On Link Quality Estimation for 3G Wireless Communication Networks

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Reference: On Link Quality Estimation for 3G Wireless Communication Networks

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Closed-loop Fast TPC for Turbo-Coded WCDMA Receiver

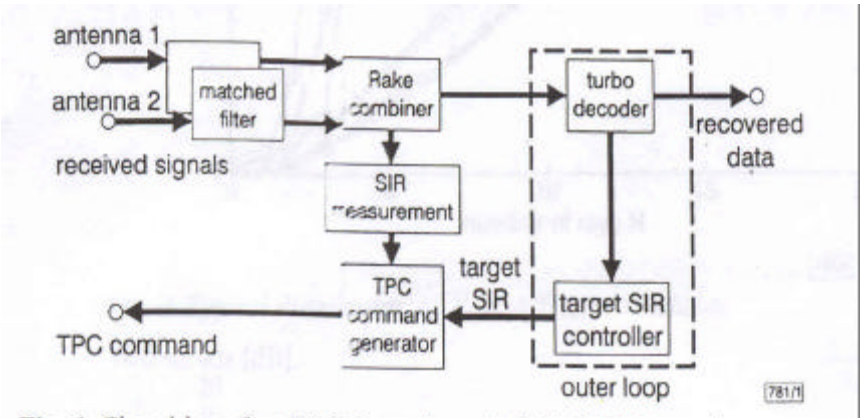

Fig. 1 *Closed-loop fast TPC for turbo-coded W-CDMA receiver*

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Abstract

- A method to assess measurements for link quality estimation in wireless networks.
- Quality of Service (QoS) is defined by delay and error rates (usually defined in terms of end-to-end delay error rate such as BER or BLER.
- Reliable and precise quality estimation in terms of the error rate is critical in mobile networks.

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Introduction

- Summarize existing proposals for link quality measurements.
- Present the method for measurement assessment.
- The method is applied to a UMTS 12.2kbps channel.

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Quality Estimation Measures

- Cyclic Redundancy Check (CRC) reports, which indicates whether the transmitted block was in error or not.

$X = 1$: block is in error

$X = 0$: block is error free

$$H(X) = -P(X = 0)\log_2 P(X = 0) - P(X = 0)\log_2 P(X = 0)$$

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Quality Estimation Measures

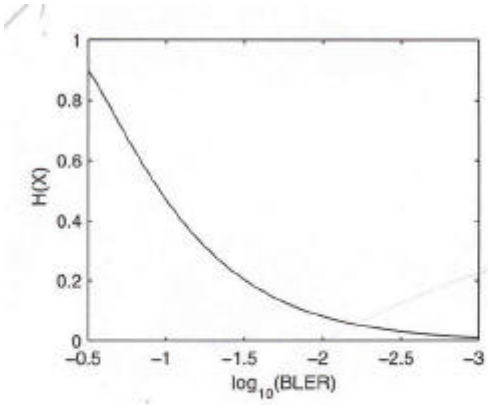

Figure 1. Information contained in the block error indication (CRC) vs. block error rate (BLER).

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Quality Estimation Measures

- **Indirect** methods incorporate the measurement of some other metrics, which are related to the actual link quality.
  - Symbol errors (raw bits) can be used for quality estimation.
    - To decode and recode the received symbols and to detect symbol errors (**SER**) by comparing the received symbols with the recoded ones.

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Quality Estimation Measures

- Yamamoto and Itoh (**YI**) have proposed to use the metric difference between the two strongest trellis paths in the Viterbi decoder.
  - If the difference of the path metric is below a threshold, the block is marked as erroneous.
- Balachandran et. Al. have proposed to use the Euclidean distance (**ED**) between the received signal and the most likely coded signal as a channel quality measurement.
- Signal-to-interference (**SIR**) statistics were ~~considered as a potential measurement~~.

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Performance Evaluation Framework

- Q: Link quality of interest
  - The link quality Q is the average of error events.
    - Average: the period should be sufficient long.
    - Average: from information theorem it's not a sufficient static.
  - Therefore, an averaging period for the evaluation of error rates and metrics of one block was used for the following analysis.
- M: The used indirect metric
- E: Environment $E ? \{e_k ? (s_k; d_k)\}$
  - We define it by speeds and delay profiles.
  - The unequal weighting is expressed by assigning certain probabilities to the different environments $P(e_k)$.

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Performance Evaluation Framework

- The measurement of interest is the current error rate on the radio link.
  - Using the information theory basics, we try to evaluate the amount of information we get on the error rate by observing the desired metrics.

$$I(M;Q) ? h(M) ? h\langle M \,|\, Q\rangle$$

  - Using link level simulations it is possible to collect two-dimensional histograms of M and Q for every environment e_k .

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Performance Evaluation Framework

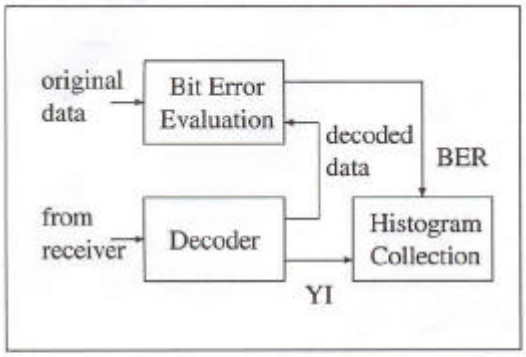

Figure 3. Example of the collection of the 2-dimensional histograms from the simulation for the measurement evaluation. In this example the BER and the YI-metric is taken into account

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Performance Evaluation Framework

- By interpolating the histograms we may approximate the conditional joint probability density function.

$$f(q;m) \approx \sum_k P(e_k) f\langle q;m|e_k\rangle$$

$$f(m) \approx \int f(q;m)dq$$

$$h\langle M|Q\rangle \approx \int\int f(q;m)\log_2\left(\frac{f(q;m)}{f(m)}\right)dqdm$$

$$h(M) \approx \int f(m)\log_2(f(m))dm$$

$$I(M;Q) \approx h(M) \approx h\langle M|Q\rangle$$

- The mutual information indicates the amount of information we gain about the measure of interest Q by analyzing a specific metric M.

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Results(Applied to a UMTS 12.2kbps channel)

- To demonstrate the performance of the proposed method, we have analyzed the above mentioned set of metrics in link level simulation.

Parameter	Value	Unit
Information bit rate	12.2	kbps
Rate matching	+22	%
Physical channel rate	60.0	ksps
Fading characteristics	case1,2,3, cf. [8]	-
Speeds	3, 13, 23, … 123	km/h
Channel estimation	ideal	-
SIR estimation	ideal	-
Channel Decoder	Viterbi	-
Power control rate	1500	1/sec
TPC error rate	5	%

Table 1. Parameters used in the computer simulation.

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Results(Applied to a UMTS 12.2kbps channel)

- Imax is the amount of information in the error events assuming a binary symmetric channel (BSC).

$$P(n) = \binom{block}{n} P_e^n (1 - P_e)^{block - n}$$

$$I_{\max} = \sum_{n=0}^{block} P(n) \log_2(P(n))$$

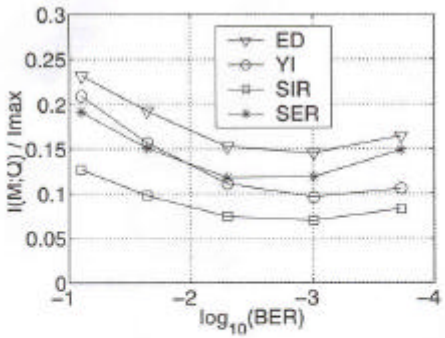

Figure 4. Mutual information between the BER averaged over one block and the desired metrics vs. the averaged BER. The mutual information is normalised to the amount of information of a binary symmetric channel (BSC).

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Results(Applied to a UMTS 12.2kbps channel)

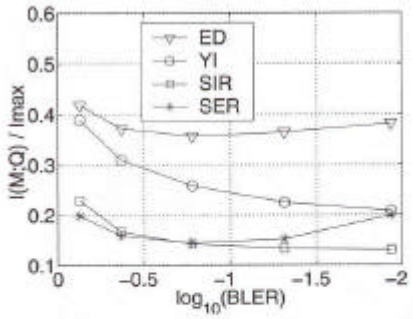

Figure 5. Mutual information between the BLER and the desired metrics vs. the averaged BLER. The mutual information is normalised to the amount of information in a binary symmetric channel (BSC).

- The CRC metric reaches Imax.

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Conclusion and Future Work

- We have presented a method to assess metrics for link quality estimates in wireless communication networks.
  - As an example, it turns out that the ED metric is the most promising for radio link quality estimation as long as BER.

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Conclusion and Future Work

- To know more about how to get the $f\langle q;m|e_k\rangle$
- How to apply these metrics into outer loop power control?
- How much does the performance improvement can be achieved?

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