Emerging Technologies in Mobile Communication

Zukünftige Entwicklungen in der Mobilfunktechnologie

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RWTH AACHEN

FACHGRUPPE INFORMATIK

Overview

- **Introduction**
  - The “beyond 3G” issue
- **The Operator’s View**
  - NGMN: Next Generation Mobile Networks
- **Standardization**
  - Recent enhancements
  - 3G LTE
- **Research and Technology**
  - UMIC View
- **Outlook**

The 3G Issue

- **The very successful 2G (GSM) introduction in the early 90's was technology driven**
  - New market
  - De-regulation in Europe
  - Mobile phones became affordable
- **The less successful 3G (UMTS) introduction in the late 90's was technology driven**
  - Existing market, predominantly voice and SMS
  - Established operators, strong competition
  - "Second introduction" via new services and QoS
- **Future mobile technologies**
  - Support of new services
  - Leverage existing infrastructure, lower cost
  - Different views of technology beyond 3G:
    - Research: 4G, (5G)
    - Industry and operators: 3.5G or 3G Evolution
      ⇨ Standardization: 3G Long Term Evolution

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The Operators View

- **To voice their view of future technology requirements, major operators recently launched an organization:**

- **NGMN – Next Generation Mobile Networks**
  - www.ngmn.org
  - Members:

    alltel wireless, at&t, 中国移动通信 CHINA MOBILE, NTT DoCoMo, kpn, orange, SK telecom, Sprint, T-Mobile, TELECOM ITALIA, Telefónica, TELUS, vodafone

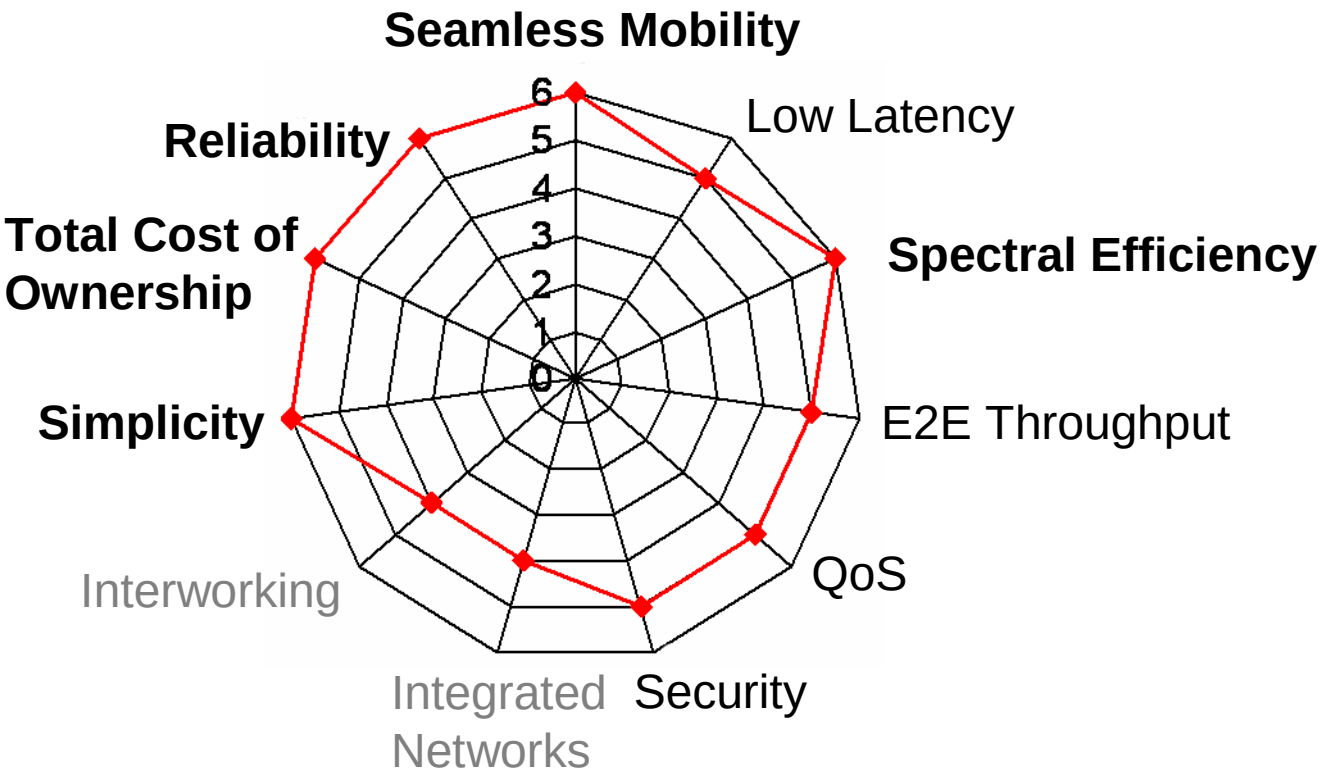
  - Advisors: University of Surrey, RWTH Aachen University (UMIC)

- **Key views summarized in white paper**
  - Next generation mobile networks: Beyond HSPA & EVDO (Version 3.0, Dec. 2006)

„In terms of cost and performance NGMN shall be as close as possible to xDSL. At the starting point and in the future.“

Beyond HSPA & EVDO *

- What is important to operators



*** High Speed Packet Access EVolution Data Optimized**

Source:
NGMN White Paper Version 3.0

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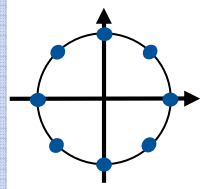
GSM

- **ETSI Standard**
  - GSM: numerous enhancements since introduction in 1989
  - GMSK modulation 1 bit/symbol
  - **Voice**, data up to ***14,4 kb/s***

- **Major enhancements over time**
  - HSCSD (High Speed Circuit Switched Data)
    Data rate increased to 8x14.4 kb/s= ***115.2 kb/s***
  - GPRS (General Packet Radio Service)
    - Data rates up to ***171.2 kb/s***
  - EDGE (Enhanced Data Rates for GSM Evolution)
    - 8-PSK = 3 bits/symbol
    - ⇨ In theory triple data rates
      actual maximum data rate ***384 kb/s***



8-PSK

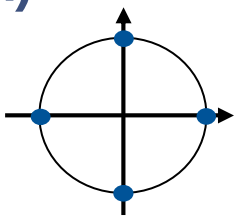
Issue:
EDGE competes with UMTS

"Virtual Wire"

Introducing *Packet Transmission*

UMTS

- **3GPP/ETSI Standard (2000): UMTS (Wideband CDMA)**



QPSK

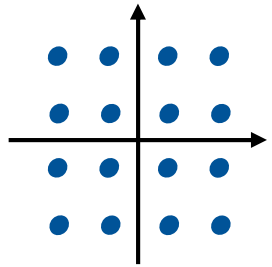
  - Voice

  - Data rates (downlink)
    - ***144 kb/s*** in macro cells
    - ***384 kb/s*** in micro cells
    - ***2 Mb/s*** in pico cells
  - Uplink data rate ≤ 64 kb/s

Zone	4	3	2	1
Radius	>20km	350m- 20km	50-300m	x10m
Mobility	<100km/h	<500km/h	<120km/h	<10km/h
Cell	World	Macro	Micro	Pico

The Standards: UMTS

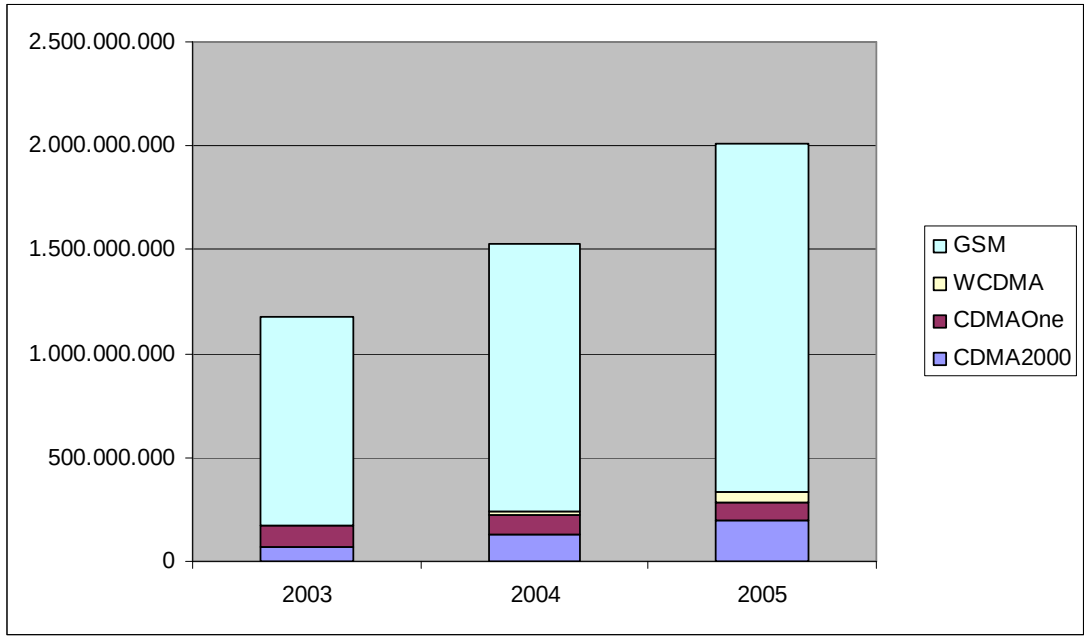
- **Enhancement (2006+)**
  - HSDPA (High Speed Downlink Packet Access)
    - 4 bit/symbol
    - Data rates (downlink) up to
      - ***2-3 Mb/s*** in micro cells
      - ***4 Mb/s*** in pico cells
    - Uplink data rate ≤ ***384 kb/s***
  - HSUPA (High Speed Uplink Packet Access)
    - Uplink data rates up to ***5.8 Mb/s***



16-QAM

Market Situation

GSM, UMTS vs. CDMA One, CDMA 2000



Market share GSM/UMTS
world wide stable @ 85%

In the works: 3G Long Term Evolution (3G LTE)

More cost efficient

- Reduced CAPEX: cheaper infrastructure
- Reduced OPEX: lower maintenance costs

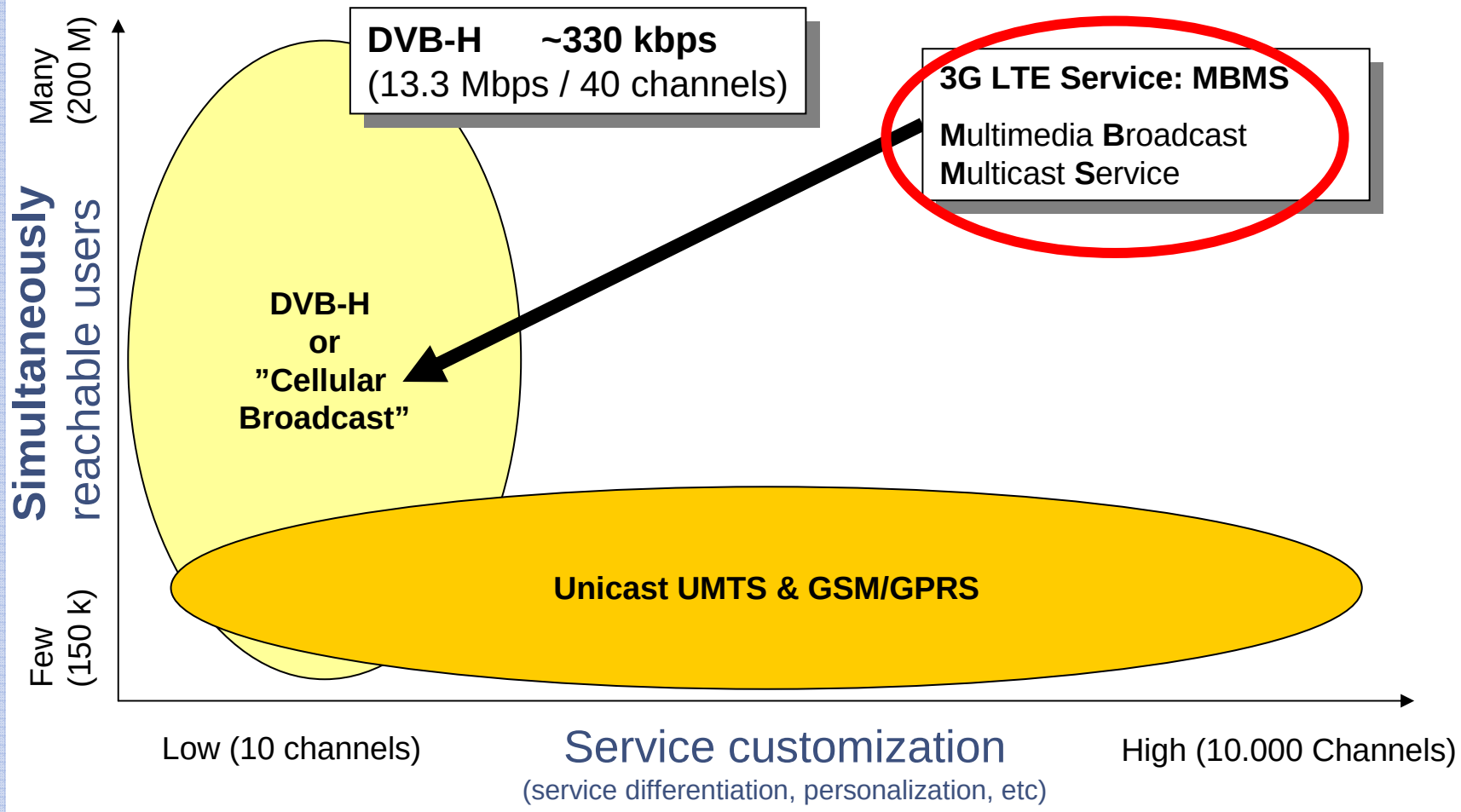
- **Higher Quality of Service**
  - Increased Coverage, improved cell-edge behavior

- **Better latency and round-trip-time**
  - Support for real-time applications

- **Higher Throughput**
  - Both per link and in the whole system

- **Support of new services**
  - Broadcast and multicast over cellular network

3G LTE: Example of New Service



Source: ERICSSON
Open Workshop on NGN, Brussels, June 22, 2005

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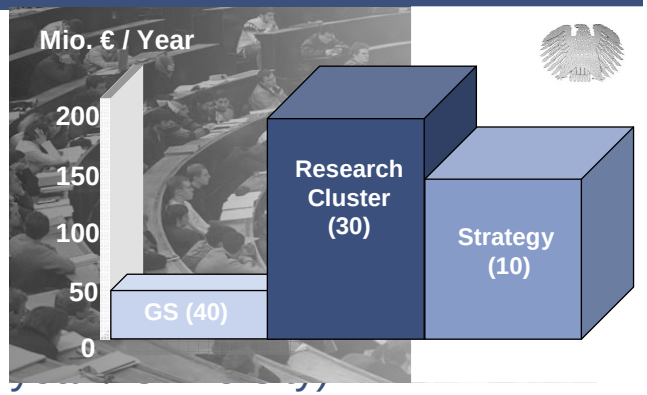
The „Excellence Initiative“

- **German government program**
  - 1,9 Bio. € total
  - Funding period: 5 years
  - Structure : 3 Funding lines
    - Graduate schools (1 M€ / year / topic)
    - Research cluster (6,5 M€ / year / cluster)
    - Strategy to develop top research (12.5 M€ /
  - Thorough evaluation by renowned international researchers



- **RWTH Aachen**
  - “Elite”-University
  - 1 Graduate school
    - Aachen Institute for Advanced Studies in Computational Engineering Sciences
  - 3 Research cluster
    - Integrated Production Technology for High-Wage Countries Chairman: Christian Brecher (WZL)
    - **Ultra high-speed Mobile Information and Communication (UMIC)** ⇨Chairman: Gerd Ascheid (ISS)
    - Taylor-Made Fuels from Biomass Chairman: Stefan Pischinger (VKA)

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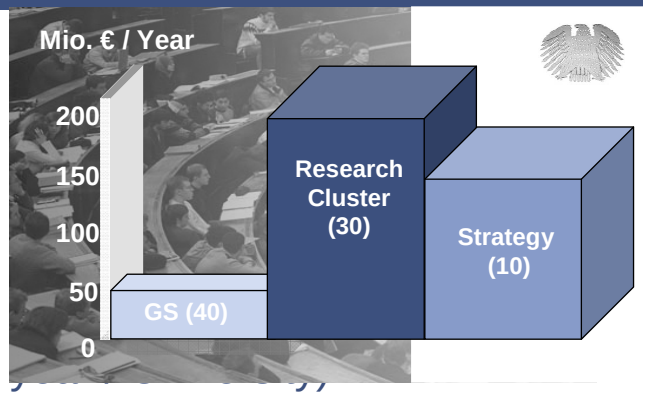

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Ultra high-speed Mobile Information and Communication (UMIC)

Sole approved „cluster of excellence“ in the domain of information and communication technology

UMIC Assumption

- **Customers' primary interest is services not technology**
  - Usefulness (existing needs, new features)
  - Quality of service
  - Price (cost-effectiveness)

- **Technology is the basis for new service offerings**
  - Match applications and mobile communication technology
  - High data rates to many users at low cost
  - ⇨ ***UMIC approach matched the NGMN dream***

- **UMIC Research Fields**
  - Applications and services
  - Wireless transport platform
  - Radio frequency subsystems and system-on-chip
  - Cross disciplinary methods and tools

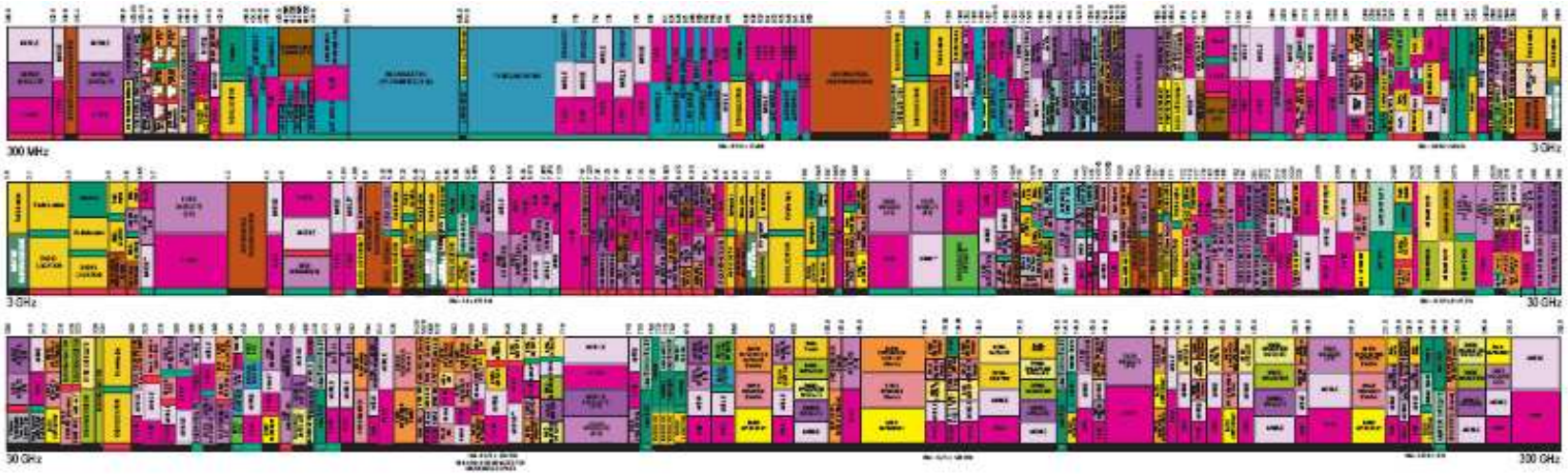
UMIC Research Areas

Wireless Transport Platform

Basic Issues of Mobile Transmission (1)

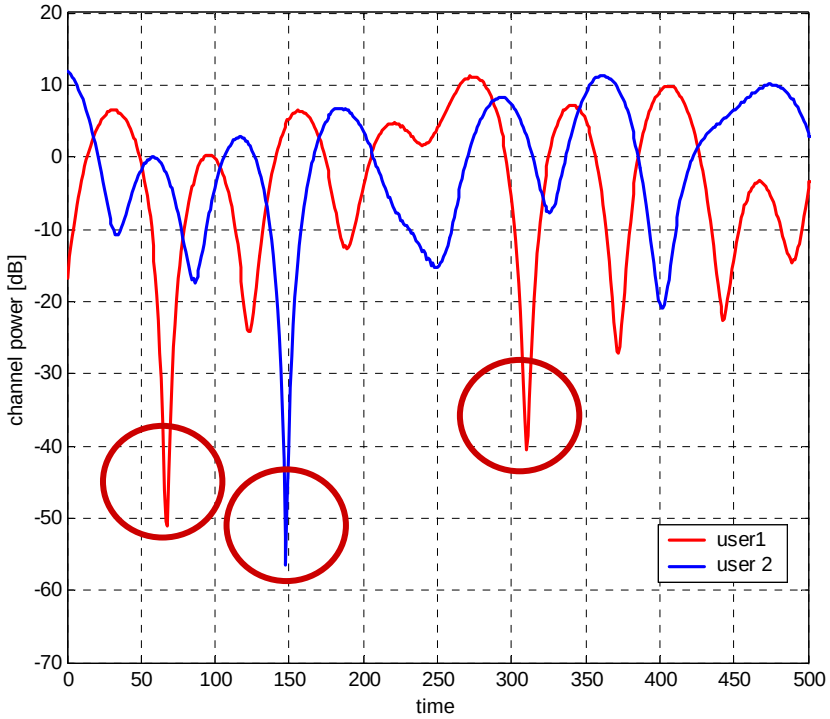
- High data rate = large bandwidth
- Available bandwidths are scarce and limited

Frequency Assignments 300 MHz-300GHz in the USA



Basic Issues of Mobile Transmission (2)

- **Time-varying signal quality**
  - short term
  - long term
    - Coverage issue („Funkloch“)
    - Hand-over
      - Cell border
      - Country border



Goal: Significantly higher Data Rates

Optimal Use of Bandwidth

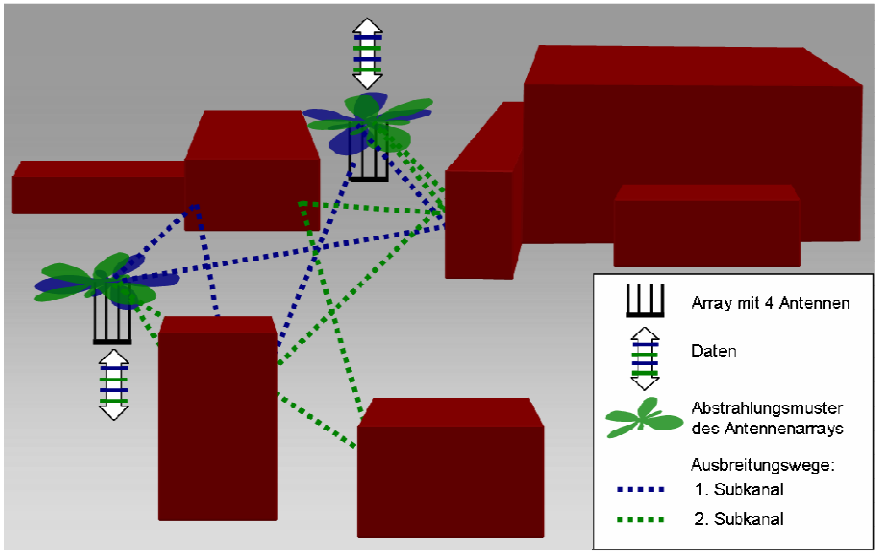
Transmission close to theoretical optimum

⇨ Little room for improvement left

Optimum use of „space“ at link level:

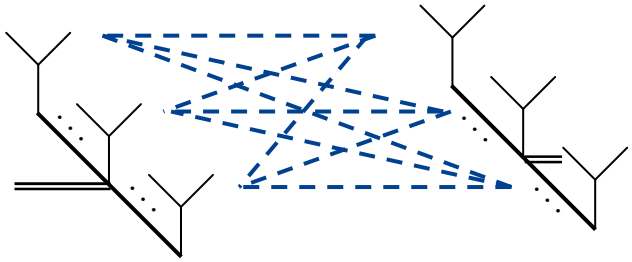
Using multiple antennas

⇨ higher transmit capacity
or higher transmit quality



Multiple Antenna Systems

Multiple antennas on transmit and receive side



- In principle multiple paths between transmitter and receiver
- Mapping N_s data streams on N_T antennas:
  Multiple use modes implemented
  just by different digital preprocessing

$$\mathbf{s}_{n,m} = \mathbf{P}_{SM}(n,m) \cdot \mathbf{d}_{n,m}$$
$$[N_T x 1] = [N_T x N_S]\,[N_S x 1]$$

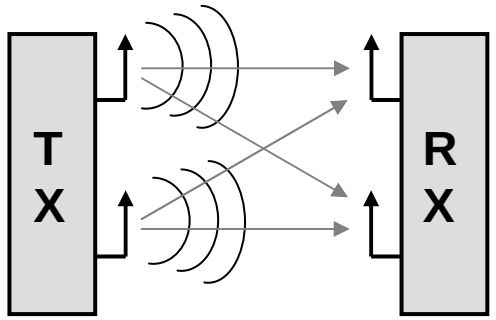
Multi-Antenna Techniques

Multiple data streams

to one user:

Spatial Multiplexing

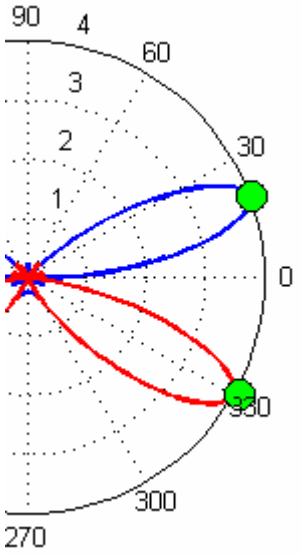
- Requires uncorrelated antenna elements
- Transmission of multiple data streams along independent spatial modes
- Requires multiple receive antennas
- Requires complex receiver processing



to multiple users:

Space-Division Multiple Access

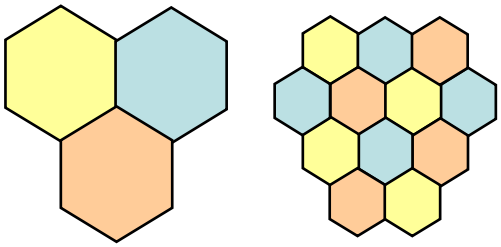
- Users are separated by their spatial signature
- Multiple data streams, but only one per user
- Does not require multiple receive antennas
- Does not require complex receiver processing



Goal: Significantly higher Data Rates

Optimum use of „space“ at network level

- Smaller cells
  = higher transmission capacity per area



⇨ Examples of research topics:

- Performance of complex, dynamic networks
- Efficiency of multi-hop transmission
  (forwarding of data to the backbone network)

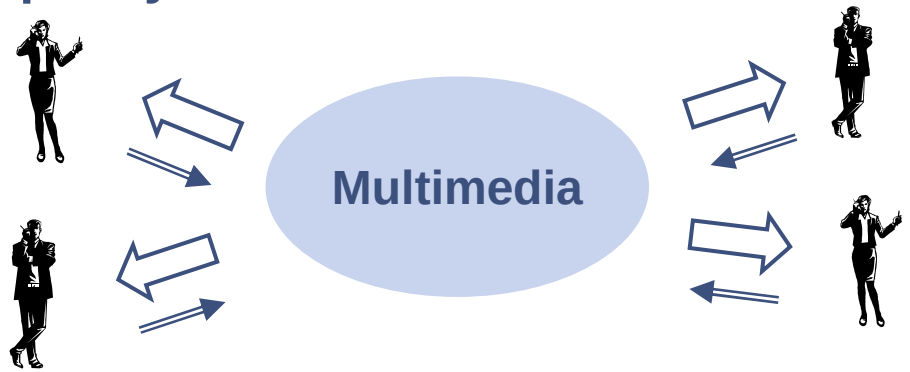
⇨ Requirement:

small, efficient, low-cost
base stations and relays

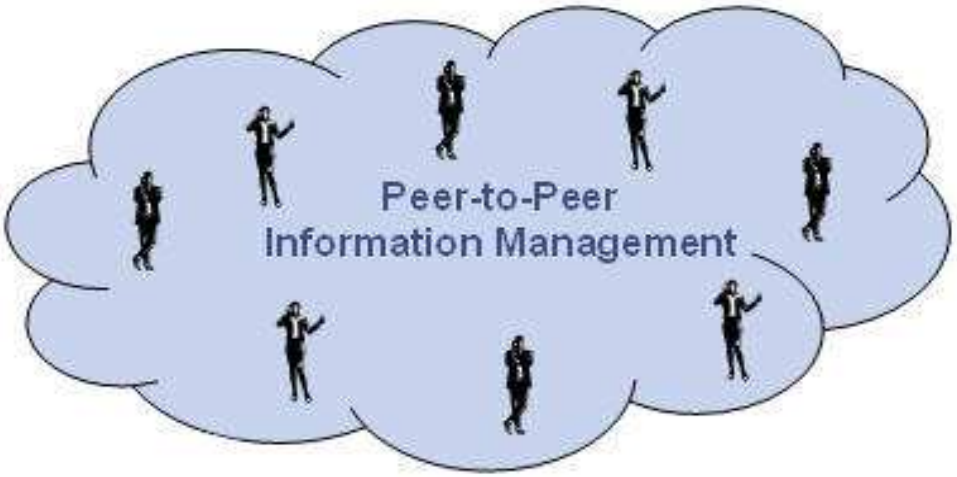
Applications and services

Representative Application Classes

- **High quality mobile multimedia transmission**



- **Mobile, context sensitive, adaptive peer-to-peer information management**



Distributed information generation and information access

Mobile P2P Context Management

- **Body area networks**
  - Wearable sensors
  - Mobile connection to internet
- **Examples**
  - Health monitoring
  - Fire fighters
  - ...

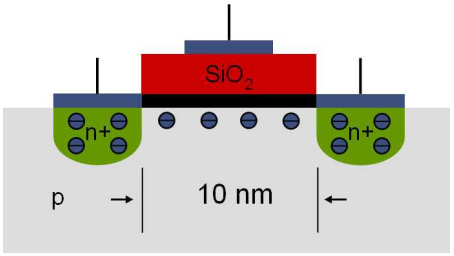
UMIC Research Areas

Radio frequency subsystems and system-on-chip

Silicon Technologies

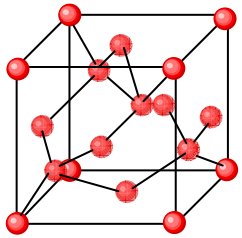
- **Current smallest size in commercial use:**
  Channel width of a switch (MOSFET): ***45 nm***

  CMOS Silicon usable at most down to 10nm



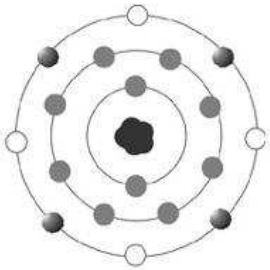
Transistor

→| ~0,5 nm| ←



Silicon crystal

← 0,11 nm →



- **Issues**
  - Linear analog / RF elements
  - Power consumption
  - Design of complex systems

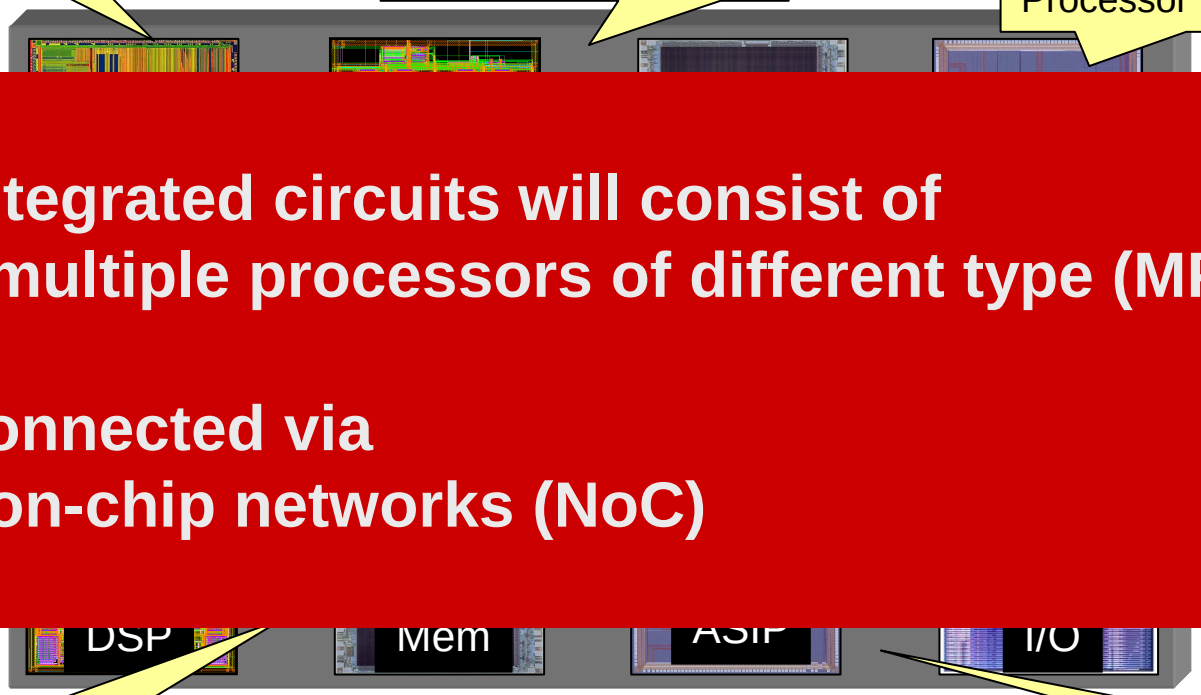
- **What will be next???**
  - Nano wires, spin transistors?

Addressing Tool Challenges

Software Development Tools

Multi-Processor Platform Design Tools

Processor Design Tools



Integrated circuits will consist of
- multiple processors of different type (MPSoC)

connected via
- on-chip networks (NoC)

Virtual platforms: Software Development without Hardware

Multi-Processor Programming Tools

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Outlook

- **Future mobile systems will offer**
  - higher data rates
  - higher QoS
  - context sensitive services

  and
  - connect local/mobile sensor networks to the wide area network (internet)

- **There are**
  - many interesting research topics
  - significant „disruptive technology“ needs
  - new application and service opportunities

  = Chances for start-ups!