

# A Novel Hybrid CQI Feedback Method For Throughput Improvement In 3GPP LTE Systems

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**Abstract**— Frequency Selective Scheduling (FSS) is a prominent characteristic in 3GPP LTE systems. Frequency scheduling depends on Channel Quality Indicator(CQI) feedback report by mobile station. CQI being control information must use minimal bits maintaining the performance of system. This paper recommends a new CQI feedback method which uses existing schemes for improvement of performance of system. It throws light on enhancing throughput of Distributed Haar scheme with suitable usage of Best-M scheme. Proposed technique improves throughput while maintaining overhead reduction achieved by Haar compression schemes. Performance results indicate noticeable rise in throughput of the system as compared to Distributed Haar technique.

**Keywords**— 3GPP LTE CQI, LTE uplink feedback, Distributed Haar feedback, Best-M feedback.

## I. INTRODUCTION

This 3GPP Long Term Evolution(LTE) adopts interesting OFDMA air interface for proper management of available spectrum [1]. OFDMA permits simultaneous downlink transmission on different frequency channels for different users. e-NodeB (base station) schedules users for allotment of frequency channels. Each frequency channel is group of subcarriers known as sub-band. This frequency scheduling requires channel quality information from every user.

Channel Quality Indicator (CQI), an integer value ranging from 1 to 15, indicates quality of each sub-band by computing its SINR value [2]. This CQI-SINR mapping could also consider multipath delay spread [3]. Reference signals are transmitted from time to time by e-NodeB to user equipment for CQI measurement. UE sends back CQI value to e-NodeB with one of the feedback method [4]. CQI feedback information being the control information, must use minimum possible bits. Use of lower number of bits which could be achieved by feedback of partial information, leads to declination of average throughput of the system [5]. A balance has to be struck between overhead bits and throughput of the system.

Many CQI feedback methods have been proposed which could be broadly categorized as full band & sub-band methods [6]. In full band methods, CQI for entire bandwidth is fed back to e-NodeB. For this, certain compression scheme was also been used [7]-[8]. Sub-band methods transmit partial CQI information to e-NodeB. Best-M individual method, one of the sub-band method, transmits best M CQI values along with average CQI value of remaining bands [9]-[10]. Another method employs haar compression in distributed fashion with

best-M individual method [11]. Both these methods have been used for hybrid method.

This paper is structured as follows : Section II explains best-M individual & distributed haar best-M individual methods. Limitation of distributed haar best-M individual method is detailed in section III. Proposed method is explained in section IV. Analysis of this method is investigated in section V. This work is concluded in section VI.

## II. BEST-M INDIVIDUAL & DISTRIBUTED HAAR

### A. Best-M Individual

Best-M individual is perhaps the best feedback amongst sub-band schemes as far as balance between throughput & overhead reduction is concerned. In this method, best M CQI values are fed back along with average CQI of remaining bands. Value of M doesn't exceed one-third of the total active bands. Label indicating M bands which are reported is also fed back.

### B. Distributed Haar Best-M individual

This feedback method was proposed for overhead reduction. In this method, all active sub-bands were divided into odd & even groups. For each of the group, best M CQI values were separated out. Haar transform was applied on array of these best M values. Transformed Haar coefficients were quantized & allotted variable length code words. More bits were allotted for approximate (first) coefficient while lesser bits were allotted to remaining coefficients. This statistical distribution which is explored in quantization process, forms the basis for overhead reduction. Moreover, distributed fashion of reporting allows lower M which in turn allows lesser number of CQI values to be transmitted in each reporting interval. Hence this method reduces overhead as compared to best-M individual method.

## III. LIMITATION OF DISTRIBUTED HAAR BEST-M INDIVIDUAL SCHEME

In [11], it was shown that throughput for distributed haar scheme was more than other feedback schemes at around 10 bits/TTI. However for a particular reporting interval (RI) best-M individual scheme provides better throughput over distributed haar scheme. Although distributed haar scheme provides overhead reduction up-to 10bits/TTI, it fails to provide better throughput, when it comes to comparison with other schemes at a particular reporting interval. This limitation of distributed haar is explored here.

Limitation of distributed haar feedback scheme lies in grouping of CQI values prior to selection of best-M values. This could be explained considering an example. Consider 10 sub-bands with CQI values as shown:

Sub-band Number	1	2	3	4	5	6	7	8	9	10
CQI value	13	12	14	10	5	8	8	7	4	5

Let us apply above explained distributed haar scheme with M=3. Thus it first divides bands into even and odd groups.

13	14	5	8	4
12	10	8	7	5

Applying Best-M individual with M=3 for each group, following set of values are to be transmitted.

14	13	8
12	10	8

Haar compression is applied on these values and are transmitted separately in two consecutive reporting intervals.

Now applying Best-M individual on same 10 bands with M=4 we have

14	13	12	10
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As observed lower CQI values such as 8 are part of distributed haar scheme whereas these values are avoided in best-M individual scheme, lowest value being 10.

After scheduling at e-NodeB, user equipment (UE) might carry out its downlink data transmission on channels with one of lower CQI values, as in case of distributed haar scheme. Due to this, throughput offered for distributed haar scheme could be lower than that for best-M individual scheme.

This explanation shows that best M band values need not be the only values to be part of feedback in case of distributed haar scheme. Some lower CQI values may be part of this feedback.

#### IV. HYBRID FEEDBACK METHOD

In this method, best M bands are first separated out from all bands to be reported. Then these bands are distributed in two groups & transmitted after haar compression.

The step by step hybrid method can be summarized as follows:

1. Get the full CQI report (CQI for all bands) & get value of M which is decided by eNodeB.
2. Separate out top M CQI values.
3. Divide these values into two groups so as to transmit in distributed fashion.
4. Get average CQI of unreported bands for each group.

5. Apply haar transformation on both these groups. Details of haar transformation on CQI array are given in [11].
6. Transmit these groups in two consecutive reporting intervals along with their labels.

The key point in this method is to apply best-M individual method first & then apply haar compression as against distributed haar best-M individual method which uses the other way round approach.

Consider an example for method with M=4 & 10 sub-bands.

Sub-band Number	1	2	3	4	5	6	7	8	9	10
CQI value	12	2	4	13	5	11	8	9	14	6

Separating out top 4 CQI values

Sub-band Number	9	4	1	6
CQI value	14	13	12	11

Divide into odd & even groups and also compute average CQI for unreported bands.

Sub-band Number	9	1	Average CQI of unreported bands
CQI value	14	12	7

Sub-band Number	4	6	Average CQI of unreported bands
CQI value	13	11	7

Apply haar transformation on these groups & transmit in two reporting intervals along with labels indicating location of bands in each group.

#### V. PERFORMANCE ANALYSIS FOR HYBRID FEEDBACK METHOD

Hybrid method could be analysed depending on number of best M bands reported. Specifically, M above & below certain value leads to different behaviour of this method. Throughput for various feedback methods was compared with hybrid method as part of performance analysis. Various parameters

considered for simulation are shown below. Performance simulation was done for 3kph & 15kph UE speed's.

Table I: SIMULATION PARAMETERS

Parameters	Values
System bandwidth	10 MHz
RB bandwidth	180 kHz
Carrier frequency	2 GHz
Scheduler	Proportional Fair
Number of TX antennas	1
Number of Rx antennas	2
Channel model	Pedestrian B
UE speed	3km/h, 15km/h
CQI feedback delay	2 TTIs
FFT size	1024
Number of sub-carriers	600
Target BLER	10%

Value of M is decided by e-NodeB for each of its users considering various factors. Performance of hybrid scheme depends on value of M.

A. Lower M (less than 6)

Number of minimum bands reported in single reporting interval for distributed haar best-M individual scheme generally are 3. Hence for schemes with best bands lesser than 6 provide lesser throughput for distributed scheme than hybrid scheme. For 3 bands in each reporting interval, total 6 bands are reported by distributed haar scheme & hybrid scheme. If best M CQI bands are less than 6, then distributed haar would report even low CQI values along with best M values, as explained in section III. The limitation of distributed haar scheme explained in section III finds its place in this case. It was observed that hybrid method provided better throughput than distributed haar scheme in this case. Hence maintaining the overhead reduction by distributed haar scheme, its throughput was seen to do better.

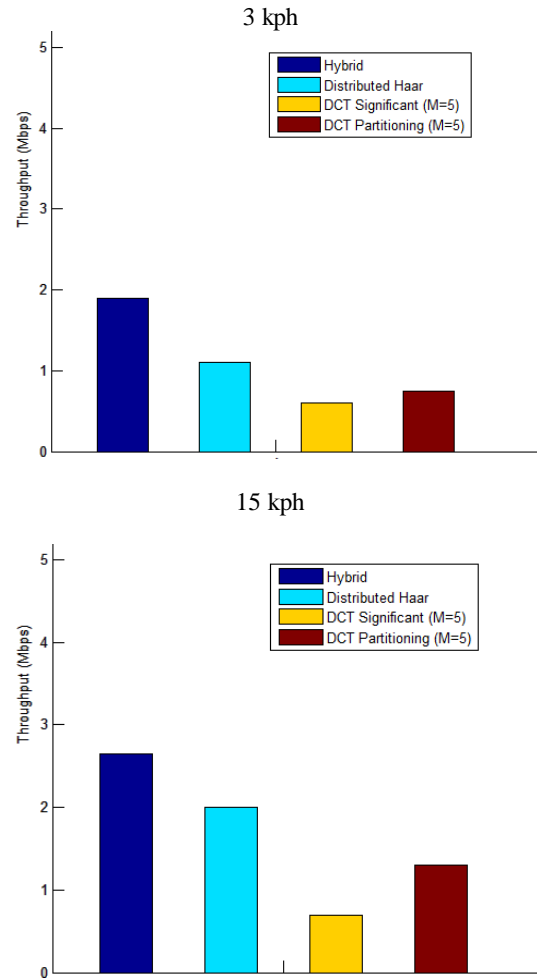


Figure 1: Throughput comparison for UE speeds of 3kph & 15kph for lower M (less than 6)

B. Higher M (higher than equal to 6)

For best M CQI bands greater than 6, there is a higher probability that distributed haar scheme would have only best M values as a part of its feedback. However, this depends on order of occurrence of these values, as even & odd grouping is done prior to haar transformation. It was hence observed that hybrid method provided smaller improvement in throughput over distributed haar method, as compared to the previous case.

VI. CONCLUSIONS

This paper proposes a new hybrid CQI feedback method for LTE systems. This method used best M individual & distributed haar best M individual method for its formation. This method primarily aimed at improving the existing distributed haar method. The limitation of distributed haar method was analyzed in this paper & hybrid method was suggested to overcome that limitation. Application of best M individual method first & then haar compression forms the basis for hybrid method. It was shown that proposed method improves throughput of distributed haar method under different values of M. It was also shown that hybrid method responded differently for two different ranges of M. As hybrid method used distributed haar scheme, it maintained the overhead reduction, at the same time it improved throughput. Thus hybrid method was seen as one of the best balance between overhead reduction & throughput.

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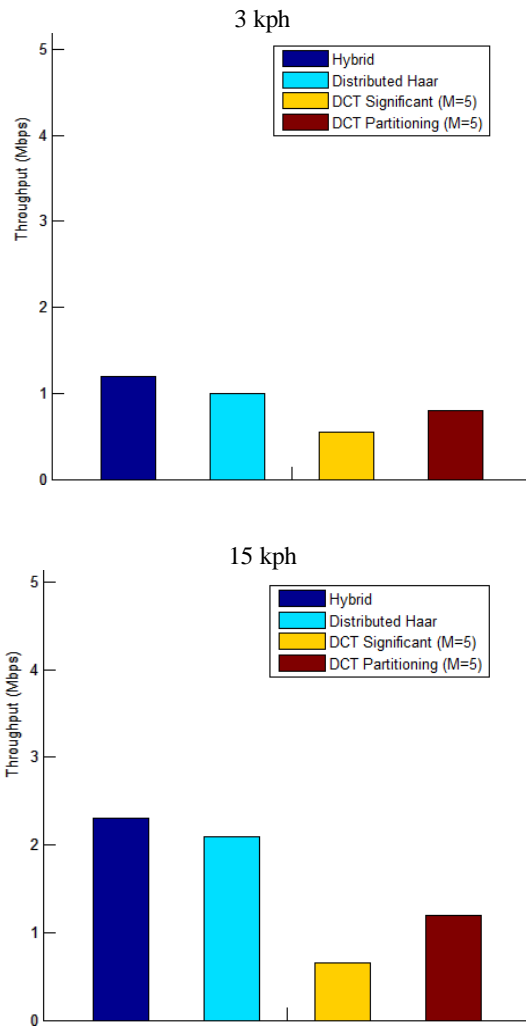


Figure 2: Throughput comparison for UE speeds of 3kph & 15kph for higher M (greater than equal to 6)