SIEMENS

Corporate Technology

Capacity evaluation for multi-layer GSM networks with voice and data traffic

Kurt Majewski
Siemens AG, Corp. Tech., Munich, Germany

joint work with

Andrzej Maciołek
Nokia Siemens Networks, Wroclaw, Poland

Networks 2008, Sept. 28. – Oct. 02.08, Budapest, Hungary

Copyright © Siemens AG 2008. All rights reserved.

Overview

- Motivation
- Approach
- Example

 © Siemens AG, Corporate Technology

GSM network planning

Motivation: 670 GSM networks with 1.7 billion subscribers demand

- New networks and network extensions
- Hardware upgrades and modifications
- Improved configurations with increased performance
- Adaptations to traffic and load shifts

Goal: Cost-conscious planning and optimization of entire GSM networks

- Site locations
- Number of sectors
- Antenna locations
- Antenna types
- Azimuths
- Mechanical and electrical tilts

*Mostly **discrete** parameters!*

© Siemens AG, Corporate Technology

GSM network planning

Obstacle: Fast evaluation of prospective network performance

- Cost (capex and opex)
- Coverage (versus "no reception")
- Capacity (versus "no free transmit channel")

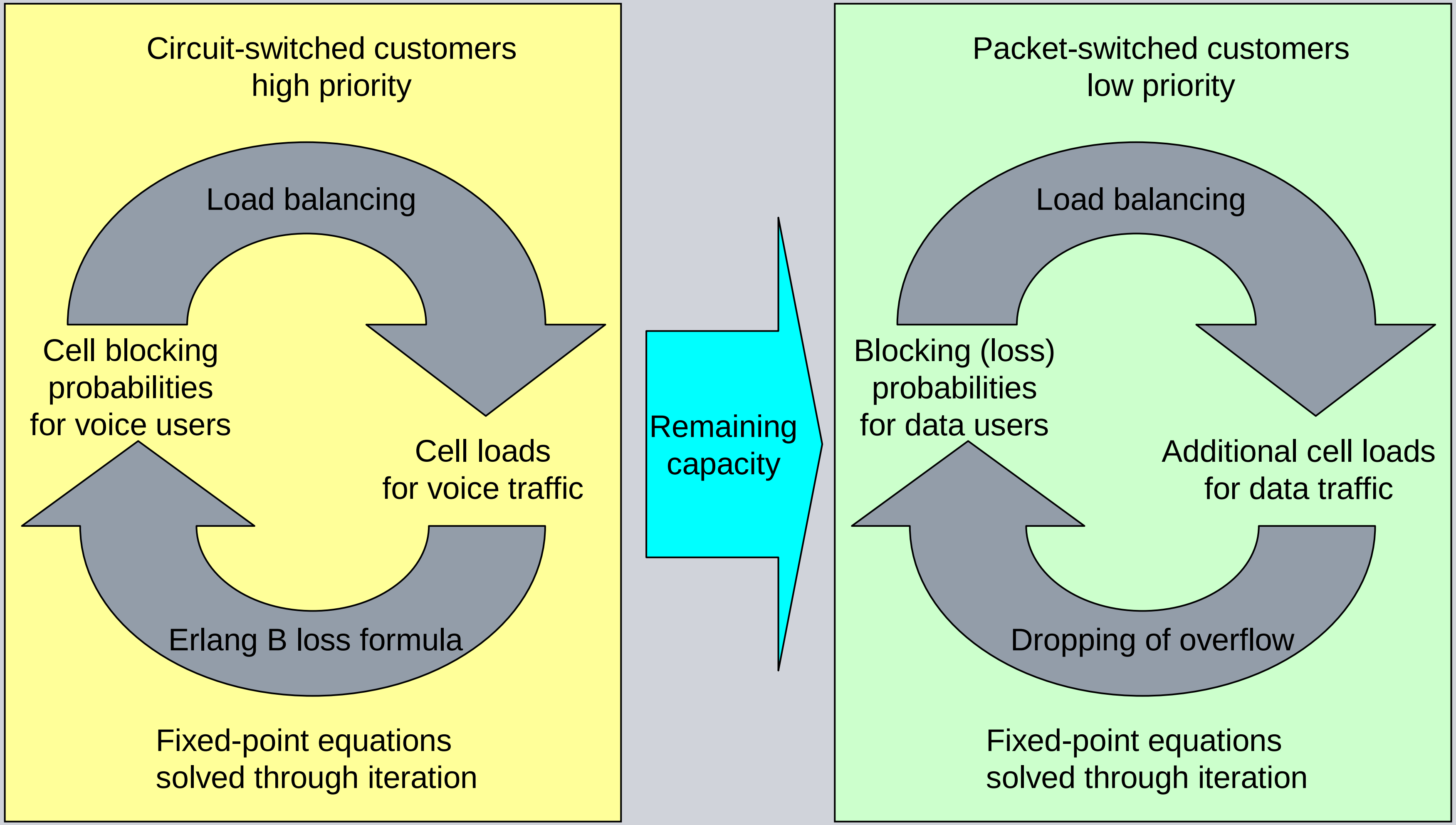
Optimization algorithms rely on **fast** performance evaluations

Additional challenge: Prevailing multi-layer architectures
(e.g. GSM 900 and GSM 1800 frequency layers)

- User can be served by each of the available layers
- Seamless handover between parallel layers
- Handover mechanisms balance the load between the layers

© Siemens AG, Corporate Technology

Overview of our approach



Capacity of network can be deduced from resulting blocking probabilities

© Siemens AG, Corporate Technology

GSM network planning

Limitations of our approach:

- No interference (responsibility of frequency/channel assignment)
- Downlink only (uplink is nearly symmetric)
- Much simplified load balancing
- All dynamic mechanisms and effects ignored
- Mean (or median) values only

Alternative approaches:

- Snapshot simulations
- Markov chain model for load balancing

Greater level of detail, but far to slow for optimization of entire networks

© Siemens AG, Corporate Technology

Our approach

Basic set-up

Talk is restricted to voice traffic only!
Handling of data traffic in proceedings.

- $\boldsymbol{M_{cs}}$ denotes set of **circuit-switched voice** service users
- ***C*** is set of **cells** relevant for planning area
- $\boldsymbol{P_{c,m}}$ is **receive power** of cell $c \in C$ at mobile station $m \in M$
- ***L*** is set of **network layers**
- ***l(c)*** *∈ L denotes* **layer** of cell $c \in C$

 © Siemens AG, Corporate Technology

Our approach

Identify potential server for each mobile station

- Potential server must reach required receive strength at mobile station
- At most one potential server per network layer
- Cell with highest receive strength within its layer

Extension of “best server analysis” to multi-layer situation

We let *C(m)* be the set of **potential server** of mobile station *m* Є *M*. Mathematical definition:

$$C(m) := \{c \in C : P_{c,m} \geq P^{required} \wedge \forall d \in C \; l(d) = l(c) \Rightarrow P_{c,m} \geq P_{d,m}\}$$

We assume w.l.o.g that C(m) contains at most one cell per layer

 © Siemens AG, Corporate Technology

Our approach

Define total order (= ranking) "$>_m$" on C(m)

c $\boldsymbol{>_m}$ ***d*** for two potential server *c, d* of mobile station *m,*
if and only if receive strength of cell *c* is greater
than receive strength of cell *d* at mobile station *m*.
(Again ties are broken arbitrarily.)

Mathematical definition

$$c >_m d :\Leftrightarrow P_{c,m} \geq P_{d,m}$$

(Alternative definitions possible, e.g. through a fixed layer hierarchy.)

 © Siemens AG, Corporate Technology

Model for load balancing

Idea for distributing mobile stations over layers:

Mobile station *m* asks potential server *C(m)* in the order $>_m$ for service. (First asks highest ranked potential server. If blocked by this server second highest ranked one is asked, and so on, until it is accepted by one of the potential server or rejected by all potential server.)

We let $\boldsymbol{\beta_{cs}(c)}$ be the **blocking probability** of cell *c* (to be calculated).

Mobile station is accepted by cell *c* with probability $1 - \beta_{cs}(c)$ if mobile station *m* asks cell *c* for (voice) service.

Probability that user $m \in M_{cs}$ asks cell $c \in C(m)$ for service:

$$\prod_{d \in C(m),\, d >_m c} \beta_{cs}(d)$$

(An empty product gets the value 1.)

© Siemens AG, Corporate Technology

Voice user fixed-point equations

Given the blocking probabilities, we can calculate the number of **transmit slots** which are **requested** from voice users of cell *c*

$$\tau_{cs}(c) := t_{cs} \sum_{m \in M_{cs},\, c \in C(m)} \prod_{d \in C(m),\, d >_m c} \beta_{cs}(d)$$

t_{cs} is average number of transmit slots needed to serve one voice user.

Given the requested transmit slots, we can calculate the **blocking probability** of cell *c* for its **voice** users (Erlang-B loss formula)

$$\beta_{cs}(c) := \frac{\tau_{cs}(c)^{\sigma(c)} / \sigma(c)!}{\sum_{n=0}^{\sigma(c)} \tau_{cs}(c)^n / n!}$$

σ(c) is number of **transmit slots** of cell *c.*

Set of |*C*| fixed-point equations. Numerical convergence in 5 iterations.

© Siemens AG, Corporate Technology

Network capacity

We define network capacity as fraction of served mobile stations

Mobile station *m* **cannot be served** by the network with probability

$$\delta(m) := \prod_{c \in C(m)} \beta_{cs}(c)$$

Hence **network capacity** in percent is

$$\frac{100}{|M_{cs}|} \sum_{m \in M_{cs}} (1 - \delta(m))$$

Planning should grant a network capacity above e.g. 97 %

 © Siemens AG, Corporate Technology

SIEMENS

Continuous traffic distributions

Discrete users can be replaced with continuous traffic distribution.
We let $\boldsymbol{T_{cs}}$ distribution of voice users on planning area A.

Old formula:

$$\tau_{cs}(c) := t_{cs} \sum_{m \in M_{cs},\, c \in C(m)} \prod_{d \in C(m),\, d >_m c} \beta_{cs}(d)$$

New formula:

$$\tau_{cs}(c) := t_{cs} \int_{A(c)} dT_{cs}(x) \prod_{d \in C(x),\, d >_x c} \beta_{cs}(d)$$

C(x) is set of potential server at position x,
A(c) subarea on which *c* is in potential server list,
$d >_x c$ means that cell *d* has higher rank than *c* at position *x.*

Area coverage in percent is:
(Must reach target e.g. 97 %)

$$\frac{100}{\int_A dx} \int_A 1_{\{\exists c \in C\ P_{c,x} \geq P^{required}\}}(x)\,dx$$

 © Siemens AG, Corporate Technology

SIEMENS

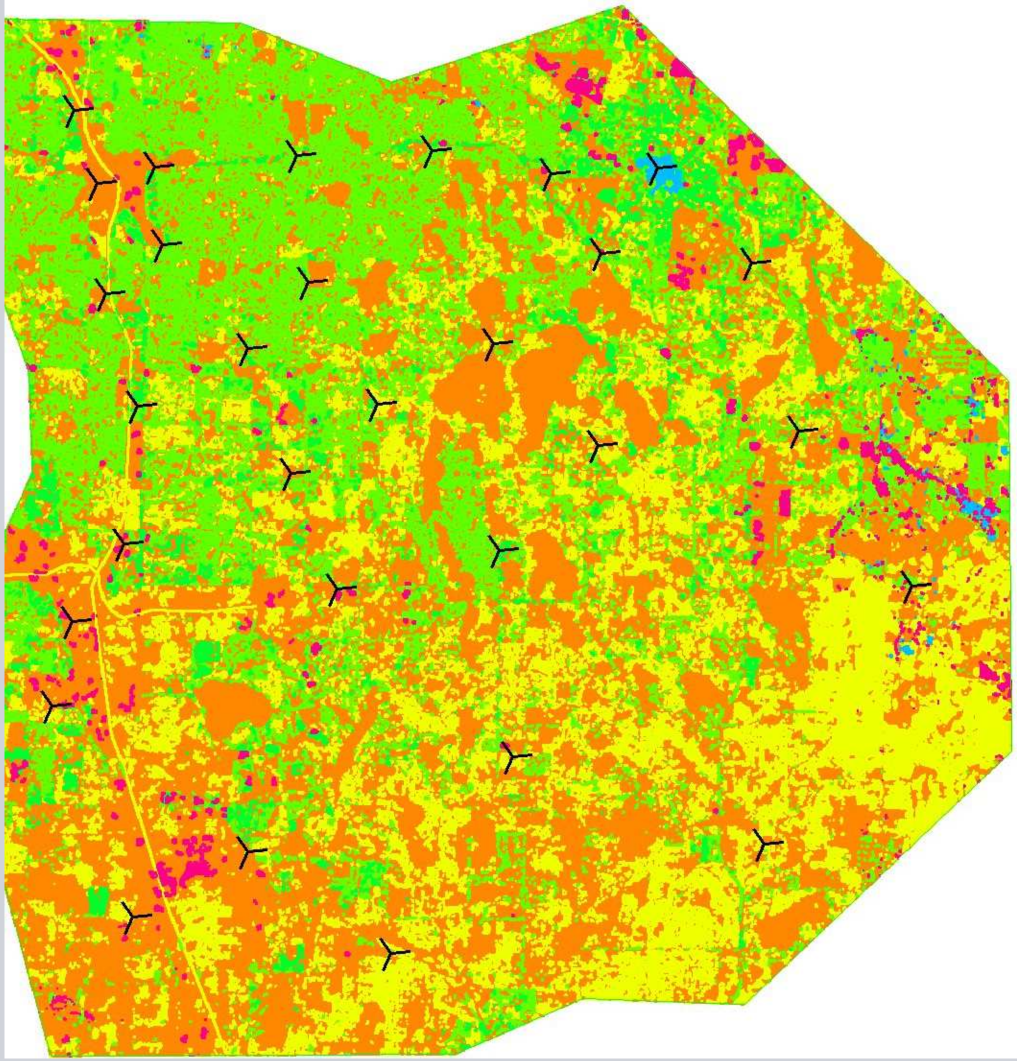
Planning example

30 potential site locations

3 GSM 900 cells per site and
3 GSM 1800 cells per site
sharing the same azimuths

Total traffic distribution
green = little traffic
red/blue = hot spots

Planning area 778 km^2 is
divided into 875 000 pixels



© Siemens AG, Corporate Technology

Planning results: site selection

Which potential sites should be equipped?

Minimize costs subject to
- **97 % area coverage**
- **97 % network capacity**

GSM capacity evaluation implemented in internal Nokia Siemens Networks wireless network planning tool.

Design name	Sites	Cells	Coverage	**Capacity**
All sites	30	180	99.97 %	**97.56 %**
Site selection	21	126	99.91 %	**97.17 %**

© Siemens AG, Corporate Technology

Planning results: site selection

Which sites should be equipped?

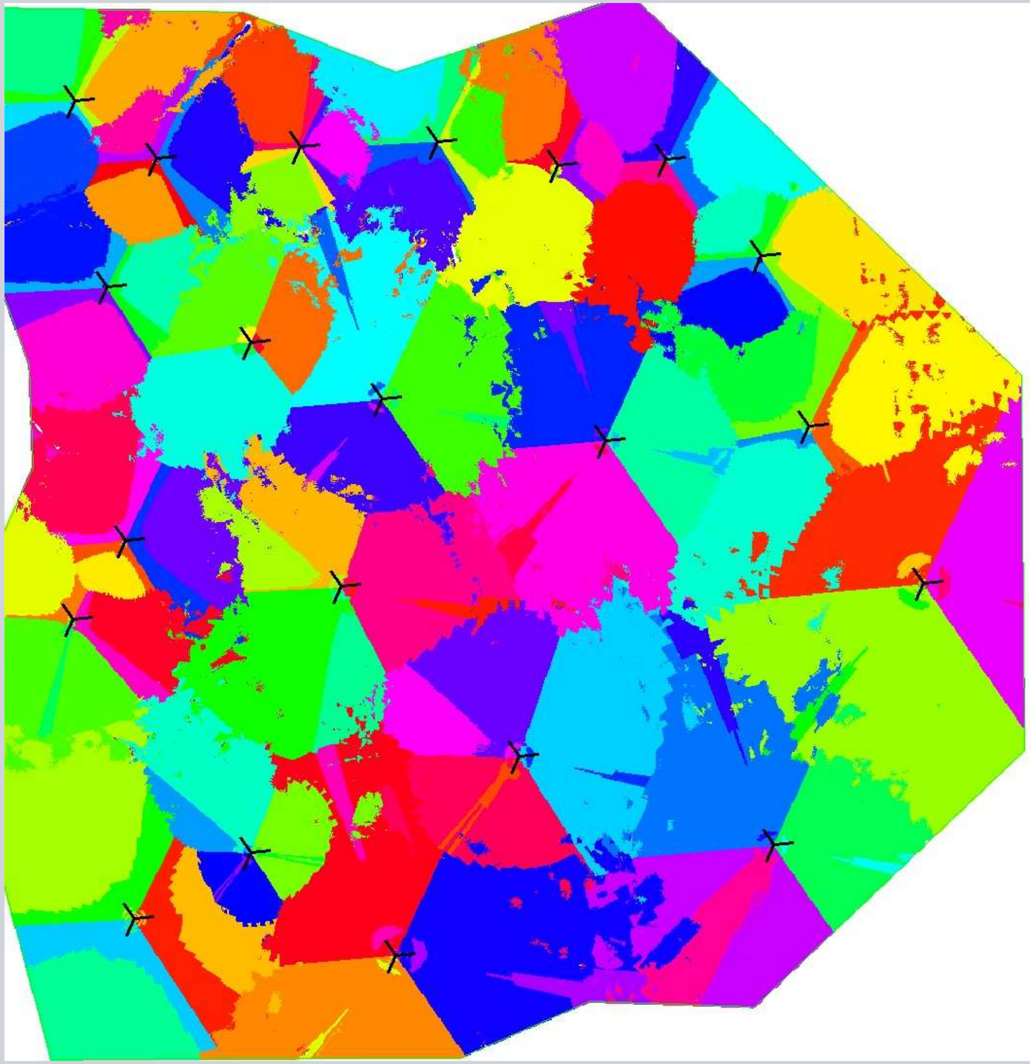
Algorithm: Start with all sites.

For each remaining site:
Calculate coverage and
capacity without this site.

Remove site without which
performance is best.

Iterate as long as performance
meets targets.

21 remaining sites
250 evaluations in 30 seconds



 © Siemens AG, Corporate Technology

Conclusions

Simple **load balancing model**
and **loss assessments**
result in **fixed-point equations**
for **cell loads** and **blocking probabilities.**

Solved through **iteration.**
Network capacity deduced from solution.

Simple and fast.
Optimization on top of this performance evaluation.

Site/cell selection and **site/cell configuration optimization**
problems can be addressed.

© Siemens AG, Corporate Technology

SIEMENS

Planning results: site selection

Which potential sites should be equipped?

Minimize costs subject to
- **97 % area coverage**
- **97 % network capacity**

Design name	Sites	Cells	Coverage	**Capacity**
All sites	30	180	99.97 %	**97.56 %**
Site selection	21	126	99.91 %	**97.17 %**
Site selection and azimuth and tilt optimization	17	102	99.82 %	**97.46 %**

 © Siemens AG, Corporate Technology

Site selection and azimuth and tilt optimization

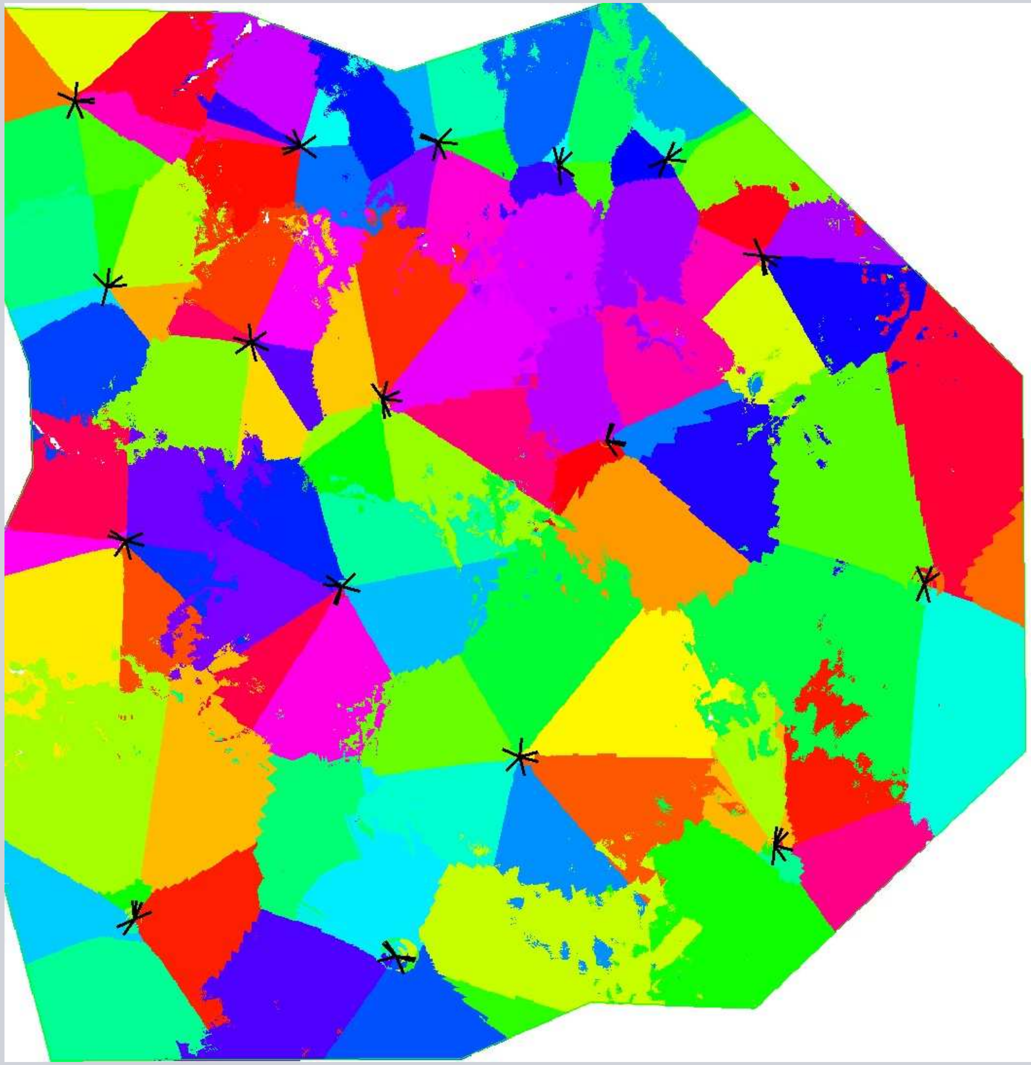
Which azimuths and tilts?

Iterative approach:

Optimize azimuths
Optimize tilts
Remove sites
...

17 sites remaining

10 000 performance evaluations in 2 hours on a 3 GHz processor.



 © Siemens AG, Corporate Technology