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Title	**CQI Error Modeling for System Simulations**
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Re:	Call for contributions for 802.16m Evaluation Methodology
Abstract	Provides an approach to model the CQI measurement errors in system simulations
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Notice	
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CQI Error Modeling for CINR Feedback

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Purpose

In typical system simulation, MS is assumed to feedback a physical CINR (PCINR) or effective CINR (ECINR) metric to the base-station on a feedback channel. The feedback channel on which this information is transmitted back can be assumed error free or modeled with an erasure probability. However, the feedback itself is computed at the mobile receiver based on a measured channel response on the downlink pilots, data or the preamble and thus suffers from estimation errors. For example, RCT test documents specify limits on the allowed measurement errors [MS-05.1 in [2]].

This contribution is to propose to model the physical CINR measurement error as Gaussian random variable with a mean bias and standard deviation defined according to WiMAX wave-2 RCT. We also show how this error on PCINR can affect MMIB in the link-to-system mapping. This documents content can be applied to replace lines 27-28 in the current EVM document section 5.2.2 [3].

CQI Model

The derivation below shows that the error in CINR estimation can be approximated and modeled as Gaussian. Typically CINR is measured as a ratio of signal power to noise plus interference power. For example, signal power could correspond to RSSI measured on the preamble.

$RSSI_{est} = \sum |\hat{H}_i|^2$ (Each $|\hat{H}_i|$ Gaussian with mean of $|H_i|$)

(Chi-Square with mean $RSSI_{ideal} \Rightarrow$ For large N, Gaussian with mean $RSSI_{Ideal}$)
(Central Limit Theorem applies to Chi-Square distribution)

Write $RSSI_{est} = RSSI_{ideal} + x$ (x-zero mean Gaussian variable)

$(I+N)_{est} = \sum |\hat{\eta}_i|^2$ (Each $|\eta_i|$ Gaussian with mean of $|\eta_i|$)

(Chi-Square with mean $(I+N)_{ideal} \Rightarrow$ For large N, Gaussian with mean $(I+N)_{Ideal}$)

Write $(I+N)_{est} = (I+N)_{ideal} + y$ (y-zero mean Gaussian variable)

$$\text{Absolute Accuracy(dB)} = \log\left(\frac{CINR_{est}}{CINR_{ideal}}\right)$$

$$= \log\left(\frac{RSSI_{est}}{RSSI_{ideal}}\right) - \log\left(\frac{(I+N)_{est}}{(I+N)_{ideal}}\right)$$

$$= \log(1+x) - \log(1+y) \quad (x \text{ and } y \text{ zero mean Gaussian})$$

$$= x - y \quad (\log(1+z) = z \text{ for small } z)$$

With this approximation, absolute accuracy is Gaussian with mean zero,
in the absense of bias in both RSSI and noise estimates.
Otherwise it is Gaussian with the corresponding mean

Physical CINR

With the above development, the PCINR used at the BS for scheduling decisions and MCS selection can be modeled as

$$PCINR_{est}(dB) = PCINR_{Ideal}(dB) + \mu(dB) + \eta(dB) \quad (1.1)$$

where μ is the fixed bias in dB for a user and is generated at the beginning of each drop from a uniform distribution in the range $[-U, U]$. Typically this fixed part corresponds to the bias generated due to one or more fixed parameters in the system like interference, Doppler, channel model etc., The variable part η is generated for every frame (or every time a measurement is assumed performed for feedback) from a zero mean Gaussian distribution $N(0,\sigma)$. The recommended value for the parameters of distributions can be tabulated as below.

μ	1.0 dB + 0.5 dB (QE)
η	1.0 dB

Table 1 – Parameters of Distributions for CQI Error Modeling

Due to the finite size of CQI feedback (steps of 1 dB), a quantization error of 0.5 dB is added to the fixed component only.

Effective CINR or MCS Feedback

In 802.16e, effective CINR feedback is MCS feedback. The MS uses a PHY abstraction algorithm like EESM or MMIB to select an MCS and feedback a 3 bit MCS index to the BS. The measurement error could affect the MCS feedback much like the physical CINR feedback.

Note that however, the above model can be applied with some minor modifications. The metrics used for MCS selection are effective CINR (EESM), or MI values in MMIB and RBIR approaches. All these are obtained typically by applying convex functions to per subcarrier SNRs and as such differ in range from the actual physical SNR. In these cases we suggest the following general error model

$$X = X + \delta(X)(\mu + \eta) \quad (1.2)$$

where $\delta(X)$ is a slowly varying weighting function and can be stored as a simple look up table. For example, the following table is found to be applicable to MMIB simulations (approximately independent of modulations or MIMO mode).

MMIB Range	δ_X
[0.0 0.1]	0.01
[0.1 0.2]	0.01
[0.2 0.3]	0.06
[0.3 0.4]	0.06
[0.4 0.5]	0.06
[0.5 0.6]	0.06
[0.6 0.7]	0.06
[0.7 0.8]	0.06
[0.8 0.9]	0.02

[0.9 1.0]	0.02

Table 2 – Mapping function for Error Modeling in MMIB

μ	1.0 dB
η	1.0 dB

Table 3 – Parameters of Distributions for ECINR Error Modeling

Note that quantization error need not be added for ECINR modeling, since quantization is simulated in MCS selection from a finite set of values.

Proposed Text

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5.2.3 CQI Estimation Error modeling

Physical CINR

The PCINR used at the BS for scheduling decisions and MCS selection can be modeled as

$$PCINR_{est}(dB) = PCINR_{Ideal}(dB) + \mu(dB) + \eta(dB) \quad (1.3)$$

where μ is the fixed bias in dB for a user and is generated at the beginning of each drop from a uniform distribution in the range $[-U, U]$. Typically this fixed part corresponds to the bias generated due to one or more fixed parameters in the system like interference, Doppler, channel model etc., The variable part η is generated for every frame (or every time a measurement is assumed performed for feedback) from a zero mean Gaussian distribution $N(0,\sigma)$. The recommended value for the parameters of distributions can be tabulated as below or must otherwise be provided by the proponent.

μ	1.0 dB + 0.5 dB (QE)
η	1.0 dB

Table 4 – Parameters of Distributions for CQI Error Modeling

Due to the finite size of CQI feedback (steps of 1 dB), a quantization error of 0.5 dB is added to the fixed component only.

Effective CINR or MCS Feedback

In 802.16e, effective CINR feedback is MCS feedback. The MS uses a PHY abstraction algorithm like EESM or MMIB to select an MCS and feedback a 3 bit MCS index to the BS. The measurement error could affect the MCS feedback much like the physical CINR feedback.

Note that however, the above model can be applied with some minor modifications. The metrics used for MCS selection are effective CINR (EESM), or MI values in MMIB and RBIR approaches. All these are obtained typically by applying convex functions to per subcarrier SNRs and as such differ in range from the actual physical SNR. In these cases we suggest the following general error model

$$X = X + \delta(X)(\mu + \eta) \tag{1.4}$$

where $\delta(X)$ is a slowly varying weighting function and can be stored as a simple look up table. The following table is found to be applicable to MMIB simulations (to be applied independent of modulations or MIMO mode).

MMIB Range	δ_X
[0.0 0.1]	0.01
[0.1 0.2]	0.01
[0.2 0.3]	0.06
[0.3 0.4]	0.06
[0.4 0.5]	0.06
[0.5 0.6]	0.06
[0.6 0.7]	0.06
[0.7 0.8]	0.06
[0.8 0.9]	0.02
[0.9 1.0]	0.02

Table 5 – Mapping function for Error Modeling in MMIB

μ	1.0 dB
η	1.0 dB

Table 6 – Parameters of Distributions for ECINR Error Modeling

Note that quantization error need not be added for ECINR modeling, since quantization is simulated in MCS selection from a finite set of values.

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References

[1] IEEE Std 802.16 – 2004, “IEEE Standard for Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Systems”

[2] WiMAX Forum Mobile RCT, v 1.1.0.

[3] IEEE 802.16m Evaluation Methodology 037r1.