Link Layer Simulation for 3G EDGE Air Interface

Neil McDonald, Monica Casado-Fernandez, Sen Lin Zhang

BT Adastral Park, Martlesham Heath, Ipswich, IP5 3RE

Abstract: *The prospect of a new generation of a high bit rate mobile technology without excessive additional expense on existing infrastructure has made network operators consider the possibility of technologies other than WCDMA. EDGE (Enhanced Data Rates for GSM Evolution) is one of such technologies that provides an increased data rate over GSM by changing primarily the modulation scheme from GMSK to 8-PSK. However, this modulation scheme is more susceptible to noise and distortion due to the operating environments. This paper presents simulation results of the 3G EDGE air interface and shows its performance in various environmental conditions, ranging from 3GPP prescribed channel models to custom-designed 'worst case' scenarios. The simulated curves for Bit Error Rate (BER) vs Carrier to Noise Ratio (CNR) show that EDGE is able to operate under most channel conditions specified in the 3GPP standards but suffers too high a BER when 'worst case' models are used.*

1. Introduction

GSM has been a worldwide success for personal communication applications. Transmission of speech and data is available with GSM. However, the evolution plan for GSM aims at a new standard capable to support data rates adequate for multimedia services. Among the improvements introduced, GPRS (General Packed Radio Service) and EDGE are emphasised.

EDGE is based on an alternative modulation and coding scheme with a 200kHz carrier bandwidth, within the same frequency bands as existing GSM. This will allow the use of the present GSM networks, which is an advantage for current cellular communications service providers and for the manufacturers developing the new terminals for GSM and for the third generation mobiles.

EDGE consists of several channel coding schemes and two modulation schemes, the original GMSK and the recent 8-PSK. These are combined using dynamic switching which is dependent on the channel conditions and gives the system an adequate robustness for the environment.

This paper investigates the physical layer performance of the 3G EDGE air interface using a computer simulation tool SPW. The BER of a switched circuit connection is shown as a function of CNR for a selection of channel environments. New 'realistic' channel models have been created to simulate 'worst-case scenarios' for different channel conditions, and the BER is recorded for this scenario.

In this paper, a brief description of some components of EDGE is presented and a block diagram of an 8-PSK system using SPW is also shown. Results of the simulations of this system are given, which includes the performance of the Viterbi equaliser, and the improvement that the encoder/decoder process can add to the recovery of signals in different propagation environments. The BER is used to assess the system performance in each case.

2. Overview of the 3G EDGE System

The block diagram for the simulation of the 3G EDGE air interface is shown in Figure 1. The simulation consists of three discrete sections: the transmitter, the RF channel and the receiver. The transmitter produces a stream of encoded data that is then modulated by an 8-PSK generator. The resultant signal is transmitted across the air interface, the spectrum of which is filtered to conform to ETSI emission regulations.

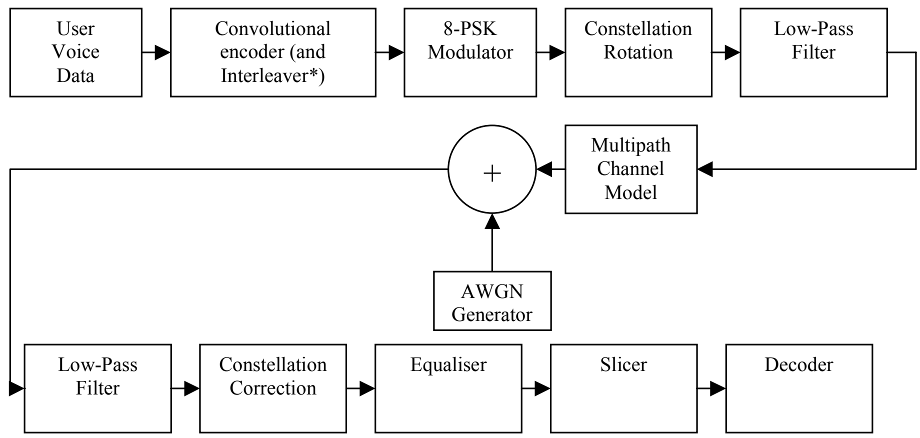

Figure 1: Configuration of the EDGE Uplink System

Multipath is considered in the channel model and white Gaussian noise is also added. The multipath model has been created according to the ETSI channel models, however, some modifications have also been done for some simulation cases to create a more realistic scenario. The white Gaussian noise source is included to simulate both interference from other users and thermal noise at the receiver. Its power is varied to allow a sweep of CNR.

The receiver module includes a low pass filter, a signal equaliser to compensate for the effects of the channel model and an 8-PSK slicer and decoder to recover the original data. The system transmits at 270,833 symbols per second, and the simulation is managed such that only one timeslot per frame is used by the mobile.

3. Simulaton Work

Four different cases were simulated in order to assess the performance of the EDGE system. The first two cases use channel models for a pedestrian and a vehicular environment respectively – these models are those specified in [4]. The other two cases use modified 'real' channel models.

For each of the following cases, the EDGE signal is transmitted through a channel model and the system BER is calculated for a sweep of CNRs. Only raw bit error rate is shown: i.e. the number of incorrect symbols received at the receiver *before* the decoder.

Three curves are shown on Figure 2 and Figure 3. For comparison, a theoretical curve is shown in the figures which represents the BER performance for the system for the case the transmitted signal passes through an ideal channel with additive Gaussian white noise. This can be thought of as the performance of an EDGE system that has an equaliser with complete multipath cancellation, and is based on theoretical calculation. The 'ideal' curve shows the performance of the EDGE system when used with the 3GPP suggested channel model. The 'real' curve is created using the modified 3GPP channel and represents the results of EDGE performance in a 'worst-case' scenario.

3.1 Pedestrian Model

The first environment studied was the 3GPP 'pedestrian' model and the results of this are shown in Figure 2. This consists of several multipaths closely spaced together in the time domain, each of which fades with a Rayleigh fading characteristic and a Doppler frequency of 5.56Hz. This is equivalent to a pedestrian travelling through a simulated urban environment at a speed of 3km/h.

The 'ideal' model can be seen to start near to the theoretical line, but deviates rapidly. The system reaches a raw bit error rate of 10^{-2} by 25dB CNR, and reaches 3×10^{-4} by 40dB CNR.

The 'real' model exhibits a different curve characteristic from the ideal case. The real model starts with a higher BER than the ideal scenario and the difference remains until about 15dB CNR. After this point the 'real' curve starts to shallow out and reaches an error floor at about 25dB CNR.

This error floor is due to the effect of high Doppler frequencies which are present in the modified channel profile. The equaliser is unable to compensate for the fast-changing nature of these multipaths and leads to errors that cannot be corrected. Thus after about 25dB CNR an increase of the carrier power leads to little improvement in the performance of the system. Before this value, however, the effects of low frequency fading dominates, which can be effectively compensated by the equaliser.

3.2 Vehicular Model

The second environment investigated is the 3GPP-approved "Vehicular B" model. This consists of 8 paths widely spread across the time domain, and each path suffers from a high Doppler frequency shift of 222Hz - equivalent to the handset travelling at 120km/h. The results of this simulation are shown in Figure 3. For both 'ideal' and 'real' scenarios the same characteristic curves can be identified : an initial curve following the shape of the 'ideal' curve, followed by a 'shallowing' of the curve at higher CNR. As in the 'worst-case pedestrian' model, the system performance is greatly affected by the high doppler frequencies in the model, and causes a high BER. The achieved BER is only 0.16 for a CNR of 25dB.

4. Summary

The performance of the link layer of 3G EDGE interface has been simulated for various environmental conditions. Our simulation results show that EDGE is able to operate under most channel conditions specified in the 3GPP standards but suffers too high a BER when 'worst case' models are used.

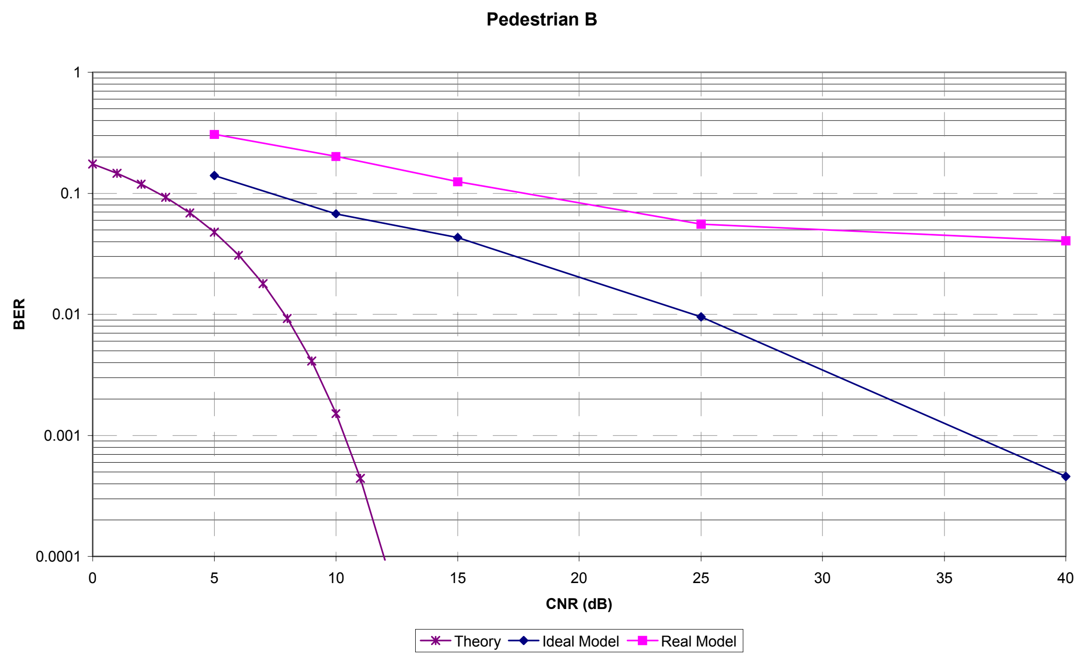

Figure 2: Simulation Results for Pedestrian B 3GPP and "Worst Case" scenarios

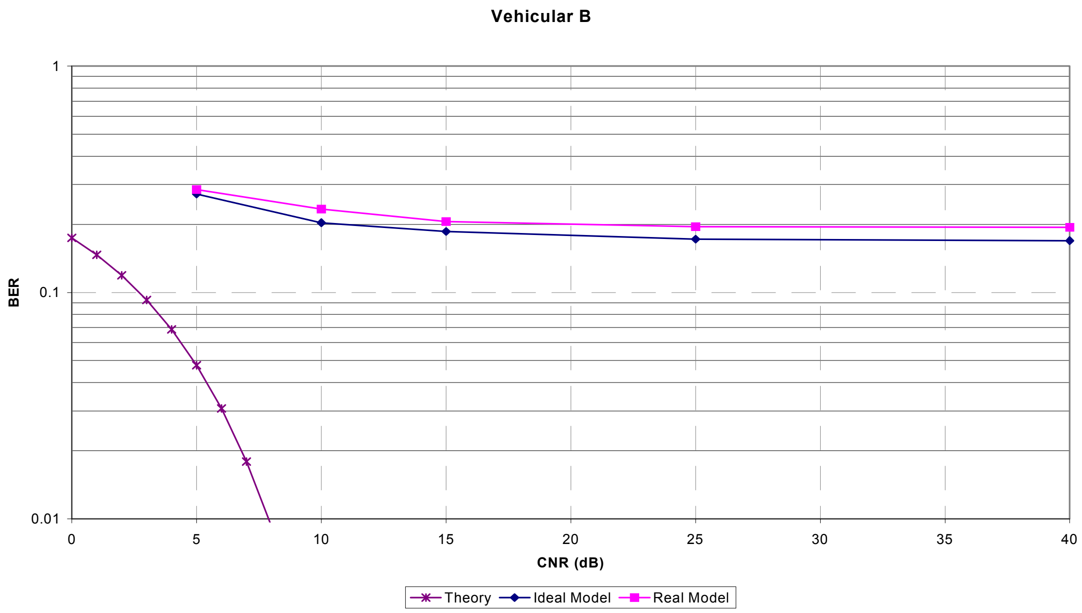

Figure 3 : Simulation Results for Vehicular B 3GPP and "Worst Case" models

References

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