

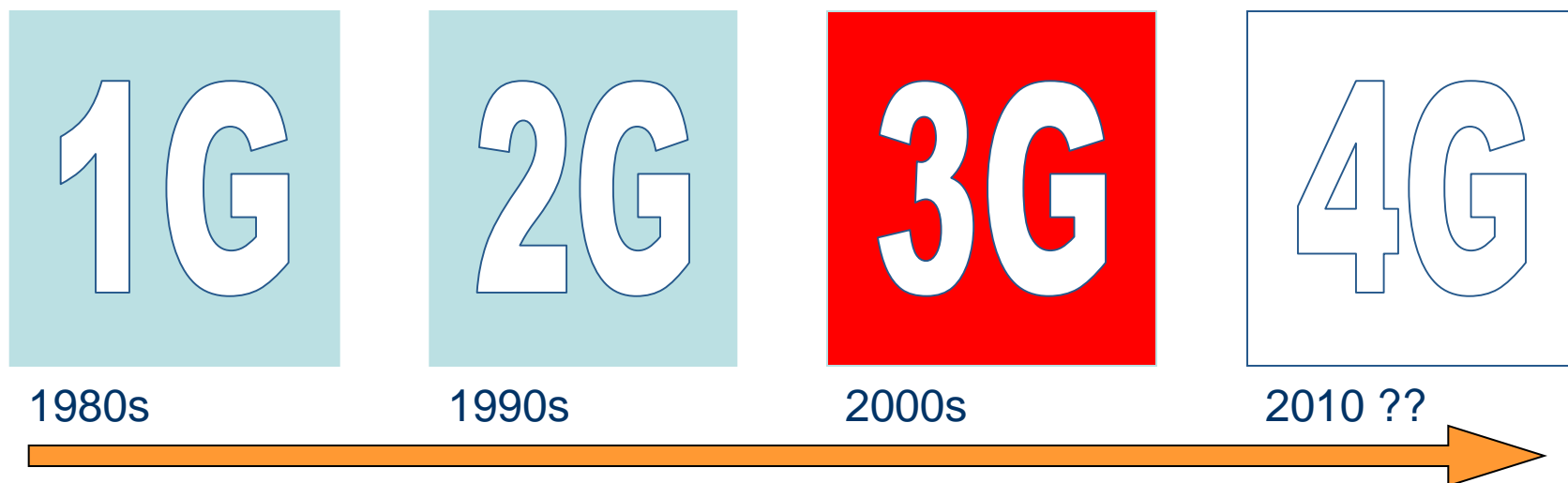


# Radio Network Design

Andreas Eisenblätter



# Evolution of Mobile Telecommunications Systems

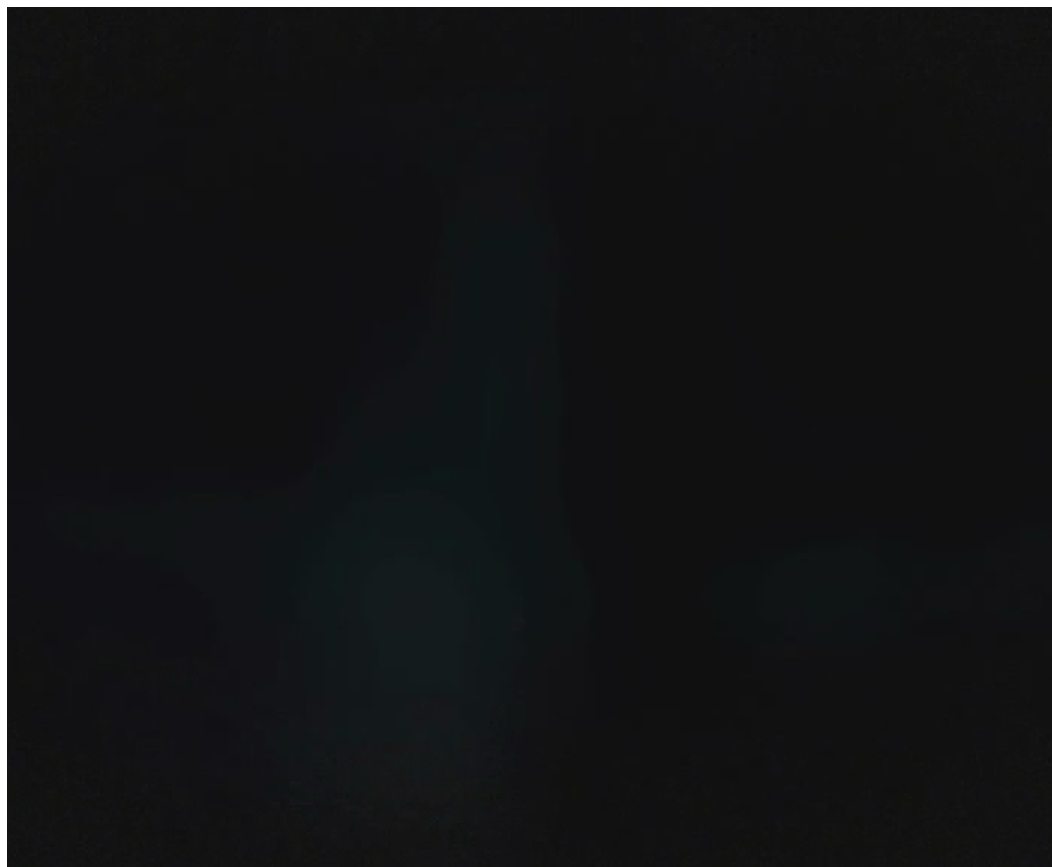


- Analogue
- Voice Only

- Digital
- Voice & Data
- **GSM** mass market
- PCS
- cdmaOne/IS95

- **UMTS, WiFi/WLAN, cdma2000**
- Data Rates  $\geq 384$  kbit/s
- Various Services

- **UMTS LTE**
- WiMAX
- Data Rates  $\sim 100$  Mbit/s
- Mobile Internet
- LTE Advanced



**UMTS**

**Radio Network Optimization**



## Radio Networks

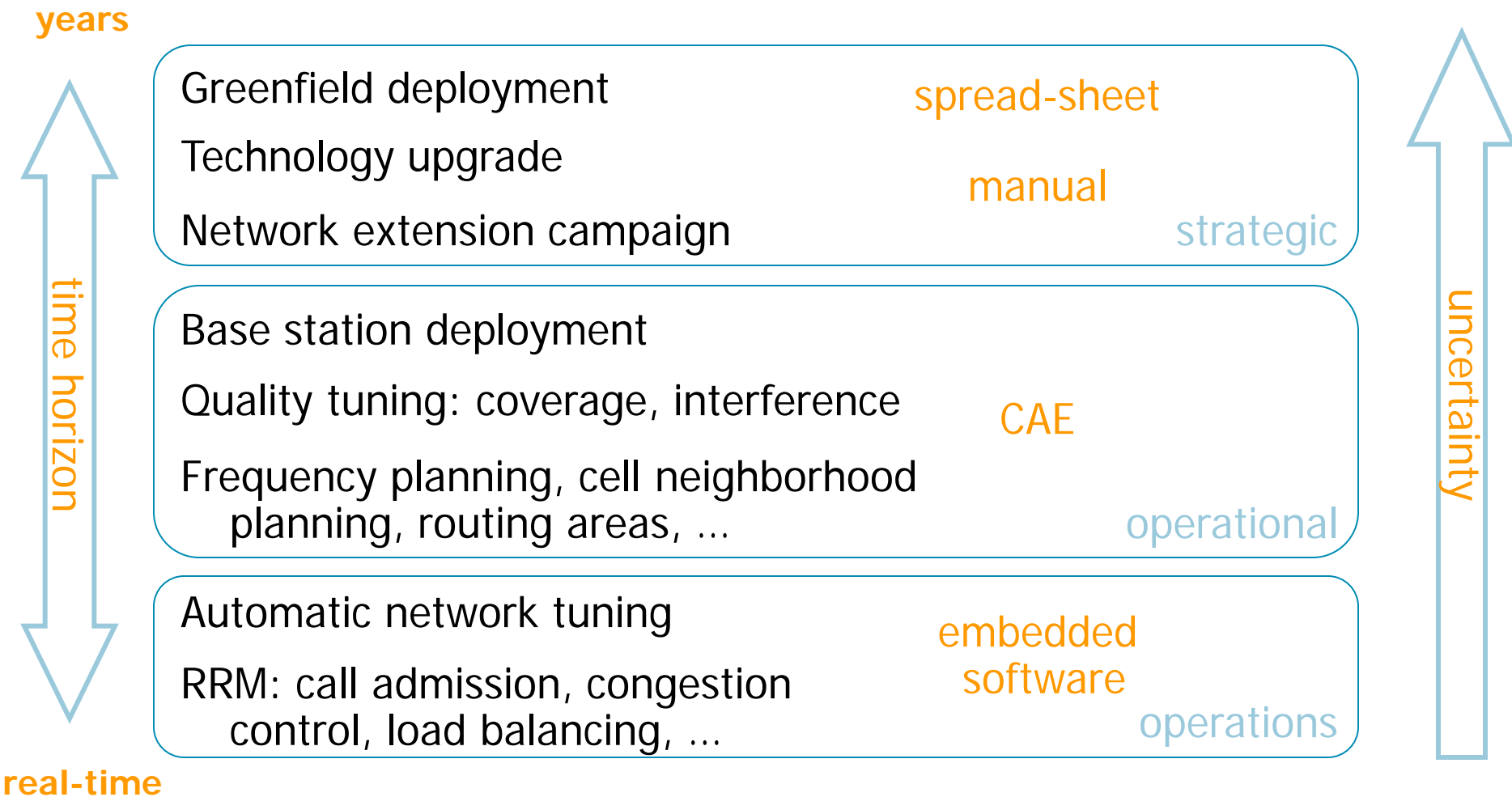
Challenges in Network Planning

Applications

Conclusions



# Network Planning and Operations





## Standards

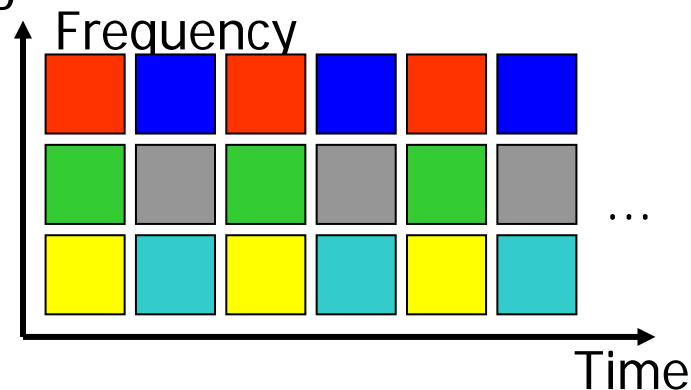
- GSM, GPRS, EDGE
- IS95, cdma-One
- UMTS, HSDPA, CDMA2000
- IEEE 802.11 (W-LAN, Wifi)
- IEEE 802.16 (WiMAX)
- DVB-T
- DAB
- ...

## Booming Industry

- Large Investments
- Large Revenues

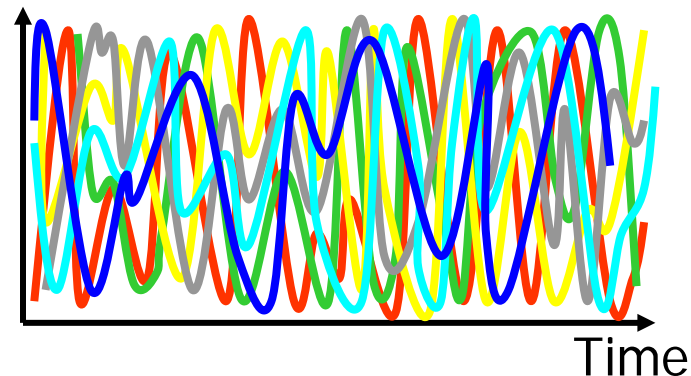
## Multiplexing

- TDMA
- FDMA



## CDMA

- SDMA (smart antennas)

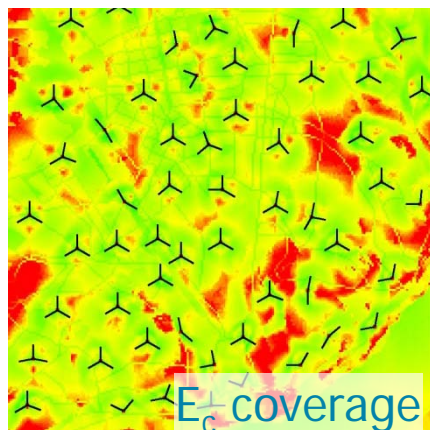




## UMTS network simulation

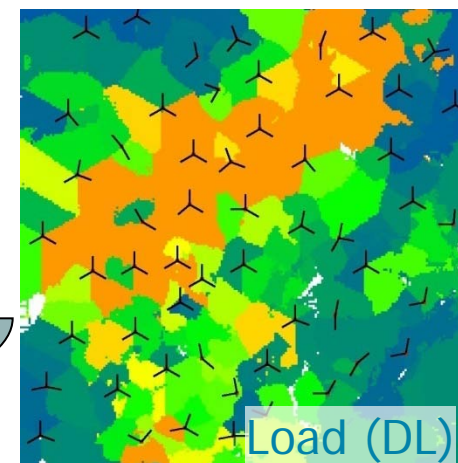
### Coverage

- Quality of pilot signal
- Pilot  $E_c$  coverage
- Pilot  $E_c/I_0$  coverage



### Load

- How many users served?
- How much capacity left?



→ "Simple" Optimization Models



Radio Networks

Challenges in Network Planning

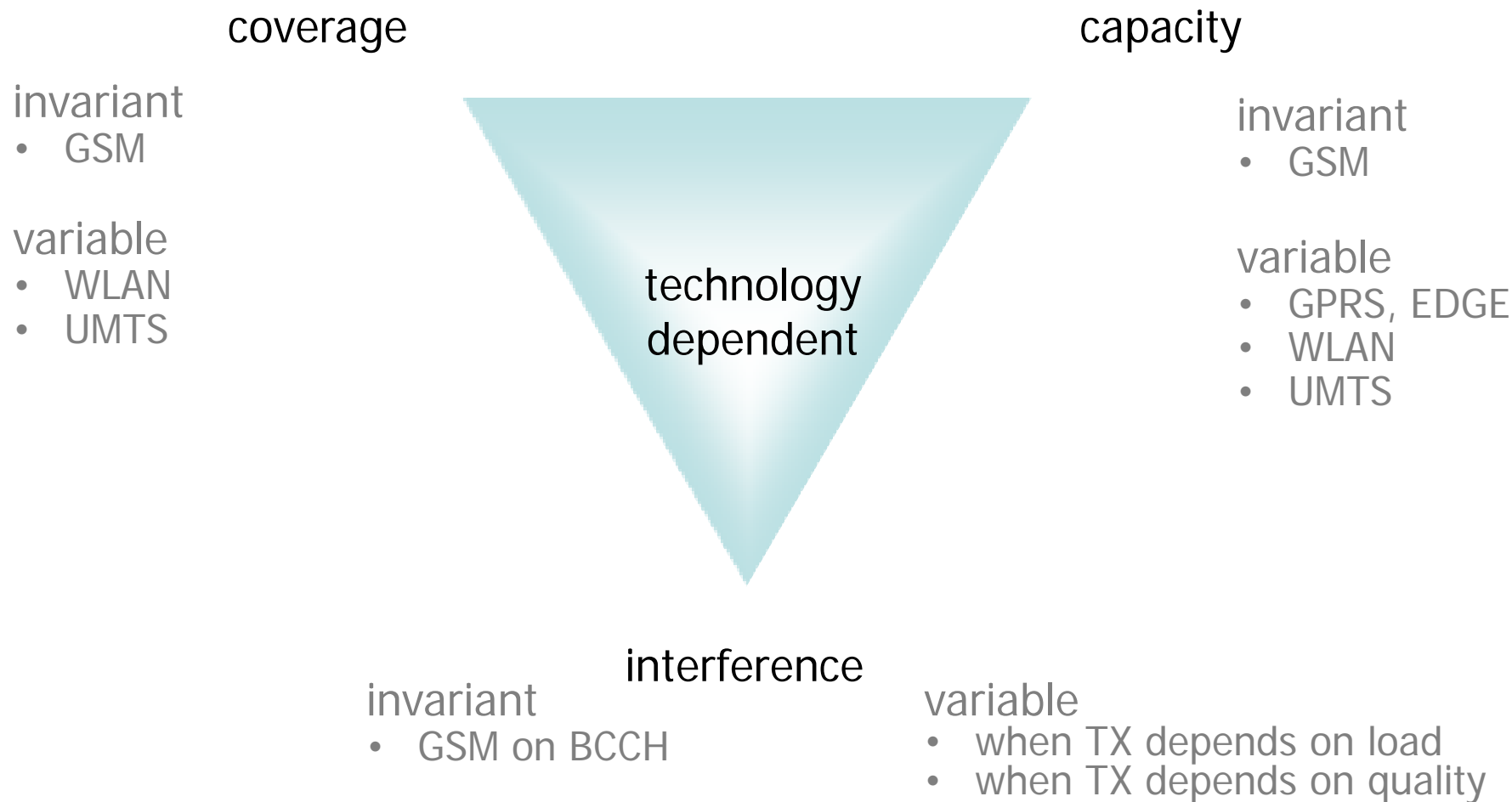
Applications

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# Challenges in Radio Network Design





→ may inhibit service and/or reduce capacity

## Signal-to-Interference Ratio

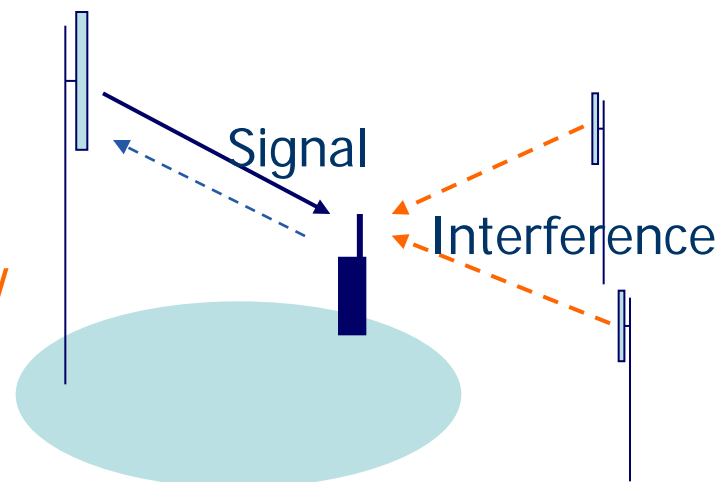
$$\frac{\text{Signal}}{\text{Noise} + \sum \text{Interference}} \geq \text{Threshold}$$

Minimum SIR needed for good transmissions

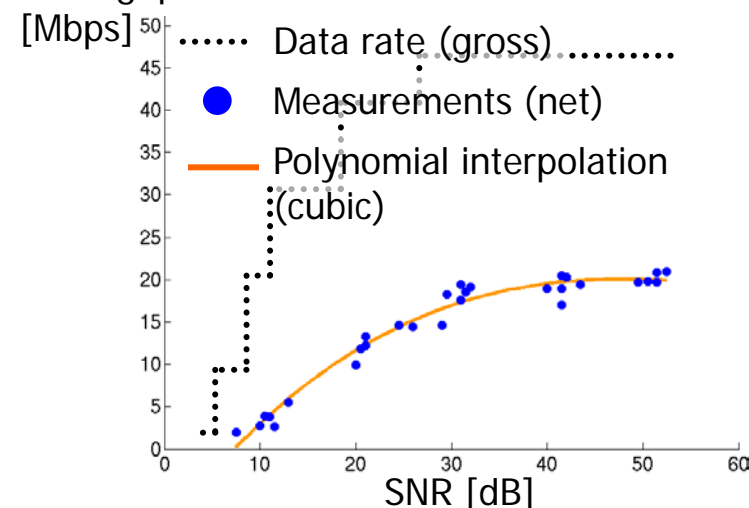
Increase signal strength

Rate adaptation

→ Reduce or eliminate interference



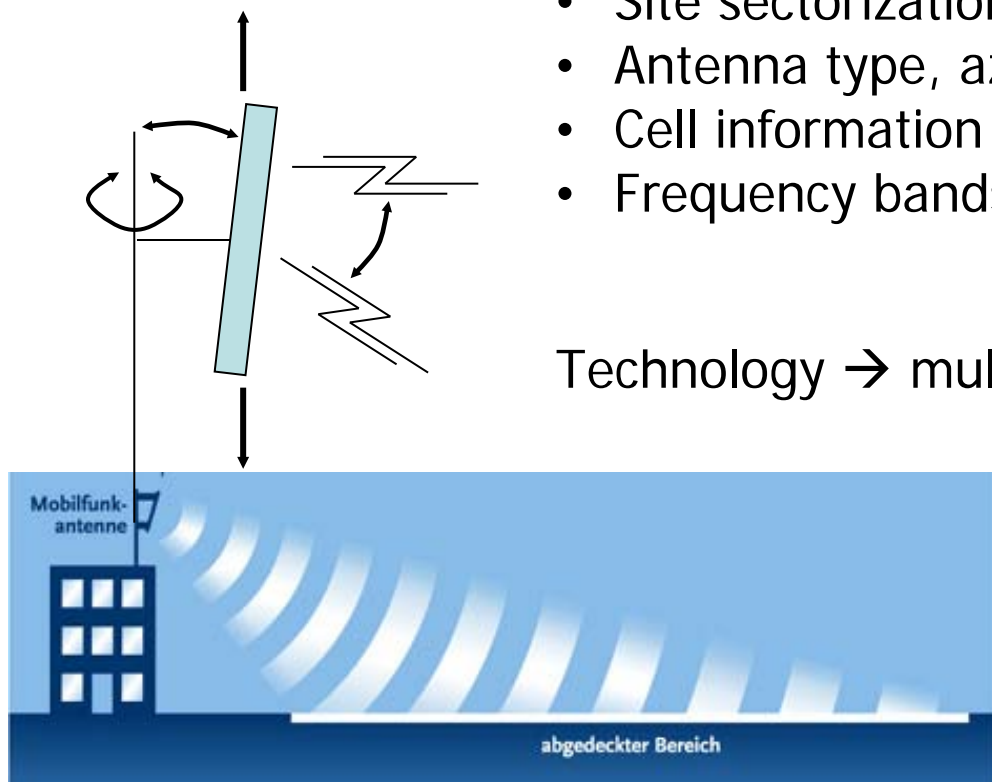
## Throughput





- Location of base stations / access points (including antenna height)
- Site sectorization
- Antenna type, azimuth, mechanical & electrical tilt
- Cell information broadcast power
- Frequency bands

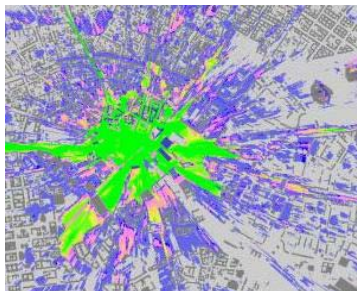
Technology → multi-RAT networks





## Isotropic Prediction

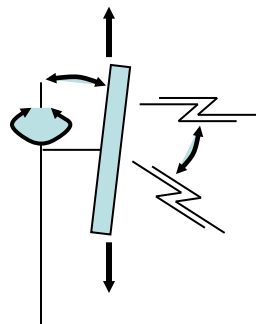
- Available for each potential antenna location



© Digital Building Model Berlin (2002),  
E-Plus Mobilfunk GmbH & Co. KG

## Antenna Configuration

- Azimuth
- Tilt
- Height

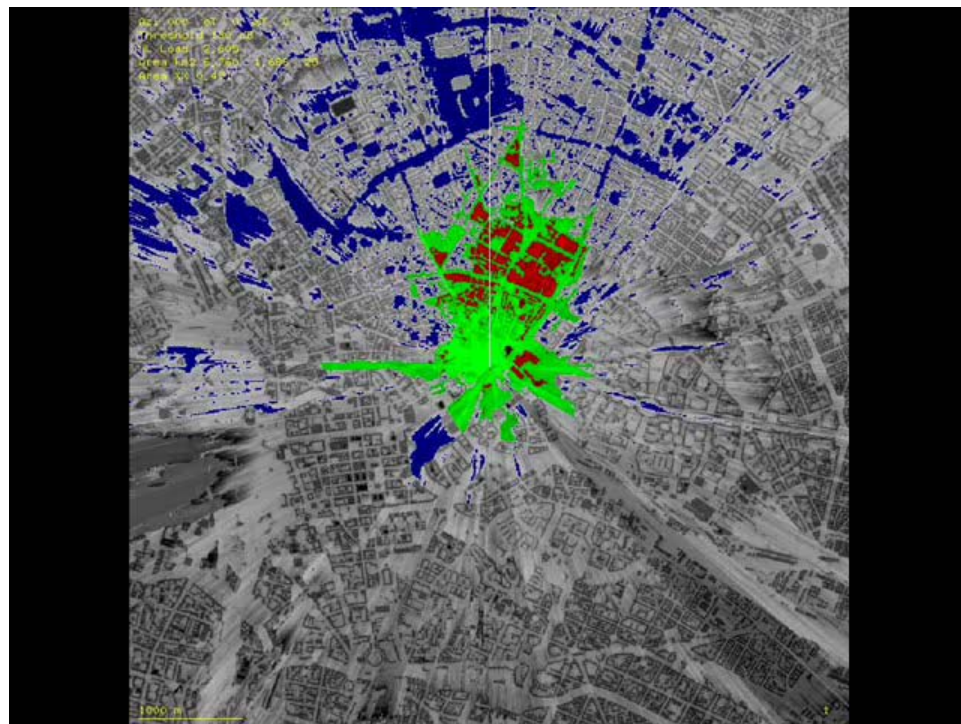


## Antenna Diagram

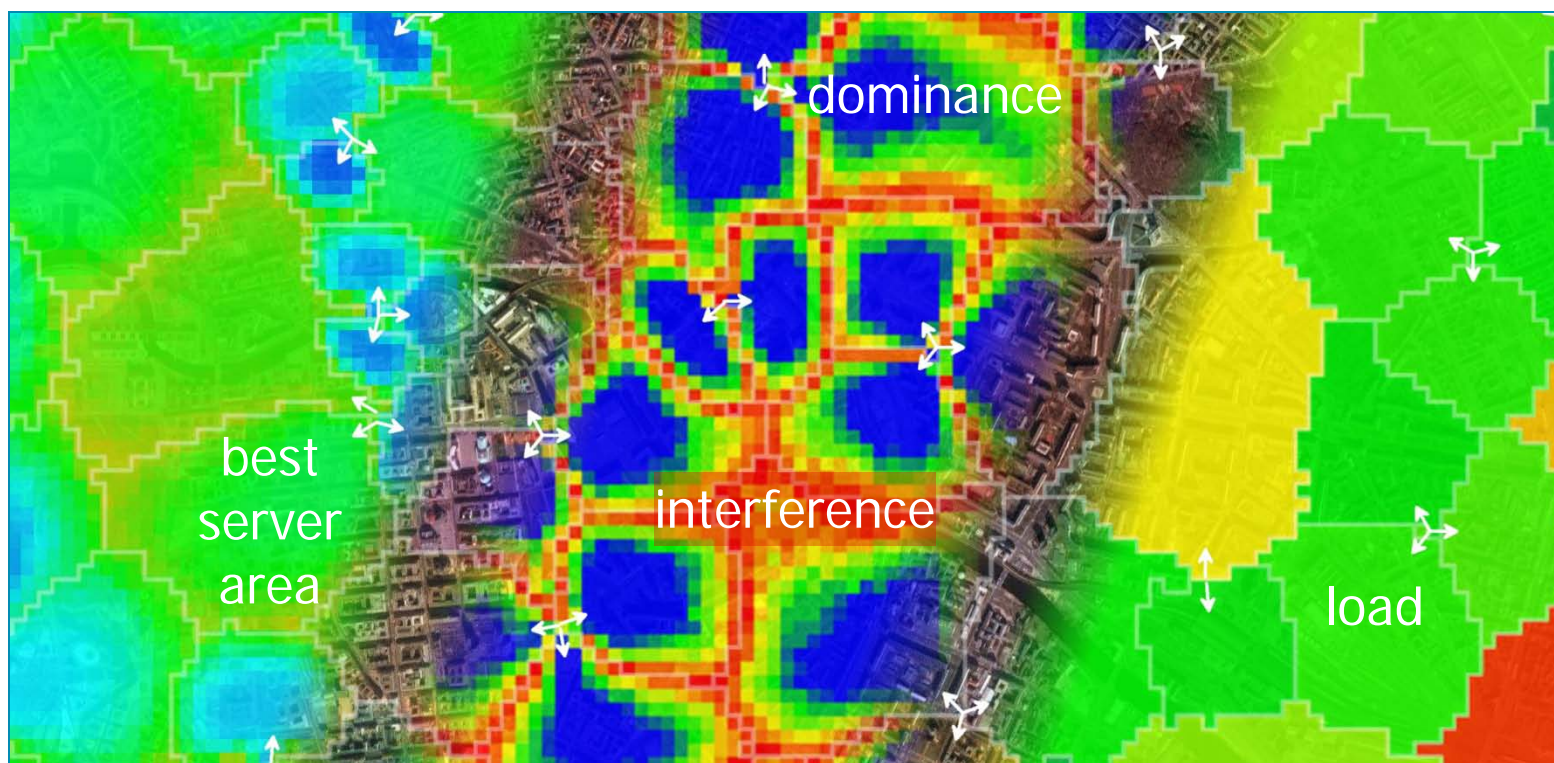
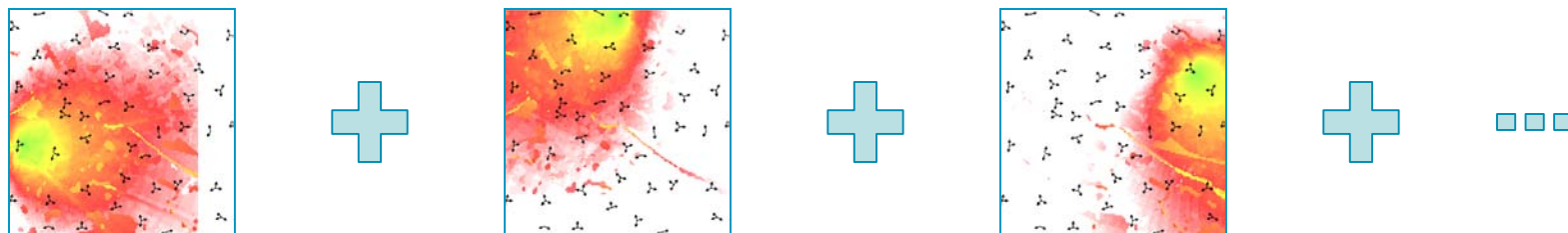
- Signal propagation in different directions



## Antenna Prediction



© Digital Building Model Berlin (2002), E-Plus Mobilfunk GmbH & Co. KG, Germany  
height: 41m, electrical tilt: 0-8°, azimuth 0-120°







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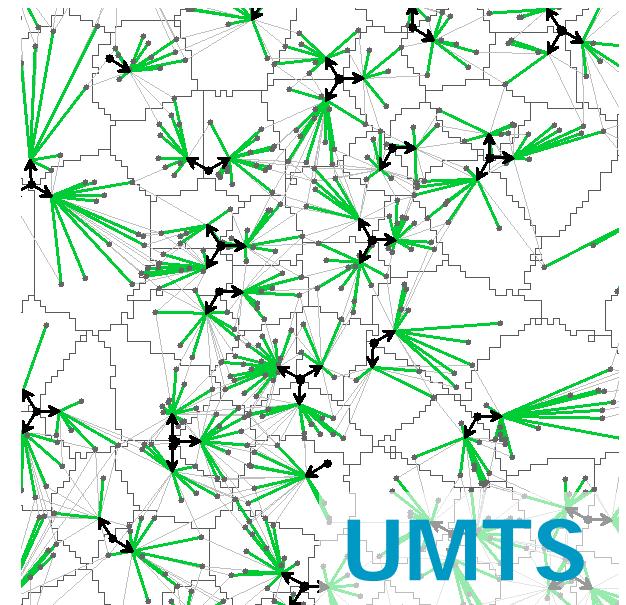
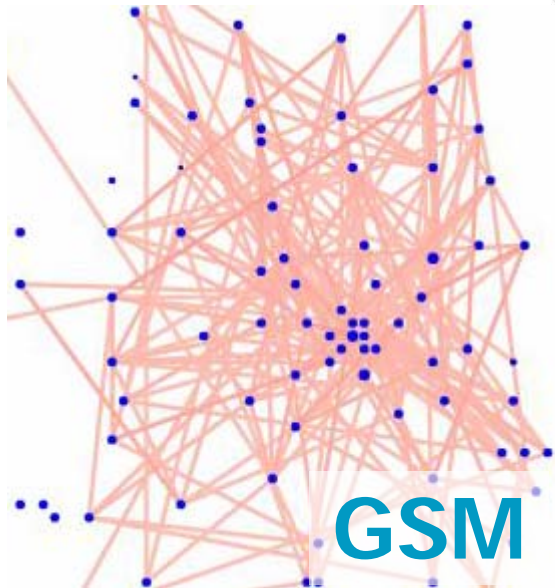
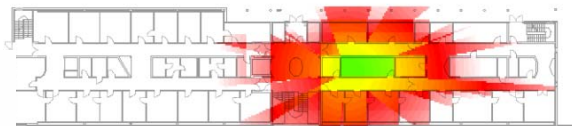
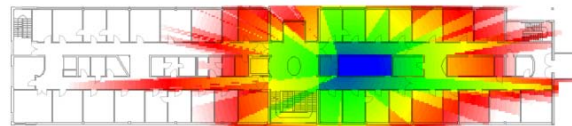
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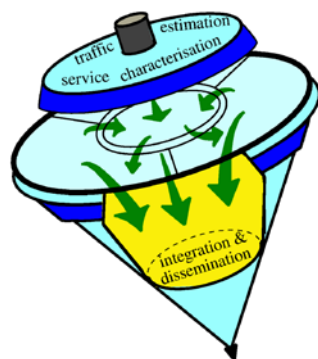


# Network Optimization for Different Technologies





# MOMENTUM & MORANS Provide UMTS Data



## Momentum

Contains references to all data that constitute the scenario in one file.

## EnvironmentData

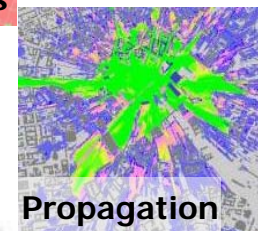
Reference to Environment file. The scenario's name is fixed here.



Clutter Types

## EquipmentData

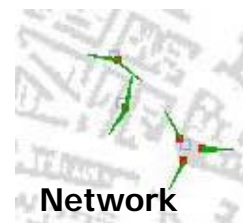
Contains references to all equipment and bearer fact sheets.



Propagation

## NetworkData

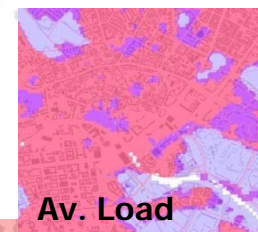
Contains references to xml files containing configured networks and RRM settings.



Network

## TrafficData

Contains references to all traffic/demand data, that is, BHCA and average load. Several nodes are possible for different traffic forecasts.



Av. Load

## ServicesData

Contains references to source model and service specifications.



Op. Env.

## Scope

- Path loss predictions
- Traffic modelling
- Mobility modelling
- Network analysis
- Network optimization

<http://momentum.zib.de/data>





Radio Networks

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## Collaboration with Engineers

- ▶ indispensable for system modeling and optimization goal

## Systems Models & Realistic Data

- ▶ very complex
- ▶ models often implicit, solution quality from simulations
- ▶ models often used as basis (oracle) within local search methods

## Mathematical Optimization

- ▶ set covering (with bounded overlap)
- ▶ k-partition of graph  
(with or without ordered partitions)

## Significant Impact

## Mostly Unresolved

- ▶ robust optimization
- ▶ migration planning / multi-stage planning

