

Agenda item: 6.7.3
Source: Broadcom Corporation
Title: UE Feedback Classification and CQI Feedback Characterization
Document for: Discussion

1. Introduction

Numerous Contributions have addressed the UE FB (feedback) requirements and its benefit to the E-UTRA network (see Reference List). Applications and benefits have a wide scope and obviously come with a price, either in complexity, or, more critically, with a load on the Up-Link.

In order to assist the convergence of the work on this topic and bring it, fast, into solid recommendation, we propose in the 1st part of this presentation, the partitioning of the uplink FB into three classes that are distinct. Two classes of FB are discussed in R1- 070168 and R1-070169. The 3rd FB class is represented in the 2nd part of this contribution. The classification highlights the criticality of each class and its FB rates. It provides an efficient frame-work for the WG1 members, so we hope, by identifying three non-overlapped areas and goals.

We propose an umbrella name to these sets of FB as “Precoding and MIMO CQI FB”. It is based on most common names used in previous contributions. The umbrella name is necessary, so we feel, in order to distance it from various other control information the UE must provide to UTRAN.

This partitioning eliminates future confusion and facilitates the contributions that address specific aspects of receiving and decoding with multiple antennas.

2. Numerology, Simulation, and Channel Model Assumptions

The simulation assumptions are as follows:

Table 1: Throughput Simulation Parameters for OFDM Downlink

LLS Parameter	Details
Channel Bandwidth	5 MHz.
Sub-Frame Duration	0.5E-3
Sub-Carrier-Spacing	15E3 Hz.
Sampling Frequency (time-domain)	7.68E6
FFT Size	512
Useable Carriers	301
TX/RX Antenna Configuration	2x2 MIMO, 4x2 MIMO, 4x4 MIMO
PRB Used (12-Tones / PRB)	6 / 72 Tones (Localized)
Bandwidth Occupied	1.125 MHz.
CP Length (s/sample) - Short	4.69/36 x6, 5.21/40 x1
Test Geometry (SNR) Throughput Simulations	10 [dB]
TTI - Coded Frame	0.5E-3
DL Modulation	QPSK, 16QAM, 64QAM
Coding	TURBO, R=1/3, Max Block Size = 5114
INTER-TTI, for HARQ	6
HARQ Processes	6
MCS Feedback Delay	2-TTI
Maximum Retransmissions	4
HARQ	Incremental Redundancy Per-Transmission
Channel Estimation	Ideal
Receiver Structures	4 by 4
Beamforming	SVD-Based
Carrier Frequency	2GHz.
Channel Model	ITU-PED 6-Ray Channel
Doppler Frequency	250Hz
TX Antenna Correlation Coefficient	0
RX Antenna Correlation Coefficient	0

3. Three Classes Of: FB For Precoding and MIMO CQI

Table 2 Definitions Of Three Classes Of Feedback

FB Class	Name	Rate	Fields/Bits	Comments
1	MCS	Process Rate	TBD	Modulation, Code Rate per code or per antenna (TBD); 2 ACK/NACK at each process TTI
2	Beam-Forming	Multiple Process Period	TBD	BF Updating is per multiple process period
3	Capacity Profile (CP)	Infrequent	TBD	Per Event; per service, geometry (replacing the CQI)

Table 2 identifies the three types of feedback required for MIMO operation. The first two types (MCS and beamforming; see Figure 1) may be considered as the feedback that facilitates a relatively constant data streams with built in flexibility to overcome dynamic range due to geometry changes.

Three Classes Of Feedback

1. MCS (modulation & code-rate) is feedback at the process-rate (highest rate)
2. Beam forming is feedback at multiple process-period
3. CQI is measured as per service, event or geometry change

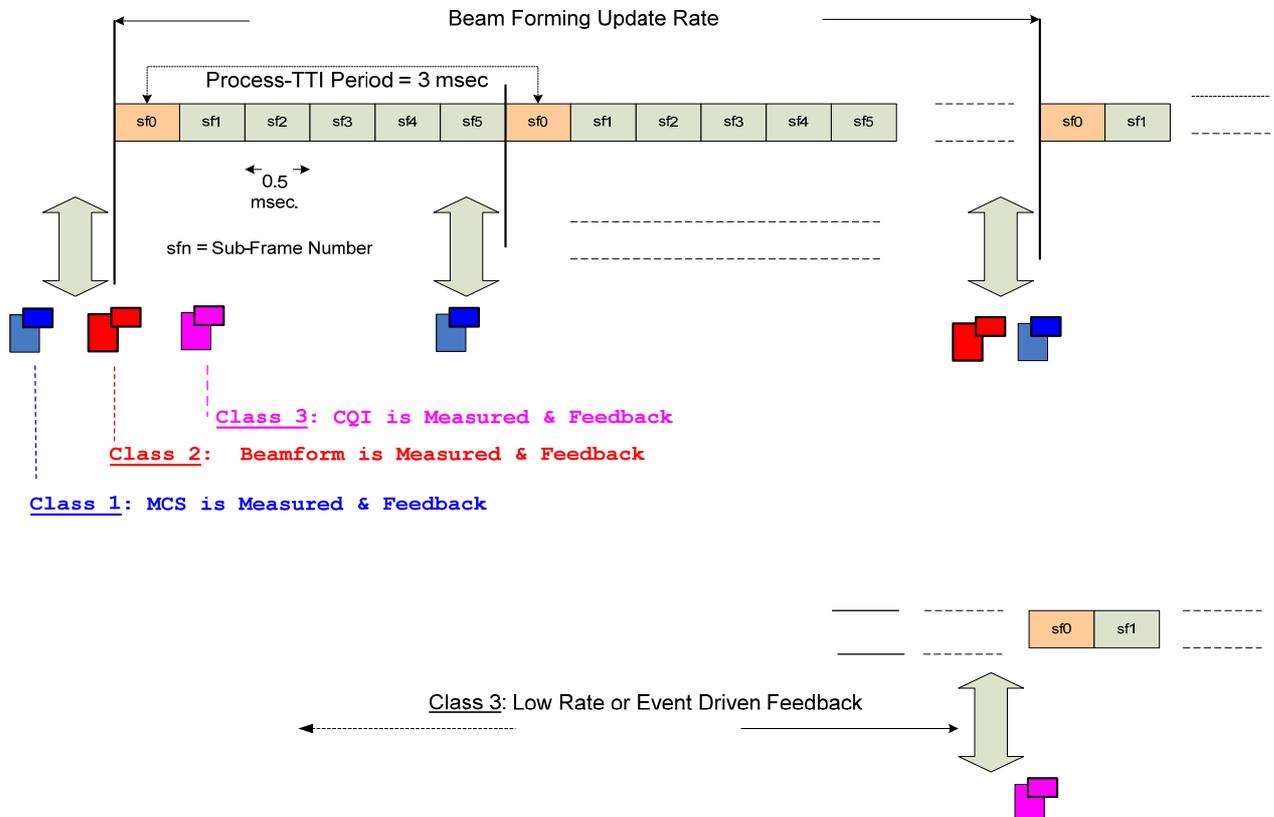


Figure 1: Three Types of Feedback

4. CQI based On PRB Capacity-Profile (PRB-CP) – 3rd Class FB

In essence the UE potential data rate is governed by its ergodic capacity per tone. Define C_{PRB} the average capacity measured over 12-carriers (a PRB)

$$C_{PRB} = 1/12 \sum_k \log_2 \left| I_M + \frac{H_k \cdot H_k^H}{N_0 \cdot M} \right|$$

Where the sum is over H_k adjacent 12 carriers and :

- M - Number of transmitting antennas
- H_k - Channel response for carrier – k
- N_0 - Thermal Noise + Interference

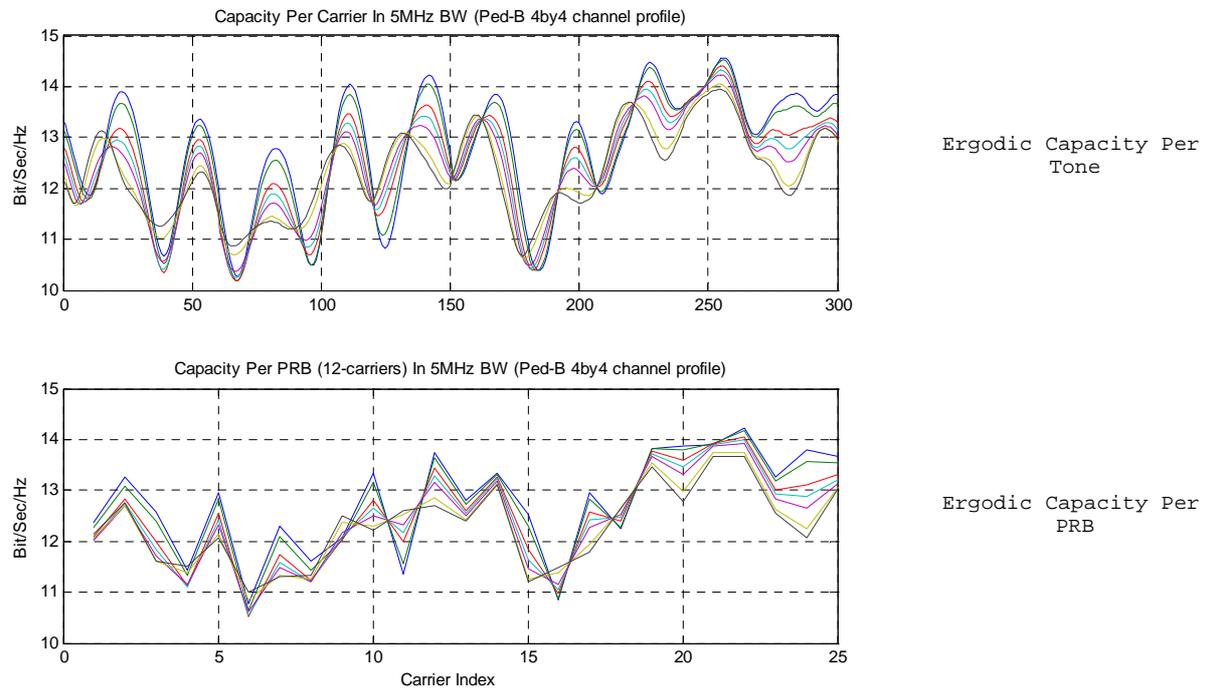


Figure 2: Sample of Capacity Map Over 7 Symbols Per Tone & PRB

Figure 2 shows a sample of the capacity per tone and per PRB (multiple curves show the change at 250Hz Doppler over 7 adjacent symbols). Indeed, as shown in the figure, resources allocation that fit a UE profile may have a major roll in creating highly efficient E-UTRAN.

4.1. Scenarios PRB –CP May Be used

The PRB-CM will be useful in several scenarios and will contribute to over all the efficient UTRA in providing wide range of services:

1. Interference avoidance
2. Random Allocation
3. Hand-over
4. Service Event
5. Geometry Event

In the first two cases above, knowing the CP of a UE enables Node-B a better a channels allocation. In 3. the neighbor cells will perform efficient resource allocation based on the availability and the UE CP. In 4. a request for, say, a short burst of data will be accepted by best resources base on the UE CP, thus minimizing the request impact . In 5. Node B will be able to reallocate resources in order to avoid drop-outs.

In many ways the PRB-CP may fulfill or assist to fulfill functions associated with what is known in previous mobile networks as a searcher, a critical element in supporting mobility.

5. Capacity-Profile Accuracy, Reporting Schemes and Bit Allocations

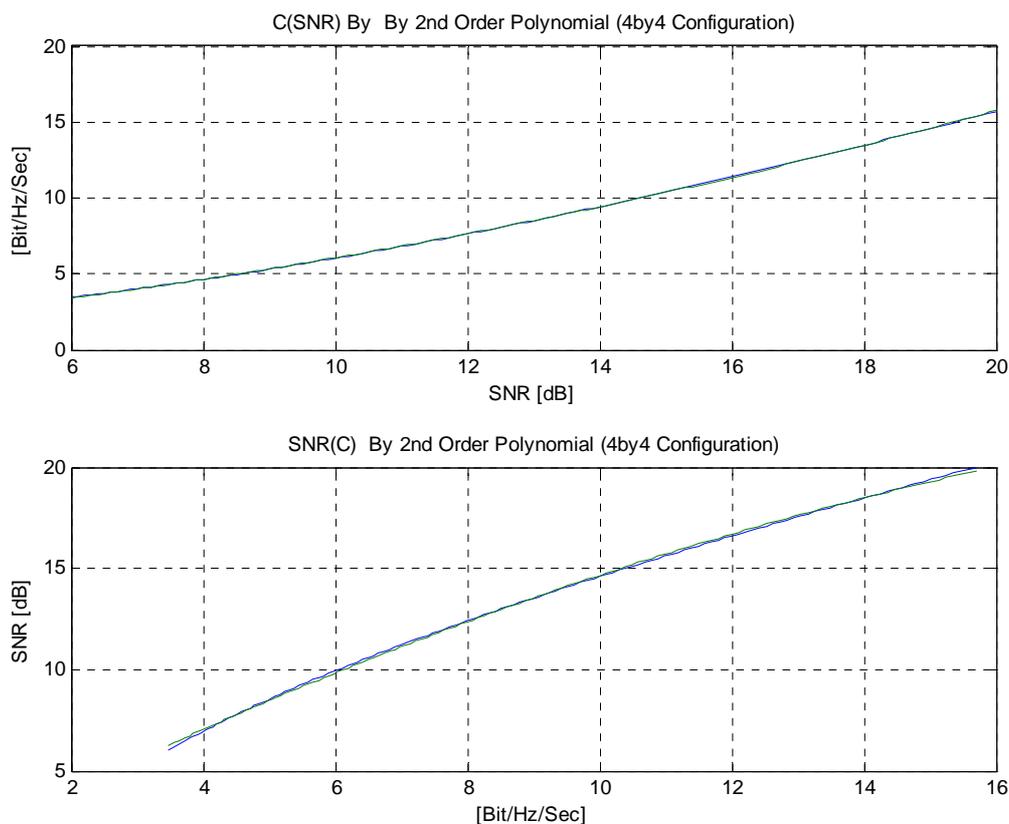


Figure 3 Ergodic Capacity vs. SNR, and SNR vs. Ergodic Capacity (4 by 4 MIMO)

Figure 3 shows the relations between the ergodic capacity and the SNR. It is well modeled by the following approximation in the range of interest:

$$\text{Ergodic-Capacity} = -0.0218 \cdot \text{SNR}^2 + 0.3161 \cdot \text{SNR} + 0.7280 ; \text{ [Bit/Sec/Hz]}$$

$$\text{SNR} = -0.0310 \cdot C^2 + 1.705 \cdot C + 0.7430; \text{ [dB]}$$

Where C is the ergodic capacity per PRB ; the SNR is in [dB].

5.1. Reporting Capacity-Profile by Mean and Difference

We have simulated a reporting scheme based on the mean of the ergodic capacity per TTI and evaluate the added accuracy when the quantized change $\Delta q(k)$ for each PRB is allowed:

$$Cq(k) = Cmeanq + \Delta q(k);$$

Where $Cq(k)$ is the quantized PRB for PRB – k ; ($k = 1:25$)
 $Cmeanq$ is the mean PRB value of the current TTI
 $\Delta q(k)$ is the quantized difference $C(k) - Cmeanq$

Channel characteristic is based on the ITU-PED channel model; The antenna configuration is 4x4. Table 3 shows the percentile error for three bit allocation schemes and ± 0.5 dB SNR error (or greater).

For example, in reporting just the mean PRB (1st row) rounding to integer, the reporting has 36% of the PRB's an error of ± 0.5 dB or greater. Figure 4 shows the percentile-error for error in the range of 0.1:2dB.

Table 3 Percentile For ± 0.5 dB SNR Error

Cmeanq Bit allocation	Δq Bit allocation	SNR Percentile Error ± 0.5 dB	Total Bits/TTI	Comment
5	0	36%	5	Unsigned < 32
5	2.0	17.5%	55	5 + 25 x 2
5	3.0	12.5%	80	5 + 25 x 3
5	3.1	5%	105	5 + 25 x 4

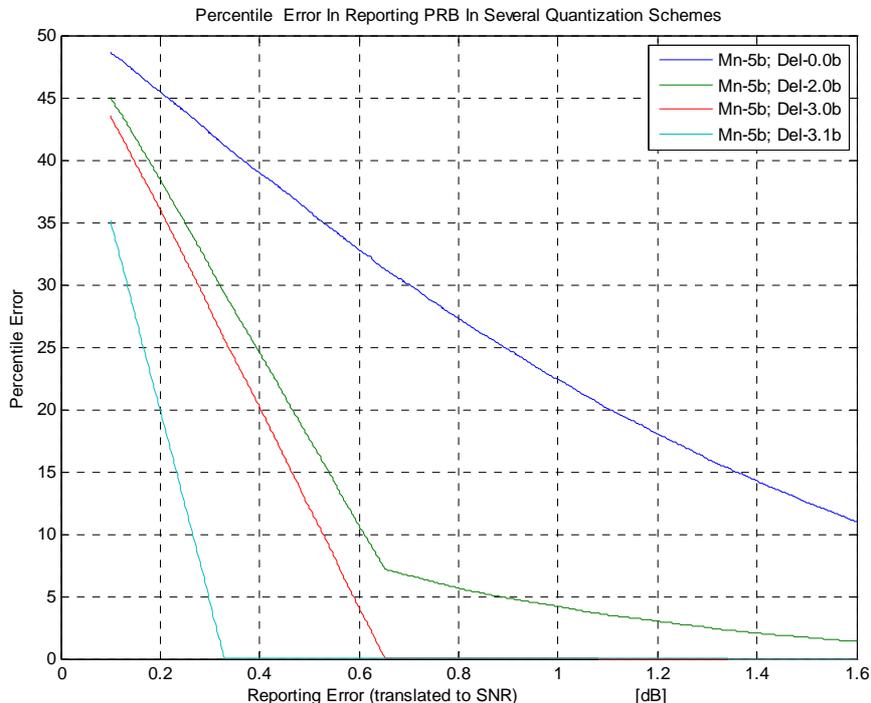


Figure 4 Percentile Error Function of Error in SNR For Quantization Schemes

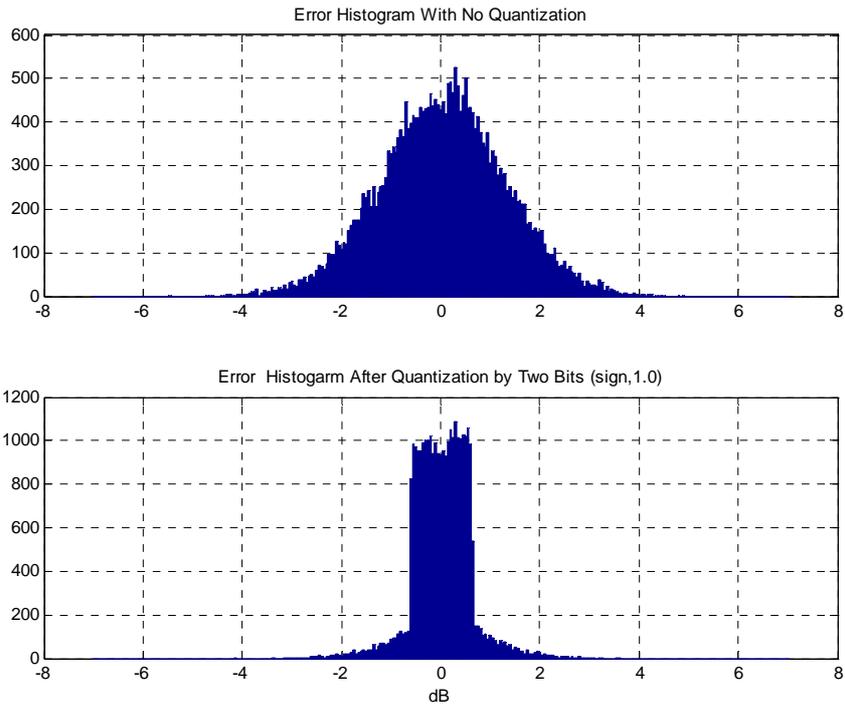


Figure 5 Error Histogram of Two Reporting Cases: By PRB Mean (top) and Quantizing Δq By 2 bits (2.0)

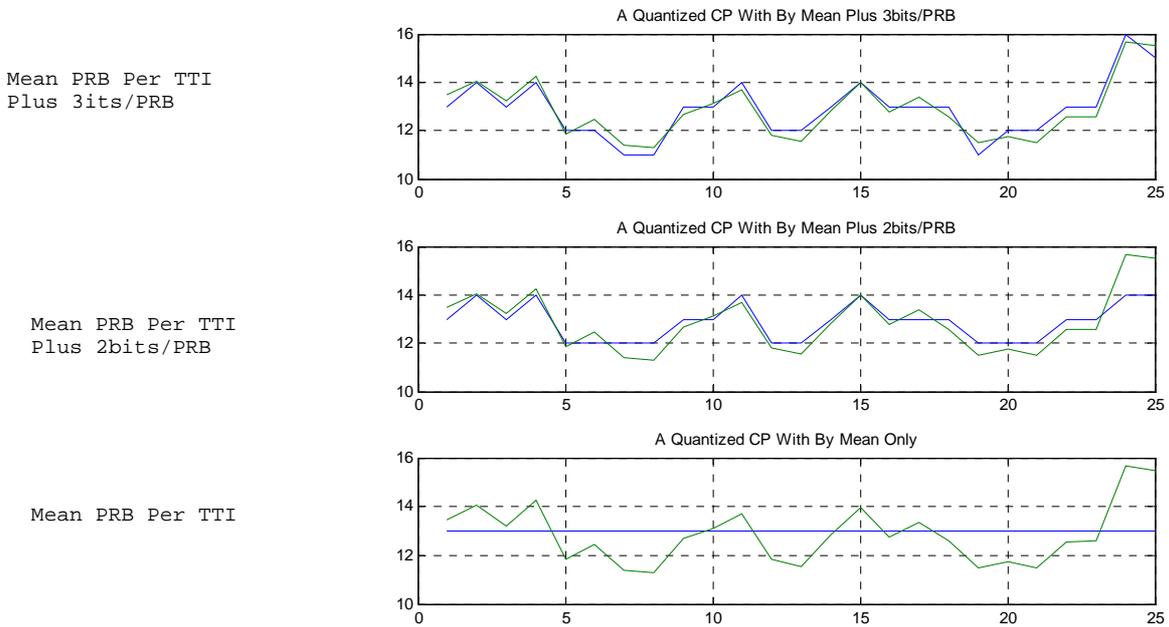


Figure 6 Capacity Profile with the Quantization Schemes

6. Recommendations

- The partitioning of the FB required by the UE is, in our view, a small step that will assist in identifying and making the foundation for the E-UTRAN Standard structure. As merely procedural step we are looking forward for it's acceptance, or, at least, initiating a discussion that lead to similar results.
- The benefits to E-UTRA for reporting the Capacity Profile may be beneficial in numerous scenarios, yet it may be limited in some cases, for example, in high mobility (high Doppler). It is also associated with a certain data load in the Uplink direction. We recommend further work along the following lines:
 - Parametrizing several scenarios where the CP may be used and comparison work among members may be carried out
 - Further simulations and evaluations specific to the cases defined above

7. References List

- [1] R1-063374 Nokia "Reduced CQI design for DL-SUMIMO"
- [2] R1-063035 Huawei "Overhead reduction of UE CQI signaling for E_UTRA DL"
- [3] R1-063132 Ericsson "E-UTRA Incremental CQI Reporting Using DCT"
- [4] R1-062842 Nokia "CQI design and its impact of DL performances"