Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Missing definitions for CINR in OFDMA PHY
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Re:	IEEE P802.16REVd/D5-2004
Abstract	Add missing definitions of CINR in OFDMA
Purpose	Adopt changes
Notice	
Release	
Patent Policy and Procedures	

Missing definitions for CINR in OFDMA PHY

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1. Motivation

The definition of CINR in 8.4.11.3 is incomplete and doesn't allow correct operation (setting DL burst profile and other related parameters (boosting/repetition/permutation zone) by the BS.

2. Details

2.1. Problems in current definitions

It is not defined what the CINR value relates to. Does it relate to data carriers of a specific burst, to data carriers overall, or to the pilots or to the preamble ? different SS implementations may choose different sources to estimate CINR from resulting in large difference in the result. These differences will not enable the BS to correctly choose the burst profile, boosting, repetition, permutation and so on, or will result in high margins in the BS.

(1) Treatment of boosting: if the SS measures CINR directly on data subcarriers of specific DL bursts (directed to it) then boosting is taken into account. If it measures CINR overall then boosting (on average) is not included in the report.
(2) Weighting of interference versus noise: since pilots and preambles are boosted (in 7dB and 2.5dB accordingly), then CINR resulting from noise is weighted differently than CINR resulting from interference. The standard doesn't define should an SS estimating CINR from pilots/preambles scale the result according to the pilots/preamble boosting or not, and this may result in difference of 7dB between SS. Even if normalization is defined, the problem with different weighting of noise and interference exists.
(3) Taking partial collisions into account: The pilots/preamble and data subcarriers may suffer from interference from other BS, when there is a collision on that tone (=other BS uses same tone). This results in different C/I on pilots and data. For example, for BS that use the same RF channel and same PUSC segment, partial collisions occur on the data subcarriers (depending on the BS load), however all the pilots and the preamble tones are in collision (to will measure higher CINR). For BS with different PUSC segments, and different Cell-ID (in the permutation), there is no interference on preamble tones, partial interference on pilots and data tones. To conclude, different measurement methods will give completely different results, depending on the deployment.
(4) The standard doesn't define if CINR includes implementation losses (phase noise, quantization, channel estimation, etc). In our opinion it should include implementation losses as much as possible, so that BS can put SS with poor performance and SS with good performance on the same CINR scale when selecting downlink rates.
(5) The current definition of CINR relates to "CINR on a message". However it is not clear which message this relates to. It doesn't make sense to average on all messages since SS is not always capable of receiving all messages (and potentially not aware which messages were directed to it).
(6) The indication of the averaging factor (α) appears in REP-REQ (bits 3-6 of "Report type"), but there is no definition of this factor for FAST_FEEDBACK.

2.2. Discussion

Two issues need to be determined:

- What does the CINR value represent (i.e. what does the SS estimate?).
- Is there a need to force all SS to perform the measurement in the same way.

2.2.1. What does the CINR value represent

Since the BS is expected to determine DL burst profile based on CINR, the CINR should represent in the best possible way, the ability of the SS to decode DL data, while giving the BS the ability to anticipate whether or not the SS will be able to decode any burst profile with any boosting/repetition/zone, etc. Therefore a good definition is the signal to noise and interference per data tone.

2.2.2. Imposing a uniform estimation method

Under the given definition there can be several measurement methods:

1. Estimate CINR directly on data subcarriers. The CINR can be estimated either by hard-slicing the constellation points (and then compensating for the inaccuracy of the method), by decoding and re-encoding, or by using the state metrics in viterbi decoder. The CINR can be estimated on specific bursts (e.g. FCH / map) or the entire DL data.
2. When estimating from the FCH there can be several variations – for example, in order to obtain good results without decoder-feedback, the SS can measure the CINR after the repetition combining, and then compensate $10\cdot\log_{10}(R)$ dB in the CINR report.
3. Estimate CINR indirectly by estimating strength of each received BS (e.g. using the preamble/pilots), estimating the thermal or non-802.16 interference noise, adding known implementation losses and combining these results to obtain a CINR estimate:

$$CINR = \left(\sum_{BS} \frac{\mathrm{Re}\,ceivedPower(BS)}{\mathrm{Re}\,ceivedPower(ServingBs)} \cdot Ind(SameSegment) + SNR\_estimate^{-1} \right)^{-1} \frac{1}{implementation}$$

Cons of imposing a uniform estimation method are:

- Not enabling SS manufacturers to optimize performance by selecting different CINR criterions (including "cheating" by inserting other factors into the CINR).

Pros of imposing a uniform method:

- The SS may be unaware of the system deployment. In order to estimate CINR on data tones inferred from power received from other BS, the SS needs to assume something about the deployment.
- Since interference and signal levels may change during the frame (e.g. because of zones in this BS or in other BS-es, partial loading of subchannels in other BS-es, etc), the BS can partially compensate for these changes if it knows what the SS estimates CINR on. If each SS estimates CINR on different parts of the DL, the information is less useful to the BS.

Our recommendation is to impose CINR measurement on the FCH/map unless indicated otherwise, but not to impose the specific measurement method. We show below that measuring CINR on the FCH is can be done in a simple way.

2.2.3. Basic CINR estimation on the FCH using hard slicing

CINR can be estimated on QPSK or BPSK samples by hard slicing. Following we describe the simple method of estimating the CINR and its performance.

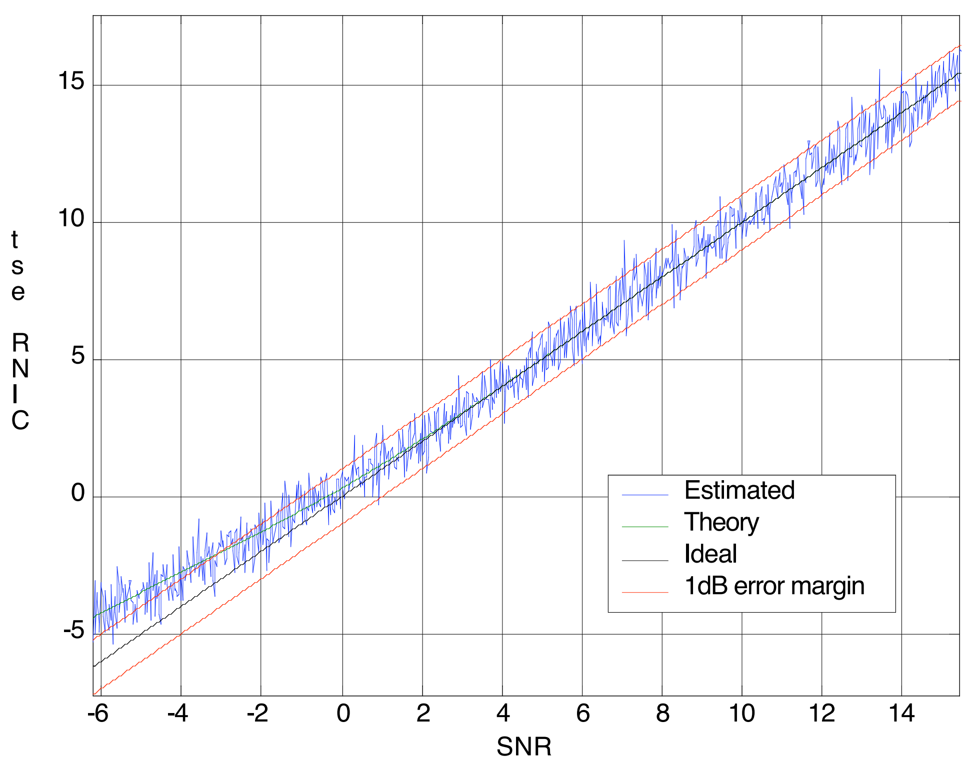
When estimating from QPSK signal with given SNR, the I and the Q can be treated as BPSK signals with the same CINR. In BPSK, assuming the expected signal level is normalized to 1, the CINR is estimated as $E((r - \text{sign}(r))^2)$. For additive Gaussian noise $N(0,\sigma^2)$, the expectancy of the estimated CINR is: $E((r - \text{sign}(r))^2) = \sigma^2 + 4\cdot Q(\sigma^{-1}) - 4\cdot\sigma/\text{sqrt}(2\pi)\cdot\exp(-1/(2\sigma^2))$. This represents the inherent distortion of the results due to hard slicing.

The distortion starts affecting the estimation at around 6dB SNR (0.3dB offset @ 6dB). Therefore by combining the 4 repetitions of the FCH, the distortion will start at 0dB SNR. Another advantage of using the repetitions is that the noise distribution becomes similar to Gaussian. After combining the repetitions we are left with 48 tones which include 96 BPSK samples, on which CINR can be estimated by hard slicing.

The following plot shows the performance of this scheme

The standard deviation of the results is approximately 0.64dB over the entire scale, which guarantees 1dB accuracy with probability 95%.

CINR estimation on FCH with 4 repetition combining



Similar results are obtained for flat and for iid Rayleigh fading channels.

The SS can improve the accuracy of the CINR measurement by applying similar method on the DL-MAP, or by averaging.

2.3. Proposed solution

We recommend to measure the CINR on the FCH or on the DL-map. The advantages are:

- Estimation on the map/FCH suffers from interference only from the relevant PUSC segment.
- CINR on the map/FCH weights interference and noise the same way they are weighted on other data tones.
- Since FCH and map are modulated by QPSK, it is relatively easy to compute CINR by hard-slicing.
- The SS may obtain better CINR results by using the repetitions on the FCH (i.e. combine repetitions, slice, then calculate CINR).

The drawbacks of this solution are:

- It doesn't take into account partial collisions between co-channels (due to the permutation).
- There is no mechanism to estimate CINR on other permutation zones (except PUSC).

In spite of the drawbacks since at least a basic definition of CINR is required, we suggest to adopt this solution.

3. Changes summary

8.4.11.3 CINR mean and standard deviation

[Add the following text at the end of the section]

The SS is required to estimate the CINR at the input to the decoder, so that implementation losses (due to non-idealities of the receiver) are included in the estimate. In addition, any implementation losses of the decoder should be added to the CINR estimate. The reported value should be computed such that the SS reporting CINR value higher or equal to a C/N value appearing in table 332 (Normalized C/N per modulation) is able to demodulate data in the respective modulation and coding rate in a flat AWGN channel with the same average SNR per subcarrier with BER $\leq 10^{-6}$. For example, a SS reporting CINR=6dB should be able to decode QPSK rate 1/2 in a flat channel with SNR=6dB per subcarrier.

When repetition code is applied it is considered part of the coding, and the CINR value doesn't include the SNR improvement resulting from repetition. CINR value refers to non-boosted data subcarriers.

Unless indicated otherwise, the CINR for REP-RSP and FAST_FEEDBACK reports shall be estimated on the data subcarriers of the FCH or the broadcast DL-map.

The averaging parameter (α_{avg}) is given in DCD for FAST_FEEDBACK and CQICH indications as well as for unsolicited REQ-RSP, and in REP-REQ for invited REP-RSP reports. If not transmitted in DCD, the default value of α_{avg} shall be 1/4.

11.4.1 DCD channel encodings

[Add the following line in Table 356, p. 665, line 20 after "H-ARQ ACK delay"]

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
RSSI and CINR averaging parameter	XX	1	Averaging parameter α_{avg} for CINR and RSSI measurements not indicated by REP-REQ (e.g. FAST_FEEDBACK, CQICH), in multiples of 1/32 (range [1/32, 16/32])	OFDMA

4. Optional changes summary

In case the decision is not to impose measurement on the FCH, we propose the following changes on top of the above changes:

~~Unless indicated otherwise, the CINR for REP-RSP and FAST_FEEDBACK reports shall be estimated on the data subcarriers of the FCH or the broadcast DL-map.~~
When estimating CINR from the preamble/pilots rather than directly on data subcarriers, the SS is required to separate between interference and noise on the preamble/pilots and apply the correct compensation due to different boosting of the preamble and the pilots with respect to data subcarriers.