SDL-Simulation Tool for Advanced Handover Protocols

Jan Steuer, Matthias Lampe, Klaus Jobmann

University of Hanover
Institute for Communications
steuer@ant.uni-hannover.de

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 of rates up to 2 Mbit/s in the UMTS band.

The physical influences of mobile radio channels on protocols have to be considered within the system level simulation for mobile radio systems, since channel allocation and handover protocols need physical parameters.

One application of our simulation tool is the examination of a new approach for a advanced handover protocol. This handover protocol uses the direction of arrival estimation of adaptive antennas in combination with other mobile movement prediction methods to reserve capacity in the next predicted radio cell to reduce blocking rates and signalling.

1 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 on protocols should be considered within the system level simulation for mobile radio systems. Varying bit error rates, burst error structures and changing delays during the data transmission cannot be neglected. These 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 by comparing different algorithms. 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 (simplified in Figure 1 (A)) are still too complex for state of the art 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 as in Figure 1. This figure omits the signalling transmission paths. The modulator and demodulator are replaced by the digital channel model block.

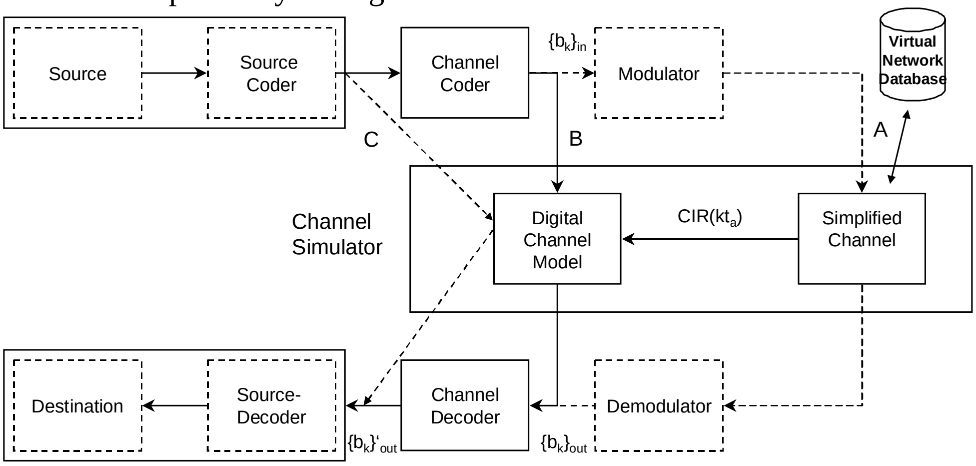


Figure 1 Simplified Channel Model

The bit error rate for raw uncoded transmission $\{b_k\}_{in}$ -$\{b_k\}_{out}$ is determined from a CIR / BER graph using the calculated carrier to interference level. This CIR / BER graph could be generated in separate link level simulations. The simulation of dynamic channel allocation and handover protocols but also error correction procedures like hybrid ARQ II schemes requires this link level parameter.

Another possibility would be to use a CIR / BER graph for encoded data transmission to determine only the rest error ratio as shown in path C. The disadvantage of this method is that the delay of hybrid ARQ II schemes cannot be modelled. On the other hand, no calculation of channel coding and decoding is needed.

To examine the dependence of channel allocation algorithms on the network load, changing network conditions modelled with moving mobiles and traffic generators are required. When evaluating new protocols the user data source coders can also be omitted because the simulation of the real data contents is not needed and dummy data can be sent.

2 Simulation

2.1 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 2 shows the simplified SDL process diagram of the digital channel control 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, because the implementation of the channel model is not very efficient in SDL. This can be done by the straightforward embedding of C-code. Integration into other lower level simulation tools like COSSAP is often problematic, because they use their own language. Thus we have decided to embed C-code into our SDL simulation environment SDT.

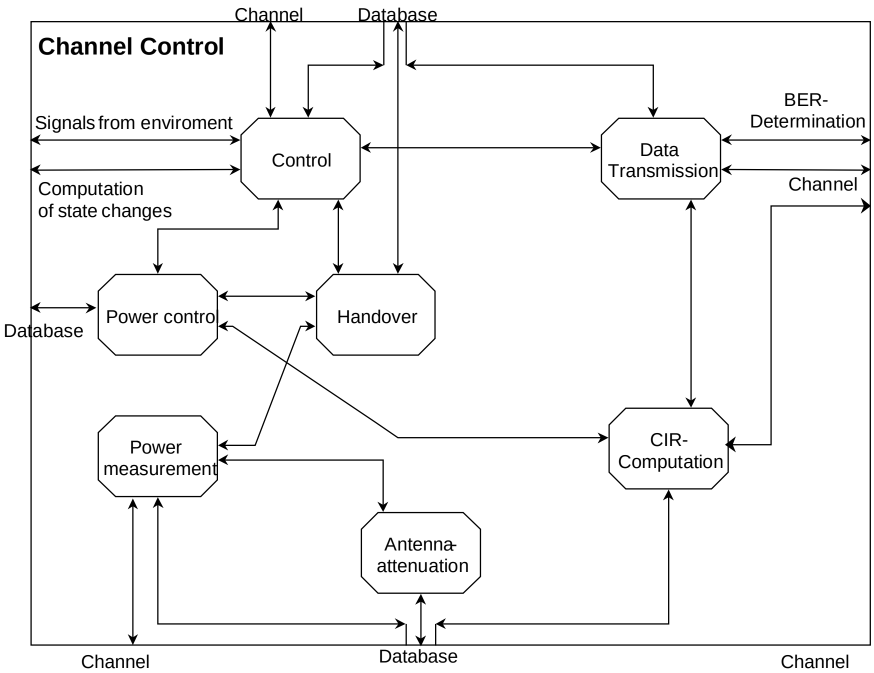


Figure 2 Simplified SDL process diagram of the digital channel control

2.2 Virtual Cellular Network Environment Model

Our new simulation library transforms an arbitrary number of base stations and mobile stations with individually adjustable parameters into a virtual cellular network structure as shown in Figure 3. Mobile stations are randomly distributed throughout the network. The density of mobile stations is kept constant. Each mobile station changes the direction and the speed within adjustable 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 adjusted 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 via the digital channel is running.

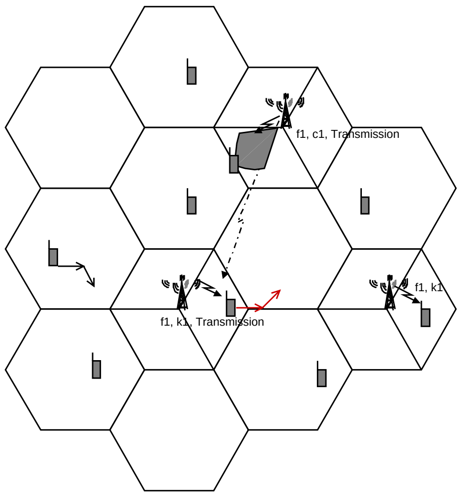


Figure 3 Virtual Cellular Network

2.3 Propagation model

Each mobile station regulates its transmitting power with the support of 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-algorithms [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 predicted the carrier to interference level. We use indoor, vehicular and pedestrian (indoor to outdoor) models, which have been evaluated by ITU-R Task Group 8/1 or rather in the European RACE project ATDMA [1] and the ACTS project FRAMES [5]. Figure 4 shows the simulated CIR-curves for one mobile station using the different path-loss models under the same conditions. The models used are compared with an evaluated path-loss curve using the path-loss model according to W.Y. LEE [9].

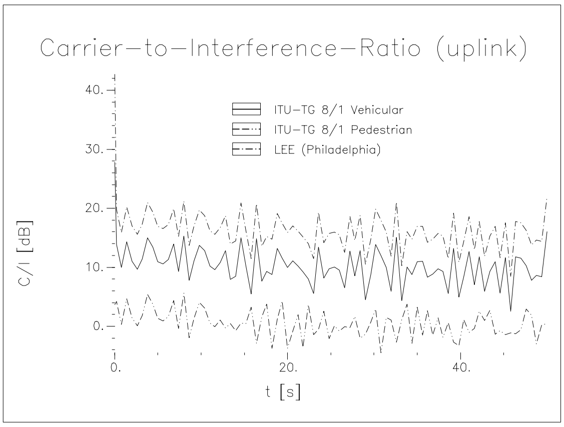


Figure 4 CIR-Curve with Slow Fading

Figure 4 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 the simulation of the influence of sectorisation and adaptive antennas on channel allocation and handover protocols becomes possible.

Fast fading is sometimes not necessary to be taken into account for 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.

2.4 Adaptive Bit Error Generator

Figure 5 shows the block structure of the channel simulator. In the block *BER Determination* 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** for the current modulation scheme. These tables can be generated more easily by other simulation tools (e. g. COSSAP). 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 exactly. 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 a CIR adaptive bit error generator. These files become very large as a result of statistical needs; also, many different pattern files are needed for every CIR level. For that reason we use the adaptive bit error generator.

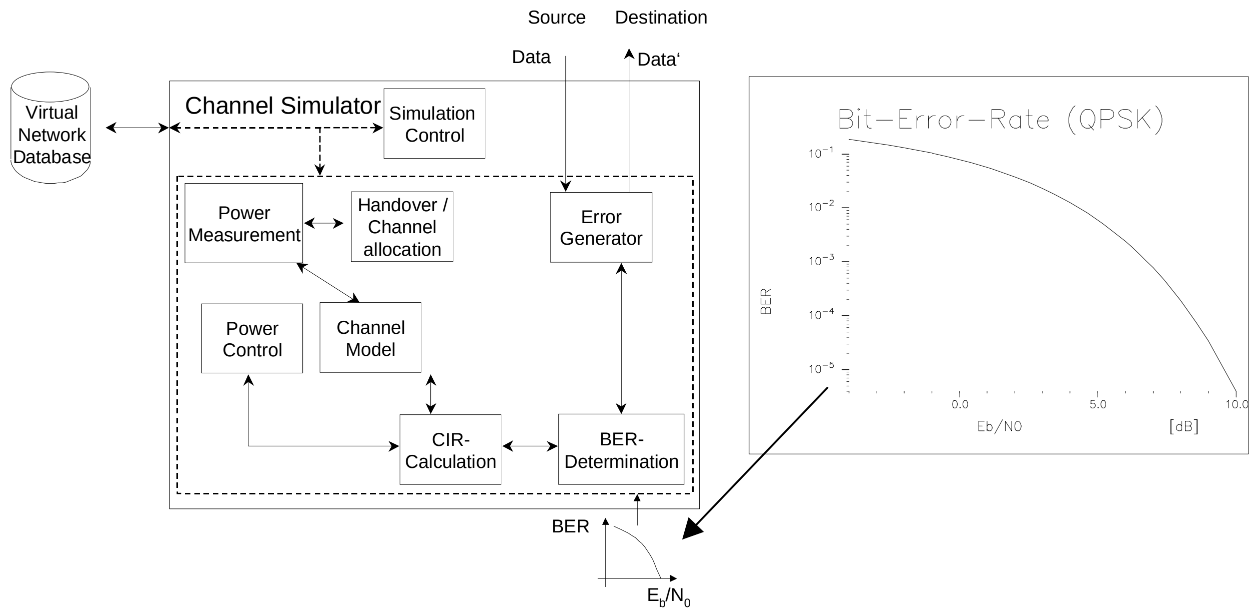


Figure 5 Block Structure of the Channel Simulator and CIR/BER- Curve

2.5 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 we use a simple handover hysteresis.

Depending on the channel models 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] shown in **Figure 6**.

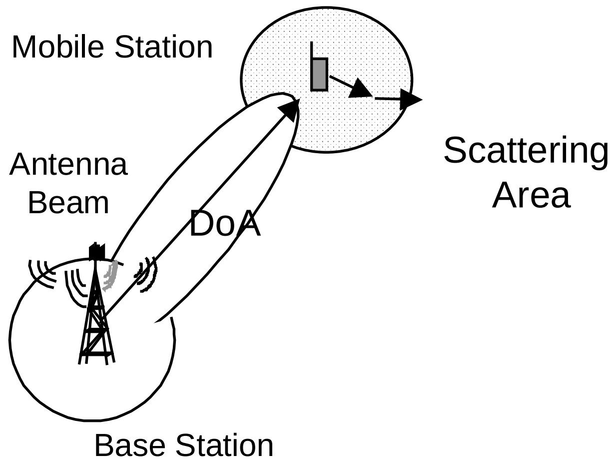


Figure 6 Model for adaptive antenna

However, much more complex handover methods with centralised network intelligence are possible. To visualise the network status we use the user interface of an other tool (ILOG Views™), since SDL, or rather our SDL tool, is not suitable for these purposes.

3 Advanced Handover Protocol

One possible application for our simulation tool is another research project at our institute, a new approach for an advanced handover protocol that uses the direction of arrival estimation of adaptive antennas in combination with other mobile movement prediction methods to reserve capacity in the next predicted radio cell to reduce blocking rates and signalling. The object of our efforts is to show that our approach shows a better performance than other methods. There are the well known standard handover protocols without any prediction as in GSM. Other suggestions can be found in the literature which use correlation of measurement reports of the mobile for example.

The Direction of Arrival (DoA) estimation of adaptive antennas (Figure 6) can be used for short-term predictions whereas long-term predictions can be made with methods that have knowledge of the user´s normal behaviour in time and location, for example neural networks [3].

With the knowledge of the next predicted cell, capacities can be pre-reserved and prioritized for the mobile in advance to reduce the blocking rate and signalling. If the cell is congested, this cell can reduce traffic load by decreasing the traffic of high data rate users or borrowing capacity from the neighbouring cells. This can be done directly by borrowing channels or indirectly by handing over users at the cell borders to other cells. This is considerably simplified by the use of adaptive antennas because beams can be adapted. For this purpose network intelligence, for example intelligent agents, need to be implemented and tested in clustered network entities.

4 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. Our next step will be the testing of advanced handover protocols that use the DoA estimation of adaptive antennas to predict the movement of mobiles.

5 Outlook

When new mobile radio interfaces in the UMTS band are introduced these will have to adapt to the ATM standards. Therefore 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 7 shows the block structure of a part 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.

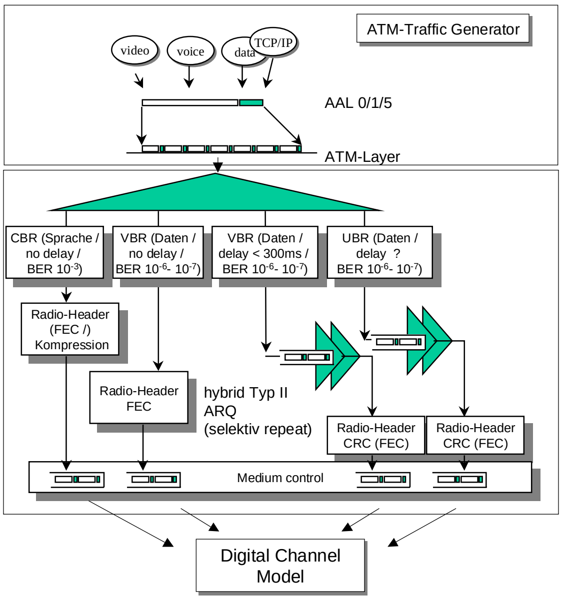


Figure 7: ATM-Traffic Generator and Service Demultiplexing

References

[1] Pizarroso, M., J. Jiménez, Common Basis for Evaluation of ATDMA and CODIT System Conzepts, deliverable b1, 1995

[2] Almgren, M., H. Anderson, K. Wallstedt, Power Control in a Cellular System, 44th. IEEE VTC ´94, Proc. Vol.2, Stockholm, Schweden, 1994

[3] Biesterfeld, J., Ennigrou, E., Jobmann K.; "Location Prediction in Mobile Networks with Neural Networks", Proc. IWANNT'97, Melbourne, June 1997, pp. 207-214

[4] Huo, Di,. Simulating Slow Fading By Means of One Dimensional Stochastical Process, IEEE VTS 46th. Vehicular Technology Conference Proc. Vol.2, 1996

[5] Xia, Howard H.; Reference Models For Evaluation of Third Generation Radio Transmission Technologies, ACTS Mobile Communication Summit ´97, Oktober 1997, Aalborg, Denmark

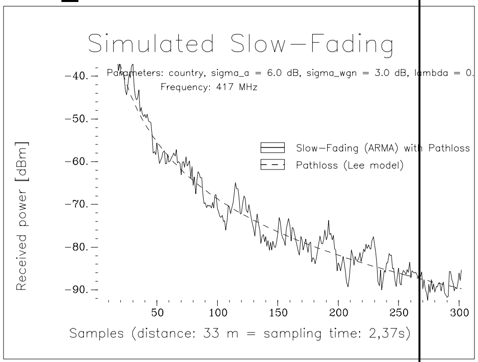
[6] Laurila, J, E. Bonek, SDMA Using Blind Adaption, ACTS Mobile Communication Summit ´97, Oktober 1997, Aalborg, Denmark

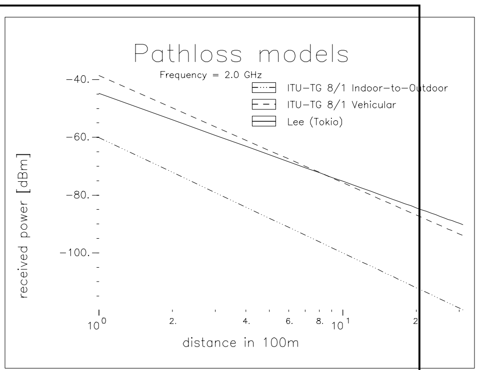
[7] Kist, H., D. Petras, Service Strategy for VBR Services at an ATM Air Interface, Proc. 2. EPMCC ´97

[8] Godara, L.C., Applications of Antenna Arrays to Mobile Communications, Part 1: Performance Improvement, Feasibility and System Considerations, Proc. of the IEEE, Vol. 85, NO. 7, July 1997

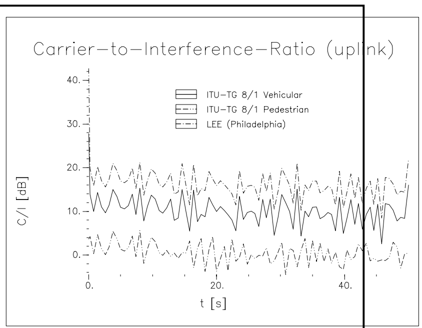
[9] Lee, W.C.Y, Mobile Cellular Telecommunications, Second Edition, McGraw-Hill. Inc,1995

slow_fast

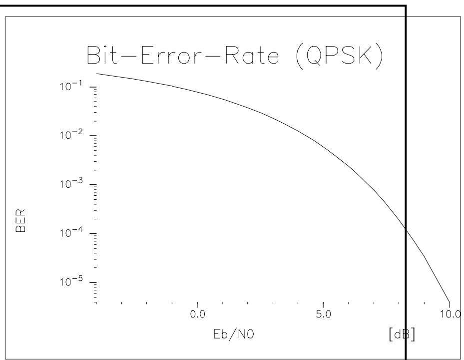




pathloss modelle dBm/m



Cir (unterschiedliche Modelle)



BER