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Title	**Interference Knowledge Impact on Link-to-System Mapping**
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Re:	IEEE 802.16m-07/031– Call for Comments on Draft 802.16m Evaluation Methodology Document
Abstract	This contribution discusses the knowledge of interference impacts on the receiver, and proposes a method to model this is in the PHY abstraction. In addition, baseline assumptions for the knowledge of interference statistics are also proposed.
Purpose	To incorporate the proposed text changes into the Draft 802.16m Evaluation Methodology Document (IEEE C802.16m-07/080r3)
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Interference Knowledge Impact on Link-to-System Mapping

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1. Introduction

This contribution describes the impact of the knowledge of interference statistics at the receiver on decoding performance, and how this impact can be modeled in the link-to-system mapping procedure. Link level and system level results are presented demonstrate the impact, and performance of the proposed solution. Baseline assumptions for the knowledge of interference are also suggested.

The discussion and proposed solution presented in this contribution is independent of the PHY abstraction method used.

2. Background and Motivation

System level simulations make use of link level simulation results in an additive white Gaussain noise (AWGN) channel to determine a transmission predicted block error rate (BLER) from a given signal-to-noise and interference ratio (SNIR). If different symbols of the same code block are received with different channel conditions, and than a PHY abstraction method (e.g. EESM, MIESM, etc.) must be used to properly map system level SNIRs to link level curves that are generated in AWGN environments. The PHY abstraction method determines a predicted BLER from component SNIRs of the code block.

In its basic form, the component SNIRs used as inputs to the PHY abstraction method are associated with inherent assumptions of the channel condition knowledge at the receiver. From example, consider the case of transmission over a frequency selective channel with only AWGN. Using component SNIRs that include the per-subcarrier channel gains of the receiver as the inputs to the PHY abstraction method will result in BLER performance consistent with the assumptions of known per-subcarrier channel gains at the receiver.

In general in system level simulations with inter-cell interference, the interference is not simply AWGN. The interference is random process with different powers on each subcarrier for each realization, due to frequnecy selective channel gains from interfering signals, different transmit power levels for different subchannels, etc. If per-subcarrier SNIRs calculated with per-subcarrier interference powers (as according to equation (25) of [1]) are used as input to the PHY abstraction, the resulting BLER performance can be shown to be consistent with a system with per subcarrier interference knowledge at the receiver.

As per subcarrier interference knowledge at the receiver is unlikely for physical systems, the PHY abstraction procedure should be changed to give performance consistent with the assumptions of interference statistics knowledge at the receiver.

3. Discussion of Proposed Method

In this contribution, link level and system level results are used to show to demonstrate the impact of interference knowledge, and suggested procedure for PHY abstraction to be consistent which interference knowledge assumptions. In particular, the proposed method is to calculate per subcarrier SNIRs using the average value of the interference over the subcarriers. For example, if the interference power is reliably known over a set of N subcarriers, then the average interference over the set of N subcarriers should be used in calculating the N per subcarrier SNIRs prior to imputing to the PHY abstraction. In general, the simulations show this proposed method results in predicted BLER performance consistent with the interference knowledge assumptions.

This contribution considers two cases of interference knowledge:

> Case A. Knowledge of average interference power across all subcarriers of the transmission, for each frame, at receiver decoder.

> Case B. Knowledge of per-subcarrier interference power, for each frame, at receiver decoder.

3.1. Link Level Simulations

The link simulations simulate turbo decoding of the received signal with the appropriate interference assumptions at the MAP decoder. The simulations consider a signal transmitted through a frequency selective channel with one interfering signal. The received signal on the ith subcarrier at a given time instant is given by:

$$y_i = h_i x_i + g_i d_i + n_i \tag{1}$$

Where h_i is the channel gain, x_i is the data modulation symbol of desired signal, g_i is the channel gain of the interferer, and d_i is data modulation of interferer for the ith subcarrier. The thermal noise for the ith subcarrier given by n_i, is ignored in this study.

At the receiver, the log likelihood ratio (LLR) makes use of the conditional probabilities for the kth bit, b_k, given by [2]

$$P(y_i \mid b_k = 1) = e^{-\frac{\left(\sum_{j=1}^{m} y_i - h_i c_j^{b_k=1}\right)^2}{\sigma_i^2}} \tag{2}$$

$$P(y_i \mid b_k = 0) = e^{-\frac{\left(\sum_{j=1}^{m} y_i - h_i c_j^{b_k=0}\right)^2}{\sigma_i^2}} \tag{3}$$

Where c_j is j^{th} point of the modulation constellation and σ_i^2 is the noise variance of the ith subcarrier.

From (2) and (3), they will clearly be a performance difference in decoding if the noise variance is known per subcarrier, or only known across a set (or all) subcarriers.

The procedure differences for the two cases for link level simulations are:

> Case A. Find average interference across all subcarriers, $\sigma_i^2 = \frac{1}{N} \sum_{n=0}^{N-1} |g_i d_i|^2$, and use the average value in MAP decoding at receiver.

> Case B. Find per-subcarrier interference powers, $\sigma_i^2 = |g_i d_i|^2$ and input to MAP decoder.

3.2. System Level Simulations

In order to simulate the two cases in system level simulations, the SNIR inputs to the PHY abstraction are made to be consistent with the respective assumptions of interference knowledge at the receiver. Modeling for each case is described below.

> Case A. System level simulations for which only the average interference at the receiver is known can be effectively modeled by (Figure 1)

>> 1. Finding the average interference across the subcarriers

$$\sigma_i^2 = \frac{1}{N} \sum_{n=0}^{N-1} |g_i d_i|^2$$

2. Calculating the per-subcarrier signal-to-noise + average interference ratios (SNAIRs), and inputting to PHY abstraction
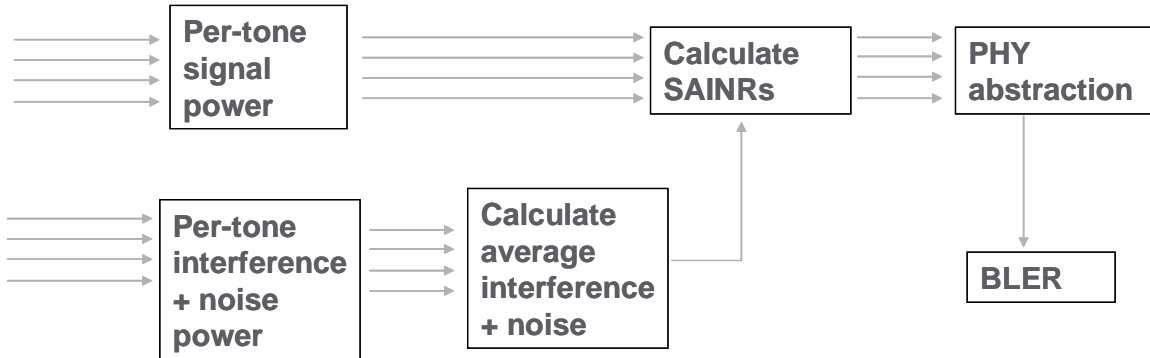

Figure 1. PHY abstraction simulation procedure for average interference knowledge.

Case B. System level simulations for which the per subcarrier interference at the receiver is known is modeled by calculating the per-subcarrier SNIRs, $\sigma_i^2 = |g_i d_i|^2$, and inputting to per subcarrier SNIRs to the PHY abstraction.

3.3. *Simulation Details and Results*

Link level and system level simulations were completed for cases A and B as described in the previous sections. Some key simulation parameters are listed in Table 1.

Table 1. Simulation parameters.

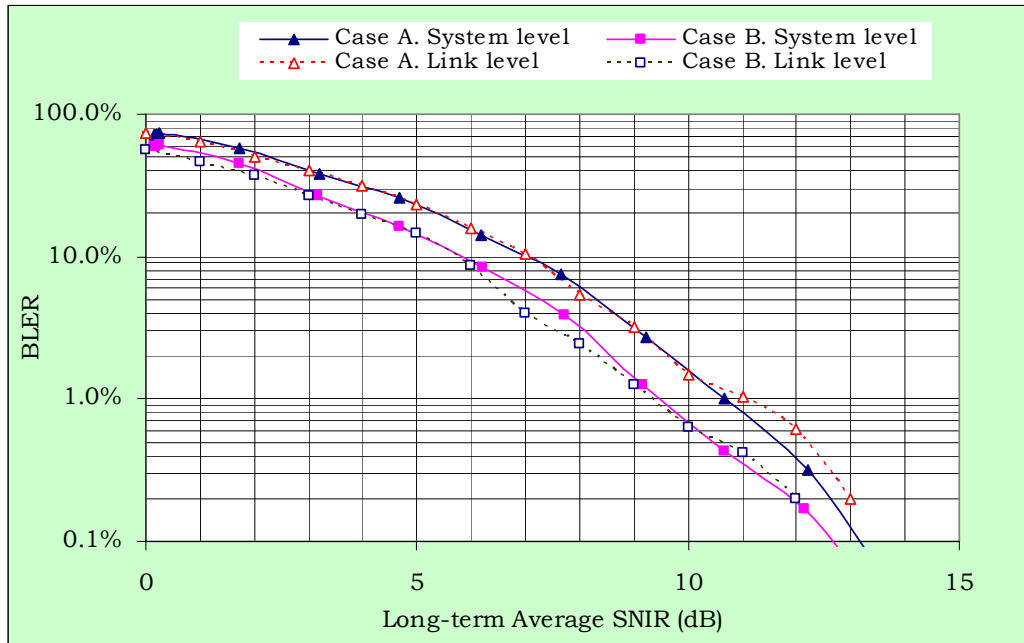| Packet	1024-bit rate ½ turbo coded
Decoder	Max-log-map
Channel	ITU Pedestrian B (both desired signal and interferer) Quasi-static fading
Bandwidth	10 MHz

Figure 2. Link and system performance for the two cases.

Link level and system level simulation results are show in Figure 2. The results indicate that using per subcarrier interference knowledge for SNIR inputs to the PHY abstraction is consistent with link level performance assuming knowledge of per subcarrier interference at the receiver. Similarly, using average interference knowledge across subcarriers and using SNAIR inputs to the PHY abstraction is consistent with link level performance knowledge of average interference across all subcarriers at the receiver.

4. Conclusions

In order to properly model knowledge of interference statistics at the receiver the PHY abstraction inputs should be modified. Calculating the average interference across the set of subcarrier over which it is known, and then calculating per subcarrier SNAIRs for input to the PHY abstraction appears to be a method that is consistent with link level findings. We suggest this method be adopted in the 802.16m Evaluation Methodology Document.

In addition, this contribution suggests adopting baseline interference knowledge assumptions for the simulations. . For a distributed subchannel, the interference used for post-processing SNIR computation is the average interference across the tones within the distributed subchannel; for an AMC subchannel, the interference used for post-processing SNIR computation is the average interference across the tones within the AMC subchannel. A proponent can assume further granularity in interference knowledge, but must provide justification for their assumption.

5. References

[1]   R. Srinivasan, J. Zhuang, L. Jalloul, R. Novak, J. Park, *Draft IEEE 802.16m Evaluation Methodology Document*, IEEE C80216m-07-080r3, August 28, 2007.

[2]   B. Vucetic, J. Yuan, *Turbo Codes: Principles and Applications*, Kluwer Academic Publishers, Norwell, Mass., 2000.

6. Proposed Text

1. Add 173r2 to table of contributions on page 56.

2. Remove to bracket text on page 68 line 28-32.

3. Divide section 4.5.6 into two sections; 4.5.6.1 Channel Estimation, 4.5.6.2 Impact of Practical Interference Knowledge

4. Add the following text to section 4.5.6.2

"In the previous sections we assumed that the receiver has knowledge of interference power per sub-carrier when computing the post-processing SINR. In practice, the per-sub-carrier interference power is unknown at the decoder. Therefore, the per sub-carrier SINR is modified by averaging the interference power across the set of sub-carriers used.

5. Add Figure 1 as Figure 11 in section 4.5.6.2. Add the following text after the figure.

"As seen from Figure 11, the interference plus noise in the post processing SINR equation are averaged over all the occupied sub-carriers. Thus, the per-tone signal-to-average interference plus noise (SAINR) is calculated and used as input to the PHY abstraction. This method of accounting for the effect of practical interference knowledge applies to all transmitter/receiver configurations."

6. Remove bracketed text on page 72 line 15 to 17.
7. Baseline assumptions for interference models in Tables 1 and 2 need to be clarified. Tables 1 and 2 the "interference model" description will be modified:

 "~~no interference awareness at receiver~~ average interference on used tones in PHY abstraction."