Consideration of Link Level Parameters in System Level Simulation of 3rd Generation Mobile Communication Protocols using SDL

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ABSTRACT

This paper discusses the need for joint link level and system level simulations for third-generation mobile radio systems and points out a way of implementing them in SDL. The simulation of third-generation mobile radio interfaces is a particular challenge to computational power. Complex systems are needed to support the demands of ATM services and high data rates of up to 2 Mbit/s in the UMTS band.
The physical influences of mobile radio channels will be considered within the system level simulation of protocols for mobile radio systems, since channel allocation and handover protocols need physical parameters.

I. INTRODUCTION

The simulation of third-generation mobile radio interfaces is a particular challenge. Complex systems are needed to support the demands of ATM services and high data rates of up to 2 Mbit/s in the UMTS band. In past and current research projects in the European Union many aspects of new interfaces have been examined.
The physical influences of mobile radio channels need to be considered within the system level simulation of protocols for mobile radio systems. Varying bit error rates, burst error structures and changing delays during the data transmission cannot be neglected. They are influenced by the current network conditions and their effect on the carrier to interference level. Thus the common simulation of transmission techniques and system level protocols is necessary in many cases. To evaluate the performance of adaptive algorithms the emulation of changing network environment conditions is needed. The test with constant parameters is not adequate for these algorithms since only isolated cases can be observed. On the other hand, the simulation tool must be designed in such a way that the test environment (or the virtual network) can be reproduced when different algorithms have to be compared. One problem is that many algorithms are not independent of each other. For example power control influences the carrier to interference (CIR) level of the network and thus dynamic channel allocation and handover algorithms and vice versa. However the computations in a complete link and system level simulation are still too complex for present-day computers. The implementation of a digital channel model that comprises only the necessary models for CIR calculation and uses the results from link level simulations is reasonable. Algorithms for path-loss, fast and slow fading and power control should be integrated into this digital channel model. The bit error rate for raw uncoded or encoded data transmission is determined from a CIR / BER graph with the calculated carrier to interference level.
This CIR / BER graph could be generated in link level simulations. The simulation of dynamic channel allocation and handover protocols as well as error correction procedures like hybrid ARQ II schemes require these link level parameters.
To examine the dependence of channel allocation algorithms on the network load, changing network conditions modelled with moving mobiles and traffic generators are required.

II. SIMULATION

A. Simulation with SDL

Using SDL (Specification and Description Language, ITU-recommendation Z.100) the generation and simulation of communication protocols is straightforward and efficient. In particular complex protocol sequences can be programmed unambiguously using SDL. The concurrent design of large systems with several developers becomes considerably simplified because of the highly modular graphic interface of SDL. Figure 1 shows the SDL processes of the digital channel implementation of our simulation environment. The processes communicate with signals so that interfaces can be clearly specified.
C code that has been automatically generated with the SDL tool must either be inserted into other simulation tools or the channel model has to be embedded into the SDL environment. This can be done by the straightforward embedding of C-code. Integration into other lower level simulation tools like COSSAP is often problematic. Thus we have decided to embed C-code into our SDL simulation environment SDT.

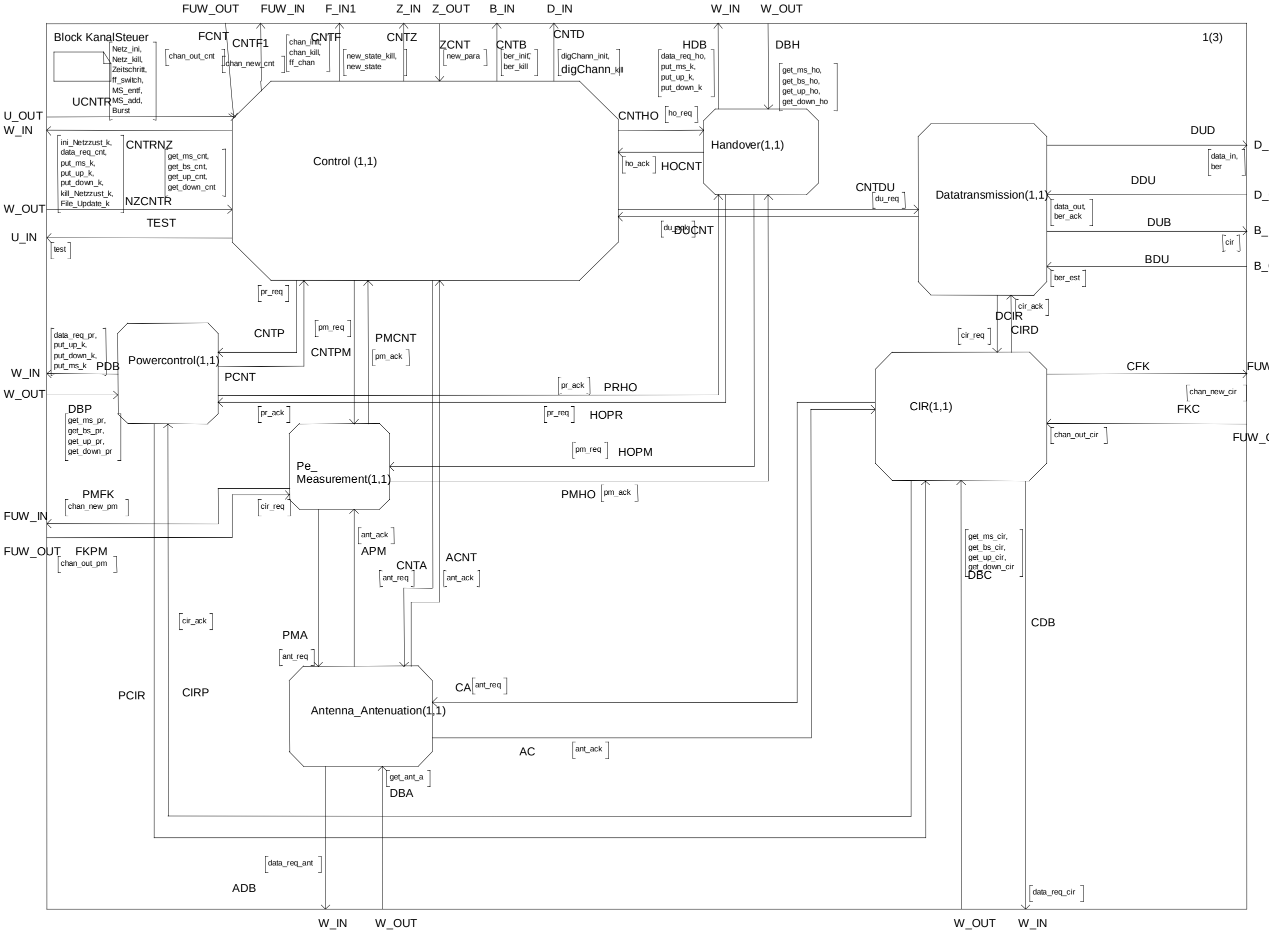

Figure 1: Exemplary SDL diagram of the digital channel

B. Environment Model

Our new simulation library distributes an arbitrary number of base stations and mobile stations with individually adjustable parameters on a virtual cellular network structure as shown in Figure 2.

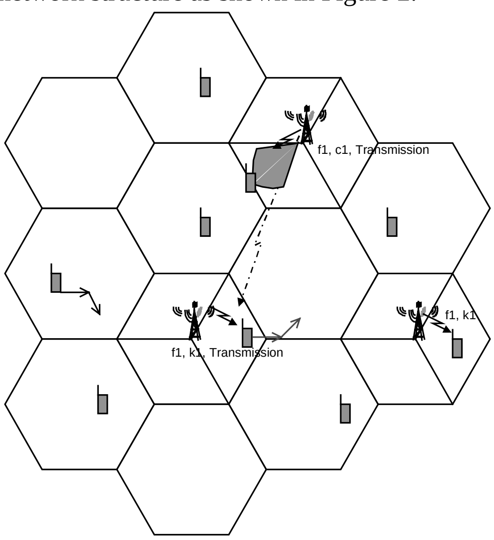

Figure 2: Virtual Cellular Network

Mobile stations are randomly distributed throughout the network. The density of mobile stations is kept constant. Each mobile station changes direction and speed within changeable parameters.

Measured time series for the respective locations and speed can be read via parameter files.

For each base station antenna sector, frequencies and channels can be assigned. The frequency and channel allocation can be either static or dynamic. Hierarchical cell structures can be built according to the assigned transmitting power.

The network structure and parameters are managed in a central data base. Other modules such as handover or resource allocation control are able to manipulate the data base. This can be done while the computation intensive simulation of data transmission is running via the digital channel.

C. Propagation model

Each mobile station regulates its transmitting power with the serving base station. In most cases that is the one with the strongest broadcast carrier. This transmitting power regulation is carried out by the asynchronous and decentralised CIR based IPC-algorithm [2], which has proven to be very robust in the simulation. The necessary signalling is neglected at present.

At the moment three path-loss models are implemented to predict the carrier to interference level. We use indoor, vehicular and pedestrian (indoor to outdoor) models that have been evaluated by ITU-R Task Group 8/1 and in the European RACE project ATDMA [1] and the ACTS project FRAMES [5]. Figure 3 shows the simulated CIR-curve for one mobile station using the different path-loss models under the same network conditions. The models used are compared with an evaluated path-loss curve using the path-loss model after W.Y. LEE [9].

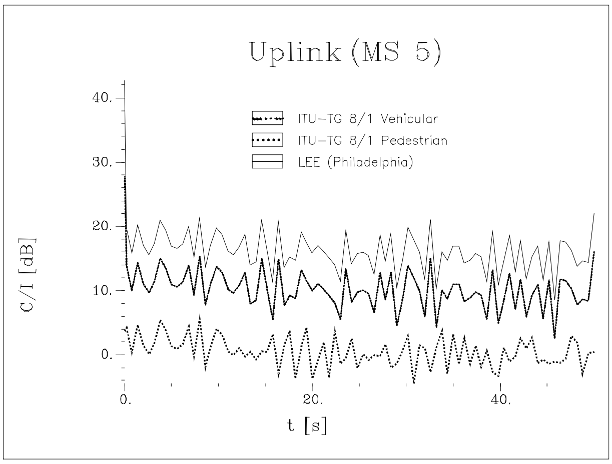

Figure 3: CIR Curve with Slowfading

Figure 3 also shows the implemented lognormal distributed slow fading model suggested by D. Huo (ARMA Auto-Regressive-Moving-Average markovian model of order(1,2)) with moving shadowers [4].
Additionally, dynamically alterable antenna diagrams and transmitting sectors can be assigned to the antennas of the base stations. At the moment we use idealised antenna diagrams.
Using these models simulation of the influence of sectorisation and adaptive antennas on channel allocation and handover protocols becomes possible.

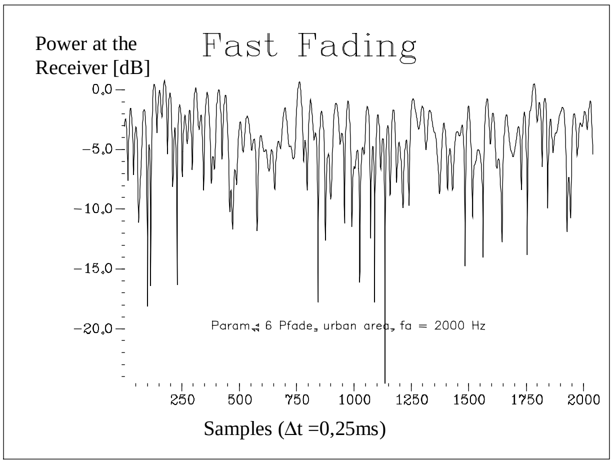

Figure 4: Fastfading

Figure 4 shows the simulated fast fading, which usually does not need to be taken into account in the simulation of protocols, because the decision for handover should not be made on the basis of short-term measurement; also, modern receivers reduce the effects of fast fading with interleaving and combining methods. Thus the Rayleigh distributed fast fading model can be switched off. Simulation time decreases considerably when doing so. Some parts of the simulation library are directly written and integrated into C for reasons of efficiency and speed.

D. Adaptive Bit Error Generator

The bit error rate is determined with the CIR of the observed mobile station in such a way that the current bit error rate is taken out of tables shown in Figure **5** as a curve for the current modulation and channel estimation scheme. These tables can be generated more easily by other simulation tools (e. g. COSSAP) using pure link level simulations. One problem with our solution is that some modern decoders need soft-decison values and channel state information. These cannot be modelled accurately this way. We have to assume a constant gain of *x* dB for simulation models with soft-decison decoders or we have to use the bit error ratio values to model a reliability estimation. Of course bit error pattern files could also be read instead using an CIR adaptive bit error generator. These files become very large as a result of statistical needs and also many different pattern files are needed for every CIR level. For that reason we decided to use the adaptive bit error generator.

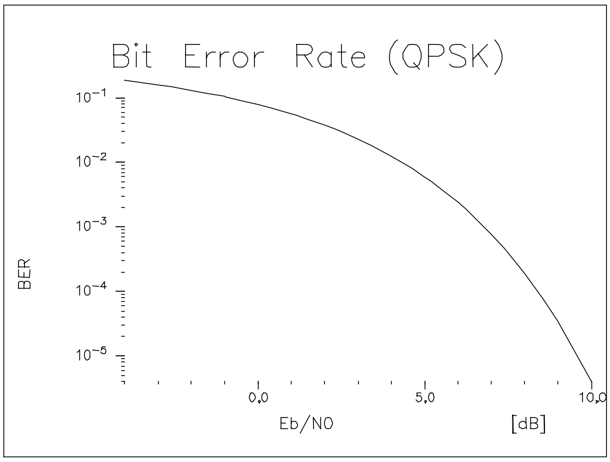

Figure 5: CIR/BER Curve

E. Modelling of Handover and SDMA

First a handover algorithm based on a simple procedure using the transmission power of the strongest broadcast channels of the neighbouring base stations was implemented. To prevent fast hopping between two base stations a simple handover hysteresis was implemented.
Depending on the channel model, the movement of the mobile stations in the virtual network environment needs to be adapted. Very fast mobile stations do not change their direction very quickly whereas pedestrians move more slowly and change their angle and direction very often. These different movement models should be mixed to test the performance of simulated handover protocols. The form of antenna beams can be assumed in an ideal way. The beam might be directed at a virtual multipath ray that can be modelled using a scattering area around the mobile stations [6]. This is especially

necessary within the simulation of effects on protocols and channel allocation algorithms when adaptive antennas are used. However, much more complex methods with centralised network intelligence are possible. This network intelligence could for example be implemented and tested in clustered network entities. The prediction of the subscriber movement can be used to support handover to enlarge the system capacity [3].
To visualise the network status we use the user interfacer of another tool (ILOG Views^{TM}), since SDL or rather our SDL tool, is not suitable for these purposes.

III. CONCLUSIONS

The paper points out a possible way of simulating system level protocols using link level parameters. The simulation of third generation mobile communication protocols is very memory and computational power intensive. Therefore it is important to implement the algorithms efficiently. With our simulation library we are now able to simulate new protocols that have to be developed with the introduction of new features, e.g. space diversity multiple access (SDMA) [8], into next generation networks.

IV. OUTLOOK

When new mobile radio interfaces in the UMTS band are introduced these will have to adapt to the ATM standards. Thus the simulation model is now being expanded to include an ATM-traffic generator with models for dialog voice, video-streams and TCP/IP data traffic. Because ATM speech and data transmission have different Quality of Service parameters these services must be treated separately. Thus the error protection and ARQ procedures that have to be implemented must be tested on the these services. The traffic generator has to model Poisson distributed subscribers and voice activity. Figure 6 shows the structure of the system consisting of the ATM traffic generator and parts of the service demultiplexing function. This demultiplexing function is needed to support the different demands on QoS, e.g. delay, cell jitter and bit error rate. Every service is treated separately with its own buffer and serving function. The ATM header should be compressed, since the air interface could be compared with a distributed multiplexer [7] with point to point connections and the spectrum has to be used efficiently. Multicast support needs to be implemented as well as support of compressed speech.

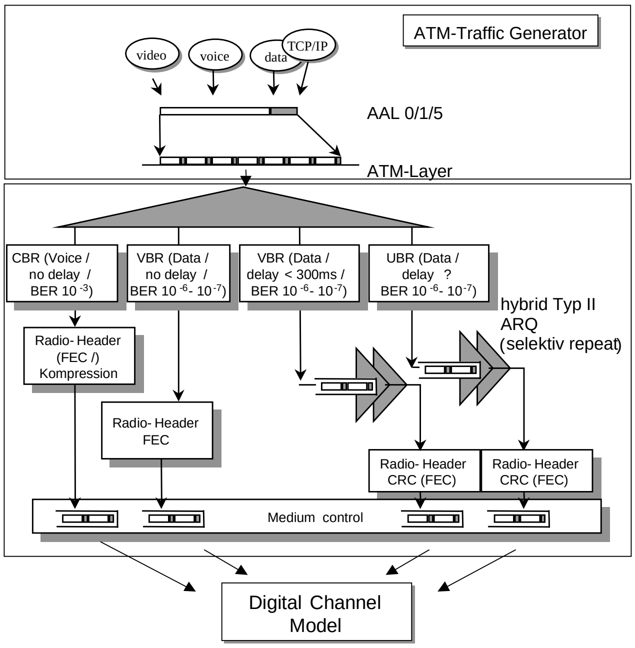

Figure 6: ATM-Traffic Generator and Service Demultiplexing

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