On the Influence of UMTS Power Control on the Link-Level Error Statistics

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Abstract — *This work analyzes the error statistics of the UMTS radio communication at link-level and how it is affected by the power control, by means of measurements and simulations. This information allows to optimize transmission power and to apply cross-layer optimization techniques such as unequal error protection. By use of a high-level Markov model we perform simulations and besides we provide an approximation for it. We show that the outer-loop power control is the only mechanism which effects the link-level error statistics. The measurements are consistent with the simulation results.*

I. INTRODUCTION

Modern Wide-band Code Division Multiple Access (WCDMA) communication systems such as Universal Mobile Telecommunication System (UMTS) need a power control mechanism for proper functionality. It reduces the transmit power of every User Equipment (UE) to a value that fulfills the required throughput and Block Error Ratio (BLER). The power control mechanism enhances the system-wide data throughput as the mutual interference created by the users is reduced [1].

The uppermost power control instance in WCDMA is called *Outer Loop Power Control (OLPC)*. It is a control loop reaching form the UE to the Core Network (CN), implemented to achieve a defined BLER by adjusting the Signal to Interference Ratio (SIR) target value. This task bears difficulties because of the low required BLER (0.1% – 1%), which cannot be measured accurately within the required response time of the control loop. The exact implementation of the OLPC is not defined in the UMTS-standard [2], but a frequently used algorithm has been proposed in [3]. In the following referred to as *jump-algorithm*. This work is focusing on the impact of the jump-algorithm on the link-level error statistics.

The jump-algorithm works as follows. If the Radio Network Controller (RNC) in the CN receives a correct data block from a UE, it communicates the UE to lower the SIR by lowering the transmit power. If an erroneous data block is received, the UE has to rise the SIR. The ratio between the hight of up-step and the down-step, K, defines the BLER by

$$\text{BLER} = 1/(K+1). \tag{1}$$

If, for example, the BLER should be 1%, the up-step has to be 99 times the down-step. Equation 1 defines the mean error probability but no other error statistics. The absolute step size is a open system parameter, which can be optimized.

II. MODELING

The jump-algorithm can be model by a discrete-time Markov chain; the SIR-target values have to be quantized with a granularity of the down-step size and each of this quantized values represents a Markov state. Furthermore there are two transition probabilities leading to state j, the first is the error probability $P_{E,j-K}$ in the Kth state below j, the second the probability of a correct received data block $P_{C,j+1}$, equivalent to $1 - P_{E,j+1}$, in the state above j. Hence the equilibrium equation for state j is

$$\pi_j = \pi_{j+1}(1 - P_{E,j+1}) + \pi_{j-K} P_{E,j-K}, \tag{2}$$

from which the state probabilities π_j can be calculated [4]. Figure 1 shows the state probabilities (dashed) and its corresponding error probabilities (solid), resulting from three different computer simulations.

Knowing both series $P_{E,j}$ and π_j, the error statistics can be calculated by

$$P_{G,n} = \sum_j \pi_j P_{E,j} \prod_{m=0}^{n-1} (1 - P_{E,j+K-m}) P_{E,j+K-n}. \tag{3}$$

Thereby $P_{G,n}$ is the probability that the gap between two errors is n data-blocks long. Possible realizations of this series are shown in Figure 2. The variations shown by the dashed curves are due to different absolute step sizes but constant ratio K.

Please note, that all the error probability curves in Figure 1 lead to almost the same probability of error gap-lengths, with maximum differences below 1% of the maximum value, see the solid curve shown in Figure 2. The fact that extremely different error probability curves result in similar statistic for error gap-lengths, makes the OLPC algorithm independent from low-level procedures. A large variety of error probability patterns can be brought to a desired gap-length statistic by using the jump-algorithm and setting the values for the ratio K and the absolute step-sizes properly.

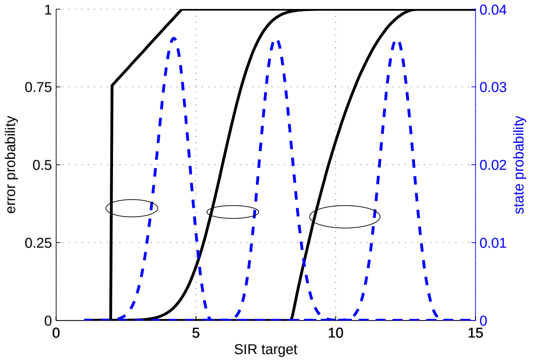

Figure 1: $P_{E,j}$ and π_j over SIR values ($K = 20$)

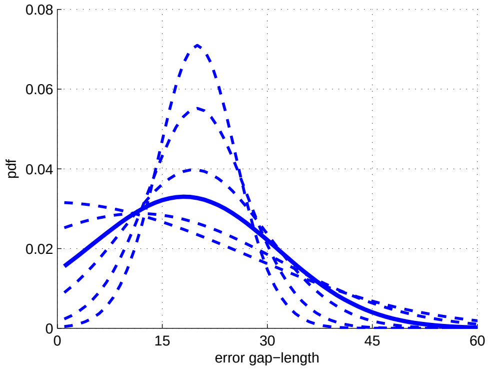

Figure 2: $P_{G,n}$ over gap-length ($K = 20$)

To gain better understanding of the transformation of the series of error probabilities $P_{E,j}$ into the corresponding series of gap-length probabilities $P_{G,n}$ we developed an approximation for it,

$$\begin{aligned} \gamma_j &= \prod_{i=j}^{\infty}(1 - P_{E,i}), \qquad (4) \\ \pi_j &\approx (P_{E,j} \cdot \gamma_j) * c_{K,j}, \\ P_{G,n} &\approx (P_{E,j} \cdot \pi_j) * (\gamma_{-j-K-1+n} \cdot P_{E,-j-K+n}). \end{aligned}$$

The auxiliary series γ_j is the probability of reaching the state j from a very high state by only down-steps. $c_{K,j}$ denotes the series of constant values $1/K$ and length K and $*$ denotes the convolution operator. The approximation is more accurate for fast increasing $P_{E,j}$ series.

III. MEASUREMENTS

We performed measurements in a live UMTS network, by means of a passive monitoring tool called METAWIN. It was developed in a earlier research project, in cooperation with the Forschungszentrum Telekommunikation Wien (FTW), see [5]. We recorded data for 30 minutes and evaluated nearly 500 phone calls. Uplink packets were inspected, which have variable data rate (0 – 4 kbit/s), a spreading factor of 64 – 256 and 1 – 2 transport blocks per transmission time interval.

The resulting error statistic are depicted in Figure 3. The solid line shows the measured distribution function and the dashed line shows a numerical fit of the above described model. Thereby the assumed error probability function has the shape of a Gauss error function. The maximum difference between measurement and fitted model is below 5%.

IV. CONCLUSION

In this work we analyze the influence of the UMTS OLPC algorithm on the link-level error statistics. Simulation results reveal that the error statistics are nearly independent from all underlying radio procedures and parameters. They are mainly defined by the jump-algorithm of the OLPC. We derived a descriptive approximation of the error statistics. To reinforce the results we performed measurements in a live UMTS system.

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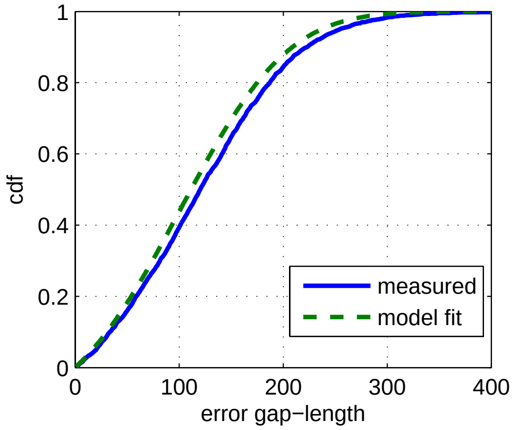

Figure 3: measured cdf of error probability