DEFINITION OF SUITABLE SIMULATION SCENARIOS FOR DYNAMIC INVESTIGATIONS IN CELLULAR NETWORKS WITH "STEAM"

Holger Pampel
Enrico Jugl
Lucent Technologies Network Systems GmbH
Thurn-und-Taxis Strasse 10
90411 Nuremberg, Germany
E-mail: {hpampel,jugl}@lucent.com

KEYWORDS

Telecommunications, Model design, Dynamic, Discrete simulation, Computer Software

ABSTRACT

This paper gives an overview on the definition of simulation scenarios for the dynamic system level cellular simulation tool STEAM used within Lucent Technologies for the investigation of radio resource management algorithms in GSM and UMTS networks. It discusses the creation of so-called "wrap-around" scenarios and equal cell loading. Afterwards the influence of dynamic effects like mobility, queuing of incoming calls and filtering of measurements on the simulation results is discussed briefly.

INTRODUCTION

Modern cellular networks are complex systems. With the introduction of UMTS they are getting even more complex. Development of the network infrastructure as well as planning and maintaining such networks are highly sophisticated tasks. Some of the most critical issues are the development of efficient and stable algorithms, the definition of reasonable parameter sets and default settings for these algorithms, and the forecast of reliable performance values for network coverage, capacity and quality under normal and exceptional circumstances.

Most of these questions cannot be investigated analytically, but require simulations. Classical Monte-Carlo simulation tools make a large number of static snapshots defining the network performance in each simulation step based on a completely new set of mobile users. This approach ignores or only approximates any kind of dynamic processes like measurement filtering and timers resulting from variations in the radio channel due to fading, mobility and interference caused by other mobile users. Additionally, efficient radio resource management algorithms for, e.g., handover, call admission control and congestion control have to consider real dynamic changes of the measured radio channels and network state.

STEAM is a dynamic system level simulation tool used within Lucent Technologies for the investigation of GSM and UMTS radio resource management algorithms and other effects in cellular networks. Initially we describe the definition of suitable simulation scenarios. At the end we discuss some of the dynamic effects to be considered.

SIMULATION SCENARIOS

Figure 1 shows the STEAM simulation process. A simulation scenario is loaded from a so-called configuration file; results are logged in statistic files. A graphical user interface is provided for scenario set-up, demonstration purposes and investigation of special effects.

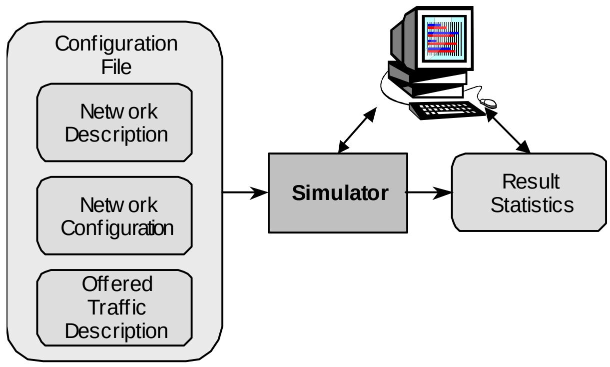

Figure 1: Simulation Process

Scenario Overview

A simulation scenario described in the configuration file consists of a network description, a network configuration and a description of the offered to the network traffic.

Network Description
The network description includes the cell locations and some parameters relevant for radio propagation. It also consists of a pre-calculated pathloss map and it is usually created by a network planning tool. The network description might be modified with the help of some special tools in advance, e.g., to limit the investigated area, to re-plan assigned frequencies or to apply additional shadow fading.

Importing of externally calculated pathloss data has several advantages: no need to implement radio propagation algorithms, support of any real world scenario and a faster simulation process as propagation need not to be calculated online.

Network Configuration
The network configuration configures each single cell including radio resource management algorithms like admission and congestion control, handover, and power control. STEAM supports a wide range of such algorithms

Proceedings 14th European Simulation Symposium
A. Verbraeck, W. Krug, eds. (c) SCS Europe BVBA, 2002

and parameters. Fine-tuning of the network configuration is a complex process requiring detailed knowledge of the underlying algorithms and general network behaviour.

Offered Traffic Description
The traffic offered to the network has significant impact on the observed network behaviour. Not only the overall amount of traffic needs to be considered, but also its geographical distribution, mobility and behaviour of the end user services significantly influence the network performance.

Any number of independent so-called “load generator” instances can be defined in a STEAM simulation scenario. Load generators maintain either a fixed number of mobile users or implement a Poisson arrival process. Each load generator references a so-called “user class” defining type and features of mobile users to be created as well as the requested services. A load generator also references a so-called “mobility prototype” defining the mobility model, desired speed and initial geographical distribution of the mobile users. Multiple load generator instances can share the same user class and mobility prototype.

Scenarios for Algorithm Investigation

The performance of cellular algorithms is usually investigated comparing results of independent simulation runs using different algorithms or parameter settings (Bernhard et al. 2000; Mueckenheim et al. 2000; Mueckenheim et al. 2002). Side effects caused by not equally configured and loaded cells must be excluded as much as possible. This is done best by using idealized non-real world simulation scenarios. Those scenarios can be created in different ways:

Classic Approach
The classic approach is to define a scenario consisting of a cell surrounded by one or better two rings of interfering cells (cf. Figure 2; Zhuge and Li 2000; Czylwik and Dekorsy 2001; Zhang and Yue 2001). Statistics are collected only for the centre cell as all other cells experience less interference. This means that only $^1/_{19}$ or about 5% of the simulation results are used. It is also difficult to define reasonable mobility in an area with such complex layout.

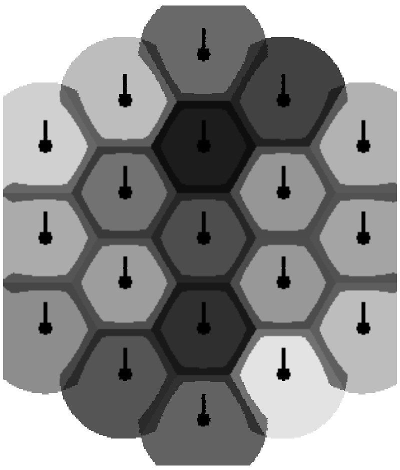

Figure 2: Multi-Ring Scenario

STEAM Approach
STEAM uses a more advanced approach defining so-called “wrap-around” scenarios as shown in Figure 3 with cells simply continued on the other side of the map. A similar approach is mentioned in (Maucher 2002). The creation of such scenarios requires an adaptation of the models for radio propagation and mobility, but all statistics can be used, as all cells have a similar interference situation.

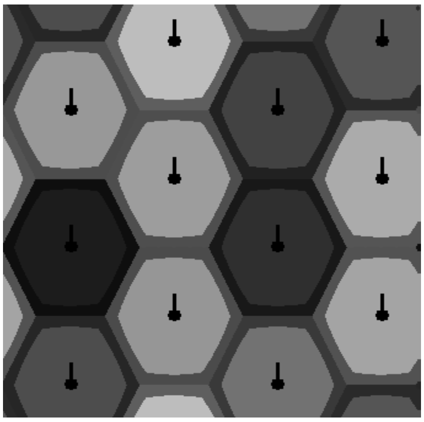

Figure 3: Wrap-Around Scenario

To define the pathloss in wrap-around scenarios the map is virtually extended by the same size in each direction resulting in a nine times larger area as shown in Figure 4.

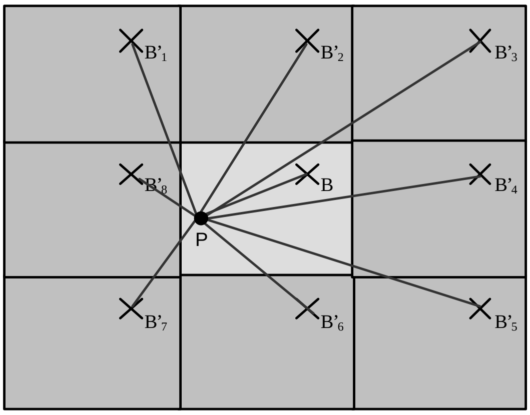

Figure 4: Calculation of Wrap-Around Pathloss

The resulting pathloss between a map location (P) and a base station (B) is defined by the following formula:

$$L'_{P,B} = \min\left(L_{P,B}, \min_i\left(L_{P,B'_i}\right)\right).$$

In other words the resulting pathloss is equal to the smallest pathloss between location P and the original base station B and all virtually created base stations B'_i. Using the minimum value ensures smooth radio propagation.

In wrap-around scenarios the pathloss must be calculated nine times instead of only once in unwrapped scenarios. But as STEAM uses pre-calculated pathloss maps this effort is transferred into a pre-processing step during scenario definition and does not slow down simulations.

Traffic Distribution

Wrap-around scenarios solve the interference problem in the border cells of classical multi-ring scenarios. Additional effort must be spent to load all cells equally.

Equal Sizing of Cells
One solution is to size all cells equally allowing for a homogeneous traffic distribution. Significant differences have been found in simulation scenarios with cells of same size (cf. Figure 3) and cells of different size (cf. Figure 5).

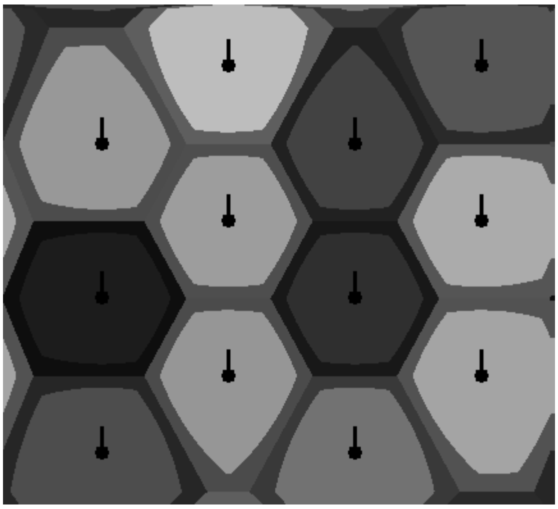

Figure 5: Wrap-Around Scenario With Not Equally Sized Cells

Figure 6 shows simulation results of GSM networks with 7 traffic channels per cell and homogeneously distributed offered traffic. The scenario with not equally sized cells shows significantly more blocking in the interesting range. The blocking calculated by the Erlang B formula with 7 servers has been provided as reference; it is mostly hidden by the curve for equally sized cells.

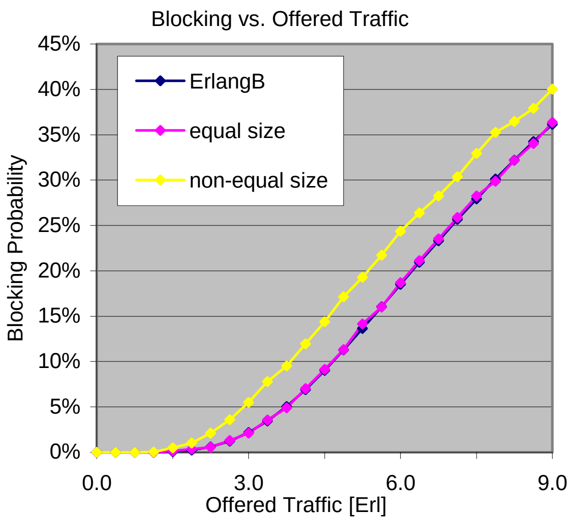

Figure 6: Comparison of Scenarios with Equally and Not Equally Sized Cells

Equal sizing of cells in wrap-around scenarios requires special scenario sizes built-up of multiple base components as shown in Figure 7 in each direction (R is the cell radius).

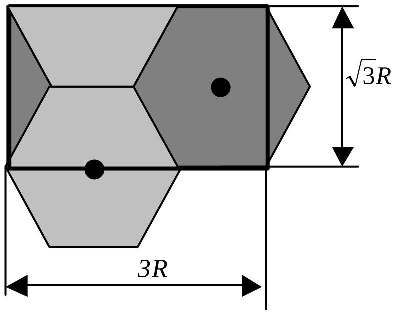

Figure 7: Base Component of Wrap-Around Scenarios

Reasonably sized wrap-around scenarios get measurable interference of the same cell from only one direction and must have consequently at least between 6 and 12 base components in each direction. Additional constraints may result, e.g., from reuse patterns, so-called “clusters”. Figure 8 shows the minimal wrap-around scenario with sectorised cells of cluster size 12 and at least one independent interference ring.

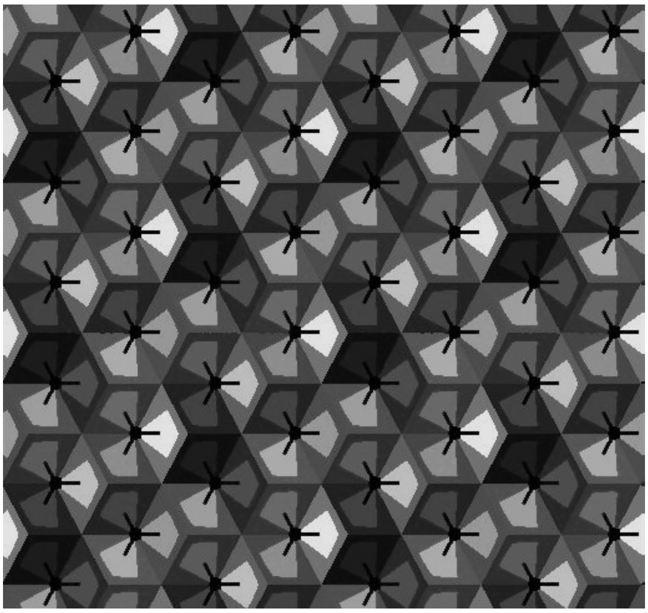

Figure 8: Minimal Wrap-Around Scenario with Cluster Size 12

Intelligent Mobility Models
Another solution is the usage of special mobility models as discussed in (Jugl 2002). They consider the area covered by the cell resulting in larger traffic densities for smaller cells and lower densities for large cells. The mobility model has to preserve the initial traffic distribution manipulating the direction of movement of each mobile user accordingly. STEAM uses for this an algorithm based on the gradient of the traffic density.

Figure 9 shows a plot of the traffic densities calculated for the wrap-around scenario with not equally sized cells depicted in Figure 5.

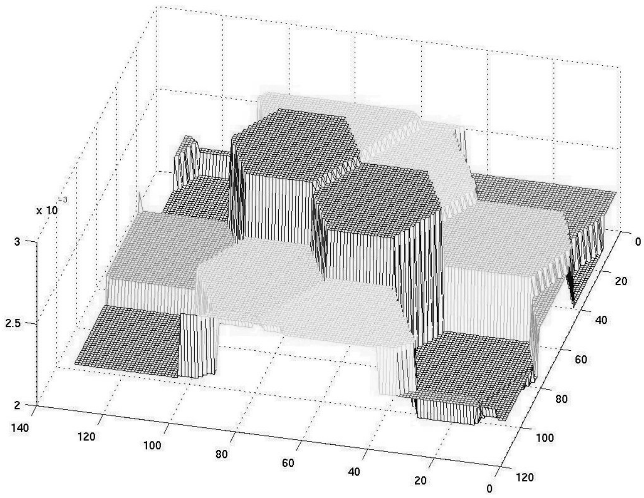

Figure 9: Sample Traffic Densities

INFLUENCE OF DYNAMIC EFFECTS

This chapter discusses selected dynamic effects having significant influence on the simulation results. With this we want to motivate that only real dynamic simulations can reflect the network behaviour appropriately especially when investigating mobility related algorithms like handover, cell selection and reselection, but also admission and congestion control.

Velocity

The most intuitive dynamic effect is user mobility. The speed of the mobile users has impact on a wide range of processes and algorithms. Faster moving mobile users quicker change cells. If all traffic channels in a newly entered cell are occupied, users must stay on their current channel under radio conditions getting worse and worse. After some time those calls "drop", i.e. the call is terminated as the bit error rate exceeds a certain threshold for a certain time. Figure 10 shows this effect of increased dropping probability on higher mobility in a GSM network.

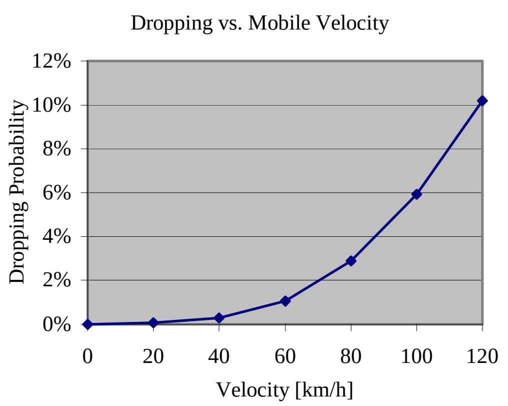

Figure 10: Influence of Velocity

Queuing

When a new call attempt is "queued" it is kept alive consuming minimal network resources waiting for a free traffic channel. Blocking of those calls, i.e. rejection of service due to missing traffic channels, can be reduced by longer queuing times. Figure 11 shows this effect in GSM.

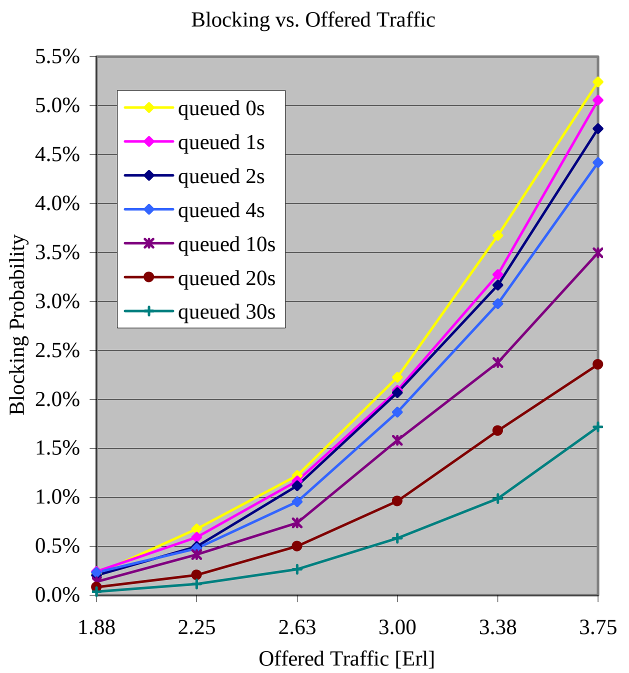

Figure 11: Influence of Queuing on Blocking

Network operators must find a reasonable compromise for this parameters value, as on the one hand a longer queuing time increases network capacity, on the other hand mobile users get frustrated when they have to wait too long.

Averaging Window Size

Mobile stations monitor the receipt level of neighbour cells. The measurements might be filtered afterwards to avoid unnecessary handovers. Figure 12 shows this effect in a GSM network varying the size a of a linear filter window.

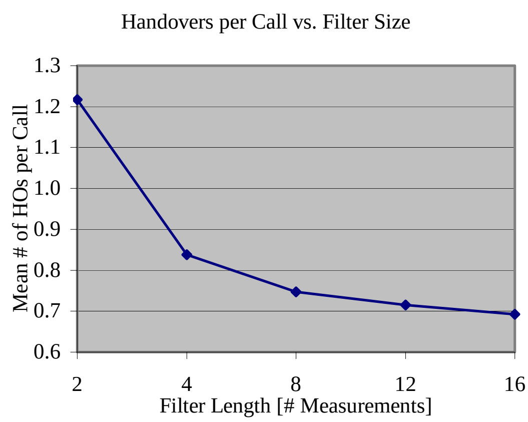

Figure 12: Influence of Averaging Window Size

Longer averaging reduces the mean number of handovers per call. But in this case mobile users change to better cells later reducing also the mean call and network quality.

CONCLUSION

We introduced a new methodology to define homogeneously loaded simulation scenarios required for the investigation of mobility related algorithms like handover, call admission control and congestion control.

Wrap-around simulation scenarios with of appropriate size ensure equally sized cells and consequently equally loaded cells on homogeneously distributed offered traffic. Intelligent traffic loading varying the traffic density based on the covered by the cell area works on any cell layout, but requires more complex mobility models. Both approaches allow for more efficient simulations as all simulation statistics can be used.

Dynamic network simulations are essential to assess network performance and evaluate mobility related algorithms. Only simulations considering all relevant timers, filters and other dynamic effects can show realistic network behaviour. We demonstrated those dynamic effects on selected examples.

Further effort will be spent to simplify the definition of simulation scenarios integrating selected functionality of network planning tools into STEAM automatically creating appropriately sized networks.

REFERENCES

U. Bernhard; H. Pampel; J. Mueckenheim; P. Gunreben. 2000 “Evaluation of Soft Handover Algorithms and W-CDMA Network Performance using Dynamic System Simulations.” *IEE 3G2000*, London, May 2000

J. Mueckenheim; U. Bernhard; H. Pampel; P. Gunreben. 2000. "Performance Evaluation of Connection Admission Control for W-CDMA Networks using Dynamic System Simulations." In *Proc. IEEE SCVT-2000*, Leuven, October 2000, 174-177

J. Mueckenheim; U. Bernhard; H. Pampel. 2002. "Application of Load Control in 3G CDMA Networks for Improved System Level Modelling and Performance Analysis." *IEE 3G2002*, London 2002

L. Zhuge and V. Li. 2000. “Interference Estimation for Admission Control in Multi-Service DS-CDMA Cellular Systems.” *IEEE Globecom 2000*, San Fransisco, USA, November 2000, 1509-1514

A. Czylwik and A. Dekorsy. 2001. “System Level Simulations for Downlink Beamforming with Different Array Topologies.” *IEEE GLOBECOM 2001*, San Antonio, USA, November 2001

Q. Zhang and O. Yue. 2001. “UMTS Air Interface Voice/Data Capacity.” VTC 2001, Rhodes, Greece, May 2001

J. Maucher and G. Kunz. 2002. „UMTS EASYCOPE: A Tool for UMTS Network and Algorithm Evaluation.” *2002 International Zurich Seminar on Broadband Communications*, Zurich, Switzerland, February 2002

E. Jugl, and H. Pampel. 2002. “Mobility Models For Cellular Simulation Tools.” *European Simulation Multiconference ESM 2002*, Darmstadt, Germany, June 2002, 332-336

AUTHOR BIOGRAPHY

HOLGER PAMPEL was born in Saalfeld, Germany. He received the masters degree in electrical engineering from Saint Petersburg Electrotechnical University, Russia, in 1989. From 1989 to 1992 he was a research assistant at the Chemnitz Technical University and IBM Scientific center in Heidelberg. Since 1992 he has been with Lucent Technologies in Nuremberg, Germany. He is working in UMTS systems engineering department on radio resource management aspects with special focus on system level simulations.

ENRICO JUGL was born in Jena, Germany. He received the masters degree in electrical engineering at the Ilmenau Technical University, Germany, in 1996. From 1997 to 2000 he was a research assistant at the Ilmenau Technical University, Germany, and was involved in the project ATMmobil, Integrated Broadband Mobile System (IBMS). In 2000 he received the doctoral degree of electrical engineering in Ilmenau. Since August 2000 he has been with Lucent Technologies in Nuremberg. His current interests are focused on mobility modeling, capacity estimation and performance evaluation of wireless communication systems.