio Base station), for which a single HS-PDSCH (High Speed Physical Downlink Shared Channel) sub-frame formatted with the transport block size, number of HS-PDSCH codes and modulation corresponding to the reported or lower CQI value could be received, and for which the transport block error probability would not exceed
- 20 10%, see 3GPP TS 25.214, v 5.11.0, "Physical layer procedures (FDD)".

- In 3GPP Release 5, five bits are used to report the CQI, resulting in a CQI value range of [0, 31], where there is a one decibel resolution, see 3GPP TS 25.212 v6.9.0, "Multiplexing and channel coding (FDD)". Among these CQI values, a CQI value of "0" is specified to be "out of range", which means that no transport block can be selected due to bad channel quality; a CQI value of 31 is not explicitly specified but in one Ericsson contribution, 3GPP R1-02-0675, Ericsson, Motorola, "Revised CQI proposal", Paris, France, April 9 ~12, 2002, the CQI value of "31" is stated to be reserved.

- 30 For the purpose of CQI reporting, the UE shall assume a total received HS-PDSCH power as

$$P_{HSPDSCH} = P_{CPICH} + \Gamma + \Delta \text{ in dB} \quad (1)$$

- where the total received power is evenly distributed among the HS-PDSCH codes of the reported CQI value, the measurement power offset is signaled by higher layers and the reference power adjustment Δ depends on the UE category, see 3GPP TS 25.214, v 5.11.0, "Physical layer procedures (FDD)". The power offset Γ is defined as the
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transmit power of HS-PDSCH divided by the transmit power of CPICH (Common Pilot Channel) in the linear scale; or on the dB scale: Γ = transmit power of HS-PDSCH – transmit power of CPICH.

- 5 Γ can preferably be set as a configurable parameter and can be configured by operators.

Therefore, UEs actually assume that

$$SIR_{HS-PDSCH} = SIR_{CPICH} + \Gamma + \Delta \text{ in dB} \quad (2)$$

- 10 The mapping between the HS-PDSCH SIR (signal to interference ratio) and CQI behind the current 3GPP design is that

$$CQI = 4.5 + SIR_{HS-PDSCH} \text{ in dB} \quad (3)$$

- where SIR means the total HS-DSCH SIR, summed over the number of HS-PDSCH codes, see 3GPP R1-02-0675, Ericsson, Motorola, "Revised CQI proposal", Paris
15 France, April 9 ~12, 2002.

- According to equation (3) above and taking the CQI range [0, 30] into account, the reportable $SIR_{HS-PDSCH}$ value in the dB scale is calculated and has a range of [-4.5, 25.5] dB. Any SIR value smaller than -4.5 dB is reported as a CQI value of "0" and SIR
20 values greater than 26.5 dB are reported as a CQI value of "30". Thus, it is important to note that the factor of 4.5 in equation (3) is not a scaling factor. Rather, it is an offset added to the SIR such that the CQI is reported in a range that starts at 0 and not -4.5.

- 3GPP TSG RAN has approved the SI description on "Scope of future FDD HSPA
25 Evolution". One way to achieve higher peak data rates is to introduce higher-order modulation (64QAM/16QAM) for HSDPA/HSUPA (High Speed Downlink Packet Access/High Speed Uplink Packet Access). However, the 64QAM (Quadrature Amplitude Modulation) modulation scheme normally requires a very good channel quality, e.g. above 25 dB $SIR_{HS-PDSCH}$ if 15 codes are available, see Figures 1a and 1b.
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Figure 1a is a graph showing bit rate versus SIR switch point, for QPSK towards the left of the graph and 16QAM towards the right of the graph (i.e. higher SIR switch point). Also shown on the graph are 15 variations showing the effect of changing the

number of channelization codes from 1 (at the bottom, i.e. relatively low bit rate) to 15 (at the top, i.e. relatively high bit rate).

Figure 1b is the same graph as shown in Figure 1a, but with the plots extended to show 64QAM on the right- and uppermost portion side of the graph (i.e. highest SIR switch point and highest bit rate).

As described in the foregoing, in Release 5, SIR values greater than 25.5 dB will be reported as a CQI value of 30. From Figure 1b, it can be seen that after introducing 64QAM, obviously these high SIR values can't simply be reported as a CQI value of "30". Otherwise, some large TBs (Transport Blocks) cannot be selected and the peak rate (~22 Mbps) cannot be reached.

SUMMARY

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This invention disclosure proposes solutions for CQI reporting after the new modulation scheme (64QAM) is introduced into 3GPP. These solutions take both the CQI signaling cost and the need of 3GPP specification change into account.

20 According to one aspect, the present invention relates to a method in a user equipment for measuring the instantaneous downlink channel quality indicator (CQI), and reporting the measured CQI to the network when higher order modulation, such as 64 QAM, can be used for downlink data transmission. The method comprises the steps of:

- deriving a true CQI based upon at least one network controlled parameter and a measured channel quality parameter;
- scaling said true CQI value to a new CQI value such that the new CQI will fall within a specified range of CQI values;
- reporting the new CQI achieved by scaling the derived CQI value in order to report every CQI value with the same number of bits over the entire reporting range.

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According to a preferred embodiment, the invention is applied in an HSDPA CDMA system. However, the invention is also applicable to other systems such as E-UTRAN in LTE.

35 According to another aspect, the invention relates to a method in a base station of receiving the downlink channel quality indicator (CQI) from the user equipment and

using the received CQI for transmitting data and if necessary using higher order modulation such as 64 QAM, comprising

- interpreting the reported CQI according to a scaling applied by the user equipment on the derived true CQI.

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According to yet another aspect, the invention relates to a method in a base station of receiving downlink channel quality indicator (CQI) from a user equipment and using the received CQI to be able to transmit data and if necessary using higher order modulation such as 64 QAM. The method comprises:

- 10 - collecting the statistics of the received CQI reports and based on the statistics reporting an event to the radio network controller in case the CQI statistics indicate significant change in the downlink channel quality.

According to a preferred embodiment, the received CQI is used for transmitting data on
15 HS-PDSCH in a CDMA (Code Division Multiple Access) system.

According to yet another aspect, the invention relates to a method in a radio network controller of configuring a user equipment with parameters to assist the user equipment in deriving CQI. Said method comprises:

- 20 - configuring the user equipment with at least two different power offset values to be used by the user equipment to derive the CQI and in addition if necessary also,
- configuring the user equipment with a threshold value (μ) to trigger which power offset value to be used by the user equipment.

- 25 Preferably, the larger power offset is configured to be used by the user equipment to report the CQI when the derived CQI is less than the specified threshold or the configured threshold (μ), otherwise the smaller power offset is configured to be used by the user equipment to report the CQI.

30 According to yet another aspect, the invention relates to a method in a radio network controller of receiving the downlink channel quality measurements and signaling to the base station the configured power offset, which is currently used by the user equipment to derive the CQI and report the derived CQI to the base station. The method comprises

- 35 - configuring an event at the base station to indicate significant change in CQI statistics.

- receiving and interpreting the event reported by the base station.
- reconfiguring the power offset at the user equipment if necessary.
- signaling the reconfigured power offset to the base station if the reconfiguration was done at the user equipment.

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The foregoing and other objects, features and advantages of the invention will be apparent from the following detailed description of preferred embodiments

BRIEF DESCRIPTION OF THE DRAWINGS

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Figures 1a and 1b illustrate bit rate vs. SIR switch point, where different modulation schemes are indicated in the figure and from bottom to top there are 15 dotted lines representing the number of channelization codes from 1 code to 15 codes.

- 15 Figure 2 illustrates part of a wireless telecommunications network according to the present invention.

Figure 3 illustrates a change in scaling factor with variation in SIR.

- 20 Figure 4 is a flow chart illustrating a method in accordance with an aspect of the invention.

Figure 5 is a flow chart illustrating a further method in accordance with an aspect of the invention.

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DETAILED DESCRIPTION

Figure 2 illustrates part of a wireless telecommunications network 10 according to the present invention.

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- The telecommunications network 10 comprises at least one radio base station 20 (alternatively called a network node, node B, or any other name familiar to those skilled in the art). The transmission area 30 of the radio base station 20 is shown as a hexagon surrounding the base station; this transmission area 30 is commonly referred to as a cell. Only one base station and its associated cell are shown for convenience; it will be appreciated that the network 10 will typically comprise many such base stations

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and cells. Cellular phones 40 (also referred to as user equipments) within the cell 30 receive transmissions from the base station 20 on one or more carriers, and send their own transmissions back to the base station 20. A core network (CN) 50, in communication with the base station 20, controls overall operation of the network 10.

- 5 The core network 50 comprises, amongst other things, a radio network controller (RNC) 55.

Those skilled in the art will appreciate that many elements of the network 10 have been omitted for clarity. The operation of the base station 20 and the user equipments 40, in particular, is described in further detail below.

A straightforward solution to the described problem is to extend the current 5-bit CQI to be a 6-bit CQI, which results in a new CQI range of [0, 63].

- 15 This is a simple way and can use the same mapping between CQI and SIR as in 3GPP Release 5. On the other hand, the CQI cost in terms of signaling bits is increased due to one additional bit for each CQI reporting, particularly in the MIMO (Multiple Input Multiple Output) case where there may be three CQIs needed for each reporting. Among them, two CQIs will be used for two streams while the third one is used for a
20 conventional single stream. In addition, the extended CQI range of [40, 60] will actually not make much sense since the highest required $SIR_{HS-PDSCH}$ for the max TB with 15 channelization codes and 64QAM is just about 34 dB. Therefore, this one additional bit extension of CQI is actually not fully efficiently utilized.

- 25 According to an alternative solution, a scaling factor is used in the derived CQI values to keep the current reporting range of [0, 30], and the UE reports the scaled CQI to RBS. This solution will be described in the following three steps:

Step 1: UE derives the true CQI in the same way as in Release 5, i.e.

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$$CQI_{true} = 4.5 + SIR_{HS-PDSCH} \text{ in dB} \quad (4)$$

Step 2: UE then applies a scaling factor to the true CQI as calculated in equation (4)

$$CQI_{reported} = \text{factor} \times (4.5 + SIR_{HS-PDSCH}) \text{ in dB} \quad (5)$$

- 35 For example, a factor of 3/4 can be used to keep $CQI_{reported}$ in the range of [0, 30], which results in the reported $SIR_{HS-PDSCH}$ range of [-4.5, 35.5] dB, which is enough for

the case of 15 channelization codes with 64QAM, where the peak rate of ~22 Mbps can be reached. The RBS can derive the true CQI as $CQI_{reported} \times 4/3$.

5 According to the rule shown in equation (5), a new CQI table for 64 QAM UEs could be specified.

As a further implementation of this solution, the mapping in a new CQI table can be constructed with a non-constant factor, i.e.

$$10 \quad CQI_{reported} = f(SIR_{HS-PDSCH}) \times (4.5 + SIR_{HS-PDSCH}) \text{ in dB} \quad (5a),$$

where $f(SIR_{HS-PDSCH})$ is a scaling factor that is a function of the estimated SIR on the HS-PDSCH.

15 Alternatively, said non-constant scaling factor can be a function of the estimated SIR on common pilot symbols, i.e.

$$CQI_{reported} = f(SIR_{CPICH}) \times (4.5 + SIR_{HS-PDSCH}) \text{ in dB} \quad (5b)$$

According to one embodiment, the UE derives the scaling factor based on the estimated SIR ($SIR_{HS-PDSCH}$ or SIR_{CPICH}) in a way that the derived CQI fits into one of the reportable values, e.g. 26, 27, ..., 30. As shown in Figure 1 the bit rate is a non-linear function of the measured SIR (i.e. $SIR_{HS-PDSCH}$). The reported CQI corresponds to a certain transport block (or data block) size that the network uses to schedule packets in the downlink. Therefore, the scaling factor, which may be a positive quantity in the linear scale, may also be a non-linear function of SIR.

25 Figure 3 shows one example of the scaling factor as a function of $SIR_{HS-PDSCH}$ in the linear scale.

30 More scaling may be needed at higher SIR and less scaling at lower SIR, as shown in Figure 3. For example, below some threshold SIR value SIR_0 no scaling is required, while above that value scaling is performed. This situation occurs when higher order modulation is used (for example, 64 QAM, MIMO, etc), where higher SIRs are achievable.

35 As mentioned above, another scenario where UE receives signals with high SIR is multiple input multiple output (MIMO) systems, e.g. 2x2 (2 transmit and 2 receive

antennae) or 4x2 (4 transmit and 2 receive antennae). Yet another example where very high SIR is achievable is a combination of higher order modulation with MIMO systems. The present invention is therefore applicable in all these scenarios since through scaling the UE could report the CQI without the need of any extra bits, as
 5 compared to the normal scenario which use lower order modulation and non MIMO systems (e.g. 1x1 or 1x2 transmit/receive antennae cases).

This solution does not increase the CQI cost in terms of CQI bits or other signaling overheads. This solution only requires that the UE and RBS need to use a common
 10 rule to derive CQIs.

Step 3: UE reports the CQI_{reported} to the RBS.

Figure 4 is a flow chart illustrating this method in more detail.
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Flow begins in step 100, where the UE estimates the SIR. As previously mentioned, in a CDMA system this may be on the HS-PDSCH or on common pilot channels (CPICH); in an LTE E-UTRAN system, this may be on downlink shared channel (DL-SCH) or downlink reference channels. Other examples may be thought of by those skilled in
 20 the art.

In step 110, the CQI is derived from the estimated SIR as in Release 5 (i.e. by adding a network controlled parameter to the estimated SIR; the network controlled parameter will typically take the value of 4.5).
 25

In step 120, the derived CQI is multiplied by a factor to generate a scaled CQI. As discussed above, the factor may be constant or variable, and may be a function of the SIR estimated in step 100.

30 In step 130, the scaled CQI is reported to the network.

In the following, yet an alternative solution is proposed, comprising an adaptive/event triggered adjustment of CQI. As described in equation (2),
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$$SIR_{HS-PDSCH} = SIR_{CPICH} + \Gamma + \Delta \text{ in dB}$$

An adaptive/event triggered power offset Γ adjustment can make the reported CQI falling in the range of [0, 30]. In 3GPP, Γ is one information element (IE) in the RRC message. The Γ range is [-6, 13] and the resolution is 0.5 dB. It will be sent to the UE together with other IEs (CQI feedback cycle k, CQI repetition factor, delta CQI).
 5 Currently, this RRC message is typically only transmitted once per connection. However, nothing prevents Γ from being updated during the duration of a connection. Of course, to minimize the RRC signaling, the number of updates should be kept to a minimum. Fortunately, it is reasonable to assume that a single UE does not need the
 10 entire dynamic range of CQI reports: the CQI reports from one single UE almost never cover the entire reporting range.

There are three ways in which Γ can be adjusted adaptively or in an event triggered fashion:

- 15 • Based on CQI statistics in the base station
- Based on downlink measurements available in the RNC (radio network controller)
- Pre-configuration of two power offset values

The alternatives will be described in the following.

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Based on CQI statistics in the base station

Ideally, the update of Γ should be based on CQI statistics. Unfortunately, such statistics are not available in the RNC. To improve the performance of the solution, a new message on the Iub interface between the base station and the RNC requesting
 25 the RNC to update the Γ may be standardized. Thus, the base station would estimate the mean of the CQI reports for a few hundred milliseconds, and then request that the RNC updates the Γ to make the CQI mean equal to 15.

Based on downlink measurements available in RNC

30 In this adaptive Γ solution, an initial Γ is transmitted to the UE during the connection set-up. Based on measurements readily available in the RNC, a new Γ is sent to the UE using measurements collected during a few 100 ms. The RNC may base this update on measurements of e.g., throughput or E_c/I_o (the ratio between received signal power to total received interference). Thus, if the throughput indicates that the
 35 UE has excellent quality, the RNC reduces the Γ by some quantity.

Pre-configuration of two power offset values

Another possibility is that the network configures at the UE more than one power offset value (Γ), for example two values (Γ_1, Γ_2), where $\Gamma_1 > \Gamma_2$. The UE initially derives the CQI using the first power offset value (Γ_1). In the case that the derived CQI value is below a certain threshold (μ) then the UE shall report the same derived CQI. On the other hand, in the case that the derived CQI using Γ_1 exceeds the threshold (μ), the UE re-derives the CQI value using the second power offset value (Γ_2) and reports the CQI using Γ_2 . The threshold value (μ) can either be standardized (e.g. CQI = 25) or it can be set by the network in an event triggered fashion. The second approach is more flexible. The solution may also require RRC signaling support for reporting more than one power offset value (for example two values) to the UE.

In the following, yet another possible solution is proposed. According to this solution the CQI cost is kept, i.e., still 5 bits, but the mapping rule is changed when the UE estimates a higher HS-PDSCH SIR value than 25.5 dB, which results in a CQI greater than 30. More specifically, the CQI value of "31" may be used to indicate a change of CQI mapping since this value is reserved in current Release 5. This is done by adding an offset value to the reported CQI values as will be described below.

If the derived CQI value at the UE is greater than 30, the UE reports a CQI value of 31 in the current TTI (Transmission Time Interval) with a high power, notifying the RBS that the following reported CQI values are actually greater than 30 and that an offset value of 30 shall be added to the reported CQI; e.g. the reported CQI "1" actually means a CQI of 1 + 30; the reported CQI "2" actually means a CQI of 2 + 30.

If the derived CQI value at the UE is smaller than 30 and the derived CQI for the previous TTI is greater than 30, the UE reports a CQI value of 31 in the current TTI with a high power, notifying the RBS that the following reported CQI values are actually the derived CQI values, i.e. without the addition of an offset value; e.g. the reported CQI "1" actually means a CQI value of 1; the reported CQI "2" actually means a CQI value of 2.

If none of the two cases above are applicable, the UE reports the actual CQI as usual as in Release 5.

Figure 5 is a flow chart illustrating a specific embodiment of this method in detail.

Flow begins in step 200, that of deriving the CQI. This is achieved as described previously (i.e. by estimating the SIR, and then adding a network controlled parameter, typically 4.5).

- 5 In step 210, the UE determines whether the derived CQI is greater than 30. If the CQI is greater than 30, flow proceeds to step 220, where the UE reports a CQI value of 31 to the network. The "31" value is reserved, and indicates a shift of the mapping rules, such that subsequent reported CQI values are calculated by subtracting 30 from the derived CQI value (step 230). That is, the network now understands that subsequent
10 reported CQI values will be in the range 31–60.

- In step 210, if the CQI is less than or equal to 30, the UE determines whether the preceding derived CQI was greater than 30 (step 240). If it was, flow proceeds to step 250, where the UE reports a value of 31, shifting the mapping rules back so that the
15 network understands that subsequent reported CQI values will be in the range 1–30. In step 260, the UE reports the CQI as derived.

- In step 240, if the preceding CQI value was not greater than 30, there is no need to shift the mapping rules, and so the flow can proceed directly to step 260.
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- This solution does not increase the CQI cost in terms of the number of CQI bits. However, in this solution, the RBS may need to have the change history of CQI. That is, the history of the CQI and whether it is above or below 30. This solution is therefore more suitable for a system with a relatively flat radio quality, and less suitable for large
25 fluctuations where radio quality changes more frequently (e.g., TTI 1: 25 dB, TTI 2: 38 dB, TTI 3: 20 dB). However, the system works adequately in both scenarios.

- This solution might be extended to use a CQI of 31 together with a CQI of 0 to indicate the change of CQI mapping, which can improve the reliability of this indicator. In other
30 words, the unique CQI sequence [31 0] may be used to indicate the change of CQI mapping.

- The invention has in the foregoing been described with reference to HSDPA systems. However, the invention is also applicable to CQI Reporting in E-UTRAN (Evolved
35 UMTS Terrestrial Radio Access Network), as will be described in the following.

The E-UTRAN system is purely packet oriented. This means the downlink scheduling and link adaptation are highly dependent upon the CQI reports from the UE, see 3GPP TR 25.814, "Physical Layer Aspects for Evolved UTRA". In E-UTRAN higher order modulation (e.g. 64 QAM) is likely to be used. This means the CQI may also require
5 more than 5 bits due to higher order modulation. In E-UTRAN the CQI in principle can be reported for each resource block. A resource block is a two-dimensional time-frequency resource. The E-UTRAN bandwidth contains several resource blocks and the actual number depends upon the cell bandwidth. This means there will be considerable signaling overheads in E-UTRAN. Therefore there is strong motivation to
10 reduce the signaling overheads in E-UTRAN especially when higher order modulation is used in the downlink.

The solutions relating to scaling of true CQI values, adaptive/event triggered Γ adjustment and change of the CQI mapping rule described in the foregoing are equally
15 applicable to the CQI reporting in E-UTRAN. The exact definition of CQI in E-UTRAN may be different; however, it is likely to be a function of some network controlled parameter and the measured SIR on some known reference symbols. Hence, the idea of scaling the derived CQI when the derived CQI exceeds a certain threshold as described in the foregoing is applicable to CQI reporting in E-UTRAN. For example,
20 the derived CQI can be scaled by a scaling factor which is a function of the SIR estimated on DL-SCH or on downlink reference signals in an LTE E-UTRAN system.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the
25 invention is not to be limited to the disclosed embodiments, but is intended to cover various modifications within the scope of the appended claims.

Claims

1. A method in a user equipment (40) for measuring the instantaneous downlink channel quality indicator, CQI, and reporting the measured CQI to the network when higher order modulation of 64QAM and above can be used for downlink data transmission, the method comprises the step of:
 - deriving (110) a true CQI based upon at least one network controlled parameter and a measured channel quality parameter;the method being characterized by the further steps of
 - scaling (120) said true CQI value by multiplying with a scaling factor to a new CQI value such that the new CQI will fall within a specified range of CQI values;
 - reporting (130) the new CQI achieved by scaling the derived CQI value in order to report every CQI value with the same number of bits over the entire reporting range.
2. A method according to claim 1, wherein the derived CQI value is scaled (120) by the scaling factor which is a function of a signal-to-interference ratio, SIR, measured by the user equipment.
3. A method according to claim 2, wherein the derived CQI is scaled (120) by the scaling factor which is a function of the SIR estimated on HS-PDSCH in a CDMA system.
4. A method according to claim 2, wherein the derived CQI is scaled (120) by the scaling factor which is a function of the SIR estimated on common pilot symbols in a CDMA system.
5. A method according to claim 2, wherein the derived CQI is scaled (120) by the scaling factor which is a function of the SIR estimated on DL-SCH.
6. A method according to claim 2, wherein the derived CQI is scaled (120) by the scaling factor which is a function of the SIR estimated on downlink reference signals.
7. A method according to any of the previous claims, wherein the user equipment (40) takes into consideration at least two network signaled power offset values, where the first value is larger than the second one, to scale the derived CQI depending upon the value of the derived CQI in relation to a certain threshold.

8. A method according to claim 7, wherein the user equipment (40) initially derives its CQI using the first power offset value, i.e. the larger value.
9. A method according to claim 8, wherein if the derived CQI is smaller than the threshold then the user equipment (40) shall scale (120) the CQI according to the first value of the power offset otherwise the second value of the power offset is used to scale (120) the derived CQI.
10. A method according to any preceding claim, wherein the higher order modulation is 64 QAM.
11. A method according to any preceding claim, further characterized by:
Scaling (120) said true CQI value to a new CQI value by a scaling factor which is a function of a second channel quality parameter measured by the user equipment.
12. A method as claimed in claim 11, wherein the second channel quality parameter is the same as the first channel quality parameter.
13. A user equipment (40), for communicating with a radio base station (20) in a wireless telecommunications network (10), wherein the user equipment (40) is configured to measure the instantaneous downlink channel quality indicator, and report the measured channel quality indicator to the network, by means of the method according to any of claims 1 to 12.