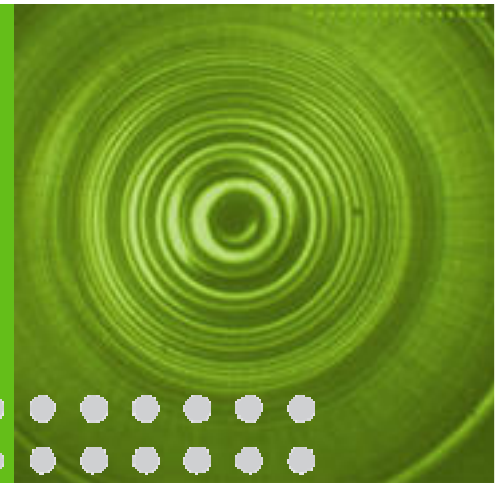# Trends in Simulating Mobile Networks
– attempt to survey and identify trends –

Bernd Gloss

ITG FG 5.2.4/FG 5.2.1 Workshop on "Simulating Mobile Networks"

June 19, 2008, Stuttgart

Trends in Simulating Mobile Networks

1. Scope of simulation studies

2. Simulation technologies

3. Multiscale problems and computational complexity

4. Software engineering and modeling issues

5. Conclusions

1 Scope of simulation studies

Scope of simulation studies
Study aspects

Technology aspects of mobile and wireless networks

- Antenna configurations

- Modulation and coding schemes

- Wireless resource scheduling

- Interference mitigation

- Data Link Layer mechanisms like ARQ/HARQ and flow control

- Transport flow control

- Mobility protocols

- Handover procedures

- Ad-hoc routing protocols

- Performance of signalling: WLAN, GPRS, LTE, WiMAX

- ...

Modeling aspects

- User mobility

- Channel properties

- Application performance models

- ...

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Protocol stack view

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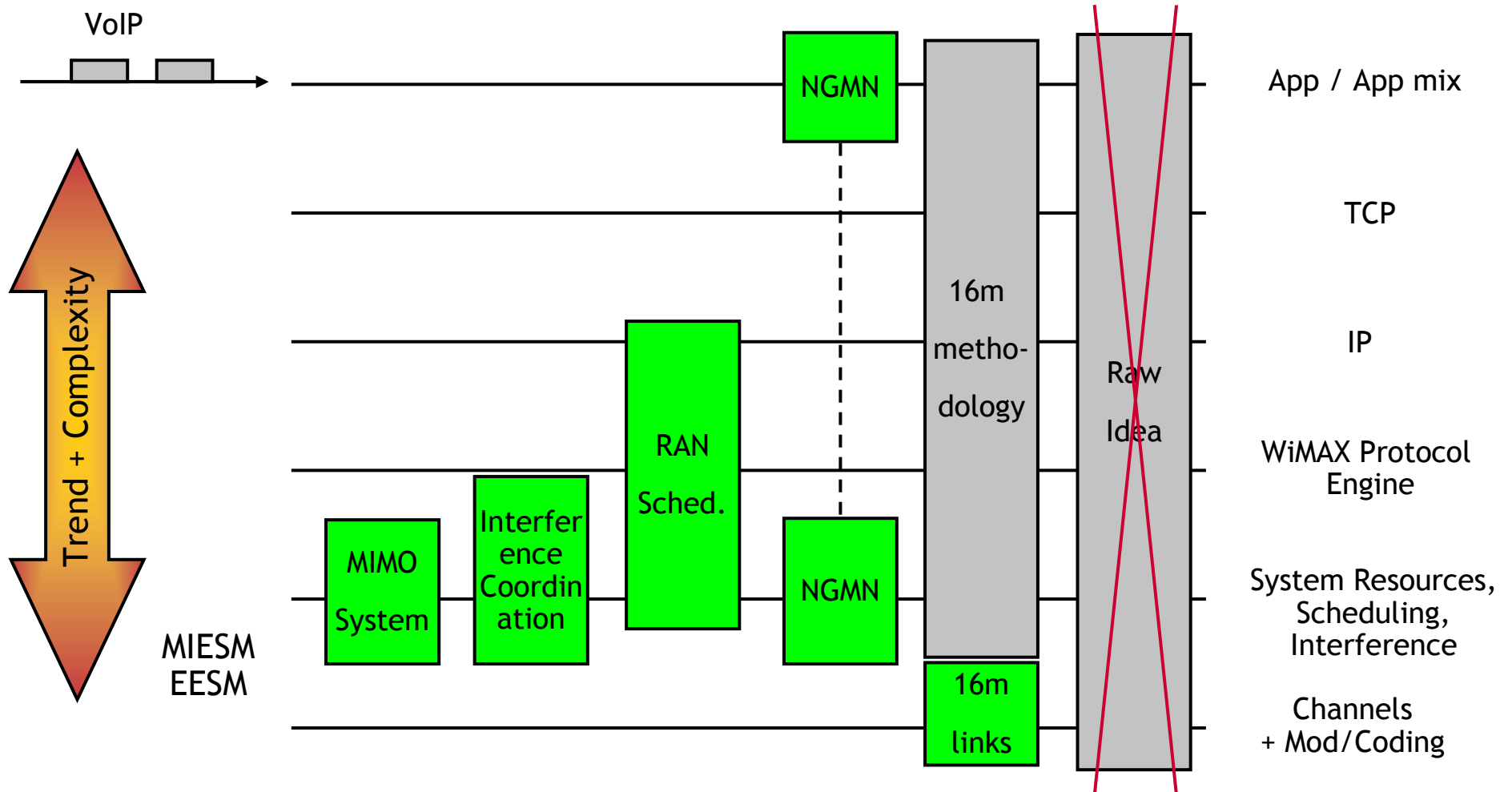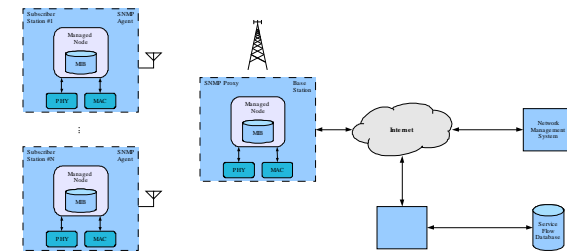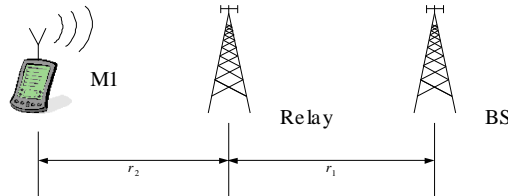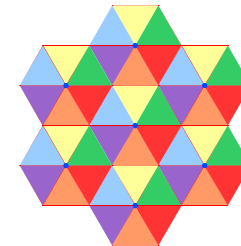
System aspects

- Link

- Sector / Cell

- Cell-cluster

- Multi-hop

- RAN / ad-hoc networks / mesh networks

Trend + Complexity

M1

BS

r_1

M1

Relay

BS

r_2

r_1
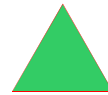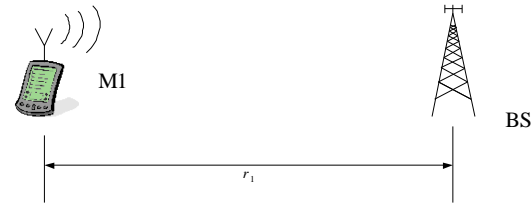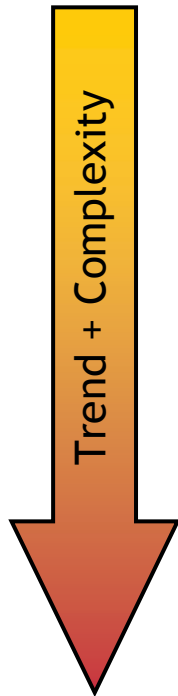
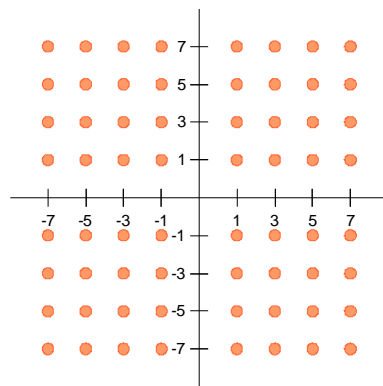From IEEE Std 802.16f-2005, Copyright IEEE 2005, All rights reserved.

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Scope of simulation studies
Time view

Scope of studies

...

- from one aspect to inter-working aspects
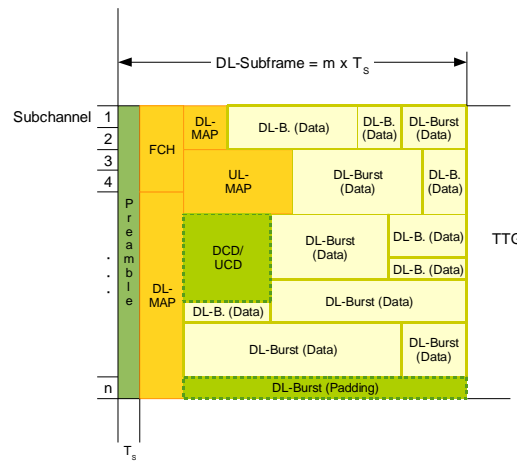
Version	IHL	Type of Service	Total Length	
Identification			Flags	Fragment
Time To Live		Protocol	Header Checksum	
Source IP Address				
Destination IP Address				
Options				Padding
Data				

TCP Flow

IP Packet

DL-Subframe = m x T_S

Subchannel 1 2 3 4 ... n

FCH
Preamble
DL-MAP

DL-MAP
UL-MAP
DCD/UCD
DL-B. (Data)
DL-Burst (Data)
DL-B. (Data)
DL-Burst (Data)
DL-B. (Data)
DL-B. (Data)
DL-Burst (Data)
DL-Burst (Data)
DL-Burst (Padding)

T_s

TTG

1 MAC Frame

7 5 3 1
-7 -5 -3 -1   1 3 5 7
-1 -3 -5 -7

1 Symbol

Trend + Complexity

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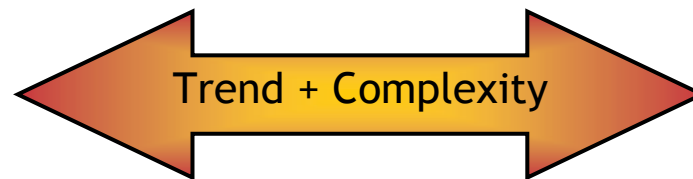
Scope of simulation studies

Trends and interim conclusions

State of the art

- Single mechanisms have been studied

  - Optimizations are done for many cases
 - System evaluations are focused

Trends

- Scope extensions in all dimensions: layers, nodes, time, …

  - Software complexity rules!
  - Methodology documents intend to restrict complexity by specifying simulation models and scenarios for studies of selected components, e.g. IEEE802.16m Evaluation Methodologies, NGMN Evaluation Methodologies, ITU Evaluation Methodologies, …
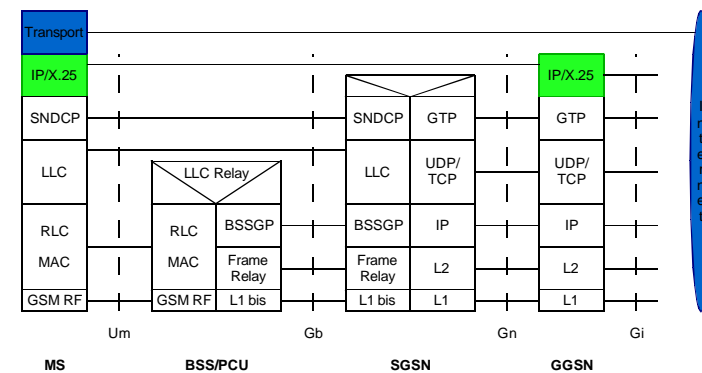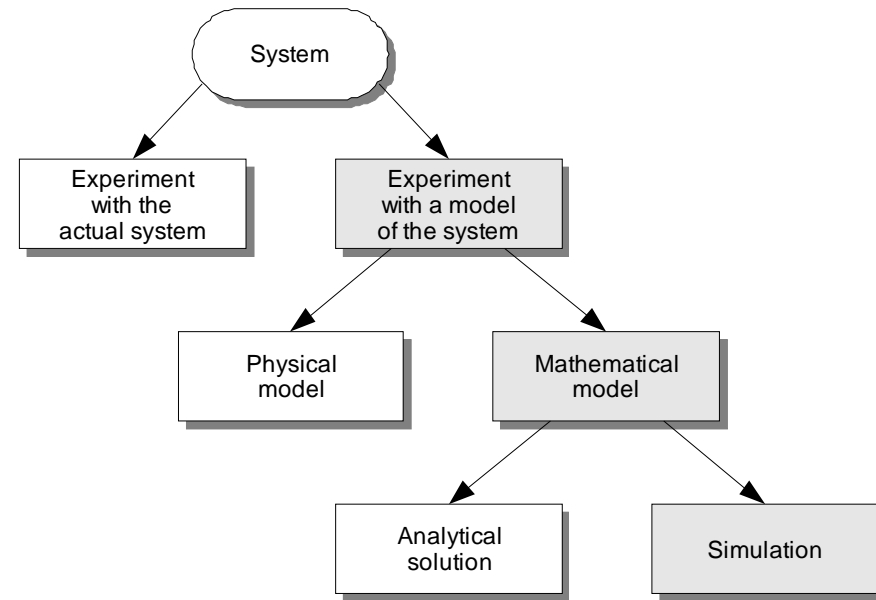
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2

Simulation technologies

The notion of Simulating

- Simulation = Modeling + Execution

```
                    ┌───────────┐
                    │  System   │
                    └───────────┘
                    ╱           ╲
          ┌──────────────┐  ┌──────────────┐
          │ Experiment   │  │ Experiment   │
          │ with the     │  │ with a model │
          │ actual system│  │ of the system│
          └──────────────┘  └──────────────┘
                            ╱              ╲
                  ┌──────────────┐  ┌──────────────┐
                  │  Physical    │  │ Mathematical │
                  │   model      │  │    model     │
                  └──────────────┘  └──────────────┘
                                    ╱              ╲
                          ┌──────────────┐  ┌──────────────┐
                          │  Analytical  │  │  Simulation  │
                          │   solution   │  │              │
                          └──────────────┘  └──────────────┘
```

Methods to perform simulations are:

From Law, A. M. & Kelton, W. D.
Simulation modeling and analysis
McGraw-Hill, 1991

- Calculation tools: Matlab, spreadsheet programms, …

- Event-driven simulators: NS2, OPNET, OMNET, IKR SimLib, …

- Prototypes and test environments: Wireless Lab Environments, MADWIFI/XIAN based wireless 802.11 Protocols, IP-based lab networks, …

- Heterogeneous approaches with network emulators: The Cloud, NistNet, IKR SimLib + EmuLib, …

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Main advantages of the simulation approach

- Non-existing systems can be evaluated at lower costs

- Decoupling of real time and simulation time (compression / expansion)

- Modelling can be done aiming at a reduction to relevant mechanisms

- Automated parameter studies

- Better access to systems owing to
  - More flexible parameterization of systems and environments
  - Improved access to measure points of interest

Trends and interim conclusions

- Simulations are good!

- Basic tool sets and methodologies are stable for several years now
  - Tool-boxes in C/C++/Jave and tool environments like Matlab are available at a good quality
  - Lack of destinct models, e.g. of an vendors implementation of a BS

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3 Multiscale simulations and computational complexity

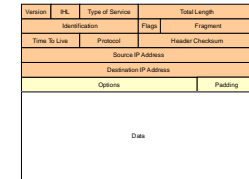# Multiscale simulations and computational complexity
## Aspects of teletraffic engineering

Time scale of interest

- **Application level: user behaviour s … min … h**

- **Connection level: protocol activities ms … s**

- **Transport level: buffering, transmission delays µs … ms**

- **Media access: scheduling, switching ns … µs**

Model examples

- **Radio channels with time variant properties**

- **Mobility of users**

- **Protocol mechanisms for flow control**

- **Routing and queue management in the Internet**

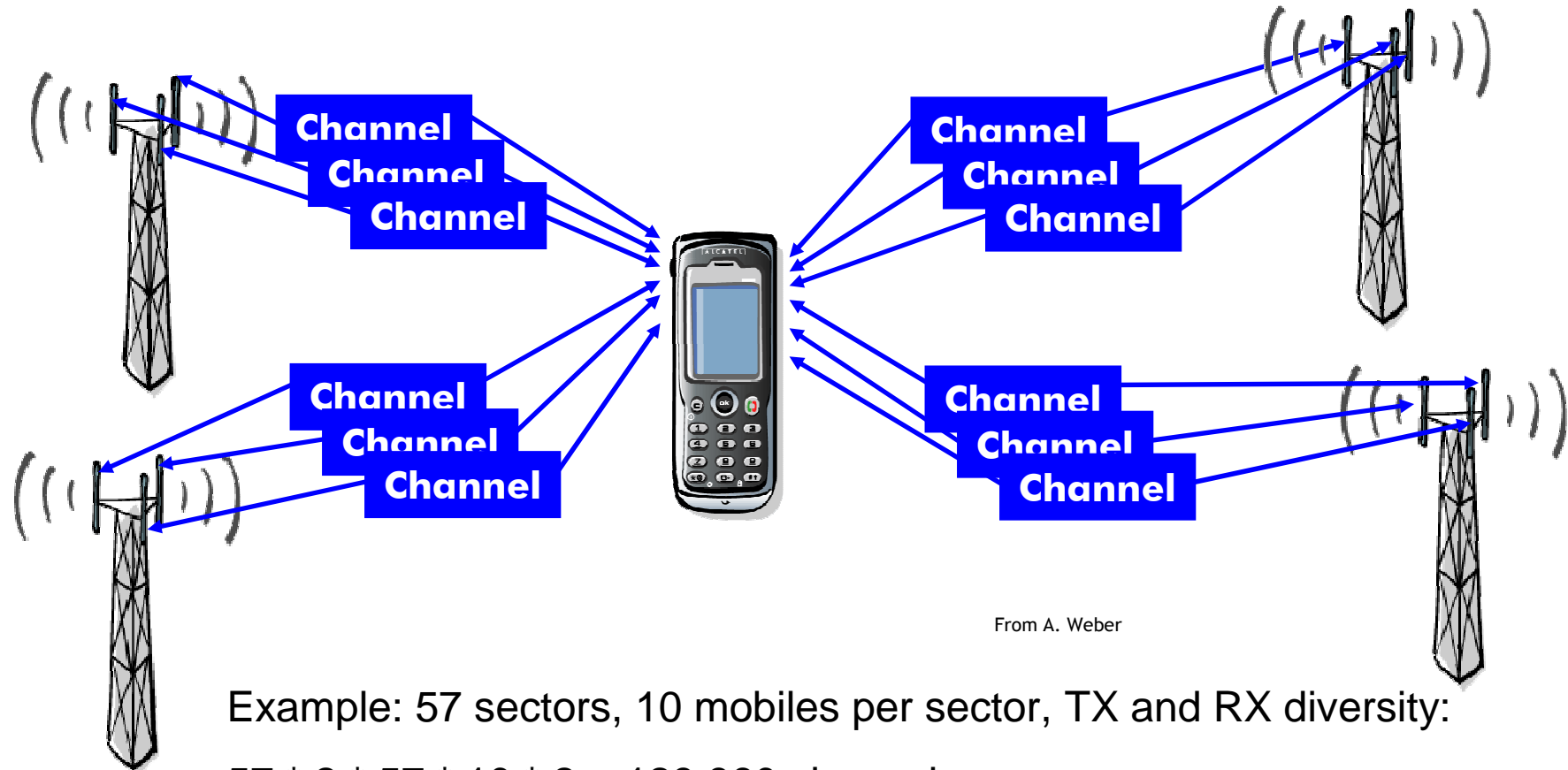- **Data access patterns, e.g. WWW or Peer-to-Peer Overlays**
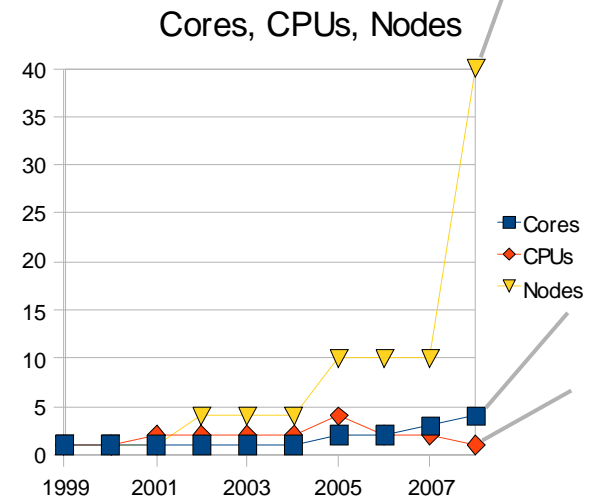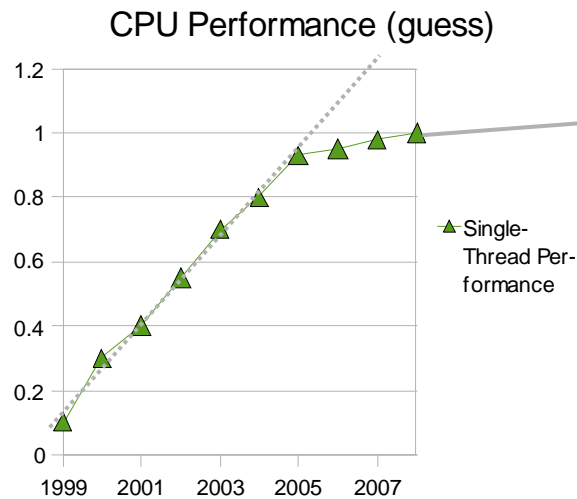
IP Packet
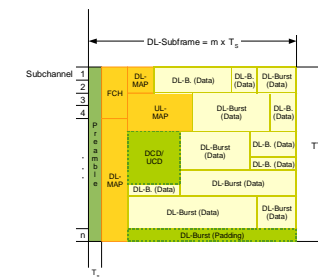
1 MAC Frame
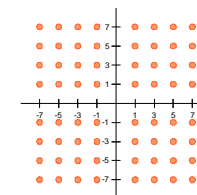
1 Symbol

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From A. Weber

Example: 57 sectors, 10 mobiles per sector, TX and RX diversity:

57 * 2 * 57 * 10 * 2 = 129,960 channels

57 * 2 * 57 * 10 * 2 * 600 = 77,976,000 channels

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Multiscale simulations and computational complexity

Trends in CPU performance

CPU Performance (guess)
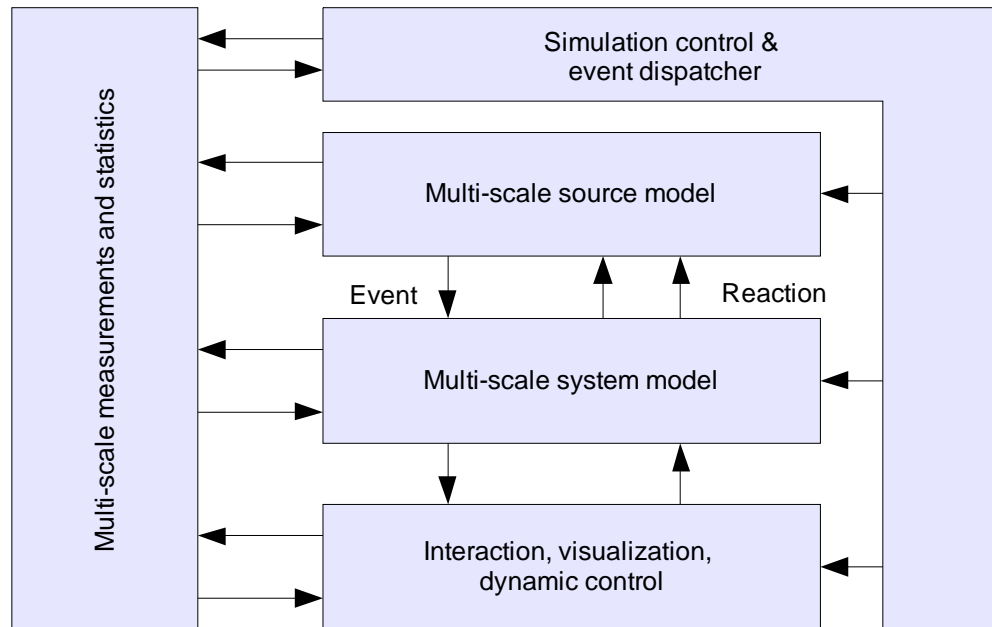
Cores, CPUs, Nodes

- Single-thread CPU performance is in saturation

- Current increases of speed owing to the number of cores, the number of CPUs and the number of Systems

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- Approach: model separation via abstractions

From P.J.Kühn, „Multiskalen-Simulation", Workshop Simulation, ITG FG 5.2.1, Bremen, 16. November 2006

➢ Multi-scale simulation techniques and modelling are currently a trend for research activities in academia

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Trends and conclusions

- Single-thread CPU performance won't increase significantly

- Simulation complexity increases

  ➢ Simulation tools in teletraffic engineernig have to find new ways, e.g. parallelization

- Multi-scale studies are not possible on any thinkable Computer environment

  ➢ New abstractions have to be found allowing reduction of computational effort

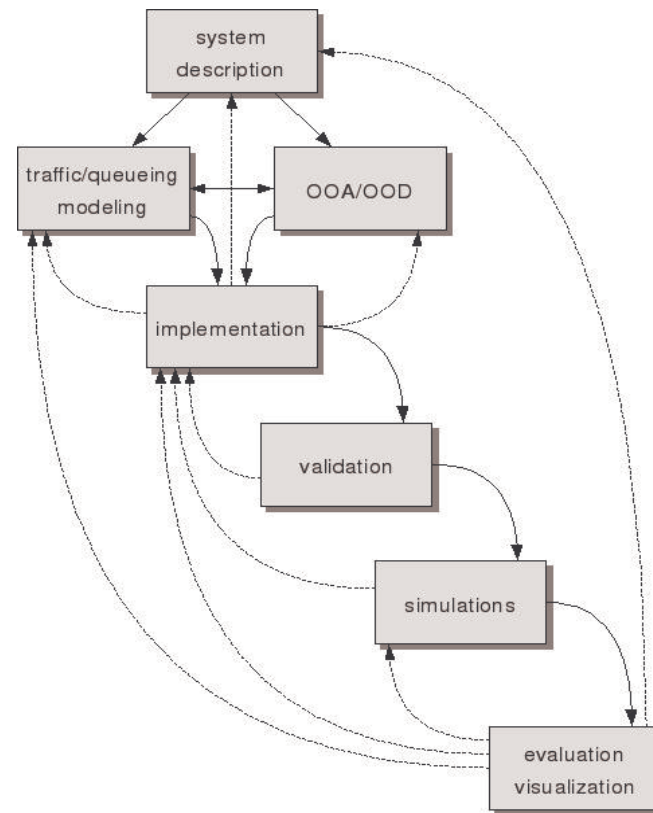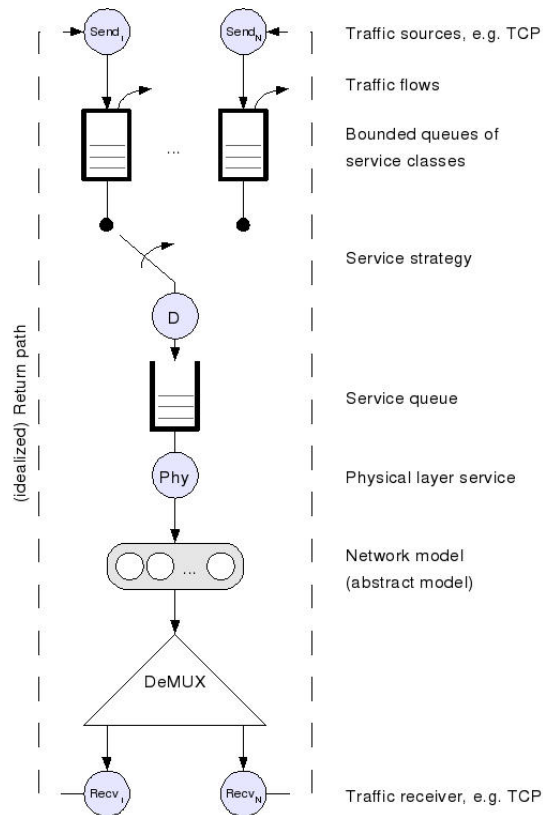Alcatel·Lucent

4

Software engineering and modelling issues

Performing Simulation Studies

➢ Model + Studies

From Bodamer, Dolzer, Gauger, Necker „Object Oriented Simulation – The IKR SimLib", http://www.ikr.uni-stuttgart.de/IKRSimLib, July 2005

- Simulators try to re-implement real systems
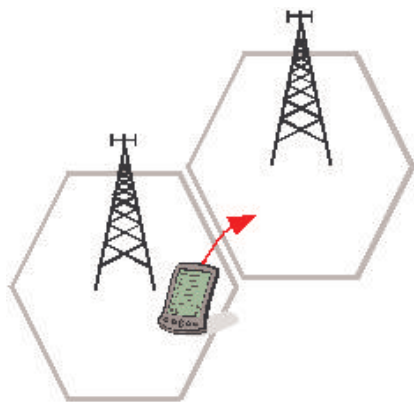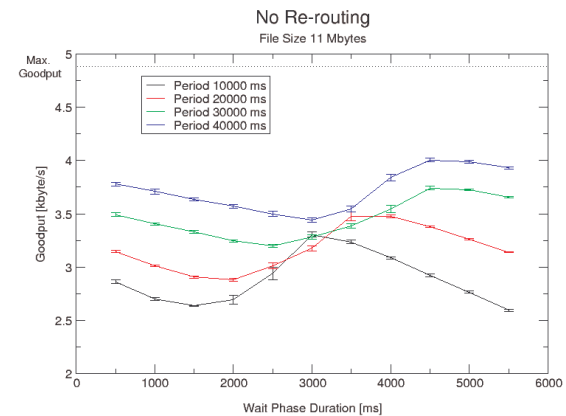- Aiming at determining real system performance values

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Project Charter

- **Aims:** investigating GPRS/TCP cross-layer interferences for handover cases

Scenario

Example Study

No Re-routing
File Size 11 Mbytes

Max. Goodput

Period 10000 ms
Period 20000 ms
Period 30000 ms
Period 40000 ms

Goodput [kbyte/s]

Wait Phase Duration [ms]

System Model

ACK packets

TCP Sender

TCP Receiver

data packets   link (rate + bounded FIFO queue)

BTS   BTS   PCU

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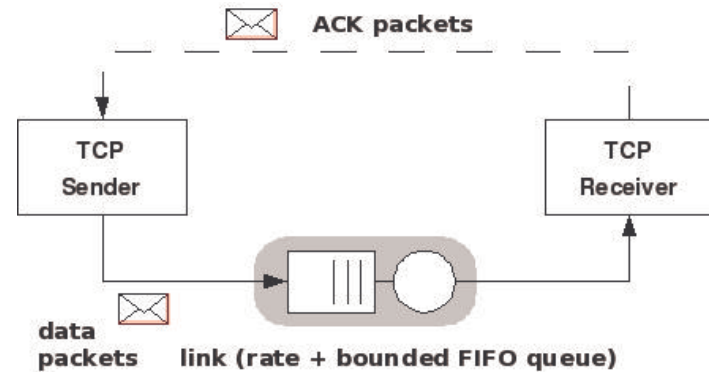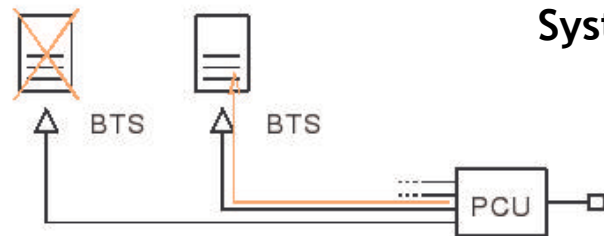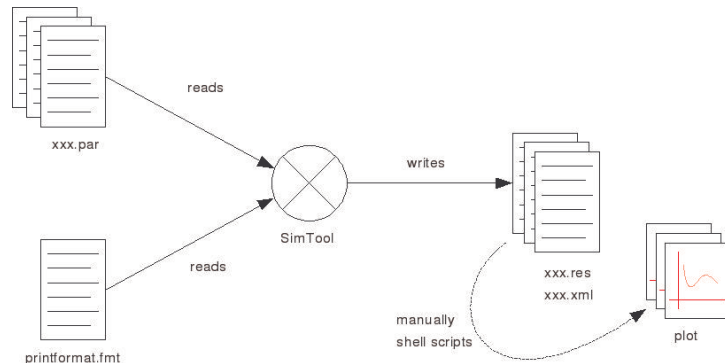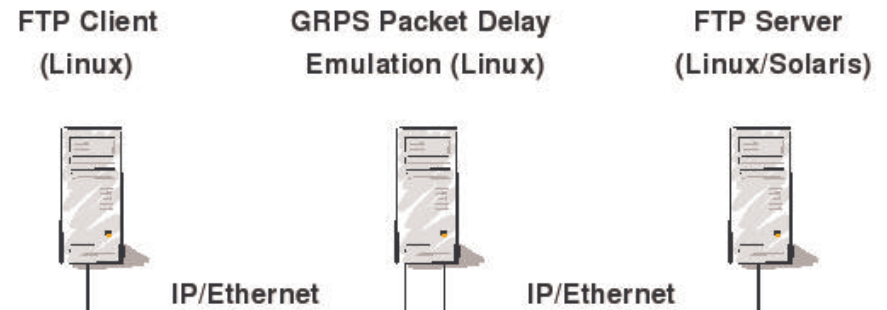
Software engineering and modelling issues
Example Study: „TCP over GPRS – Handover Performance"

Simulation Study (at IKR)

reads
xxx.par
SimTool
writes
xxx.res
xxx.xml
reads
manually
shell scripts
plot
printformat.fmt

Emulation Study (A. Weber)

FTP Client (Linux) — GRPS Packet Delay Emulation (Linux) — FTP Server (Linux/Solaris)
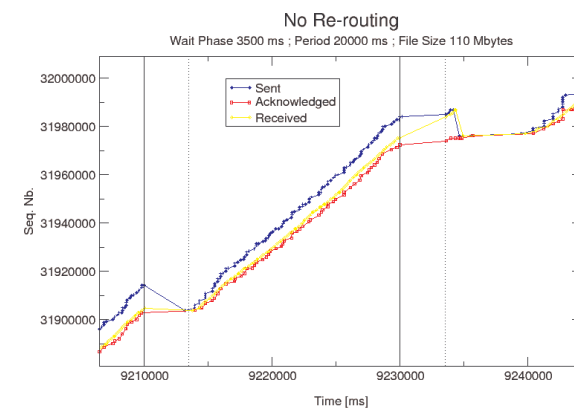
IP/Ethernet   IP/Ethernet

Study Aims

- Optimization of RAN mechanisms/parameters to alleviate cross-layer effects

Simulation pros

- Scanning of large parameter spaces

Emulation pros

- Real world
- Validation of the simulation environment
- Validation/optimization of special parameterizations

No Re-routing
Wait Phase 3500 ms ; Period 20000 ms ; File Size 110 Mbytes

Sent
Acknowledged
Received

Seq. Nb.
Time [ms]

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Computational complexity and software engineering issues
Trends and interim conclusions

Trends

- Software complexity is growing rapidly

- Model complexity is growing rapidly

➢ Mistakes and errors in modeling of complexe systems are expected to be normal rather than an exception
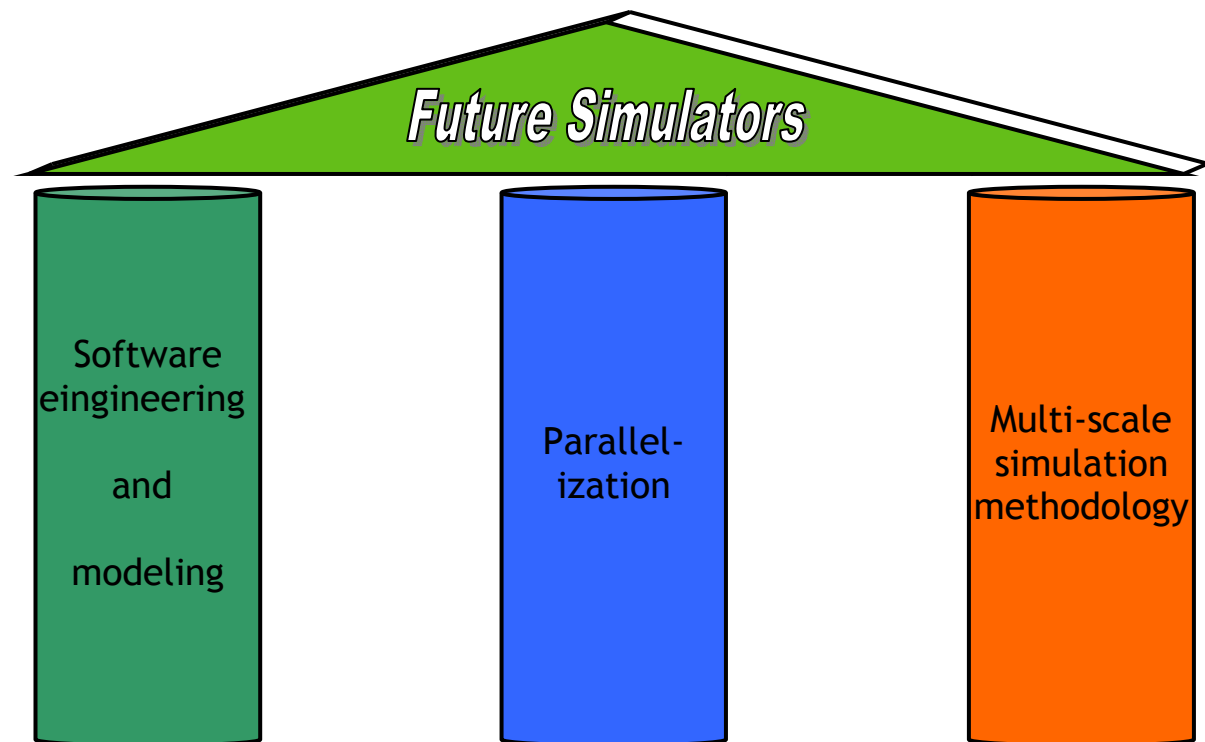
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Conclusions

Conclusions

- There are trends in various directions

  - Computational effort increases

  - Modelling complexity increases

  - Value of studies is becoming a problem

Future Simulators

Software eingineering and modeling

Parallel-ization

Multi-scale simulation methodology

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