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Re:	Call for Contributions on Project 802.16m System Description Document (SDD) IEEE 802.16m UL control channels
Abstract	Proposal for IEEE 802.16m CQI feedback framework
Purpose	Discussion and Approval
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Proposal for IEEE 802.16m CQI Feedback Framework

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1. Introduction and Background

CQI feedback is a key mechanism to optimize the overall performance of downlink. It is important (a) to feedback the appropriate metric for downlink link adaptation, (b) to reduce the feedback latency, (c) to control the feedback overhead to manage uplink efficiency, and (d) to control the feedback reliability to allow downlink optimization.

In this contribution we discuss the feedback requirements and considerations to develop a framework for the CQI feedback.

2. UL Channel Feedback Design Requirements

16m CQI feedback mechanism should be designed to support optimal downlink performance with minimum overhead and sufficient reliability. We consider the following requirements in the design of CQI feedback mechanism:

- Overhead: Should reduce the overhead
    - Less than 15% on average. Overhead for distributed is low, but for localized with MIMO would be high
    - CQI Feedback granularity: Tradeoff between accurate reporting vs. broader reporting; allow optimization for different scenarios;
- Coverage: CQICH design should be optimized for 1.5km/5km cell sizes with the assumed propagation models;
- Mobility: CQICH should be able to support optimal DL performance up to 10km/h.
- CQI feedback mechanism should support advanced PHY/MAC techniques:
    - frequency selective scheduling (FSS)
    - MIMO
    - Fractional frequency reuse (FFR)
- Error recovery: Error propagation possibility should be avoided or minimized;
- Complexity: The complexity involved in the CQI feedback scheme should be minimized

3. CQICH Channel Content

CQICH is used to feedback downlink channel information, and also to send MS information such as bandwidth request and handoff request. The table below lists all the possible information that can be carried on CQICH. Our CQI feedback mechanism should consider all possible content of the channels in various scenarios.

CQICH type	Bits	Notes
CINR	4-6	Physical CINR or effective CINR
MIMO mode	2-4	MIMO mode selection
FSS band selection	4-6	4-6 bits per-band, size depending on the total number of bands in the operating bandwidth. Total number of bits required per MS varies based on the indexing mechanism such as bitmap, indexing or hierarchical tree.
MIMO pre-coding codebook	4/11	Close-loop MIMO codebook size. 4 bits for 2x2 and 11 bits for 4x2 or 4x4, per band per user.
MU-MIMO feedback	TBD	MU-MIMO related feedback. Feedback includes CQI per stream per band and pre-coding vector per band.
SU-MIMO feedback	TBD	SU-MIMO related feedback. Feedback includes CQI per band and pre-coding vector per band.
UL bandwidth request	2	UL bandwidth request quantized to different levels
Handoff	1	UL initiated handoff

4. Primary/Secondary Feedback Reporting Framework

We need to have “primary” feedback channel to periodically receive channel and other required information from the MS. And “secondary” feedback channel is required to achieve an efficient scheduling gain and support all traffic demands.

Primary CQI feedback channel is needed to facilitate a reliable basic connection for the mobile station. Primary feedback is expected to be less frequent with low rate, i.e., the minimum amount of feedback required to support a reliable basic connection. Furthermore the primary feedback channel is periodic. Primary CQI feedback channel is used for average CQI feedback, especially for distributed resource block allocation. Note that the primary CQI feedback channel is also used for non-traffic related information such as bandwidth request and handoff.

On the other hand, secondary CQI feedback channel is required to optimize the downlink performance. Secondary CQI feedback channel is allocated and updated adaptively based on the channel variation and traffic demand, and also to provide the required MIMO support. Secondary CQI feedback channel is expected to be high frequent with high rate to provide enough feedback to optimize the downlink throughput and delay performance. Secondary feedback channel can be either periodic or event-driven based on the traffic demand and channel variation. Secondary feedback channel is mainly used for localized resource block allocation. It is important to support link adaptation on the secondary CQI feedback channel because the amount of CQI feedback information can be high based on FSS, FFR and MIMO feedback requirements. Furthermore, since the secondary feedback channel is adaptively allocated and updated link adaptation is possible.

5. CQI Reporting Control

In CQI reporting and the CQI feedback resource allocation, it is important to understand who should make decision. The uplink resources for the CQI feedback is allocated by the base station while only the MS knows what the current channel variation is across frequency and space domains. Neither base station nor mobile station can individually make the CQI feedback optimal. However, for a sub-optimal feedback we can allow the following:

- BS allocates CQI feedback resources based on traffic requirement, number of users in the sector and previous CQI reports on both primary and secondary feedback channels.
- Different reporting or CQI compression is optimal in different channel conditions based on the channel variation. Given the CQI feedback resources allocated by the base station, mobile station can choose the optimal reporting based on the current channel variation across frequency and space domain.

This adaptive mechanism would help improving the scheduling gain and user/sector throughput.

6. CQI Feedback and RB size granularities

Scheduling gain would be optimal when the resource block granularity is same as the CQI feedback granularity. E.g., when there are 64 resource blocks the CQI granularity is also on the 64 resource blocks. If best M of the resource blocks to be feedback with a bitmap as in the 16e case, it would require 64 bit bitmap. In this ideal case, the CQI feedback overhead will be high.

On the other hand, for MU/SU-MIMO it is observed that the performance deteriorates when combining several resource blocks into a band and receive only the average CQI value of the band instead of the CQI values of individual resource blocks.

To reduce the CQI feedback overhead we can support multiple tree types and hierarchical trees.

Multiple tree types can provide several meaningful sub-trees. For example, odd and even trees are supported in 16e. Odd and even trees are kind of blind sub-trees that do not take into account the need to report on consecutive bands. 16m should support various meaningful sub-trees. In this case, the mobile station report not on the whole tree but on the specific sub-tree. This mechanism reduces the CQI feedback overhead while restricting the selecting at the mobile station. Examples of tree types are illustrated in Figure 1.

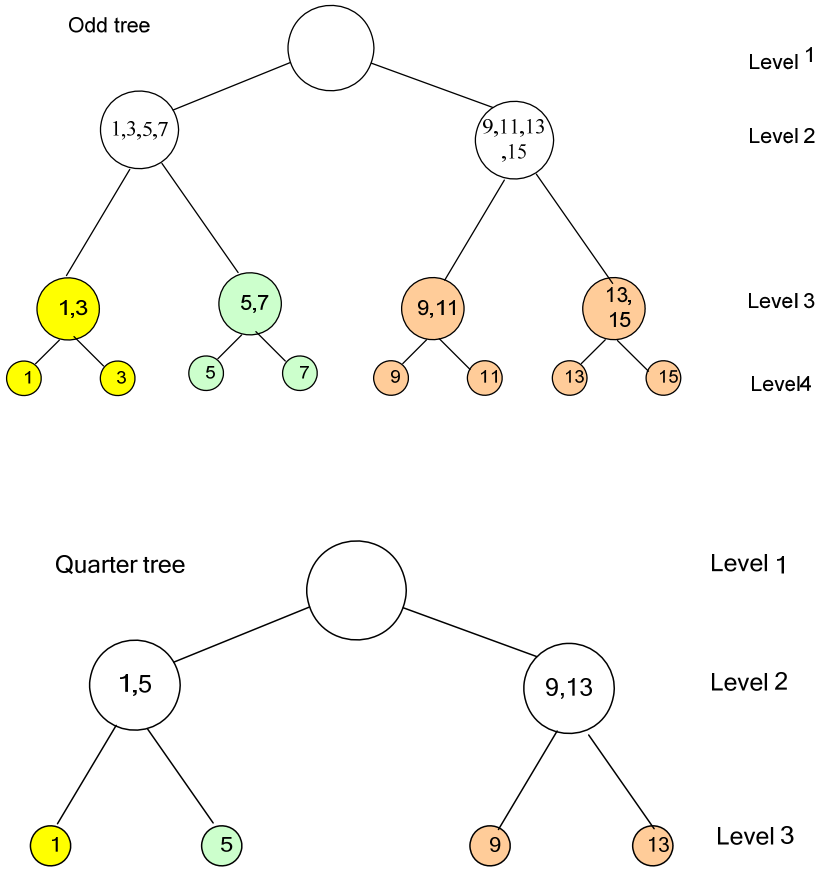

Figure 1: Example of (a) an Odd Tree and (b) A Quarter Tree

When the channel is flat across a certain frequency band higher layer node of the hierarchical tree can be chosen. This mechanism reduces the overhead by taking advantage of the flat channel and sending the average value of the flat band. In this method either more reports can be mad available at the base station for better scheduling gain or the feedback overhead can be reduced. An example of the hierarchical tree is illustrated in Figure 2.

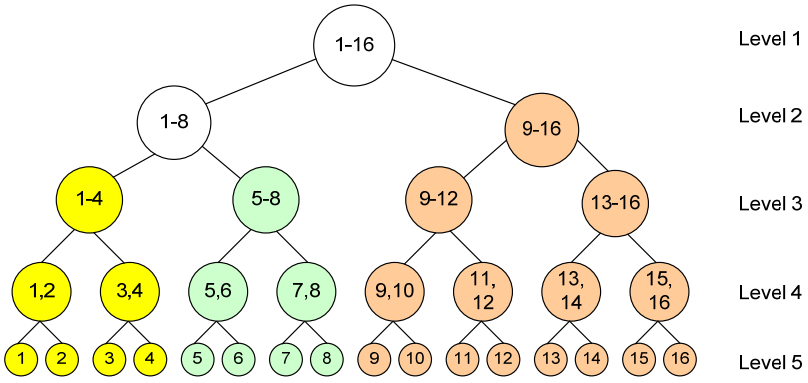

Figure 1: An example of a hierarchical tree representation

7. CQI Feedback Compression

Reporting the full CQI for the entire band is not possible since there are two many resource blocks/bands and possibly users. The overhead needs to be limited for uplink efficiency. There are several compression techniques possible in frequency, time and space domains. Techniques should support mechanisms to optimize reporting CQI granularity, CQI amount, CQI indexing, and CQI value.

The tree types and hierarchical trees discussed in the previous section are few examples of optimizing CQI feedback. The higher the CQI feedback amount at the base station the higher the scheduling gain, but also the higher the uplink overhead. CQI amount depends on the number of users in the system and the traffic characteristics of the user. CQI indexing is a mechanism to efficiently indicating the reporting resource blocks/bands along with the CQI values. An average CQI value may result in higher packet error rate and not suitable for MIMO performance, on the other hand a min CQI value may result in lower throughput. Compression techniques should consider all these issues.

8. Event Driven CQI Reporting

Event-driven CQI reporting is a time domain feedback overhead reduction technique. If the channel condition is not varying or when the traffic demand is not constant it would be beneficial to make the reporting on event driven.

The CQI feedback period and amount depend on the channel variation and traffic demand. Event driven CQI feedback should be supported so that the required CQI feedback is available when needed and the feedback can be reduced/removed when it is not required.

9. Conclusions and Recommendations

We would like to recommend the following to be incorporated in for the CQI feedback support in 16m in order to have the required CQI feedback while reducing the CQI feedback overhead:

- Support Primary and secondary CQI feedback channel framework
- Support a generic tree structure based CQI reporting so that further frequency, time and space domain compressions can be incorporated in order to keep the CQI feedback overhead within a reasonable level.
- Support event driven CQI reporting
- Support link adaptation on the secondary CQICH channel

10. Proposed Text for SDD

Insert the following text into Medium Access Control sub-layer sub-clause (i.e. Chapter 10 in [3]):

---------- Text Start ----------

10.2 UL Control Channel Structure

10.2.x CQI Feedback Channel

10.2.x.1 Primary and Secondary CQI Feedback Channel

IEEE 802.16m supports a primary and a secondary CQI feedback scheme in the uplink . The primary CQI feedback channel is to facilitate a reliable basic connection, and the secondary channel is to optimize link adaptation and scheduling performance based on channel/traffic variation. The secondary feedback channel is also important for MIMO support where the CQI allocation can be adaptively updated. The primary CQI channel is transmitted at low rate, less frequently, periodic and used for average CQI especially for distributed resource blocks. The secondary CQI channel is transmitted at high rate, more frequently, and is traffic-demand dependent and used for localized resource blocks.

10.2.x.2 Event-Driven CQI Feedback Reporting

IEEE 802.16m further supports an event-driven CQI reporting. The CQI feedback period and granularity depend on the channel variation and traffic demand. The event-driven CQI feedback support is needed in order to have the required CQI feedback when needed and the feedback can be reduced/removed when it is not required.

10.2.x.3 Link Adaptation Support for Secondary CQICH channel

IEEE 802.16m also supports link adaptation on the secondary CQI channel. The granularity of CQI feedback information can be high based on FSS, FFR and MIMO feedback required. Since the secondary CQI channel is adaptively allocated/updated link adaptation on secondary CQICH channel is implemented.

10.2.x.4 Tree Structure based CQI Feedback Reporting

IEEE 802.16m supports a generic tree structured CQI reporting scheme. Further frequency, time and space domain compressions can further be incorporated in the tree-structured CQI feedback framework in order to keep the CQI feedback overhead within a reasonable level.

---------- Text End ----------

11. References

[1] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and P802.16Rev2/D3 (February 2008).

[2] WiMAX Forum™ Mobile System Profile, Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02), http://www.wimaxforum.org/technology/documents.

[3] IEEE 802.16m-08/003r1, “The Draft IEEE 802.16m System Description Document”