Planning Cellular Networks

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DFG Research Center MATHEON *Mathematics for key technologies*
Modelling, simulation, and optimization of real-world processes

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Radio Network Planning

Goal	To create a radio network that provides the users with seamless wireless services.
Coverage Planning	to provide sufficient signal strength in the whole planning area.
Capacity Planning	to provide sufficient radio resources for all users to be served.

Degrees of Freedom

- Base Station Placement
- Antenna Configuration
- Radio Resource Management

	GSM	**UMTS**
	Global System for Mobile Communications	Universal Mobile Telecommunications System
Introduced	1992	2003
Services	Voice, Data	Voice, Video, Streaming, Web, …
Radio Access	TDMA/FDMA	WCDMA
Problems	Coverage Planning, Frequency Assignment	Coverage and capacity coupled through interference

Radio network planning is harder for UMTS than for previous technologies

Degrees of Freedom

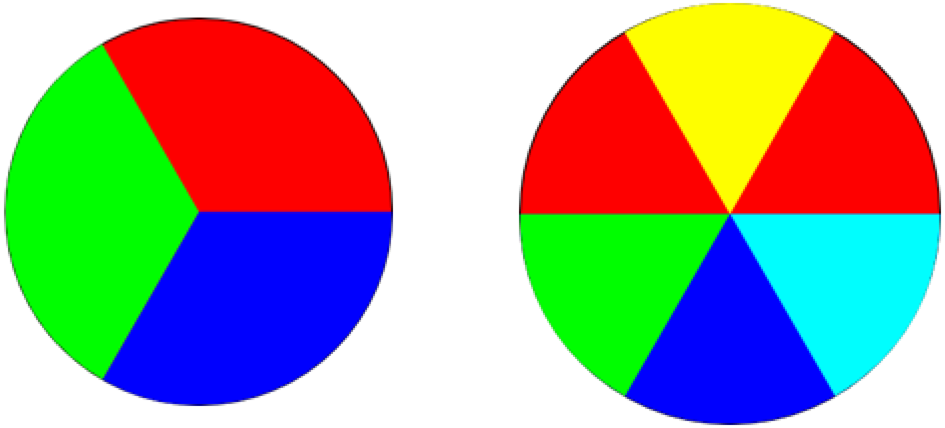
or

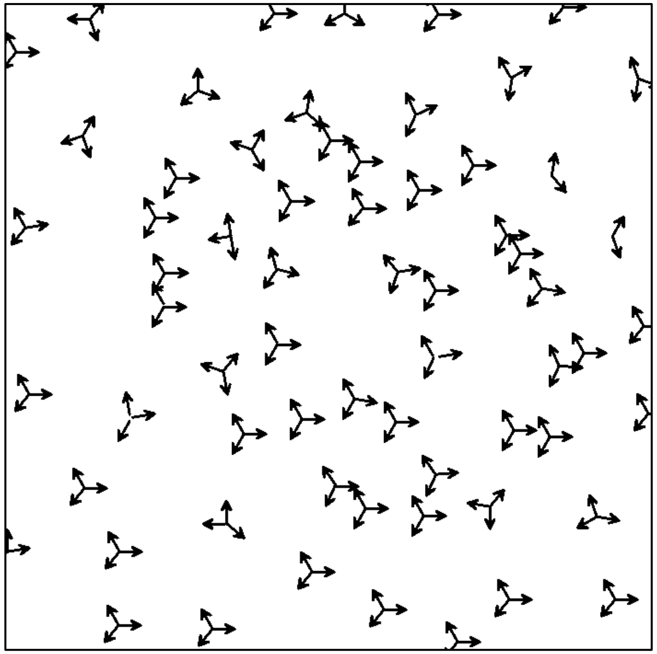
What do we have to decide?

Base Station Placement

Given a set of possible locations, select those where to place base station.

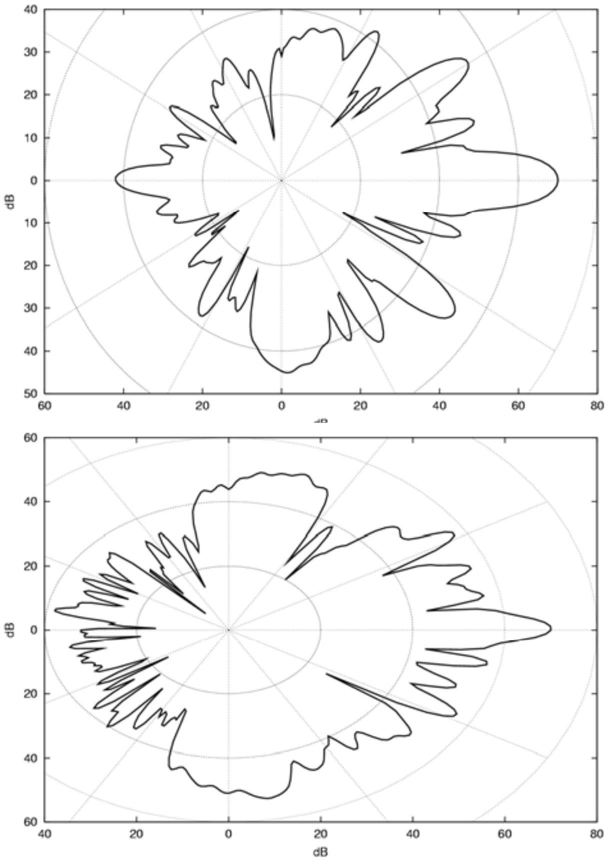
Sectorization of the base stations

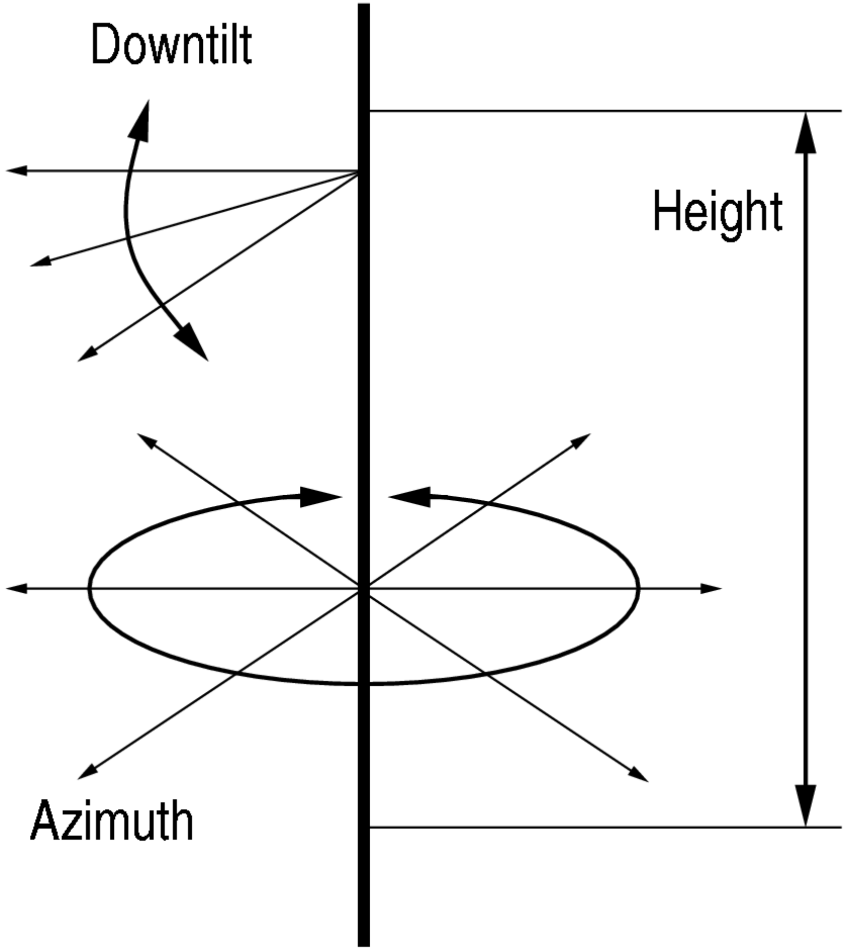




Antenna Configuration

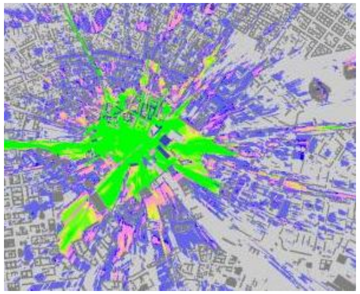
Antenna Type





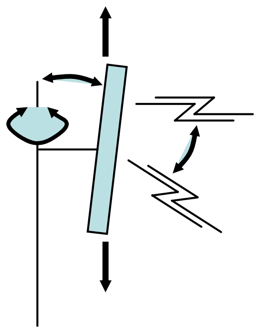
Isotropic Prediction

- Available for each potential antenna location



Antenna Configuration

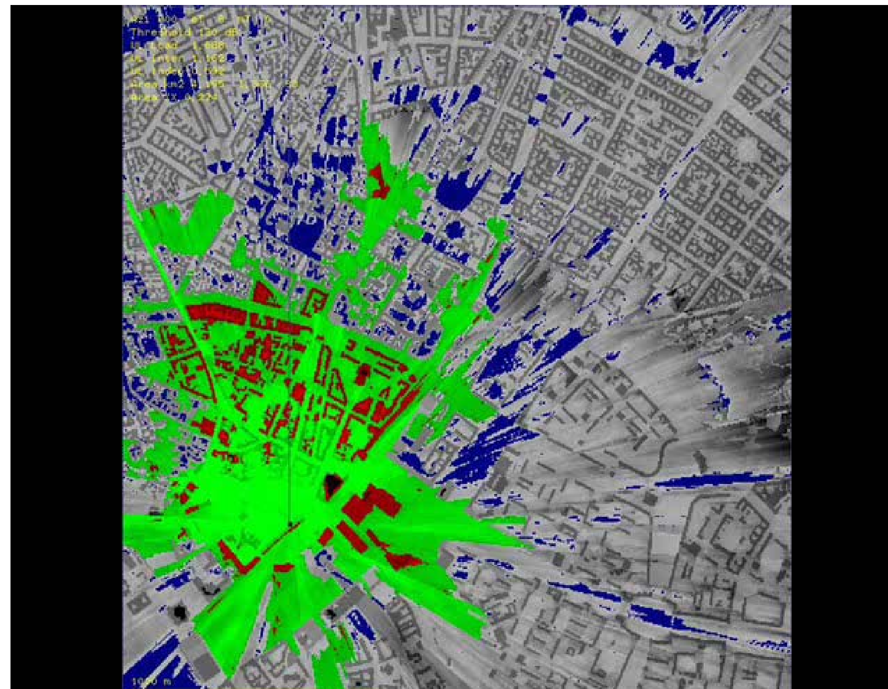
- Azimuth
- Tilt
- Height



Antenna Diagram

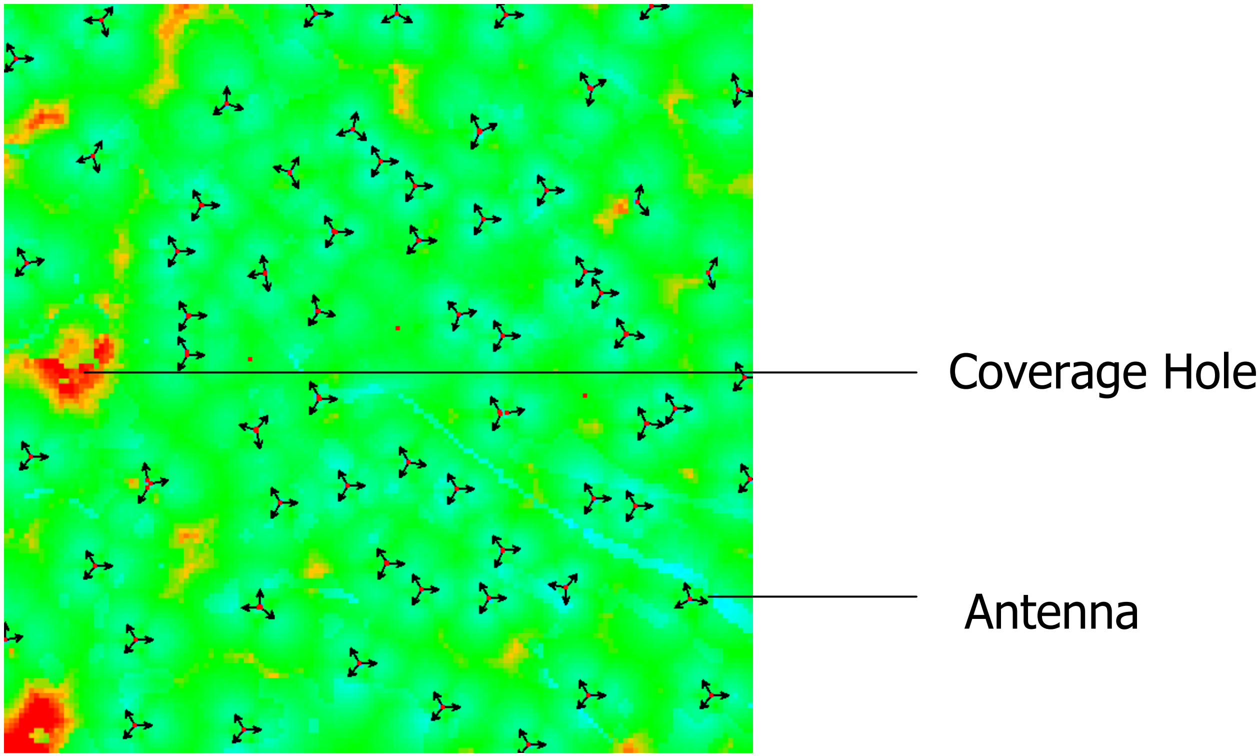
- Signal propagation in different directions

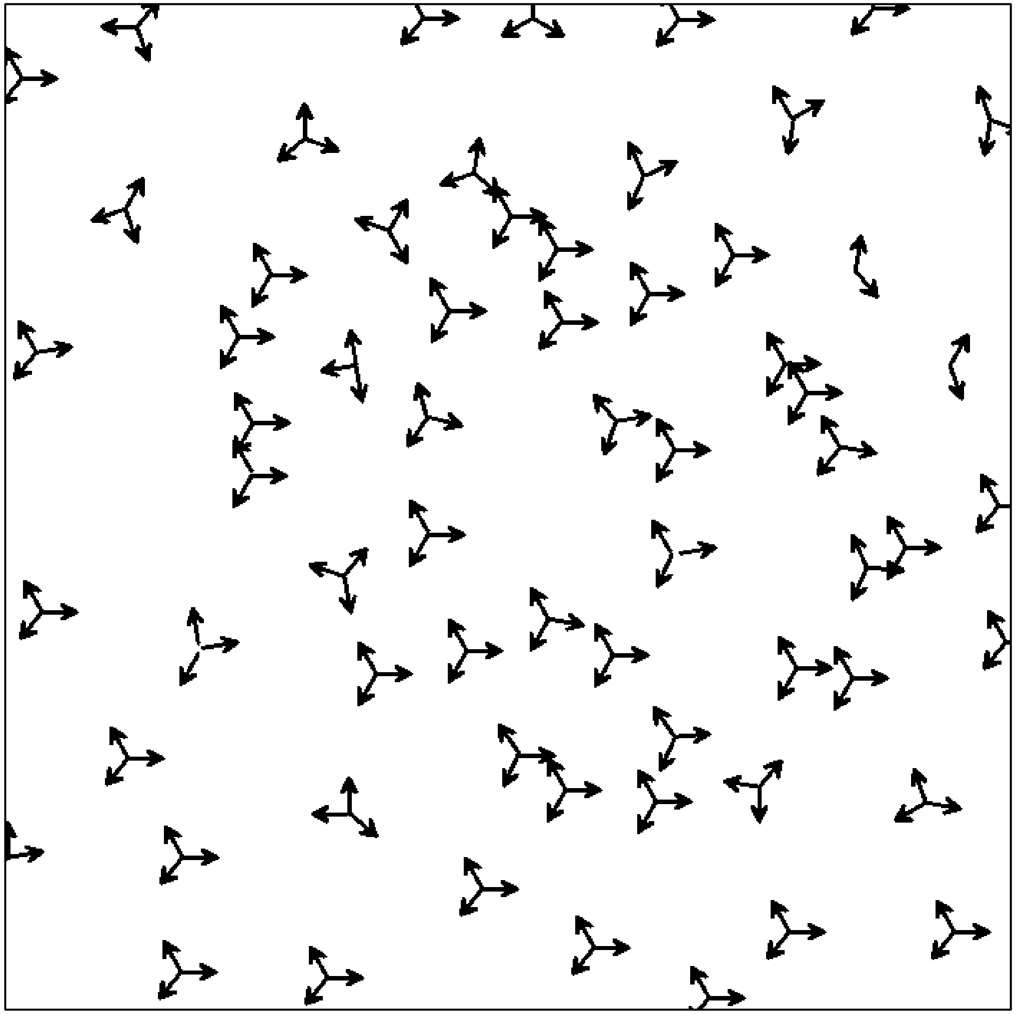
Antenna Prediction



Coverage Planning to provide sufficient signal strength in the whole planning area.

If everything is fixed, we can compute the signal strength for each pixel in the planning area.

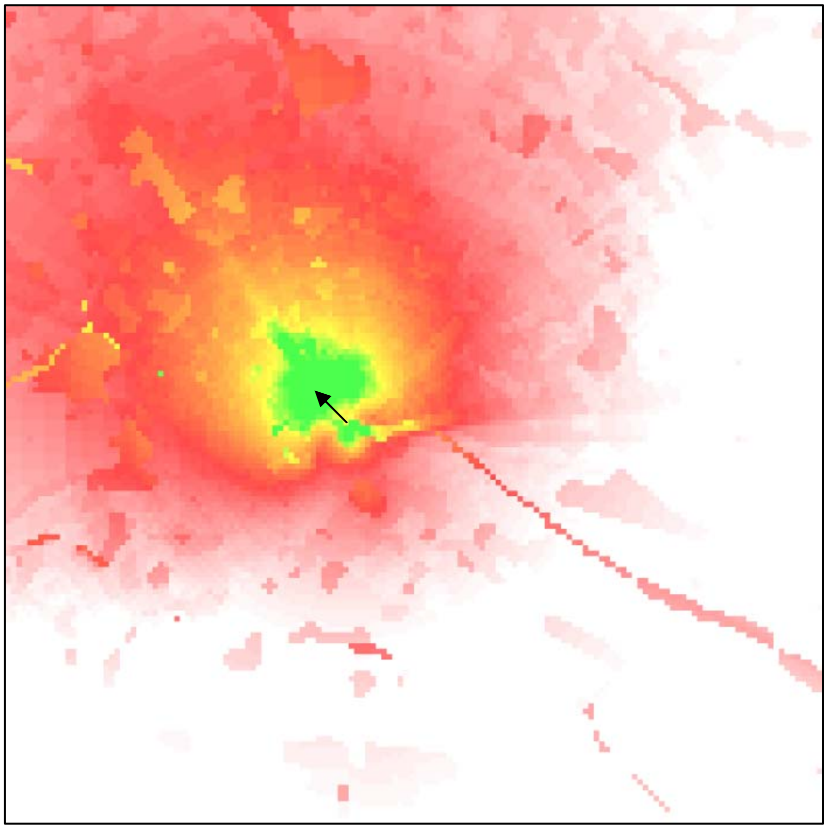




Input

A set ***S*** of potential site locations and a set ***I*** of potential antenna installations and their propagation properties

Radio Signal Propagation

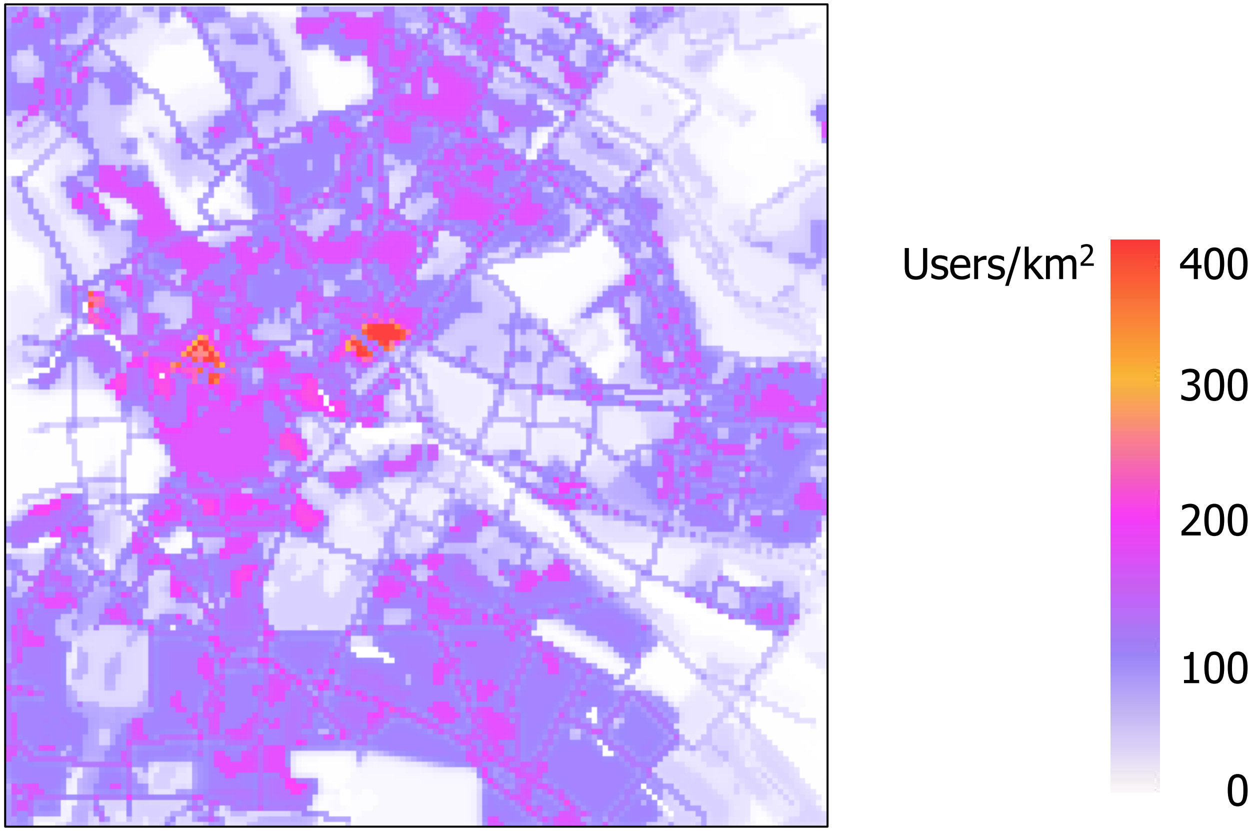


Pixel-grid dataset for each potential antenna

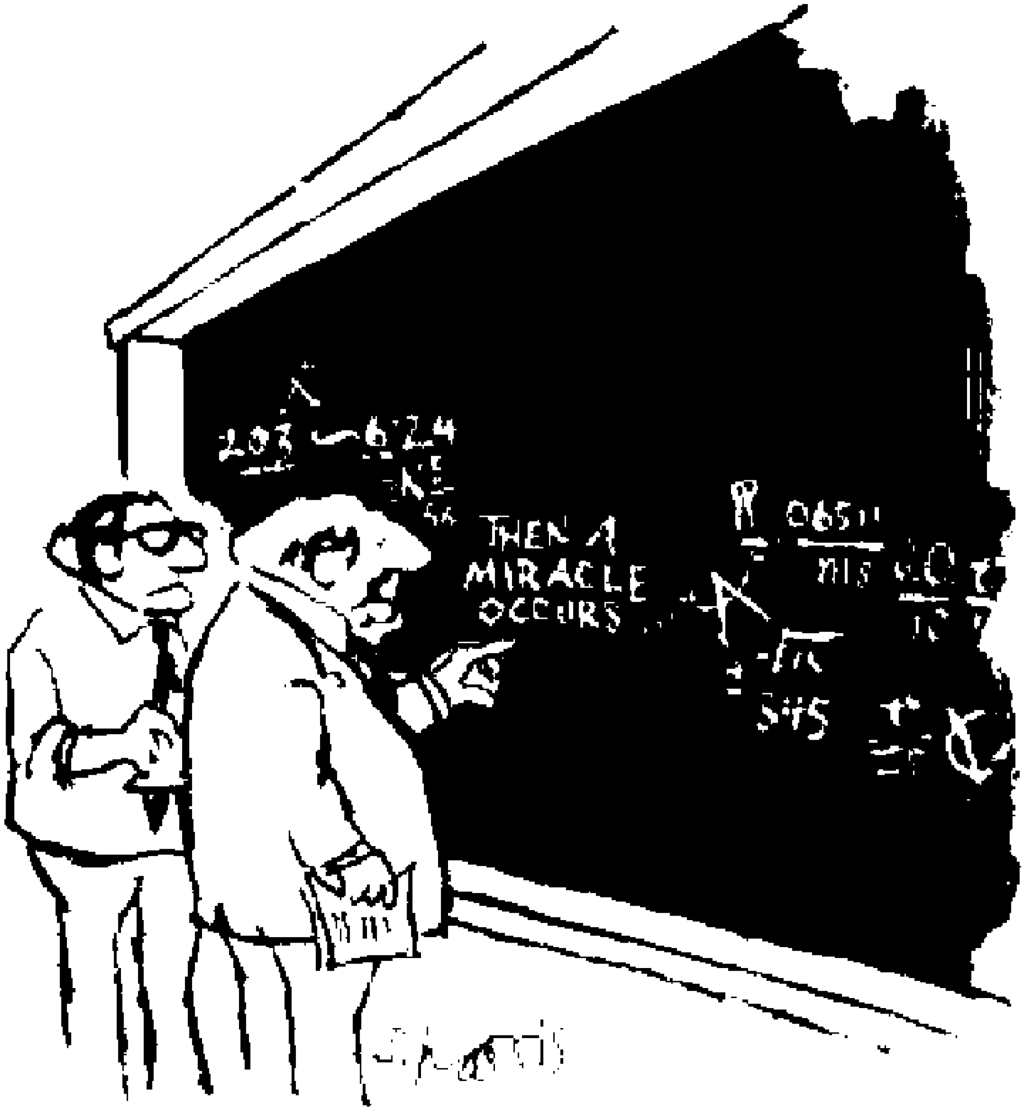
Signal attenuation

Capacity Planning to provide sufficient radio resources for all users to be served.

Average User Density



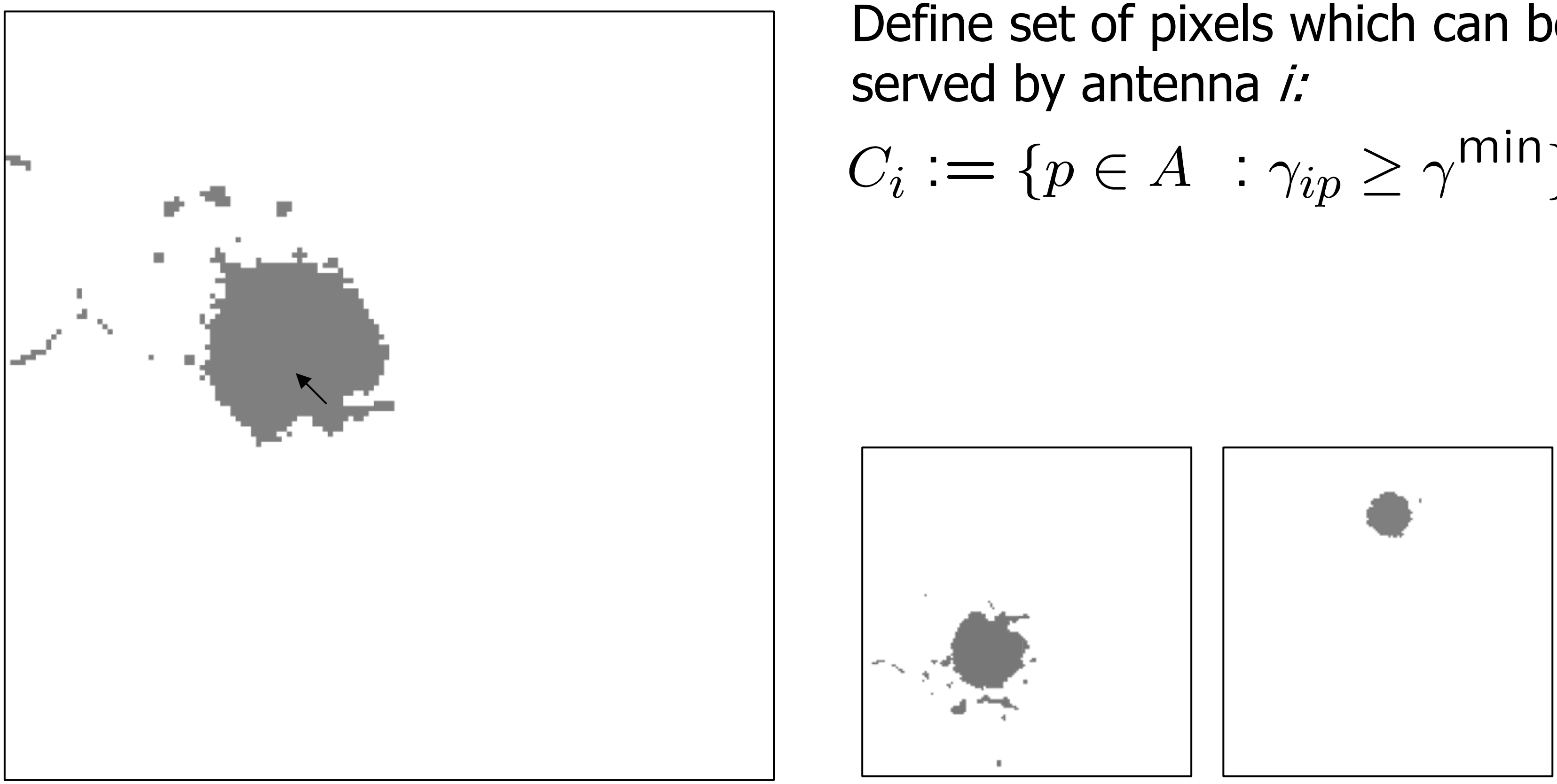
Then a miracle occurs…



Covered pixel are served pixel

Define set of pixels which can be served by antenna *i:*

$$C_i := \{p \in A \ : \gamma_{ip} \geq \gamma^{\text{min}}\}$$



C_1 C_2 $C_3 \ldots$

Set Covering Model

S	set containing all possible sites.
P	set containing all pixel.
I	set containing all installations.
$I(s)$	set of possible installations for site $s \in S$
$I(p)$	set of installations covering pixel $p \in P$
$P(i)$	set of pixels covered by installation $i \in I$
x_p	binary, 1 iff pixel $p \in P$ is covered.
y_s	binary, 1 iff site $s \in S$ is chosen.
z_i	binary, 1 iff installation $i \in I$ is active.

Get revenue for covered pixels, pay for opening sites and installations:

$$\max \sum_{p \in P} c_p x_p - \sum_{s \in S} c_s y_s - \sum_{i \in I} c_i z_i$$

Installation $i \in I$ can only be active if sites $s \in S$ is chosen:

$$z_i \leq y_s \text{ for all } s \in S, i \in I(s)$$

Site $s \in S$ can not have more than σ_s active installations:

$$\sum_{i \in I(s)} z_i \leq \sigma_s \text{ for all } s \in S$$

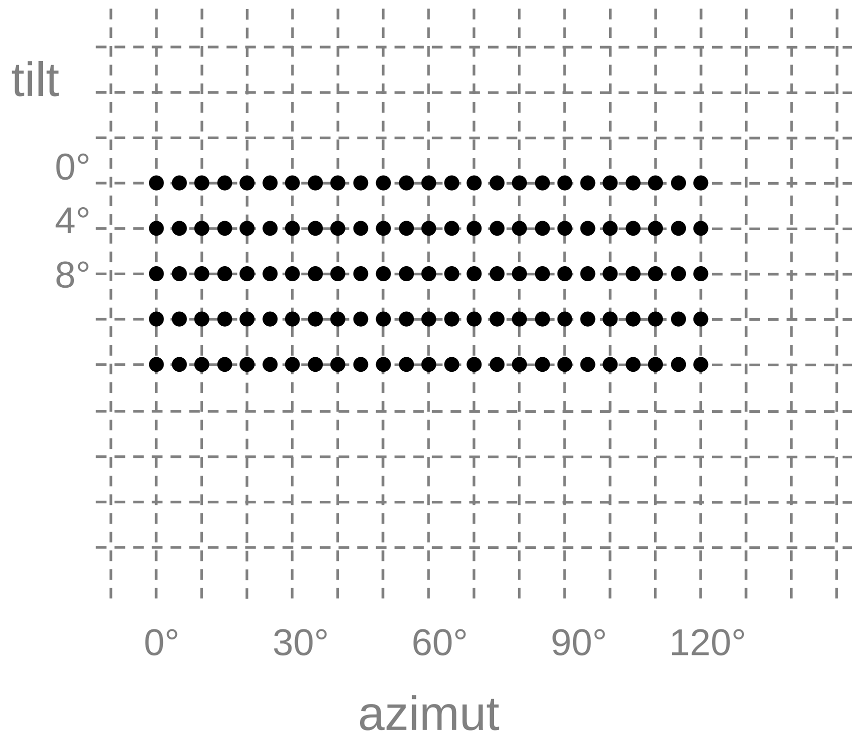
To cover pixel $p \in P$ at least one installation from $I(p)$ has to be active:

$$\sum_{i \in I(p)} z_i \geq x_p \text{ for all } p \in P$$

Many Pixels

Pixel size	Germany 356,854 km²	Berlin 889 km²
100 m	35,685,400	88,900
50 m	142,741,600	355,600
20 m	892,135,000	2,222,500
10 m	3,568,540,000	8,890,000
5 m	14,274,160,000	35,560,000

120 Installations



Sizes of real-word problems that can be solved

Sites	|S|	700
Installations	|I|	700,000
Pixel	|P|	2,000,000
Covers	Σ|P(i)|	500,000,000
IP rows		1,000,000
IP cols		1,500,000
IP non zeros		100,000,000

How to handle large problem instances

- Sophisticated preprocessing
- Decomposition of problem, both in area and decisons
- Use of OpenMP to parallelize programs
- Use of 64bit multiprocessor multicore SUN V40
- Fast evaluation tools to assess optimization results