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A UMTS DL DCH BLER Model Based on Measurements in Live Networks

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Abstract

In UMTS system level simulations DCH BLER models are used to represent the characteristics of lower layers in order to save simulation time. Usually DCH BLER statistics are taken from link level simulations or only certain fixed values for DCH BLER are used for system level simulations.

In this paper we present measurements of UMTS DL DCH BLER for 360kbit/s UDP data traffic (372kbit/s incl. UDP/IP overhead) in different mobility scenarios for three different UMTS networks in Vienna, Austria. We show in particular that the DL DCH BLER statistics do not vary much when low or high user mobility is given. Furthermore, performance differences in DL DCH BLER statistics of fixed bearer vs. dynamic bearer switching are presented.

Following the obtained statistics we develop a model for the UMTS DCH and we show that it is capable of properly describing the characteristics of the wireless channel.

1 Introduction

The UMTS system is designed to support many different services and hence various higher layer protocols are running over the system. If a new service with a certain protocol is required, it is necessary to know the performance of that service in UMTS before starting the service in live networks [1]. Especially in communications over wireless channels like in UMTS the receiver will see a higher error probability and different error characteristics compared to wired communications. Due to this fact, the channel in UMTS is highly influencing the higher layer protocols and hence the impact on the performance should be analyzed in simulations.

In order to save simulation time, system level simulations are used where the lower layers are represented via a fixed parameter [2, 3], measured or simulated traces, statistics(lookup tables) or stochastic models.

Statistics or stochastic models up to now have been derived from link level simulations [4, 5]. Due to the fact that many physical layer parameters have to be considered correctly, it is very difficult to describe the correct and real behavior of the channel within link level simulations. Our intention in this paper is therefore to present measurements out of real UMTS live networks to find statistics in typical real scenarios.

The TrCH (Transport Channel) BLER (Block Error Ratio) is specified as a parameter in [6] and it is an important indicator of the link quality in UTRAN. Furthermore, the TrCHs in the UMTS system are situated between physical layer and MAC layer [7, 8]. Therefore, the TrCH BLER statistics include a representation of all the physical layer functions as well as the channel characteristics and the properties of inner and outer closed loop TPC (Transmit Power Control) algorithm. At the same time the system level simulator can make use of different parameters for MAC and RLC layer functions. The BLER of the TrCH is thus used as a link between link level simulations or measurements and system level simulations.

This document is organized as follows. In Section 2 the measurement setup will be explained and the used parameters for traffic and system will be presented. Section 3 shows the measurement results in detail and in Section 4 the model for the TrCH BLER of UMTS DCH in DL is presented. Finally in Section 5 a summary and conclusions will be given.

2 Measurement Setup

All the measurements presented in this document have been realized in the live UMTS networks of three different operators in the city center of Vienna, Austria.

2.1 General Setup

For the measurements a UDP data stream with a bit rate of 360kbit/s (372kbit/s incl. UDP/IP overhead) in DL(Down Link) was used. The data was sent from a PC located at the Institute of Communications and Radio Frequency Engineering at the Technical University of Vienna to a notebook using a UMTS terminal as a modem. As depicted in Fig. 1 the UDP data stream goes from the PC over University LAN (ethernet), internet, UMTS core network and over the UMTS air interface to a UMTS mobile which is connected via USB (Universal Serial Bus) to the notebook. A WCDMA TEMS Mobile Motorola A835 from Ericsson Company [9] was used as terminal. On the notebook the measurements of the mobile have been captured by 'TEMS Investigation WCDMA 2.4' software also by Ericsson. By parsing the export files of this software tool, the DL DCH BLER, burstlength, gaplength and other parameters have been analyzed as explained further on (see Section 4.1) in this document.

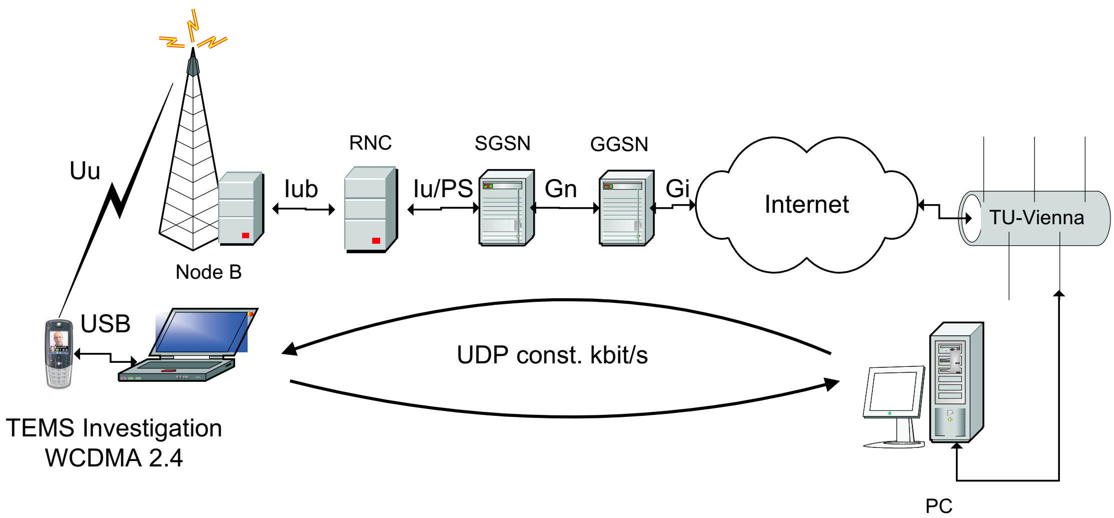

Figure 1: Measurement setup.

2.2 Mobility Scenarios

For the evaluation of the DL DCH BLER statistics, several scenarios with different mobility characteristics have been considered which are called: 'static', 'small scale movement', 'walking indoor', 'tram 2', 'car Vienna/Guertel' and 'car highway Vienna-Schwechat'. The measurements for the 'static' case were performed in a room of the Institute of Communications and Radio Frequency Engineering at the Technical University of Vienna. For these measurements the UMTS terminal was lying on the table in a typical office environment. Due to few movement of persons or other objects around the mobile station, there were only little variations in the channel. The 'small scale movement' measurements were performed by a person sitting at the table and randomly tilting and moving the UMTS mobile with his hands. In the 'walking indoor' scenario, as the name says, the measurements were obtained while walking around in the building of the Institute of Communications and Radio Frequency Engineering.

The three scenarios mentioned up to now are indoor scenarios whereas the following three scenarios are outdoor scenarios measured in the tramway number two going round the city center of Vienna ('tram 2') and going by car either on the street in Vienna called Guertel ('car Vienna/Guertel') with moderate speed or on the highway from Vienna to Schwechat ('car highway Vienna-Schwechat') with higher speeds. The speed distribution during the measurements of the latter two scenarios can be seen in Fig. 2.

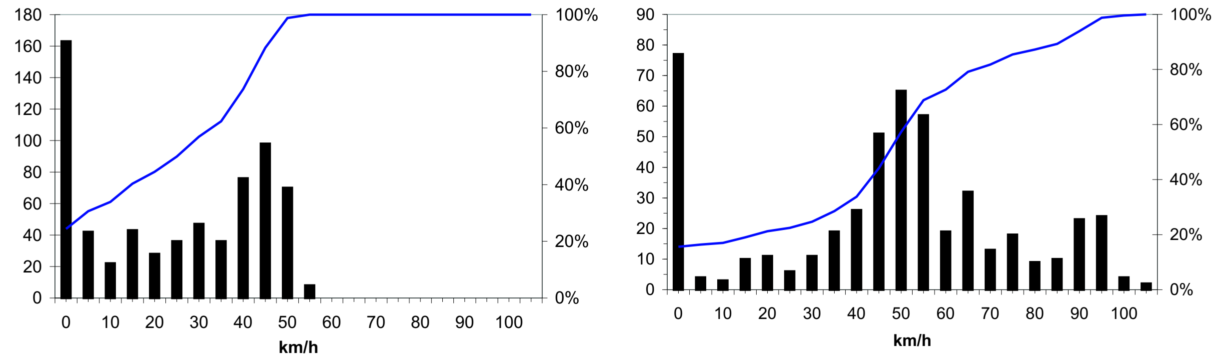

Figure 2: Histogram and empirical CDF of speed during measurements driving by car on a) Vienna/Guertel, b) highway Vienna-Schwechat.

2.3 Relevant UTRAN Parameters

In the three considered UMTS networks of three different operators in Vienna, the relevant system parameters are as follows.

As TrCH (Transport Channel) in the DL a DCH (Dedicated CHannel) and RLC AM (Radio Link Control - Acknowledged Mode) has been used. In addition turbo coding and a transport block size of 336bits has been selected. In case of the 384kbit/s bearer the SF(Spreading Factor) was 8 and the TTI(Transmission Timing Interval) was 10ms with 12 transport blocks per TTI. The 128kbit/s bearer used a SF of 16, a TTI of 20ms with 8 transport blocks per TTI and the 64kbit/s bearer was adjusted to a SF of 32, the TTI was 20ms and there were four transport blocks transmitted within each TTI.

Another very important parameter of UTRAN for evaluating the BLER is the BLER quality target value for the outer loop TPC (Transmit Power Control) which was set to 1% in all three networks used for the measurements. As a consequence the closed outer loop TPC tries to adjust the SIR (Signal Interference Ratio) target for the closed inner loop (fast) TPC in a way that the required BLER quality (1% in our case) is satisfied.

2.4 Measurement of DL DCH BLER

As already mentioned, the DL DCH BLER was measured with the TEMS mobile Motorola A835 and the TEMS software from Ericsson. The error status of the transport blocks which are transmitted in DL is reported by the mobile in every DL transport channel report, i.e. in every TTI. With that information the BLER is calculated after 200 DL transport channel reports. In case of a 384kbit/s bearer in DL where 12 transport blocks are transmitted within one TTI, the BLER is evaluated in the mean by averaging over 2400 transport blocks.

3 Measurement Results

In Figs. 3 and 4 the results of the measurements in the UMTS networks of three different UMTS network operators in Vienna are presented. The diagrams show the empirical CDFs of the measured BLER of the DL DCH.

3.1 Effect of Small Scale Movement on BLER Statistics

In Fig. 3 the BLER statistics of the 'static' scenario compared to the 'small scale movement' scenario are depicted. As expected, in the static case the TPC is able to control the link power in a proper way so that the error probability of the transport blocks is below or equal to BLER quality target value of 1% in 97% of the calculation intervals in all three networks. Surprisingly, only when moving and tilting the mobile at a small scale by hand while still sitting at the table, the TPC is not capable of compensating the channel variations in order to reach the quality target of 1% in 30% to 50% of the calculation intervals. Above all, statistics of BLER are almost identical in case of the small scale movements and in those statistics which can be measured with all other types of movement, displayed in Fig. 5 for the network of Operator A. Not even in case of going by car on the highway with speeds up to 100km/h the BLER statistics (Fig. 5) are worse.

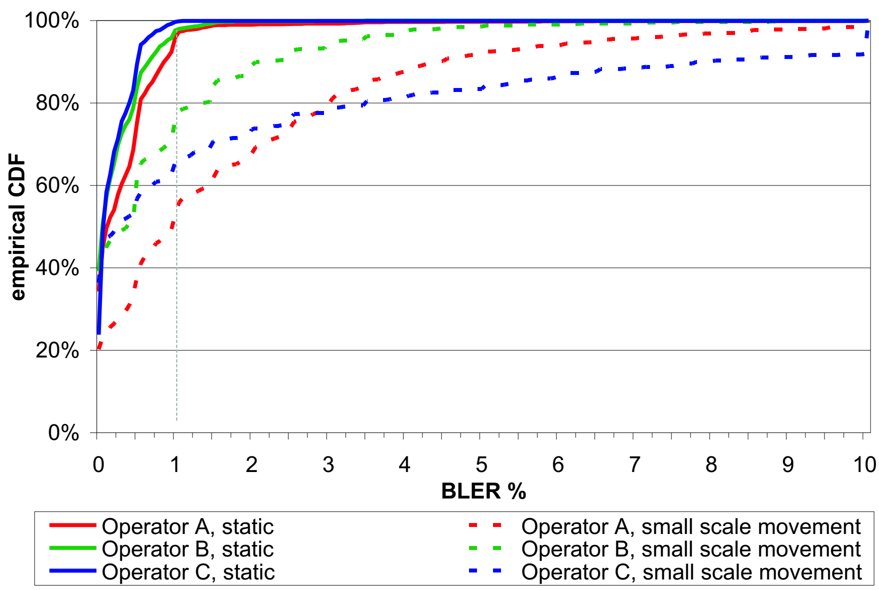

Figure 3: BLER %, Operator A/B/C static vs. small scale movement.

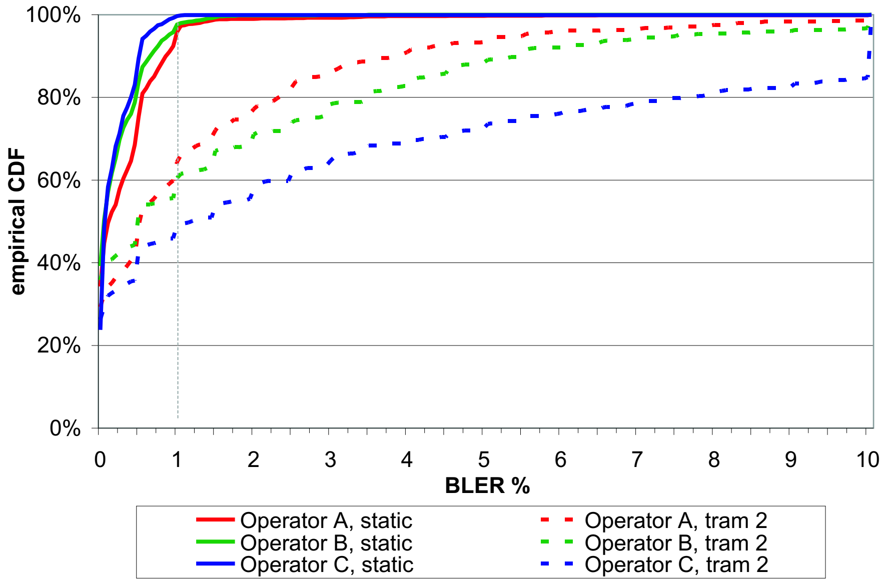

Figure 4: BLER %, Operator A/B/C static vs. tram 2.

3.2 Fixed Bearer vs. Dynamic Bearer Switching

A comparison between the measurements for the static case and the measurement data logged in the tramway number two circulating around the first district of Vienna is presented in Fig. 4. Out of all three networks considered within this measurement campaign, the network of Operator A produces the lowest BLER in case of the 'tram2' scenario. The reason for this is that Operator A makes use of dynamic bearer switching in his UMTS network while the others do not. In case of dynamic bearer switching, if there is not enough transmit power available for the link in order to adequately compensate the worsening of the channel for meeting the quality target, the used bearer will be switched down e.g. from 384kbit/s to 128kbit/s bearer. Then with the 128kbit/s bearer the transmission is more robust due to a higher spreading factor and longer TTIs. The TPC again can handle the physical channel variations better by adjusting the link power properly. On the other hand if a fixed bearer is used (384kbit/s bearer in our case) like in the networks of operators B and C, the degradation of the physical channel obviously leads to higher BLER for the DCH.

Consequently, the network with dynamic bearer switching coarsely provides the same BLER statistics for different levels of coverage in the network in contrast to the networks with a fixed bearer where the BLER will highly depend on the current status of radio access network coverage deployment. Due to that fact, for modelling the error probability of the DL DCH we will only consider measurements of the network with dynamic bearer switching (Operator A) in the following.

3.3 Dependency of BLER Statistics on Location and Time of Day (Cell Load)

In order to show the dependency of the DL DCH BLER statistics of propagation characteristics (dependent on the location) and cell load (dependent on the time of day) several measurement campains have been carried out of which the results are presented in Fig. 6. In these diagrams the empirical CDFs of the BLER statistics of the network of Operator A are shown. As can be seen, with varying location and cell loading factor between the measurements, the statistics remain almost constant. Even further, in case of the small scale movements (Fig. 6b), despite

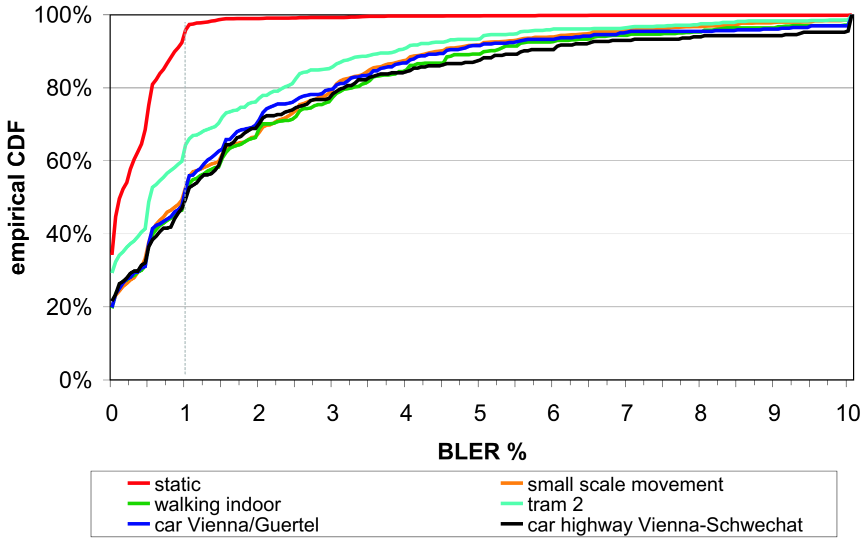

Figure 5: BLER %, Operator A, static vs. movements.

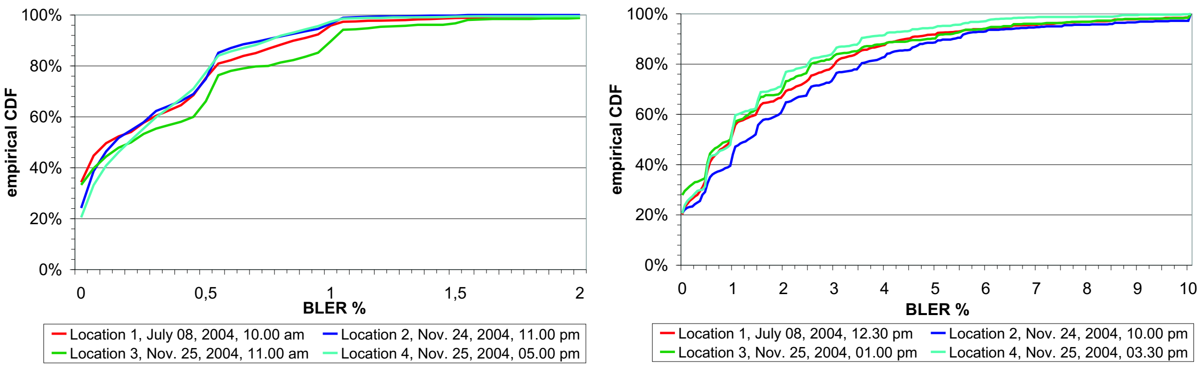

Figure 6: BLER %, Operator A a)static b)small scale movements.

the fact that the small scale movements are random processes and carried out by a person who is tilting and moving the UMTS terminal, the empirical CDFs are varying very little.

4 Modeling of DL DCH Error Characteristics

As already mentioned in this document, for modelling the error characteristics of DL DCH in UMTS we only considered measurements of the network of Operator A because of the coarse independency of BLER statistics of the current status of network deployment. This is due to the dynamic bearer switching used in the UMTS network of Operator A.

4.1 Transport Channel Analysis for Error Modeling

Investigating Figs. 5 and 6, small steps in the empirical CDF of the DCH BLER at every 0.5% are visible. The BLER displayed in the diagrams is calculated by building the mean over 2400 transport blocks of the DCH in case of a 384kbit/s bearer. At 0.5% there are exact 12 erroneous transport blocks within the calculation interval. When using the 384kbit/s bearer, there are as well 12 transport blocks transmitted in one TTI. This fact in turn provokes the assumption, that all the 12 erroneous transport blocks causing the BLER of 0.5% belong to the same TTI. When looking at Fig. 7, we can observe that this assumption is almost correct.

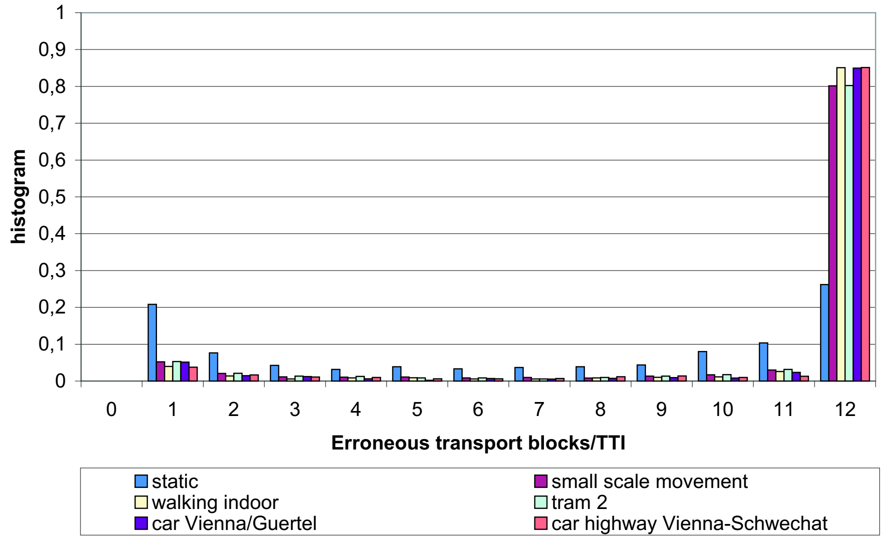

Figure 7: Number of erroneous transport blocks per TTI, 384kbit/s bearer.

The histogram in Fig. 7 shows the probability that a certain number of transport blocks are received in error within an erroneous TTI. Of course the probability (probability conditioned on the fact the TTI is in error) to have zero error blocks in a TTI is zero because only erroneous TTIs have been considered. In Fig. 7 can be observed that in case of movements all 12 transport blocks sent within a TTI are in error with a probability of 80% - 85%. Therefore, the errors in UMTS DCH downlink are of a very bursty nature just because most of the times all transport blocks in a TTI are erroneous. Only in the static scenario the probability distribution among the number of error blocks within one TTI is slightly different. These conclusions bring up the following approach for analyzing the measurements to develop a model for DCH BLER.

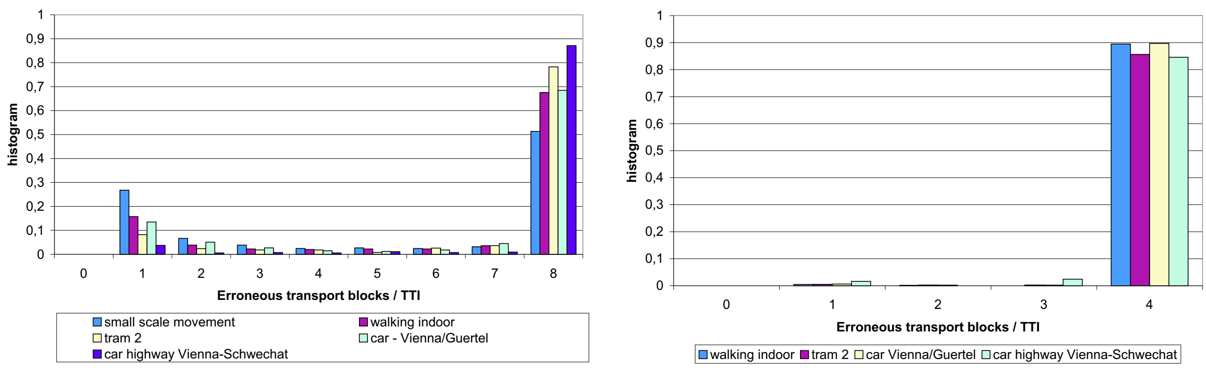

Figure 8: Number of erroneous transport blocks per TTI a)128kbit/s bearer b)64kbit/s bearer.

An analyzis method for modelling the error characteristics of the DCH by the measured data is depicted in Fig. 9. The method builds on the observation of the state of the TTIs. Especially we are looking for the number of subsequent error free TTIs what we call the gaplength

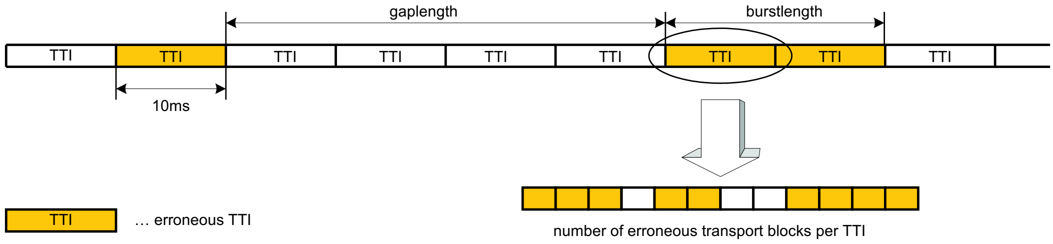

Figure 9: Error modelling approach.

while the number of subsequent erroneous TTIs is called burstlength. Then in case of an erroneous TTI the transport blocks with error within that TTI are counted and a statistic is built (Figs. 7, 8). We are only looking at the statistics of the number of erroneous transport blocks within one TTI and not at the order of transport blocks because in the measurement data the sequence of reception of the transport blocks is not well defined. Furthermore, for a simple model it would be sufficient to consider only the error states of the TTIs and not to look at the transport blocks within the TTIs due to the fact that with high probability all the transport blocks within one TTI are erroneous anyway, as already shown.

The statistics of gaplengths and burstlengths obtained from measurements in the network of Operator A in the static case and with different kind of movement is presented in Figs. 10 and 11.

From Fig. 10 as well as from Fig. 5 we can conclude that our model only has to have the capability of describing two different cases. These are the static case and the case with movement regardless of which kind of movement because both the BLER statistics and the distribution of gaplengths of all kind of movement scenarios are close together.

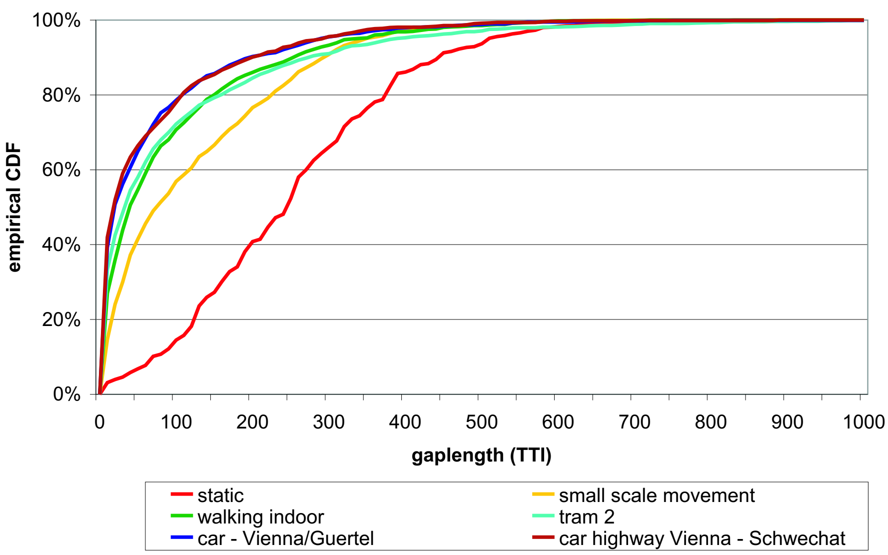

Figure 10: Measured gaplength in number of TTIs, Operator A, diff. scenarios.

4.2 A Two-state Markov Model

The intention is to find a model which describes the error characteristics of the UMTS DCH properly. However, at the same time the complexity of the model should be kept as small as

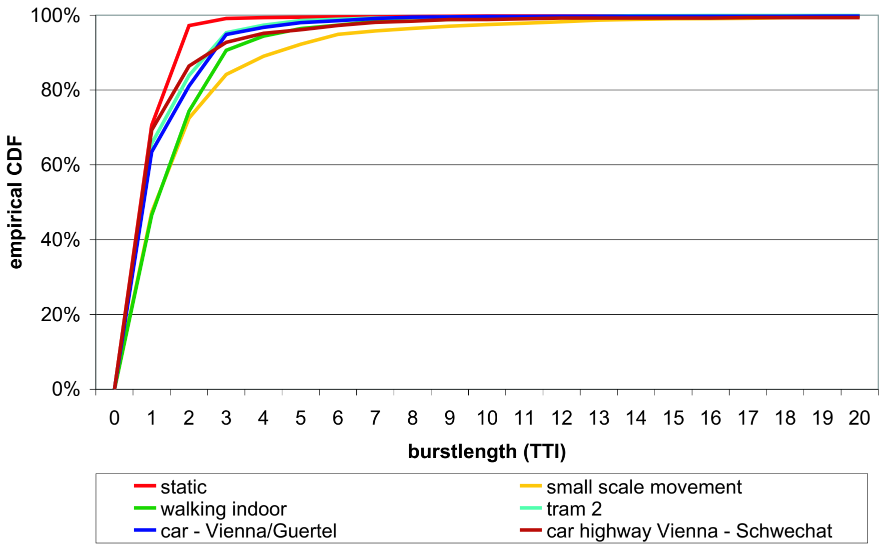

Figure 11: Measured burstlength in number of TTIs, Operator A, diff. scenarios.

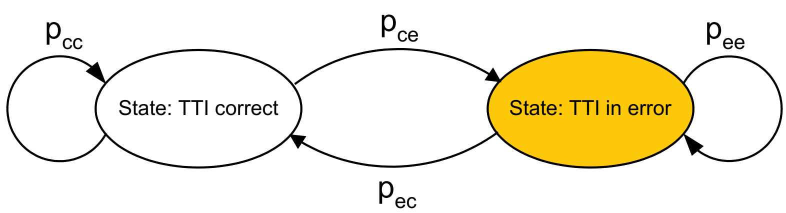

Figure 12: Two-state Markov Model.

possible. As a conseqeunce, the model should have as less as possible adjustable parameters and the values of the parameters should be readily extractable out of the measured data.

In [10] various models for modeling the error patterns of wireless digital communication channels are presented and compared to measured data from a system based on IEEE 802.11b standard. Our decision for modeling the UMTS DL DCH characteristics was in favor of a two-state Markov model due to its simplicity. Such a model was the first time proposed in the well-known Gilbert-Elliot model [11, 12] to describe the bit errors in communication channels. Furthermore in e.g. [13, 14] Markov models were used for modeling the block error process in a WCDMA system.

The two different states of the two-state Markov model are the state of correct TTI and the state of erroneous TTI (Fig. 12). Here p_{cc} and p_{ee} are the probabilities of staying in the state and p_{ce} and p_{ec} are the transition probabilities from one state to the other.

Simulation of the two-state Markov model with the transition probabilities extracted from the measured data beforehand, delivers the gaplength- and burstlength distribution as shown in Figs. 13 and 14. It can be observed in Fig. 13, the simulated distribution of burstlengths produced by the two-state Markov model meets the measured burstlengths both in the static case and in the scenario of car movements. When comparing the statistics of gaplengths as delivered by the two-state Markov model to statistics out of the measurements, it can be observed that the two-state Markov model is not capable of representing the correct gaplength distribution (Fig. 14). This is due to the fact, that the two-state Markov model delivers a geometric distribution of gaplengths. In order to handle this problem we could either consider a Markov model with more than two states (say N states) or use another modification of the model. Since our intention was to find a simple model for the TrCH BLER characteristics, we decided not to follow the idea of an N-state Markov model because of the high number of parameters which would have to be adjusted correctly in such case.

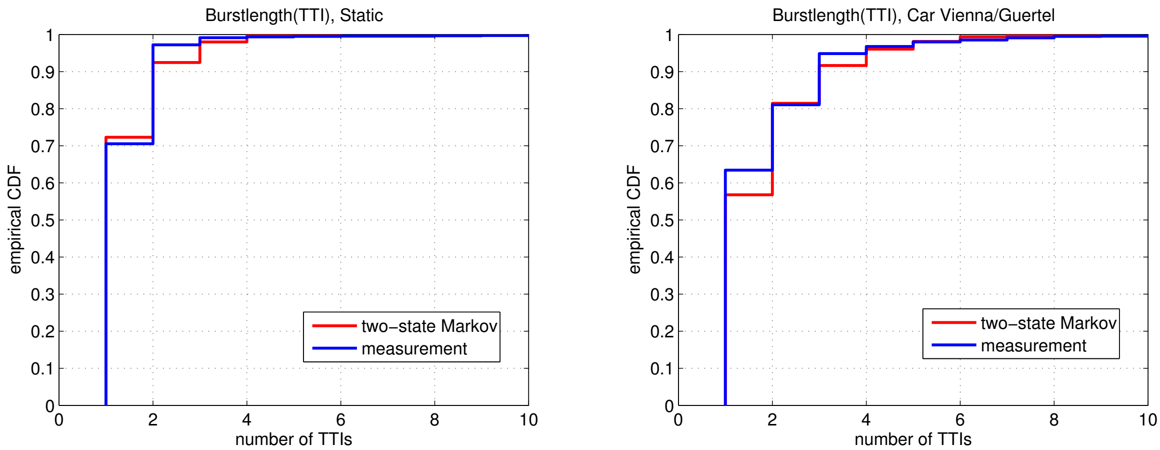

Figure 13: Burstlength (TTI), scenario: a) static and b) car Vienna/Guertel.

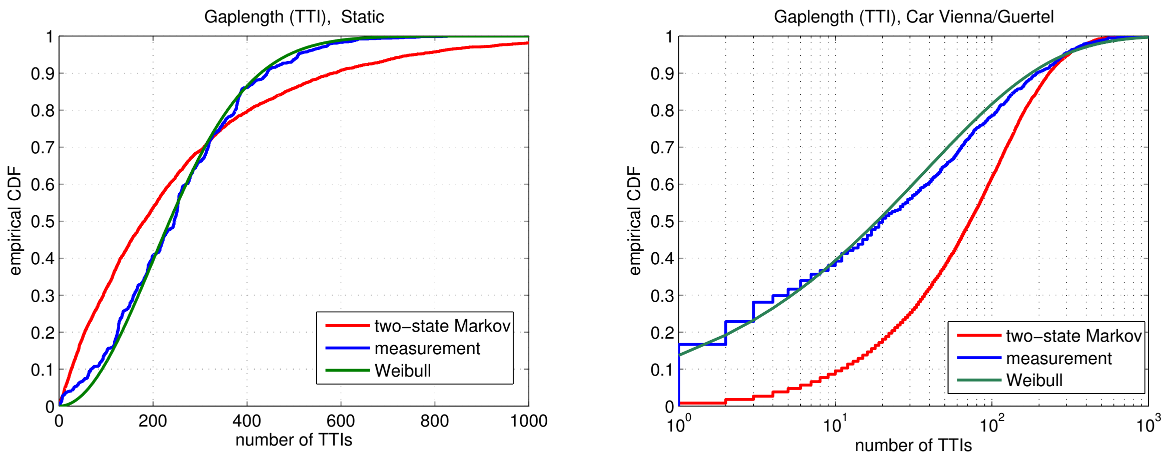

Figure 14: Gaplength (TTI), scenario: a) static and b) car Vienna/Guertel.

4.3 Modified Two-state Markov Model

It is advisable to enhance the two-state Markov model towards a modified Markov model (semi Markov model) due to its simplicity and great adaptivity. As shown in Fig. 14, statistics of gaplengths, measured in a static scenario and in the case of car movements, are met correctly by fitting a Weibull distribution. The Weibull CDF is given by

$$F(x|a,b) = \int_0^x ba^{-b}t^{b-1}e^{-\left(\frac{t}{a}\right)^b}dt \qquad (1)$$

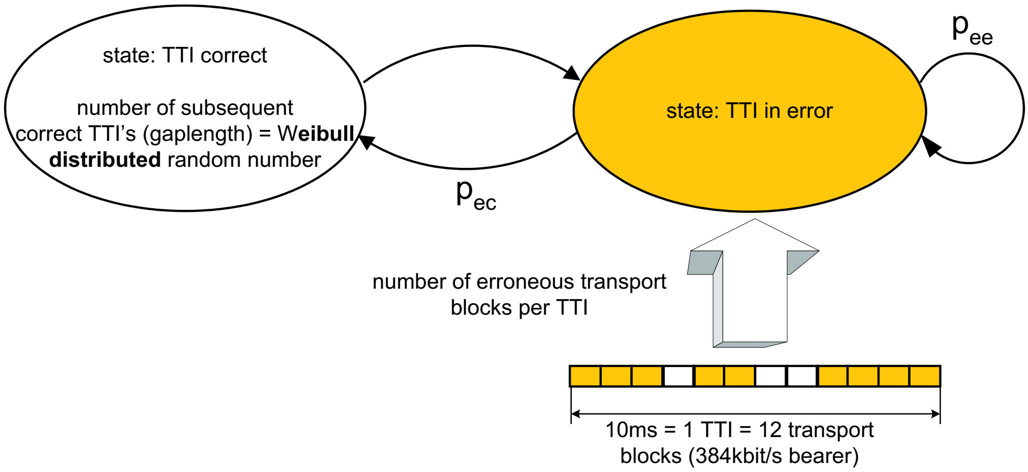

Figure 15: Modified two-state Markov model with Weibull distributed gaplength.

where a and b are scale and shape parameters, respectively. The scheme of the modified two-state Markov model is shown in Fig. 15. The error state in this model is equal to the one in the simple two-state Markov model because the burstlengths are modeled properly with such configuration. However, the error-free state of the model has been modified. In that state the gaplength is now taken from a Weibull distributed random number. If the number of error free TTIs equals the gaplength, the model returns to the error-state where the burstlength is determined via the transition probabilities.

To evaluate the fitness of the model to real error characteristics of the DL DCH, the empirical CDF of the simulated BLER is represented together with the measured BLER in Fig. 16. In the static scenario the BLER from simulation fits the measured BLER statistics very well. The simulation of the scenario with movement though does not match correctly to the measured statistics but it is close to most of the measurements. Therefore, the goal to build a model which fits the two cases static and movement with a simple model is achieved.

4.4 Further Improvement by RRC - MAC Model

In the static scenario our two-state Markov model with Weibull distributed gaplength is able to describe the BLER characteristics correctly whereas it is not able to represent the statistics of a scenario with movement perfectly. The reason for this is the dynamic bearer switching used within the network of Operator A. In our model, up to now only the characteristics of the bearer with the highest probability has been modeled. The probability for the usage of the various bearers in the different scenarios is presented in Fig. 17. In the static scenario the 384kbit/s bearer is used with a probability of 98%. Therefore in that case it is suitable to consider only this high speed bearer. In scenarios including movement of the mobile, the probability of using other bearers than the 384kbit/s bearer is higher and so these bearers have to be considered in the model as well. In order to fit the BLER statistics of the model to the measurements in all cases the RRC (Radio Resource Control) and MAC (Medium Access Control) layer has to be included in the modeling process. In order to model the dynamic bearer switching, a three-state model is necessary where each state represents a certain bearer. After every TTI the decision is made, whether to switch to another bearer or to stay in the same state.

In this extended model there are the different parameters (transition probabilities, number of error blocks per TTI, Weibull parameters) for each bearer fed into the modified two-state Markov Model and the bearer is switched with the transition probabilities of the MAC model. Fig. 18 demonstrates this model.

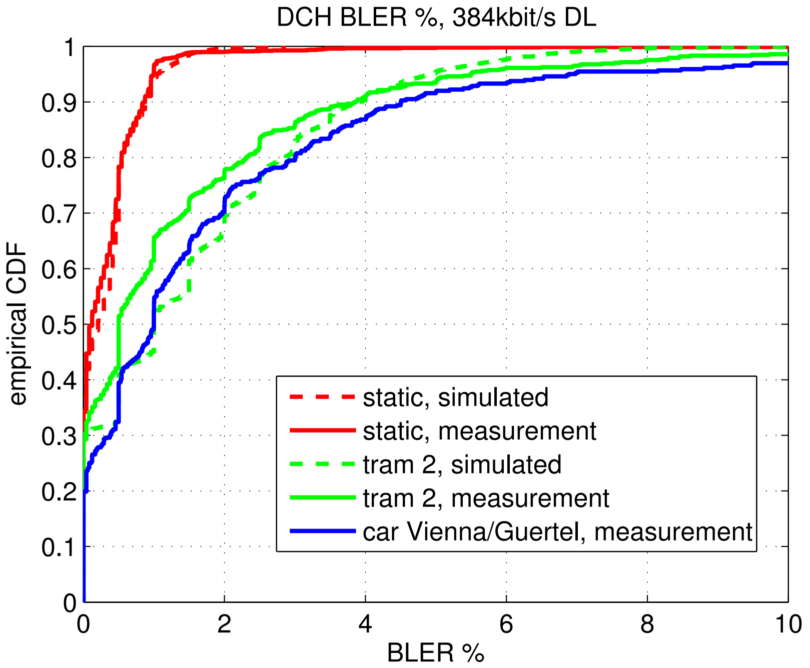

Figure 16: BLER %, simulation vs. measurement.

5 Summary and Conclusions

We have shown measurement results of UMTS DL DCH BLER out of UMTS live networks of three different UMTS network operators in Vienna, Austria. It is shown that in the static case the TPC is capable of compensating the channel variations in a proper way so that the BLER quality target is reached. It is also shown that only by performing small scale movements of the handset, the statistics of TrCH BLER are differing from the static case and are the same as in measurements when going by car on the highway with speeds up to 100km/h. We show the difference in BLER statistics between dynamic bearer switching and fixed bearer usage. The reason for a smaller BLER with dynamic bearer switching is explained and we found that in case of dynamic bearer switching, the BLER statistics are almost the same for all kind of movements. Therefore, a model for TrCH characteristics must be able to match only two different cases, the static case and a second case with movement, regardless of its kind of movement.

Finally we present a simple modified two-state Markov Model which describes the DL DCH BLER statistics, the gaplength and burstlength distribution correctly and at the same time only needs a few input parameters. By adding a RRC/MAC model, we improved the TrCH characteristics description for a system with dynamic bearer switching.

Acknowledgements

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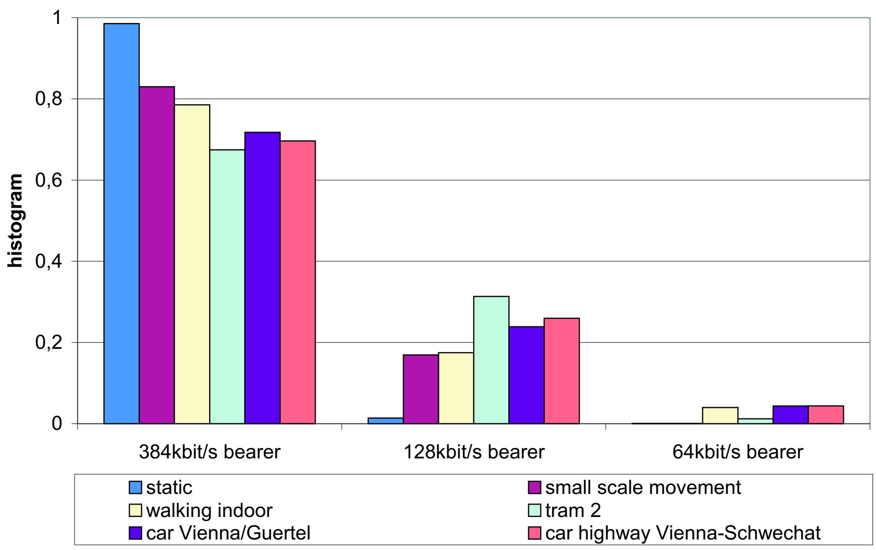

Figure 17: Relative bearer usage in various scenarios.

References

[1] M. Zorzi, R.R. Rao, "Perspectives on the Impact of Error Statistics on Protocols for Wireless Networks", IEEE Personal Communications, Vol. 6, pp. 32–40, Oct. 1999.

[2] Q. Zhang, H.-J. Su, "Performance of UMTS Radio Link Control", IEEE ICC 2002, Vol. 5, pp. 3346–3350, May 2002.

[3] N. Enderle, X. Lagrange, "Radio Link Control-Acknowledged Mode protocol performance modeling in UMTS", IEEE 4th International Workshop on Mobile and Wireless Communication Networks 2002, pp. 332–336, Sept. 2002.

[4] E. Villier, L. Lopes, S. Lambotharan, "Approaches to modelling the physical layer performance in a UMTS radio system simulator", Third International Conference on 3G Mobile Communication Technologies, pp. 560–564, May 2002.

[5] J.J. Olmos, S.Ruiz, "Transport Block Error Rates for UTRA-FDD Downlink with transmission Diversity and Turbo coding", IEEE 13th PIMRC 2002, Vol.1, pp 31–35, Sept. 2002.

[6] 3GPP TS 25.215 "Physical layer - Measurements (FDD)".

[7] 3GPP TS 25.302 "Services provided by the Physical layer".

[8] H. Holma and A. Toskala, *WCDMA for UMTS, Radio Acces For Third Generation Mobile Communications, Third Edition,* John Wiley & Sons, Ltd., 2004.

[9] http://www.ericsson.com/products/hp/TEMS_Products_pa.shtml

[10] A. Köpke, A. Willig, H. Karl, "Chaotic Maps as Parsimonious Bit Error Models of Wireless Channels", IEEE INFOCOM 2003, Vol. 1, pp. 513–523, April 2003.

[11] E.N. Gilbert, "Capacity of a burst-noise channel", Bell Systems Technical Journal, vol. 39, pp. 1253–1265, Sept. 1960.

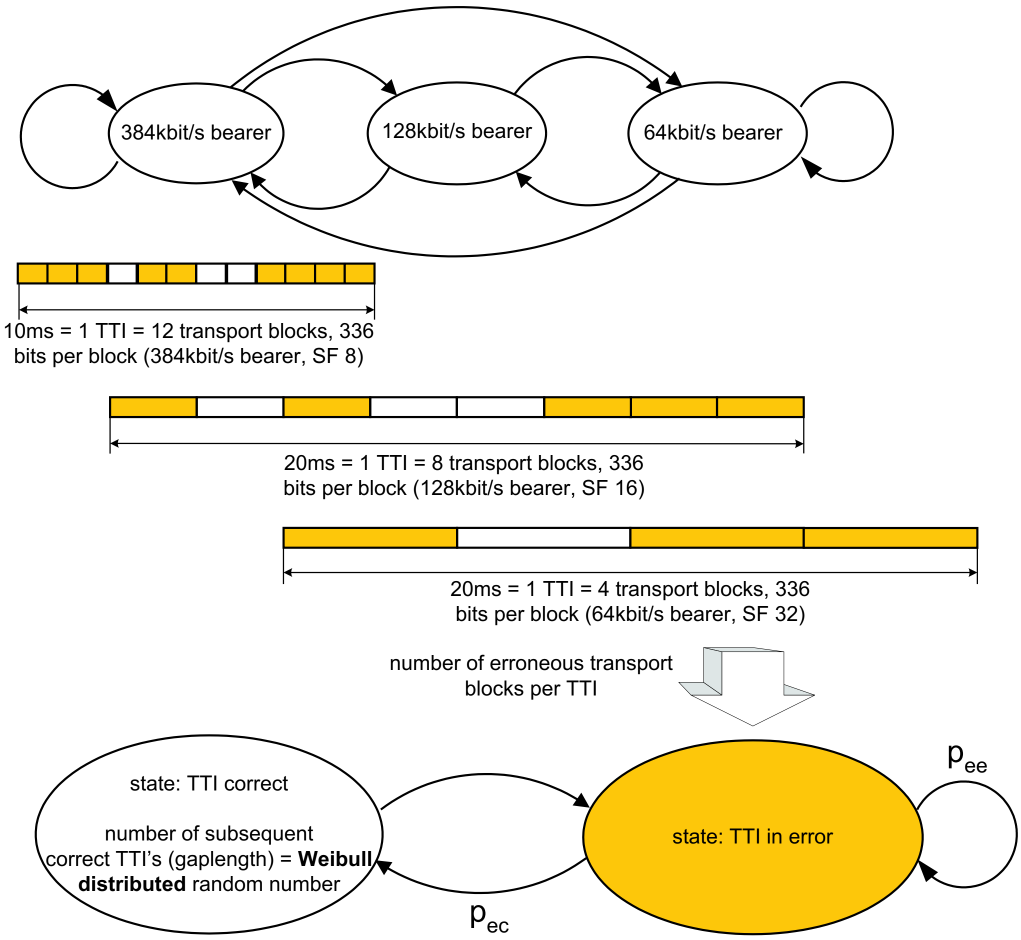

Figure 18: RRC/MAC-Model with dynamic bearer switching.

[12] E.O. Elliot, "Estimates of error rates for codes on burst-noise channels", Bell Systems Technical Journal, vol. 42, pp. 1977–1997, Sept. 1963.

[13] V. Tralli, M. Zorzi, "Markov models for the physical layer block error process in a WCDMA cellular system", IEEE GLOBECOM '02, Vol. 2, pp. 1925–1929, Nov. 2002.

[14] F. Babich, F. Santucci, F. Graziosi, "Modeling of Power-Controlled Interference-Limited Wireless Channels", IEEE 2002, 5th International Symposium on Wireless Personal Multimedia Communications 2002, Vol. 3, pp. 941–945, Oct. 2002.

[15] V. Tralli, M. Zorzi "Quality of Service and Power Consumption in WCDMA Cellular Systems with SIR-based Closed Loop Power Control", IEEE 12th International Symposium on Personal, Indoor and Mobile Radio Communications, 2001, vol. 1, pp. 22–26, 2001.

[16] F. Gunnarsson, A. Björsson, B. Knutsson, F. Gunnarsson, F. Gustafsson, "Radio Access Network (UTRAN) Modeling for Heterogenous Network Simulations", Technical Report, Control & Communications Group, Linköping, Sweden, August 2003. (http://www.control.isy.liu.se/publications)

[17] W. Turin, M.M. Sondhi, “Modeling Error Sources in Digital Channels”, IEEE Journal on Selected Areas in Communications, Vol. 11, pp. 340–347, April 1993.

[18] T. Klingenbrunn, P. Mogensen, “Modelling Radio Link Performance in UMTS W-CDMA Network Simulations”, IEEE 51st VTC Spring 2000, Vol. 2, pp. 1011–1015, May 2000.

[19] L.R. Rabiner, B.H. Juang, “An Introduction to Hidden Markov Models”, IEEE ASSP Magazine, Vol. 3, pp. 4–16, Jan. 1986.

[20] P. Kuczynski, A. Rigolle, W.H. Gerstacker, J.B. Huber, “Hidden Markov Modeling of Error Patterns and Soft Outputs for Simulation of Wideband CDMA Transmission Systems”, International Journal of Electronics and Communications (AEÜ) 2004, Vol. 58, pp. 256–267, 2004.