# Calibration of CQI reporting algorithm in HSDPA networks

Igor A. Tomić

***Abstract* — Next step in development of mobile communication systems is HSDPA (High Speed Downlink Packet Data Access). The key functionality in HSDPA networks is rate adaptation, and it is based on CQI – Channel Quality Indicators, reported by UE. In this paper, we will describe CQI report algorithm and it's calibration process. Practical experiences will be presented, and gains in terms of throughput will be shown.**

***Key words* — HSDPA, performance, throughput, CQI-*Channel Quality Indicator*.**

## I. INTRODUCTION

MOBILE communications are developing very fast. The permanent growth of bit rate demands, followed by demand for more efficient mobile systems, brought us to the systems of 3.5 generation. *HSDPA (High Speed Downlink Packet Data Access)* is defined by 3GPP recommendations (revision 5), and presents upgrade of UMTS systems – first step of the evolution of WCDMA.

HSDPA is offering speeds up to 1.8 Mbps (on physical layer) for terminal category 12, or up to 3.6 Mbps for terminal category 5 using 16QAM – see [5] and [6]. In order to offer much higher bit rates on downlink, HSDPA system has different approach comparing regular WCDMA. Some of codes with SF 16 (*spreading factor*) are dedicated to HSDPA. In ERICSSON release P4 maximum of five SF 16 codes can be assigned to HSDPA (see [15]). These codes can be used by HSDPA users only. HSDPA users are time multiplexed and they are using all codes assigned to HSDPA in each time slot, called TTI (*Transmission Time Interval*). Code multiplexing of HSDPA users is not supported in P4, but it will be supported in future releases of Ericsson equipment, when there will be also possibility to assign more than five SF 16 codes for HSDPA. With 10 SF16 codes (Terminal category type 8), HSDPA will offer throughputs up to 7.2 Mbps, and with 15 SF16 codes (Terminal category type 10) it will offer throughputs of 14 Mbps !

HSDPA is based on three key function:

- Fast link adaptation
- Fast hybrid ARQ with soft combining
- Fast channel dependent scheduling
- Higher Order Modulation

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The main difference comparing regular WCDMA is rate control instead of power control. In mobile environment radio conditions are changing rapidly, because of path loss and shadowing, interference variations and fast fading. In regular WCDMA, system is compensating varying link conditions by power control, while in HSDPA system it is done through rate control. It means that power is constant during each TTI, which is very short – only 2ms. For each TTI, system performs TFRC selection algorithm (*Transport Format and Resource Combination*) and decides how much data to send. Amount of sent data is adjusted according current radio conditions, which are reported by UE through CQI (*Channel Quality Indicator*) and information about available transmission power.

In chapter II we will describe TFRC selection algorithm process. In chapter III we will analyze impact calibration of CQI reporting algorithm and we will show performance depending on *hsMeasurementPowerOffset* parameter. Optimum values will be proposed. In chapter IV we will analyze CQI adjustment algorithm and we will show performance improvement that this feature is giving.

## II. TFRC SELECTION ALGORITHM

Mobile user is experiencing varying radio conditions. The radio propagation conditions are changing in time (i.e. fading, shadowing, interference…). All mentioned result in very high variability of radio channel. So far, mobile networks were combating all these problems through power control algorithm, which was increasing power in situations when user was suffering bad radio condition. This solution was shown as inefficient, so in HSDPA networks we have for the first time rate adaptation.

Rate adaptation means that system is instead compensating varying link conditions by increased power, adjusting amount of data. Power is constant during one TTI (Transmission Time Interval) and Node B is using for HSDPA all remaining power after R99 users are served.. TTI is very short – only 2ms. During each TTI, system adjusts amount of sent data according current radio conditions and available power. We can say that rate control is applied, with 500 adjustments per second. This method is much more efficient comparing power control.

Rate adaptation is performed through TFRC – Transport Combat and Resource Combination algorithm. For each transmission on HS-PDSCH channel (High Speed Physical Downlink Shared Channel) TFRC selection algorithm determines the transport block size.

Beside rate adaptation, TFRC determines modulation type (QPSK or 16QAM), HS-PDSCH codes, and HS-PDSCH transmission power.

In order to perform accurate and efficient TFRC selection, Node B must have information about radio channel. Inputs for TFRC selection algorithm are CQI (*Channel Quality Indication*) reports, which UE sends on uplink on HS-DPCCH (*High Speed Dedicated Physical Control Channel*). CQI is number between 0 and 30, where 30 stands for situation when radio conditions are good and UE is demanding highest amount of data to be sent during TTI. When UE is calculating CQI, it assumes available HSDPA power of:

$$P_{HSPDSCH} = P_{CPICH} + \Gamma + \Delta \qquad [1]$$

Where $P_{CPICH}$ is measured CPICH power, $\Gamma$ is signaled by higher layers and $\Delta$ is reference power adjustment, defined in CQI mapping table. In Ericsson HSDPA realization $\Gamma$ is defined as parameter called *hsMeasurementPowerOffset*. The objective of this parameter tuning is to obtain proper and balanced CQI mapping. In case that this parameter is set too low, UE will report to pessimistic CQI values, resulting lower throughputs. In case this parameter is set too high, UE will report too optimistic CQI values, resulting too many retransmissions and again lower throughput. In order to achieve good HSDPA performance, optimum values for $\Gamma$ are quite important. In chapter III we will perform this parameter optimization. CQI adjustment algorithm, described in chapter IV can improve performance and correct errors caused by wrong CQI reporting. $\Delta$ is on the other hand used by UE to report different channel qualities with 1dB resolution. Table 1. gives CQI mapping for HSDPA terminal category type 12, which are at the moment most present on the market. This terminal category does not support 16QAM modulation. We can see that UE uses different $\Delta$ values for different CQI. Even more important, we can see that different amount of data (Transport block size) and different MAC-hs throughput corresponds to different CQIs. This is actually rate adaptation performed by TFRC algorithm. More detail description of CQI mapping can be find in [4] - [6].

| CQI value | Transport Block Size | MAC-hs Bit rate [Mbps] | Number Of HS-PDSCH | Modulation | $\Delta$ [dB] |
|---|---|---|---|---|---|
| 5 | 377 | 0.17 | 1 | QPSK | 0 |
| 10 | 1262 | 0.63 | 3 | QPSK | 0 |
| 15 | 3319 | 1.66 | 5 | QPSK | 0 |
| 20 | 3319 | 1.66 | 5 | QPSK | -5 |
| 23 | 3319 | 1.66 | 5 | QPSK | -8 |
| 25 | 3319 | 1.66 | 5 | QPSK | -10 |
| 30 | 3319 | 1.66 | 5 | QPSK | -15 |

**Table 1.** *CQI Mapping, Terminal Category Type 12*

Table 2. presents CQI mapping for HSDPA terminal category 5. The most important difference between terminal category type 5. and terminal category 12. is 16QAM support. HSDPA terminal category 5. are very rarely found on the market at them moment, but we can expect them soon. We can see in table 2. that depending on reported CQI, TFRC selection algorithm selects modulation type: QPSK or 16QAM.

| CQI value | Transport Block Size | MAC-hs Bit rate [Mbps] | Number Of HS-PDSCH | Modulation | $\Delta$ [dB] |
|---|---|---|---|---|---|
| 5 | 377 | 0.17 | 1 | QPSK | 0 |
| 10 | 1262 | 0.63 | 3 | QPSK | 0 |
| 15 | 3319 | 1.66 | 5 | QPSK | 0 |
| 20 | 5887 | 2.94 | 5 | 16QAM | 0 |
| 23 | 7168 | 3.58 | 5 | 16QAM | 0 |
| 25 | 7168 | 3.58 | 5 | 16QAM | -3 |
| 30 | 7168 | 3.58 | 5 | 16QAM | -8 |

**Table 2.** *CQI Mapping, Terminal Category Type 5*

## III. OPTIMIZATION OF $\Gamma$ PARAMETER

In chapter II we have described importance of accurate CQI reporting. The main parameter for calibration is *hsMeasurementPowerOffset* which corresponds to $\Gamma$ in 3GPP specifications. In order to optimize *hsMeasurementPowerOffset* parameter we have used TEMS Investigation tool together with NOVATEL Merlin U730 Data Card based on Qualcom chipset 6275. It is HSDPA terminal category 12, supporting up to 1.8 Mbps on physical, or 1.55 Mbps on application layer.

Figure 1. shows CQI values for different EcNo with $\Gamma$ parameter values of 0 dB and 8dB. We can see how $\Gamma$ shifts the curve.

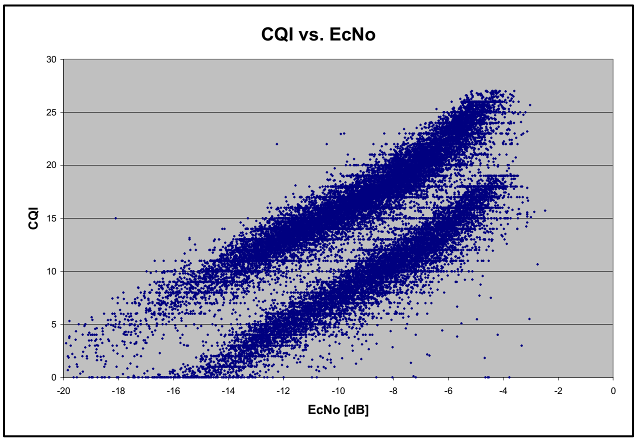


**Figure 1.** *CQI vs. EcNo*

The idea of $\Gamma$ calibration process is to achieve balanced CQI distribution curve, and to avoid cutt-off when UE reports too optimistic or too pessimistic values. Figure 2. shows CQI distribution curve for $\Gamma$ parameter values of 0 dB and 8dB. We can see that for 8dB Γ parameter value, CQI distribution curve is balanced, while for Γ parameter values of 0 dB UE is reporting too pessimistic values, so the CQI distribution curve is shifted too much to left, reporting values of 0 too often and values over 20 are never reported.

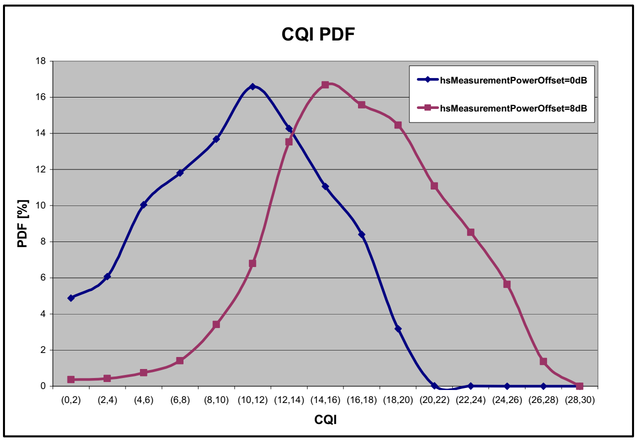


**Figure 2.** *CQI distribution*

If we analyze throughput distribution vs. EcNo curve presented on Figure 3. we can see that for good EcNo values, better then -10dB there is no much difference in throughput. But for lower EcNo values, with Γ parameter set to 8dB even 200kbps better throughput can be achieved. It is due the fact that with Γ parameter set to 0 dB, UE is reporting too pessimistic values, so rate adaptation algorithm schedules too little data.

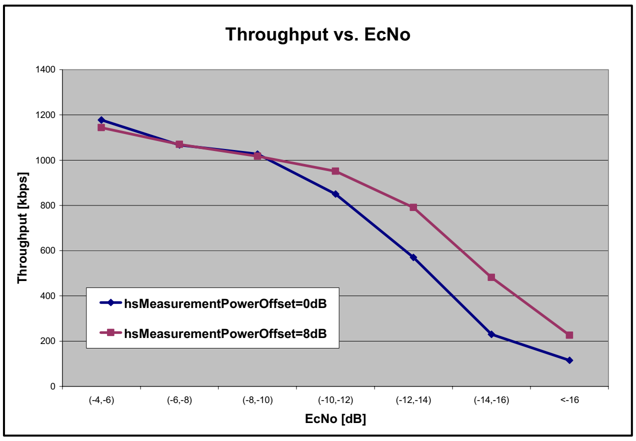


**Figure 3.** *Throughput vs. EcNo*

## IV. CQI ADJUSTMENT FEATURE

Beside calibrating Γ parameter, Ericsson offers optional CQI Adjustment feature to improve HSDPA performance. In order to avoid the negative system impact due to inaccurate CQI reports, the CQI adjustment algorithm in the RBS processes the ACKs and NACKs received from the UE to determine if the UE is overestimating or underestimating the channel quality. The algorithm strives to achieve a block error rate of 10% for the initial transmissions, i.e. excluding retransmissions and Chase combining. The output from the adjustment algorithm, CQIadjusted, is used by the scheduling and TFRC selection algorithms. If no CQI adjustment is performed, CQIadjusted is identical to the CQI sent by the UE. In order to test the impact of CQI Adjustment algorithm on HSDPA network performance, we conducted drive test, according drive test route that covers different radio environments, with CQI feature enabled and disabled. Figures 4. and 5. are showing PDF and CDF distributions for achieved HSDPA throughput and BLER when CQI Adjustment feature is turned off.

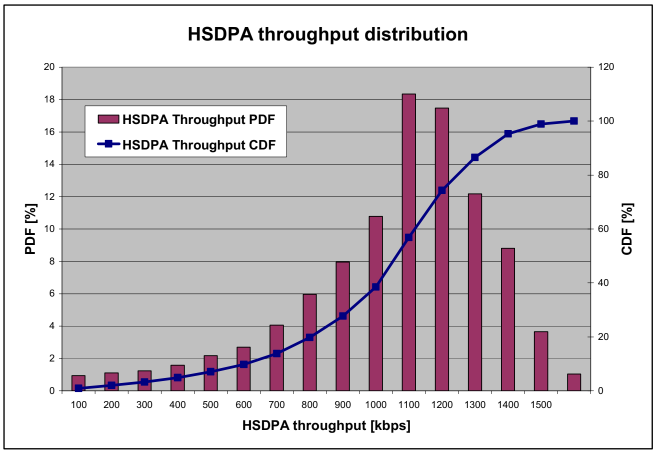


**Figure 4**. *HSDPA throughput PDF & CDF, CQI Adjustment = OFF*

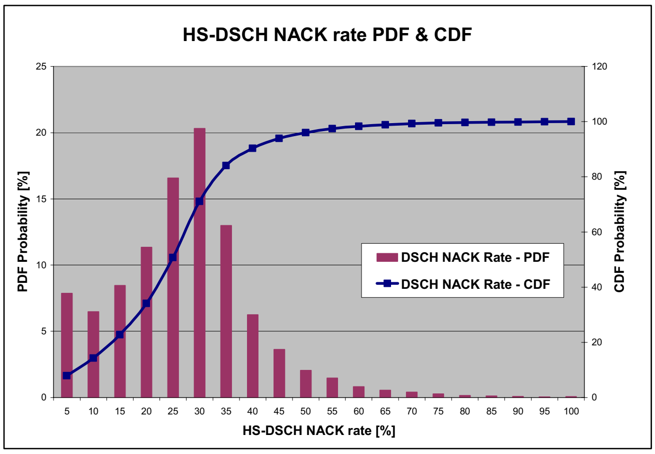


**Figure 5**. *BLER PDF & CDF, CQI Adjustment = OFF*

Figures 6. and 7. are showing PDF and CDF distributions for achieved HSDPA throughput and BLER when CQI Adjustment feature is turned on.

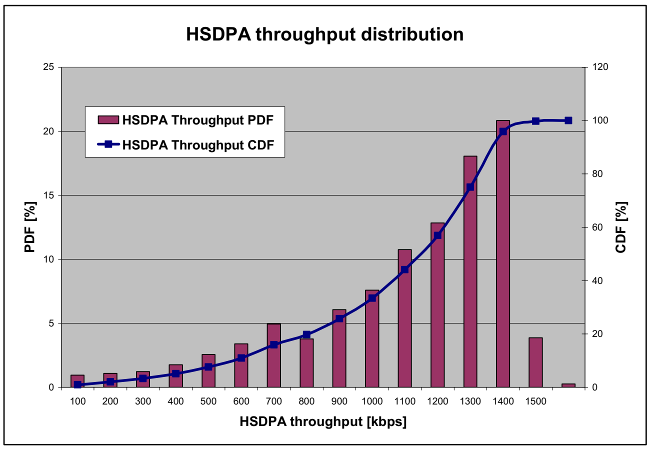


**Figure 6**. *HSDPA throughput PDF & CDF, CQI Adjustment = ON*

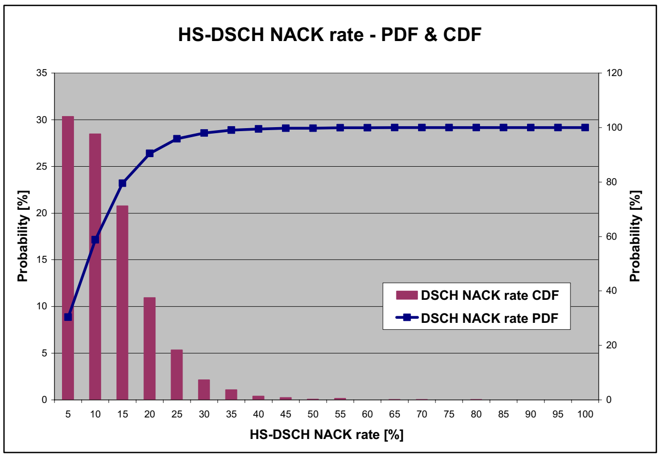


**Figure 7**. *BLER PDF & CDF, CQI Adjustment = ON*

The following table summarizes results for average and median throughput and BLER with CQI adjustment feature turned on and off.

| | | CQI Adjustment = ON | CQI Adjustment = OFF |
|---|---|---|---|
| HSDPA Throughput | Average | 1040 kbps | 1012 kbps |
| | Median | 1150 kbps | 1072 kbps |
| BLER | Average | 10.2 % | 22.5 % |
| | Median | 9 % | 23 % |

**Table 3**. CQI Adjustment feature test, results summary

We can see that throughput is improved (median HSDPA throughput from 1072 kbps to 1150 kbps, and average from 1012 kbps to 1040 kbps). This improvement is expected since BLER rate is improved (median from 23% to 9%).

## V. CONCLUSION

In this paper we have analyzed impact of accurate CQI reporting on HSDPA network performance. We have showed that $\Gamma$ parameter is very important for good HSDPA performance, and it can be calibrated by observing CQI distribution curve. Value of 8 dB seems to be optimum for good performance. It was shown that it doesn't affect throughputs in case of very good radio conditions (EcNo values better then -10 dB), but in case of EcNo is worse then -10 dB, even 200 kbps throughput improvement can be achieved with proper $\Gamma$ parameter value.

Beside $\Gamma$ parameter calibration, CQI adjustment feature can prevent inaccurate CQI reporting. CQI values are adjusted through loopback which gives information about BLER to algorithm. By trying to achieve optimum BLER of 10%, algorithm adjusts reported CQI, and improves network performance. Achieved throughputs are 50 kbps – 100 kbps better when this algorithm is activated.

All discussed analysis is performed for terminal category 12. It would be interested to perform same analysis for Terminal category 5 as well.

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## SADRŽAJ

Sledeći korak u razvoju mobilnih ćelijskih sistema je HSDPA (High Speed Downlink Packet Data Access), poznat i kao sistem treće i po generacije – 3.5 G. Ključna funkcionalnost u HSDPA mrežama je prilagođenje brzine protoka radio uslovima, koja je zasnovana na CQI – *Channel Quality Indication* reportima koje šalje UE. U ovom radu ćemo objasniti algoritam generisanja CQI reporta i pokazaćemo kako se taj algoritam kalibriše. Prezentovaćemo praktična iskustva u kalibraciji pomenutog algoritma, optimalne vrednosti parametara i ostvarene dobitke u protoku.

**KALIBRACIJA ALGORITMA IZVEŠTAVANJA CQI INDIKATORA U HSDPA MREŽAMA**

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