Radio Network Planning Aspects for Evolution from 2G to IMT-2000

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Abstract

IMT-2000 standards like CDMA-2000 and UMTS are coming up with rich features like mixture of data and voice services.

Aside the benefits for the user the new air interfaces based on W-CDMA challenges both operators and regulators in the fields of network planning and cross border coordination.

The presentation will, based on the well-understood procedures for recent 2G networks, outline issues coming up by W-CDMA and develop a method for radio network planning for IMT-2000.

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Wireless Networks –
From the Beginning to the 3rd Generation

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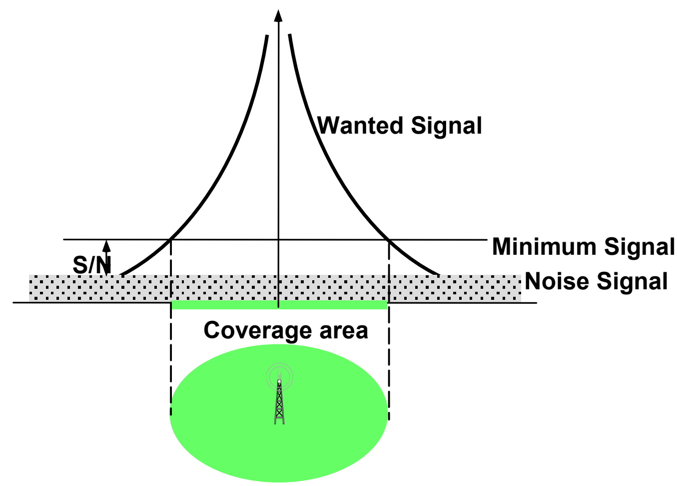
1G Systems: When it all started

- Beginning of mobile networks in the early 1960s
- Main target: to offer voice conversation
  - At any point
  - At any time
  - Without being bound to fixed network lines
- Widespread commercial deployment of 1G Systems started in the 1980s
- Key characteristics of 1G Systems:
  - Analog transmission
  - High power transmitters
  - Simple modulation schemes
  - Nationwide, incompatible systems
  - Voice-only systems



Wireless Networks – From the Beginning to the 3rd Generation

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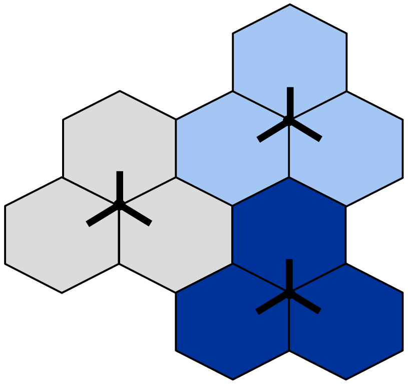
2G Systems: Digital Technology

- 2nd Generation systems ignited the ultimate success story of mobile networks in the late 1980s
- Year 2000: in some countries the number of mobile subscribers topped the number of fixed phone sets
- Key characteristics 2G Systems:
  - Digital transmission
  - Dense site placement
  - Low power transmitters
  - Enhanced modulation schemes
  - Semi-compatible systems
  - Voice focus, but first data service support
  - Step-by-step planning, coverage before QoS



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2.5G Systems: Half Step instead of One

- In the late 1990s it was realized once again that the air interface would soon become a bottle neck
- This time not due to the number of *voice* users, but by the growing demand for *data* services
- The success of the (fixed network) Internet is expected to transform more and more into a similar demand for wireless Internet services
- Key characteristics:
  - Data & voice services
  - Mixed services
  - Circuit & packet switched traffic

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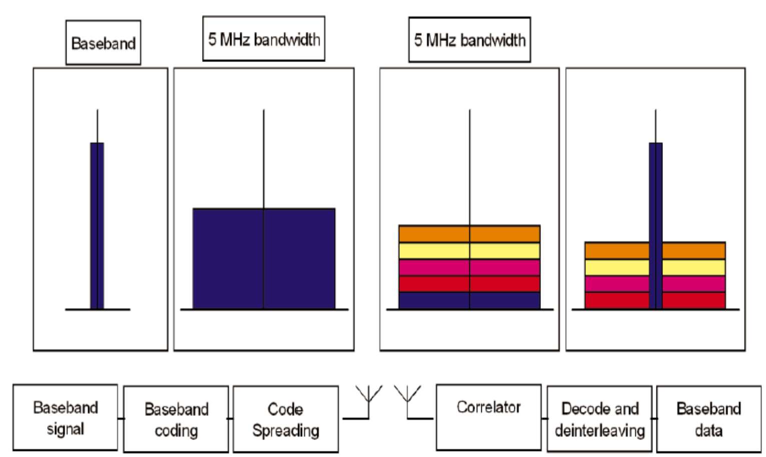
Wireless Networks –
From the Beginning to the 3rd Generation

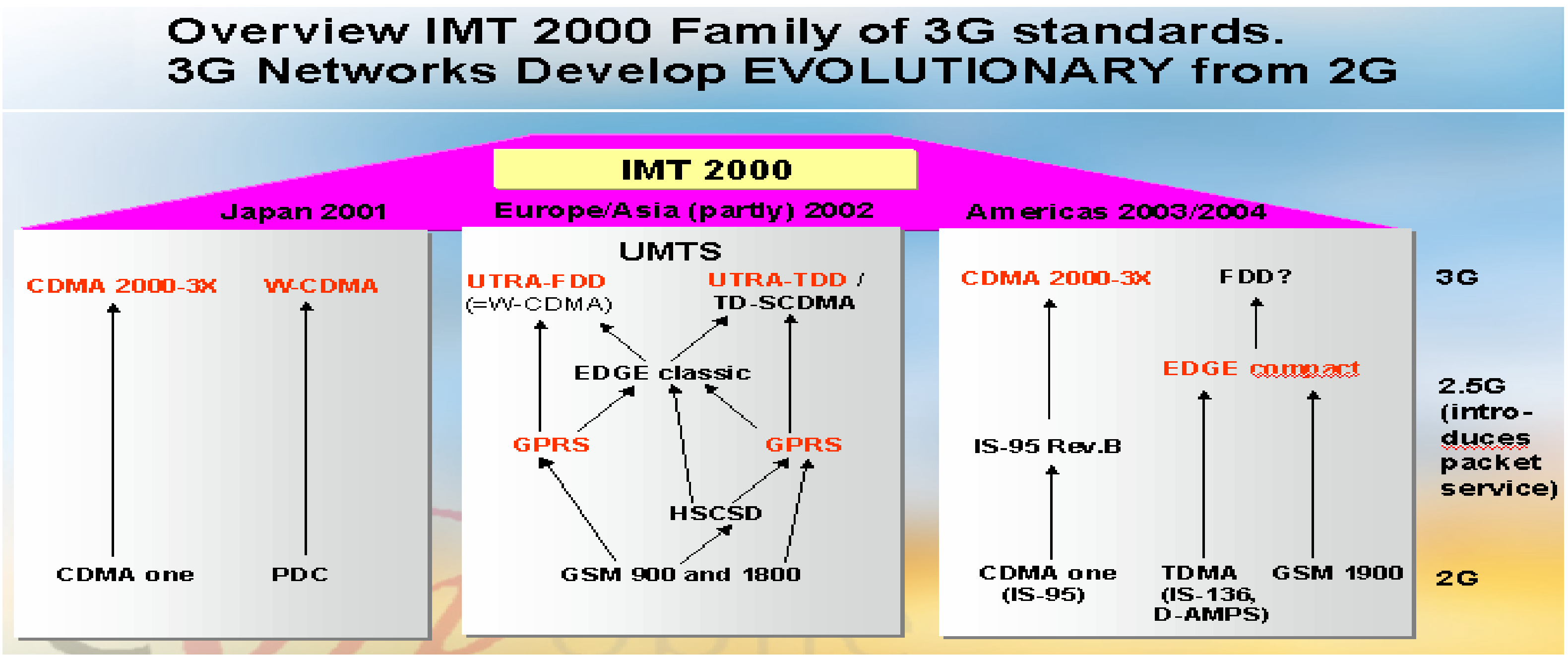
3G Systems: From "Evolution" to „Revolution"

- 3G systems do not simply extend existing 2G, they are completely new
- This forces network planners to use new algorithms and planning processes to create and engineer these systems
- Key characteristics of 3G Systems:
  - Mainly data services
  - Broad range of different data services, multi media support
  - Mainly packet switched data
  - Enhanced multiple access schemes
  - International standardization
  - All-in-one planning, coverage & QoS
  - Co-existence with 2G Systems



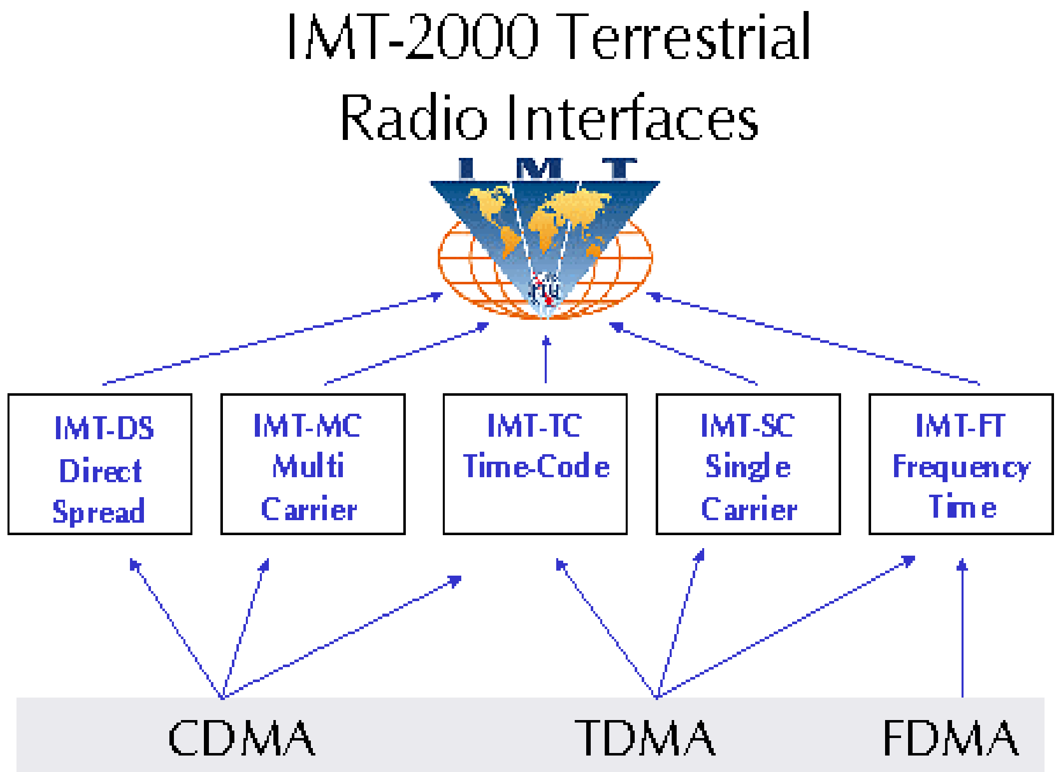
IMT-2000

- Each part of the world has different 2G systems running which determined the development of a next generation into different directions
- The so-called “3G” standard has become a mixture of several allowed air-interfaces
- The framework of this 3G standard(s) is IMT-2000 and has several family members



IMT-2000

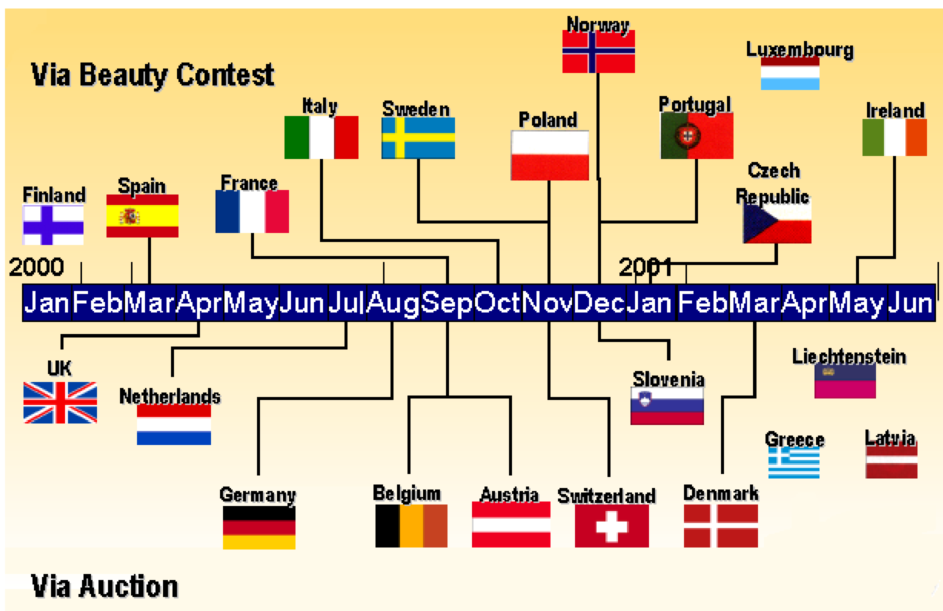
- Result for IMT 2000: Five different radio technologies
  - IMT-DS		Direct Spread
  - IMT-MC		Multi Carrier
  - IMT-TC		Time Code
  - IMT-SC		Single Carrier
  - IMT-FT		Frequency Time



- 3GPP UMTS is approved for
  - IMT-DS with UTRA-FDD
  - IMT-TC with UTRA-TDD

IMT-2000

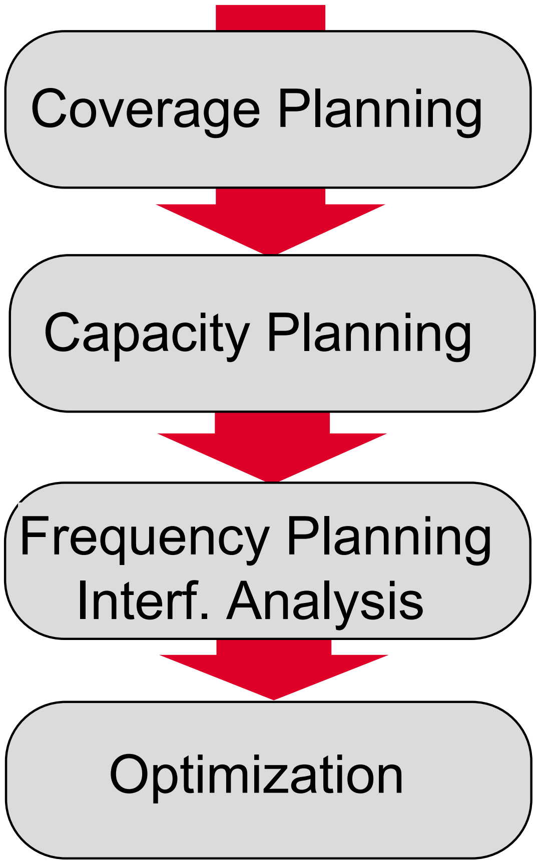
- "3G" in "GSM dominant countries" means for operators and network engineers mostly "UMTS" (wide band CDMA, FDD mode and TDD mode), whereas during the first roll out phase operators will stick to the FDD mode to be deployed for macro cellular approach.
- The following sections will concentrate on the most popular 3G technologies in "GSM dominant countries", that is the UMTS-WCDMA FDD and TDD mode used for urban and suburban environment.



Planning of Wireless Networks

- planning of wireless networks always encounters a set of parameters which must be optimized simultaneously
- some of these “global” parameters interfere each other
- a single “optimal” planning solution does not exist, but a *set* of “equally optimal” solutions
- the task of planning a mobile network is a so-called **multi-dimensional optimization problem**

Planning of 2G Networks



- to achieve the necessary coverage of the desired area
- site location planning just in terms of coverage analysis, separated from capacity, QoS and GoS evaluations

- determine the traffic load per cell
- calculate the number of frequencies needed separated

- do a frequency plan assignment
- analyze the resulting interference situation

- repeat the loop for network optimization

Please note: these steps are assumed to be **independent** from each other. If the traffic load exceeds a cell's capacity, it can be extended by adding another transceiver to the cell

Planning of 3G Networks

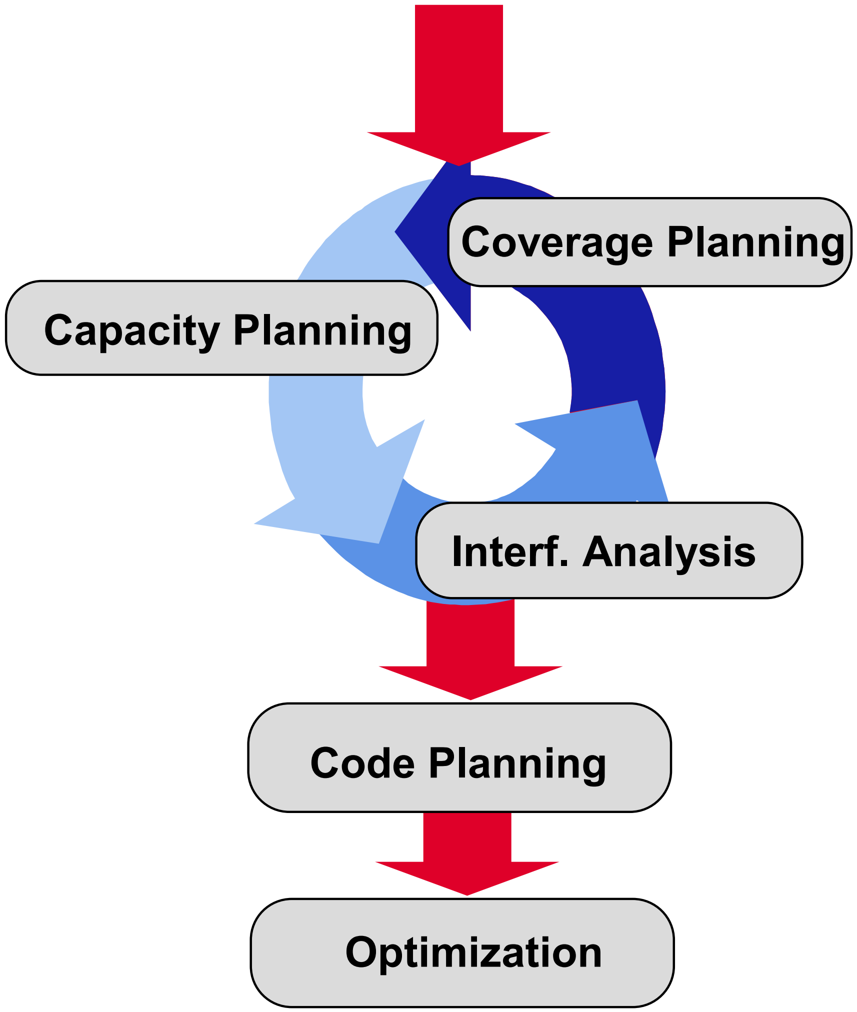
- Especially for GSM-dominant countries 3G/UMTS is a completely new technology

- There are major differences like
  - cell breathing effects (compared to GSM networks)
  - mixed traffic scenarios (packet and circuit switched)
  - mix of services (bit rates, etc.)

- There is a dependency between load and coverage area of a cell
- The separation of coverage planning, capacity planning and interference analysis will no longer work in 3G systems

⇒ new challenges for radio network planning engineers

Planning of 3G Networks



coverage planning,
capacity planning
and interference analysis
are no longer independent from each other

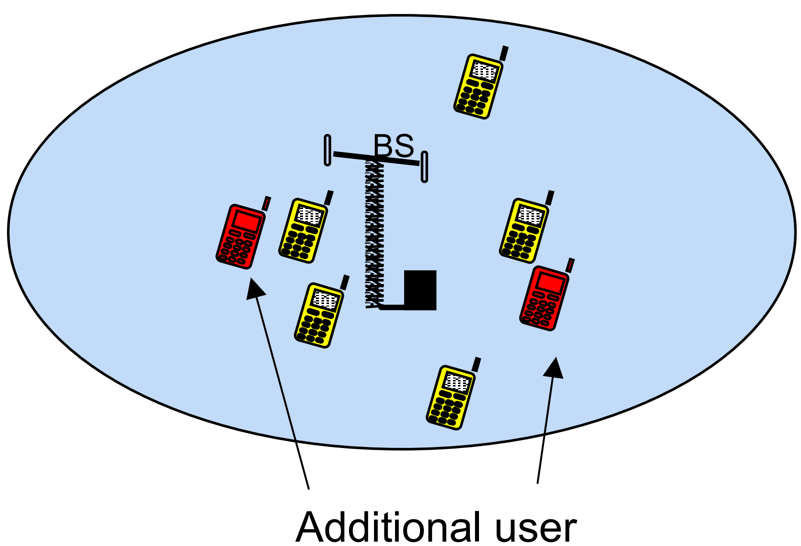
More traffic -> more interference
More traffic -> coverage area of a cell shrinks

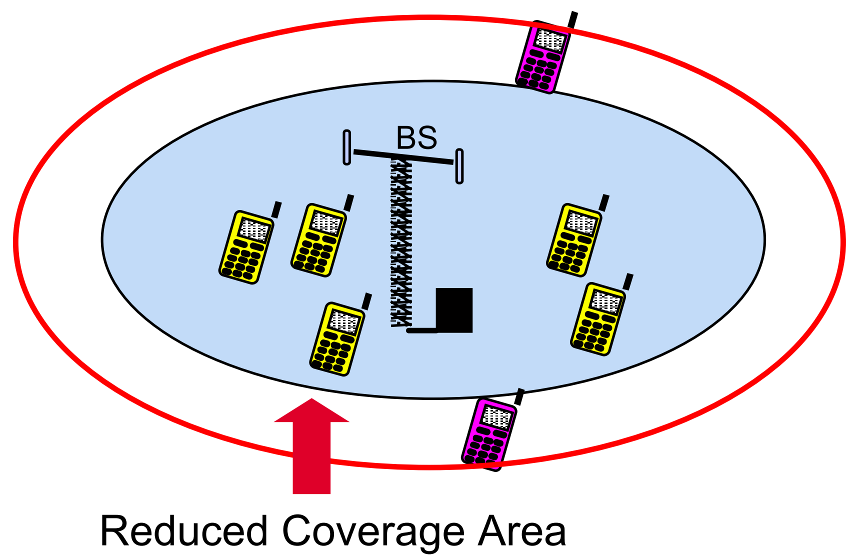
This dependency between load in a cell and cell size will make the cell edges “float” dynamically and thereby can lead to dropped users

Dynamic cell areas -> „cell breathing“

Cell Breathing

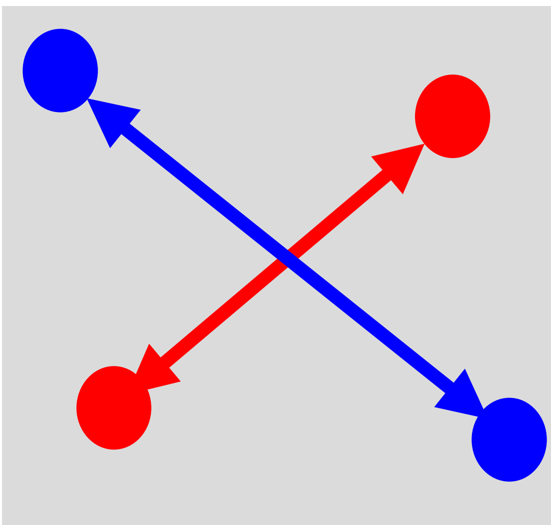
- More users inside a cell increase interference signal (noise)
- Power control has to increase the transmit power to fulfill the E_b/N_0 requirements
- Users far apart from the BS who cannot increase their power anymore
- Their connection will be lost
- When the cell load increases the coverage area shrinks and vice versa
- The cell is breathing



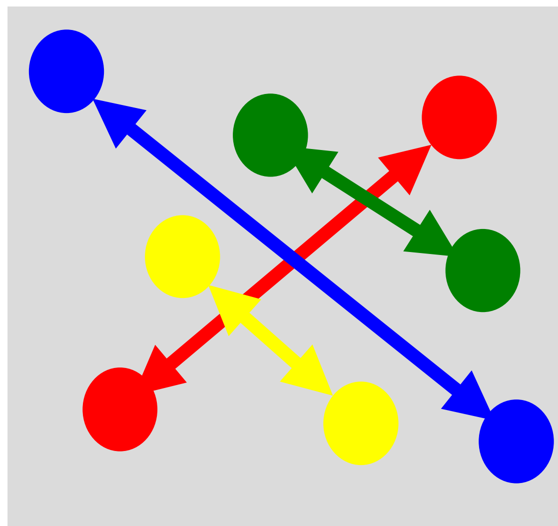


Cell Breathing

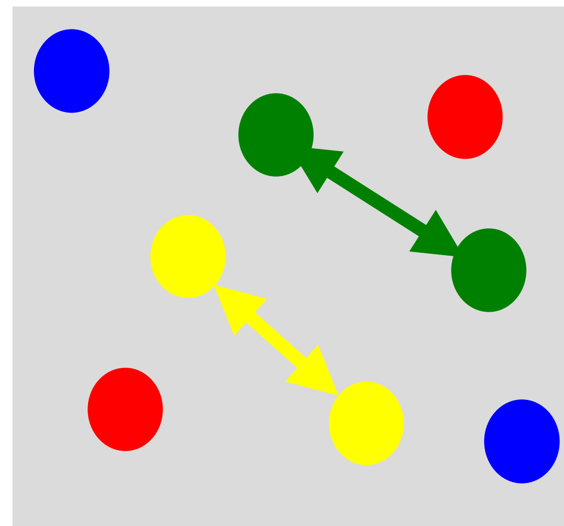
Party Scenario



- 2 couples in one room
- Noise level low
- Interference level low
- conversation possible

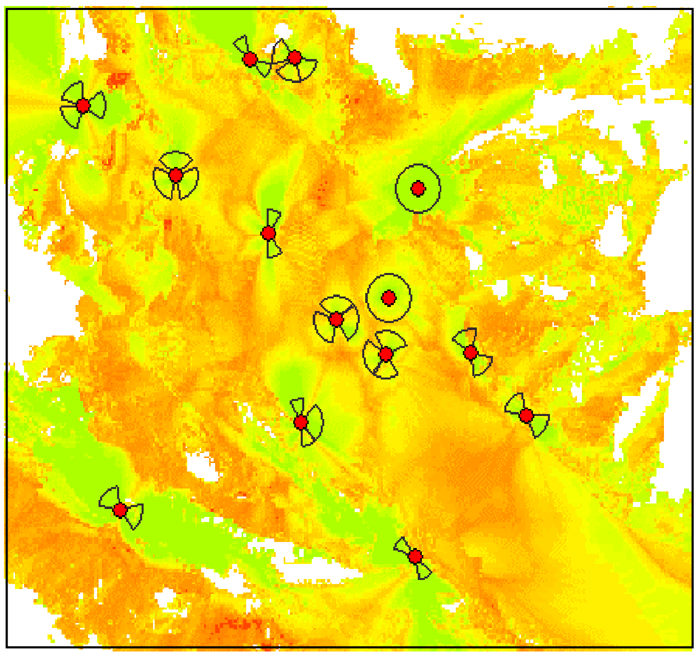


- 2 additional couples enter the room
- Noise level goes up
- Interference level goes up

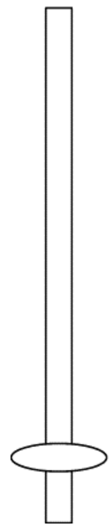


- Noise level too high for red and blue couples
- Distance to far
- Conversation no longer possible

Cell Breathing



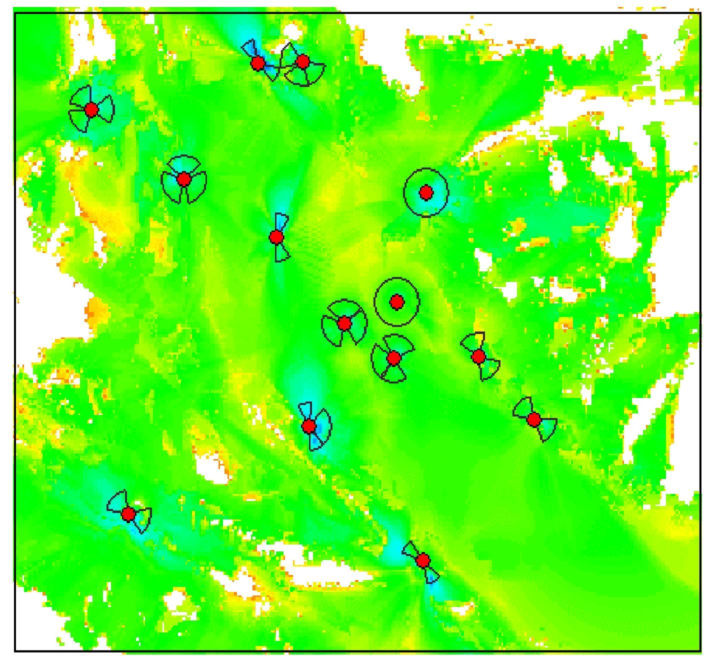
Downlink Coverage



high

Number of Users

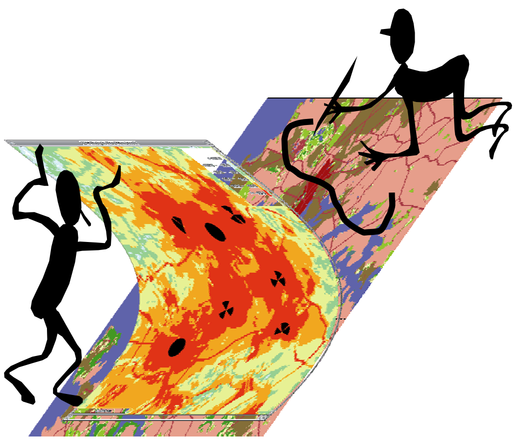
low



Uplink Coverage

Planning of 3G Networks

- Capacity enhancements have to be considered from the beginning
- It won't be possible to add another frequency /TRX
- That means at the beginning:
  - smaller cell sizes than necessary
  - More base stations than necessary
  - Higher invest



- If the traffic estimation was to low
  - Cell areas will shrink
  - Coverage holes in the network will appear

This could only be solved by adding additional base stations

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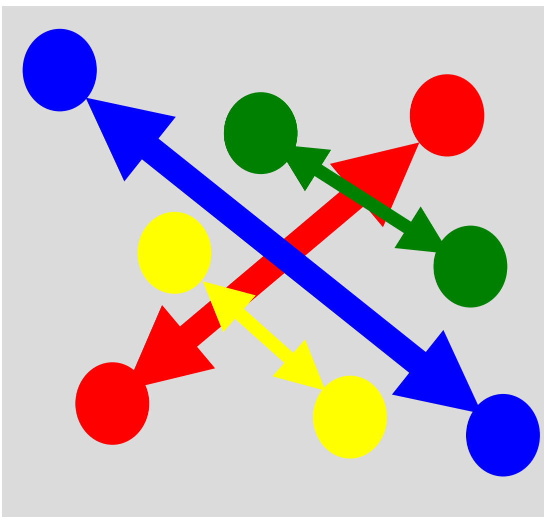
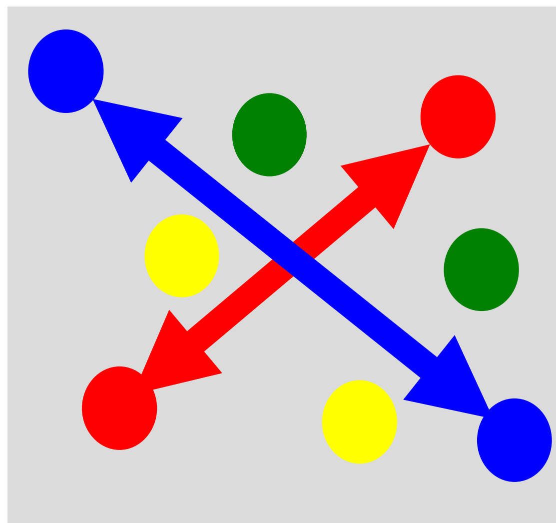
Planning of 3G Networks

Increasing the power of the base stations is not a solution!!

Party Scenario:

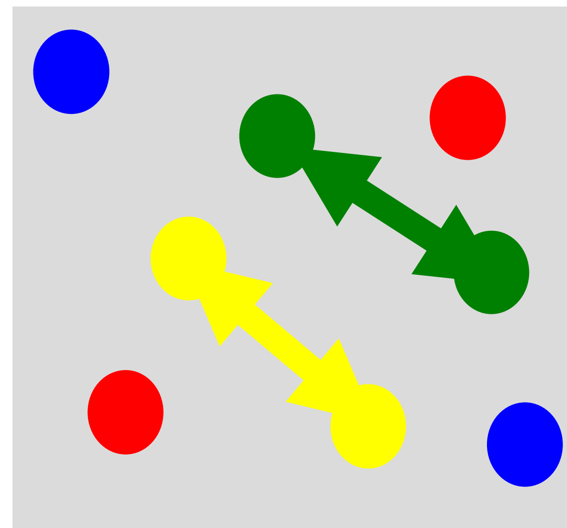


- „far-distance“ couples will speak louder
- conversation for them again possible



but now:

- others guests are interfered
- they also will speak louder



- same situation as before

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Near Far Problem

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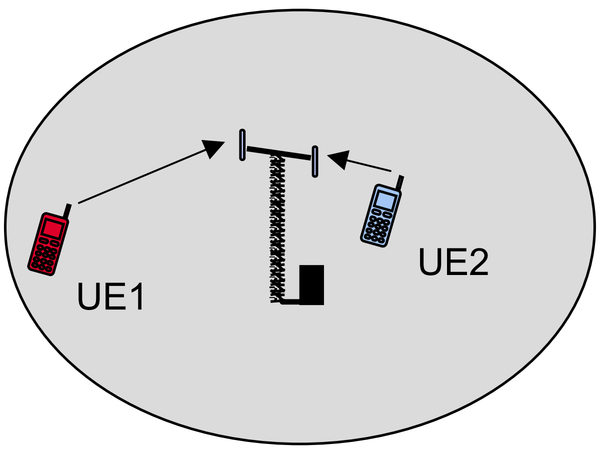
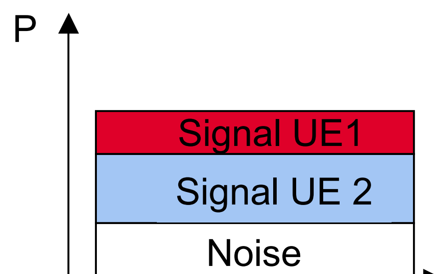
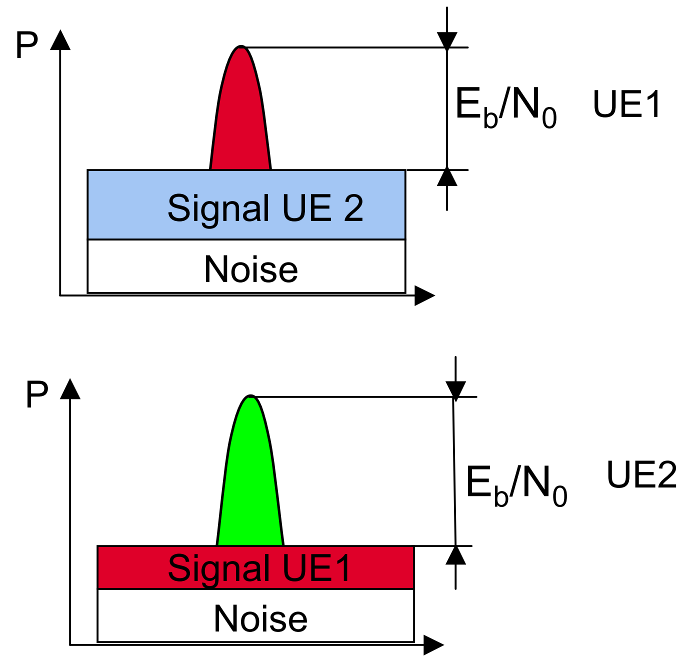
- All users share the same frequency band, causing interference to other users in the cell
- Users closer to the BS receive higher power than mobiles far from the BS
- Users nearby will constitute interference that degrades the performance of the system





Power at Base Station



Power at Base Station after de-spreading

Near Far Problem

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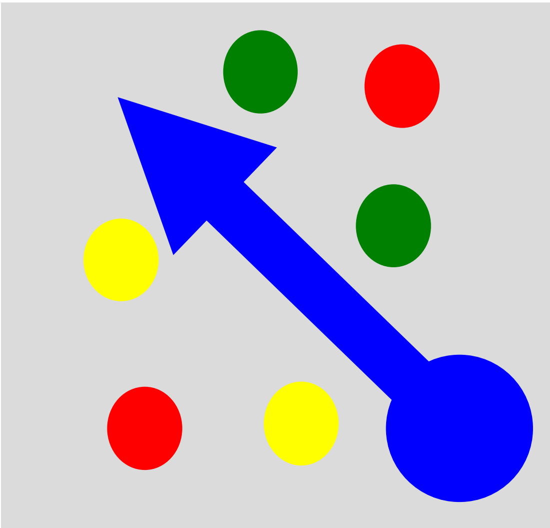
- A way to overcome the near far effect is to apply **fast power control**
- The goal is to reduce the transmitted power to the minimum
- Without power control a single “over-powered” mobile could block a whole cell by causing high interference to the other users



Party Scenario:
a single loud shouting guest could stop all conversations in a room

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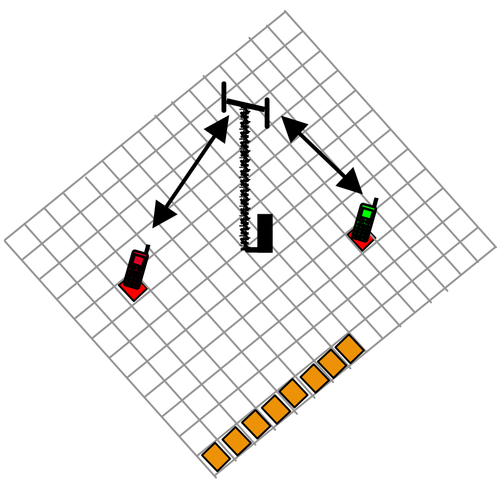
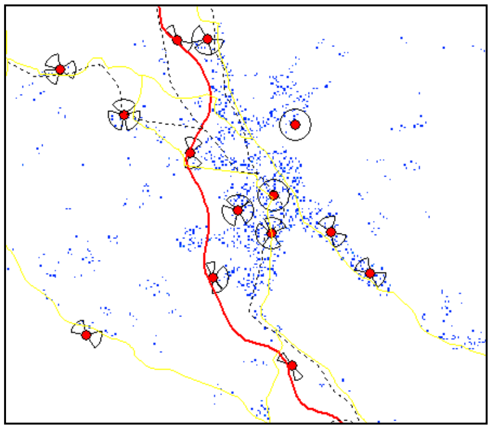
Near Far Problem

- But the Fast-Power-Control- Mechanism will not solve all „near-far problems“
- Users in a cell are also sharing the output power of the BS
- A user far away from the BS needs an over proportional part of the BS output power

The capacity of a cell is dependent on the distribution of users / mobiles in the cell





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Uplink and Downlink Planning

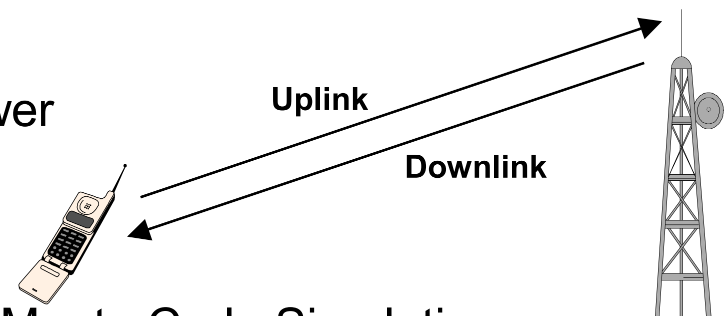
- Asymmetric traffic -> different data rates in uplink and downlink
- coverage areas and capacities are different for both directions

Up- and downlink have to be planned separately

In GSM network typically only the downlink is simulated in tools

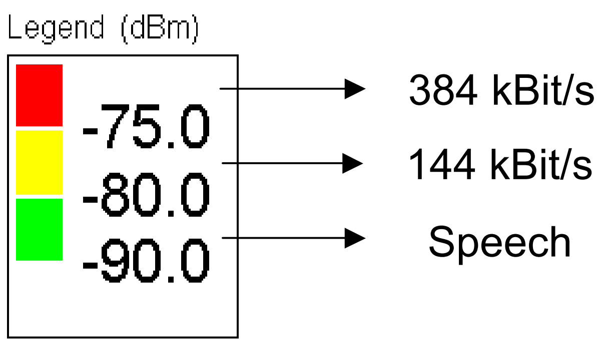
A planning procedure based on a planning tool can consist of the following steps:

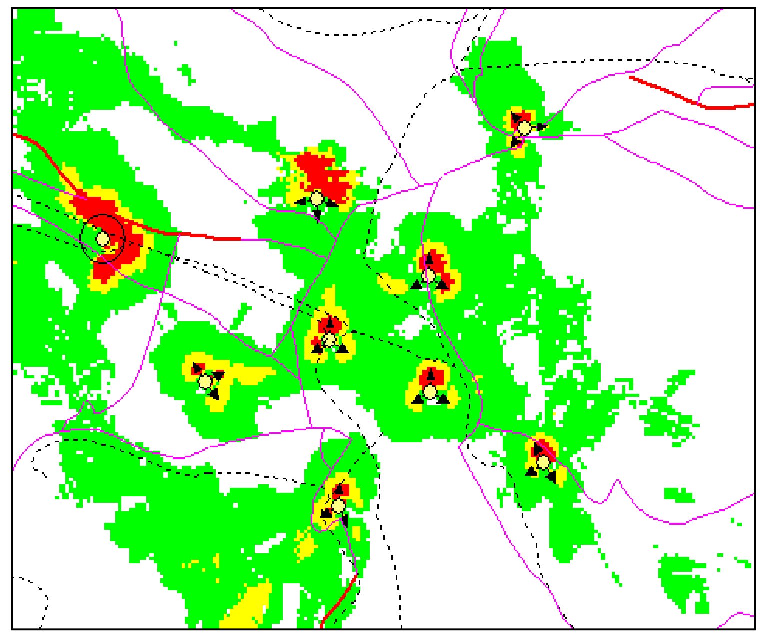
- Considering only Downlink:
  - planning of cell areas based on Pilot Power
  - establishing of handover area
- Considering Up- an Downlink:
  - Verification of the coverage areas with a Monte Carlo Simulation
  - traffic scenarios have to be known



Planning Approach Pilot Power

- determination of coverage areas by calculating the received power of the pilot channel
- consideration of the cell load by adding margins for the interference level
- a minimum needed pilot power for each service can be calculated
- an estimation of the different service areas is possible
- no exact calculation of the Uplink

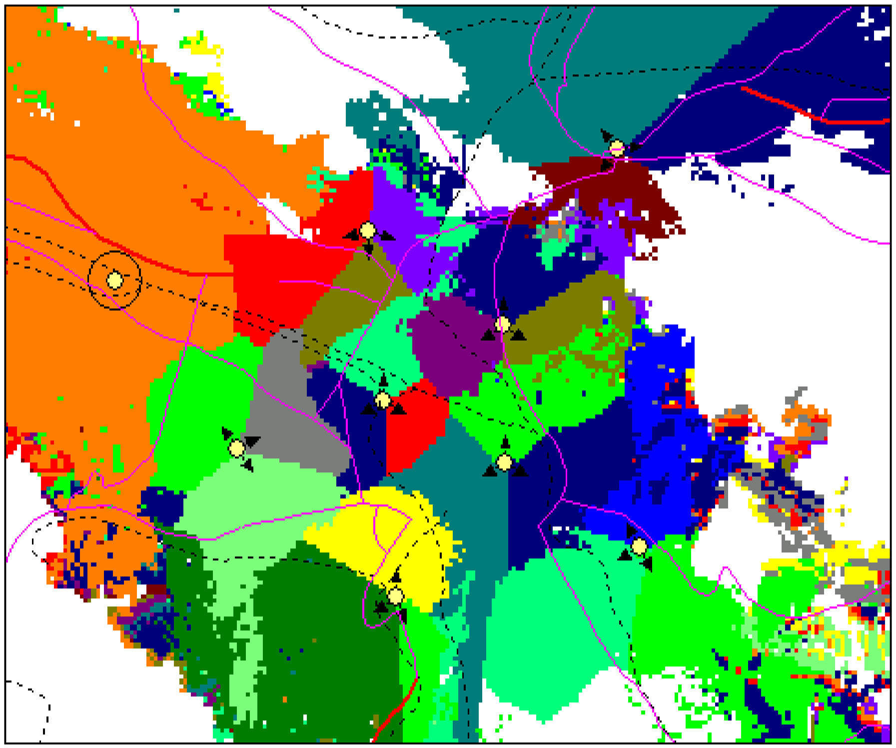




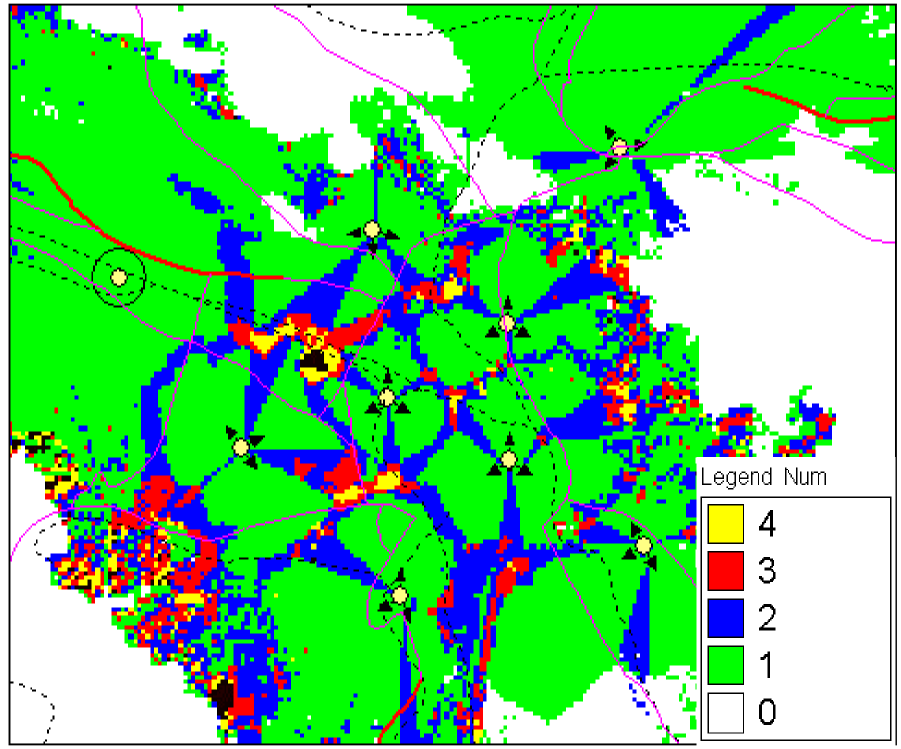
Pilot power for test network

Planning Approach Pilot Power

- Even if the approach with Pilot Power fits not perfect for the planning needs, it can be used for a first rough estimation of the coverage areas and the handover zones.



Cell Structure for Test Network



Handover Areas for Test Network

Planning Approach
Monte Carlo Simulation

To be able to compute the coverage area, the interference situation of the network must be calculated **for Uplink and Downlink**

- Needed information:
  - expected number and locations of users
  - services used by the users

One way to do this is the so called **Monte Carlo Simulation**

Steps for performing the Monte Carlo Simulation:

- Distribution of Users / Services in the Service Area
- Calculation of the interference Situation for Uplink and Downlink
- Simulation of Power Control until a stable situation is reached
- Transformation of the results achieved for the different mobile positions to the complete network area

The steps have to be done several times to achieve a good statistical relevance

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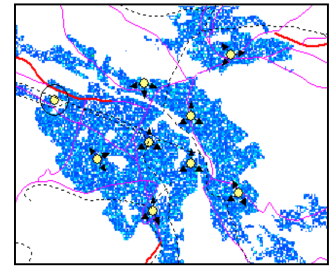
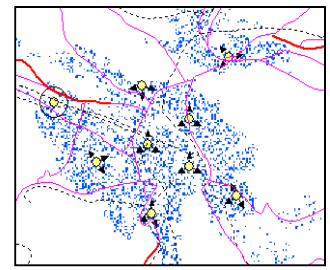
Planning Approach
Monte Carlo Simulation

Distribution of users and services in the network

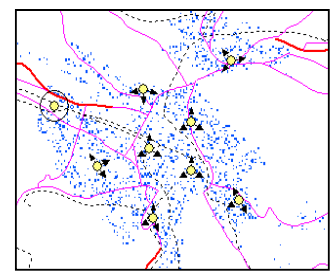
Service	Clutter Class		
	Urban	Suburban	Rural
384 kBit/s	5	2	0
144 kBit/s	10	8	
Speech	30	10	5



Subscribers Speech



3 Subscribers 64 kBit/s

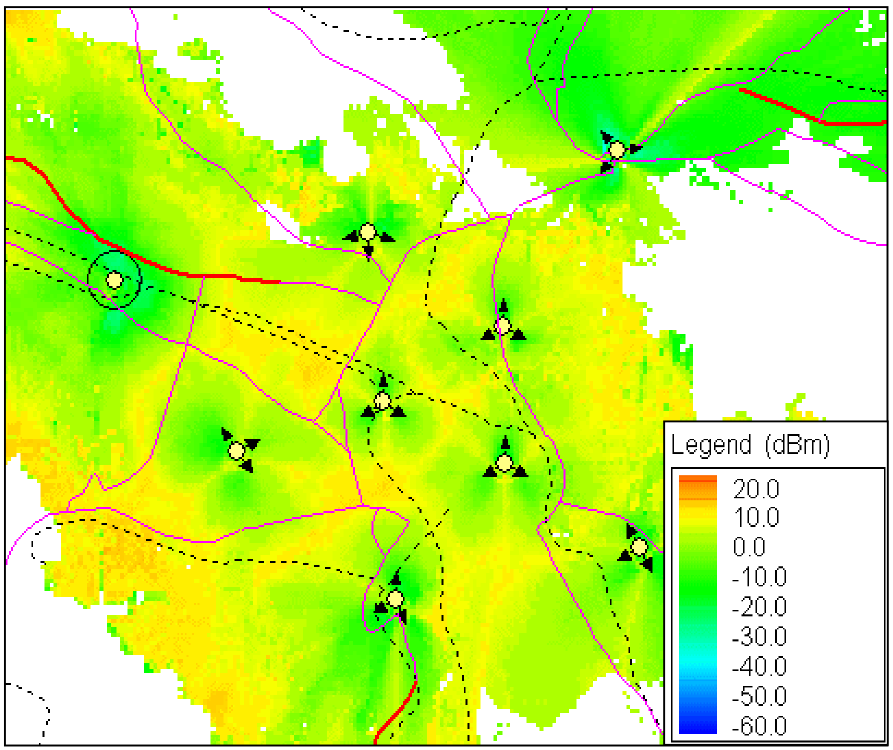


Subscribers 384 kBit/s

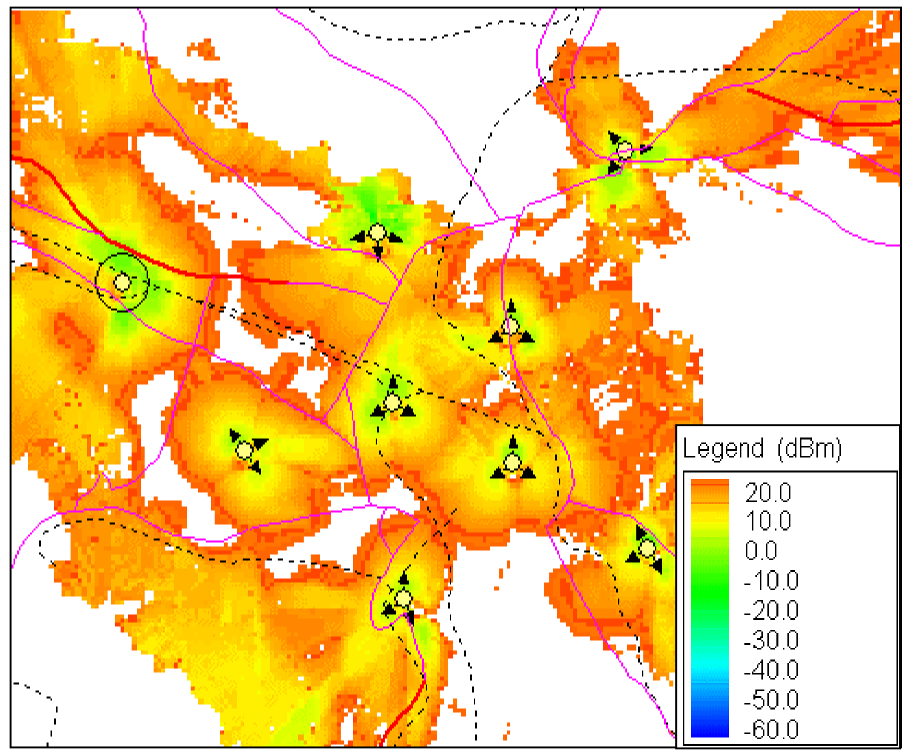
Result: Needed transmit Power

Result Type:

needed transmit power to achieve a connection for a defined service by a given network load.



Needed transmit power in **Downlink** for speech service



Needed transmit power in **Uplink** for speech service

The Impact of Service Mixes

- In 2G there was only one service, therefore **co-interference** caused by other services simply did not exist.
- Although the „cell breathing“ already did exist in IS-95, it wasn’t such a big issue, as it affected only the one and only „voice“ service.

Therefore new questions are coming up, like:

- What impact does that one new 2Mbps packet-switched data user in a cell have on the 20 (circuit-switched) voice users and the one 384kbps packet-switched data user currently logged on? – **Will you have to drop the later and/or some of your voice users?**

- Or, assume you have a stable 3G network in a city area and suddenly, a bus of tourists arrives, step out and switch on their multi-media 3G handsets to send live movies of their voyage back home. – **What will be the impact on your network?**

The Impact of Service Mixes

- One of the key features of 3G Systems is its inherent flexibility regarding data rates and service types
- there exist lots of services and they are very different from each other
  - in their data rates
  - in their traffic types
  - in their and QoS demands
- 3G networks cannot be optimized per service but only per service mix as a 3G base station serve all users and their specific services within its cell simultaneously

A cell will no longer have one coverage area,

a cell will have one coverage area for each service

But based on which service/coverage area should the planner dimension the network?

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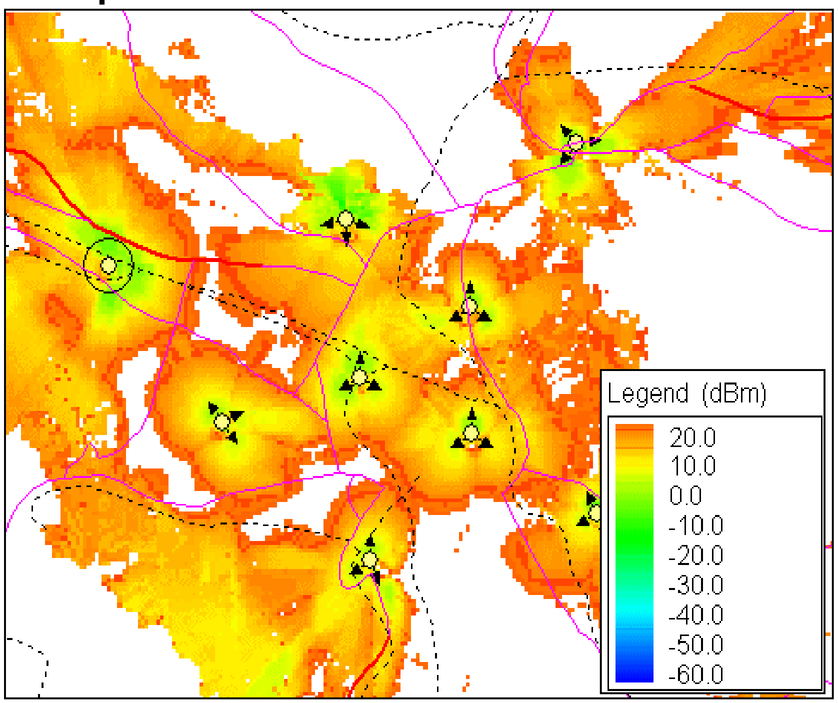
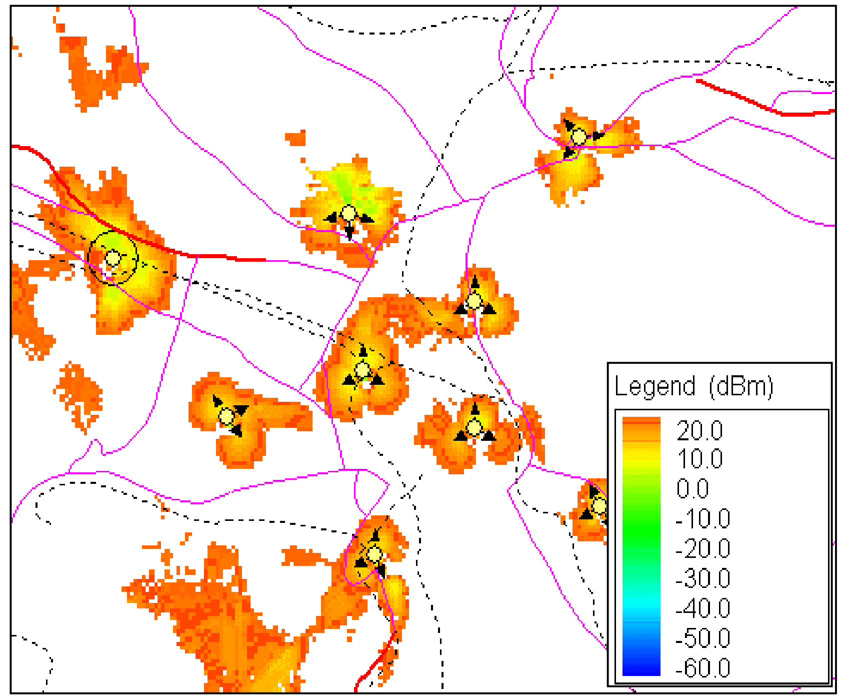
Coverage Areas for Different Services

Comparison Uplink Coverage Speech / 64 kBit/s

Needed transmit power in Uplink
for **speech service**



Needed transmit power in Uplink
for **64 kBit/s data**

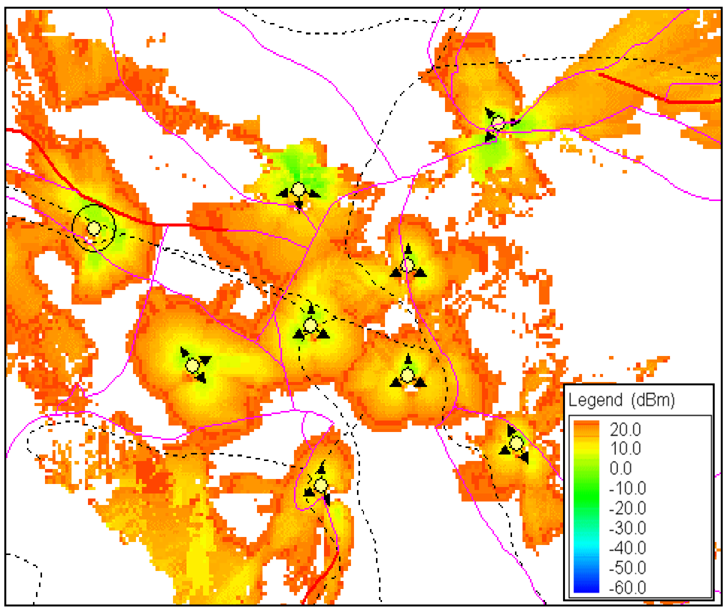


Services with a high data rate use a lower spreading factor. Therefore they operate with a small processing gain, and need in general a higher transmit power to achieve the required Eb/No. This will lead to smaller service areas compared to speech service

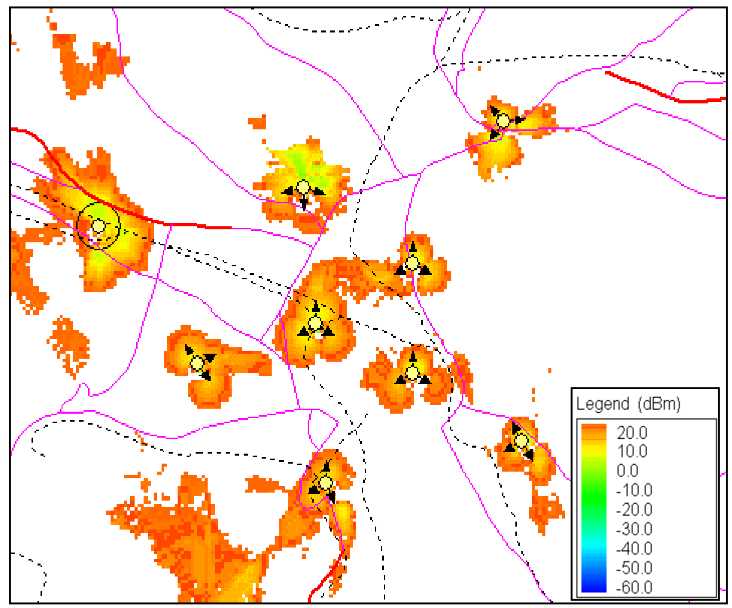
Coverage Area for one Service

- Coverage area for a specific service is not constant
- Even then, when the load on this specific service is constant
- The coverage area is also dependant on the traffic of other services in the cell

Comparison Coverage 64 kBit with and without speech subscribers



Needed transmit power for data service 64 kBit/s
No additional speech users are in the network



Needed transmit power for data service 64 kBit/s
Additional speech users are in the network

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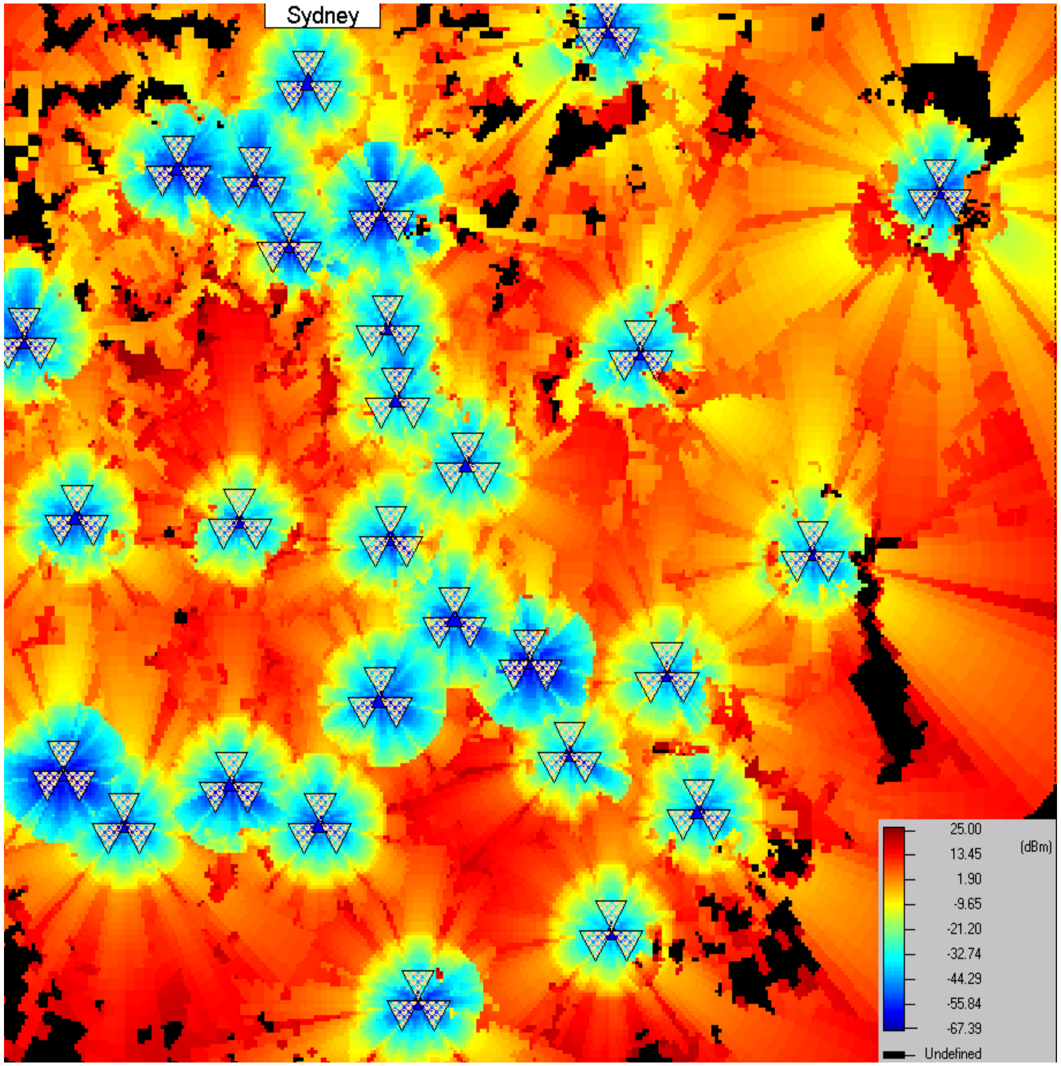
Influence of Load in a 3G Network



Network optimized for voice service

MS TX power
at voice connection

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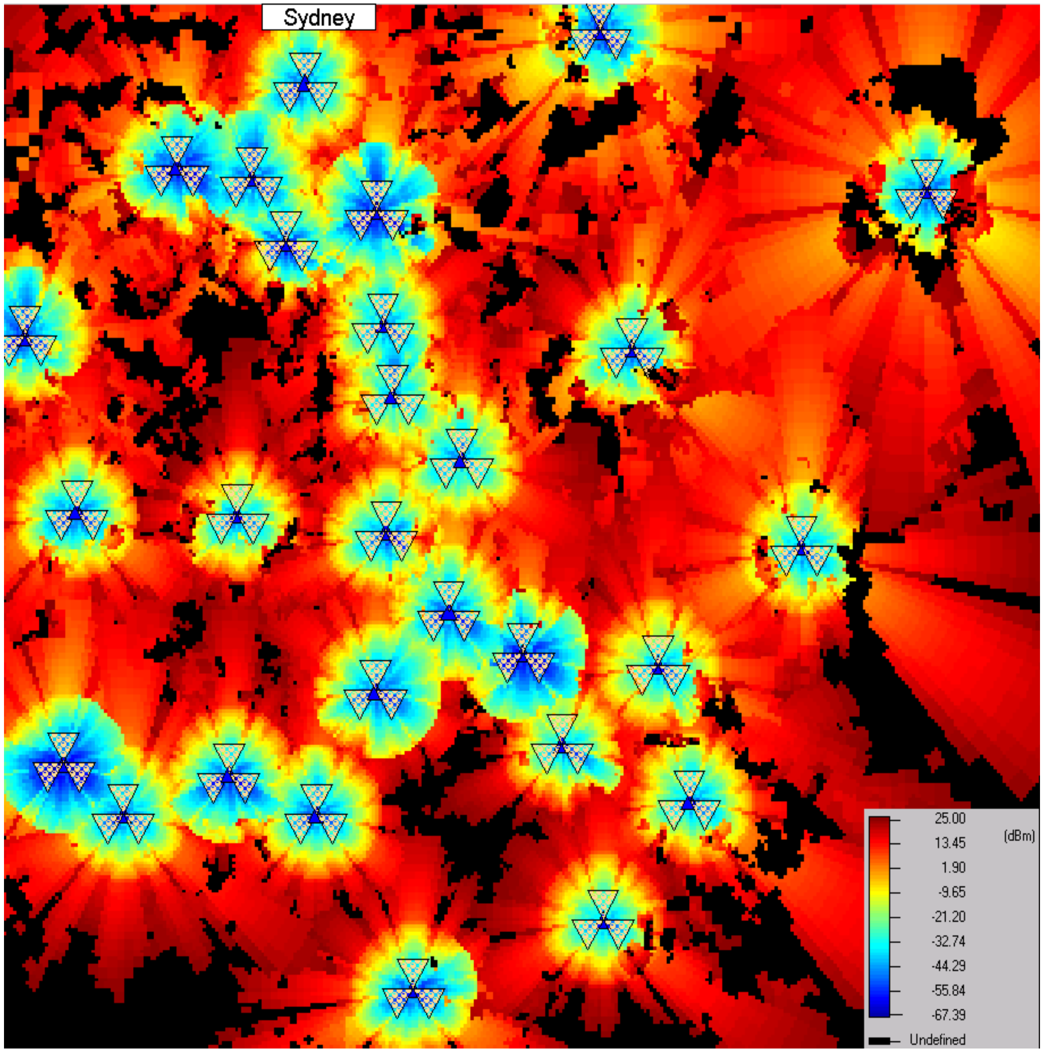
Influence of Load in a 3G Network



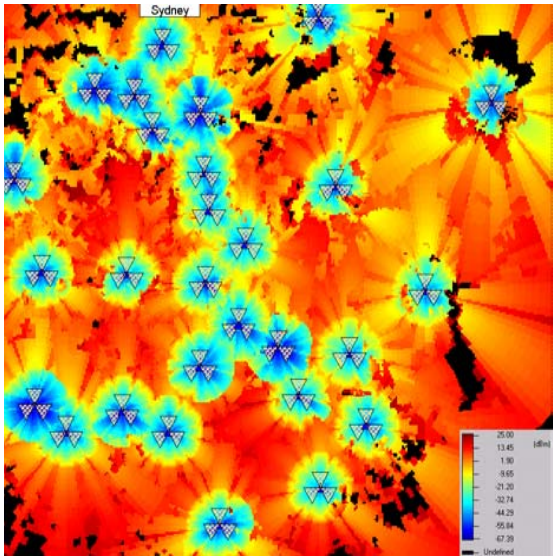
Test mobile switch to
384 kBit/s service

MS TX power for test
mobile with 384 kBit/s

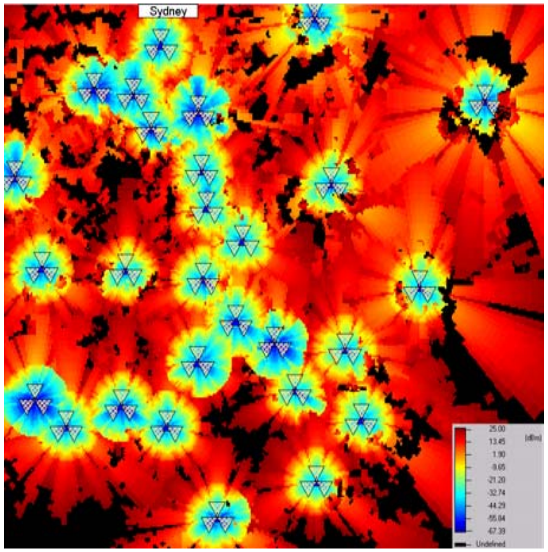
Influence of Load in a 3G Network

Comparing the two plot shows, the presence of a served user at 384 kBit/s will dramatically raise the interference and force all mobiles in the network to raise their transmit power (cell breathing effect)

Depending on the maximum TX power level of the mobiles the “black holes” in the network become larger and larger relative to the load.



MS TX power at voice connection



MS TX power for test mobile with 384 kBit/s

What needs to be considered with 3G?

Many planning jobs from 2G networks re-appear in 3G networks also, but often more complicated (e.g. neighbor planning) or simultaneously (e.g. coverage and capacity analysis)

New problems (like service mix or re-use of existing 2G sites) add to this, rendering the network design a very challenging process.

Consequences:

- forecasting of traffic is more important
- reaction times from operations to planning need to be optimised

⇒ **"Operative Planning"**

Operators who can support the required services with the demanded quality of service, will have a clear advantage in the 3G race.

Thank you for your attention

For more information:

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