A Simulation Framework for Common Radio Resource Management

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Motivation

**Different coexisting Radio Access Technologies**

- **WGAN** - Wireless *Global* Area Network
  - Inmarsat (492 kbit/s), Thuraya (60 - 144 kbit/s), Iridium (10 kbit/s), ASTRA2Connect (2 Mbit/s)
- **WWAN** - Wireless *Wide* Area Network
  - UMTS-HSDPA (14,4 Mbit/s) / LTE (326 Mbit/s - 1 Gbit/s), GSM-GPRS (171,2 kbit/s) /E-GPRS (473,6 kbit/s - 1 Mbit/s), WiMax (109 Mbit/s - 1 Gbit/s), DVB-H (15 Mbit/s)
- **WLAN** - Wireless *Local* Area Network
  - 802.11b,n (11 - 600 Mbit/s), HIPERLAN2 (54 MBit/s)
- **WPAN** - Wireless *Personal* Area Network
  - Bluetooth 3 (2,2 - 480 Mbit/s) , IrDA (16 MBit/s), DECT (552 kbit/s), WirelessHD (25 Gbit/s), W-USB (480 Mbit/s)
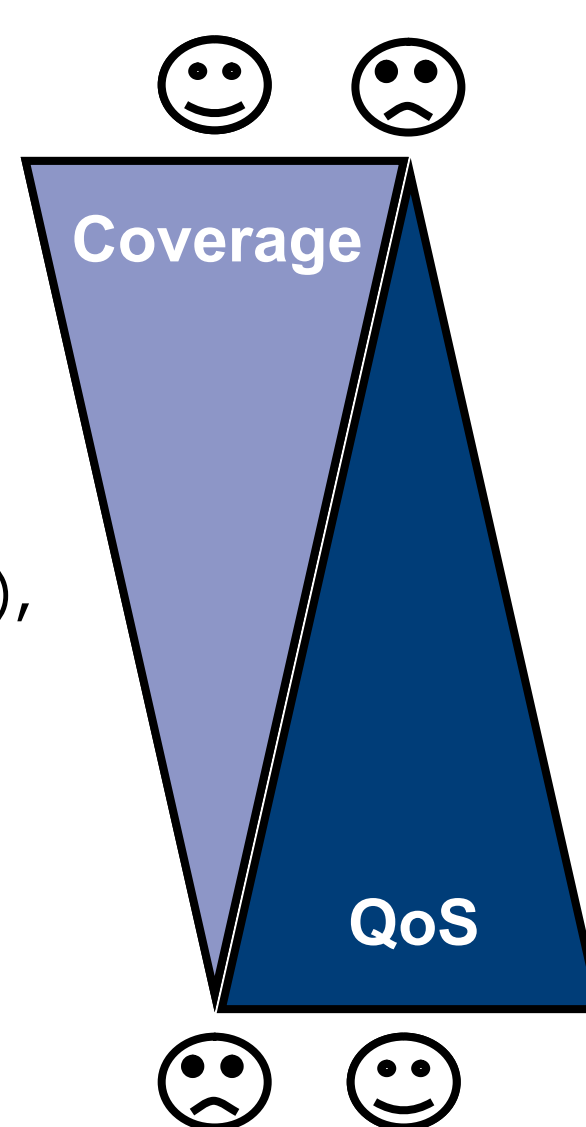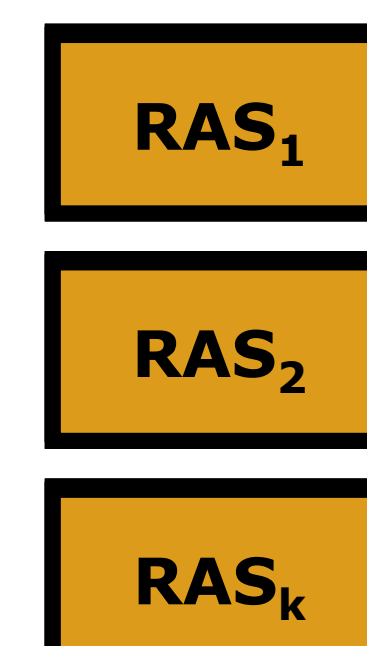
Coverage / QoS

UE in a Changing Environment

WGAN (1...n)
WWAN (1...n)
WLAN (1..n)
WLAN
WPAN
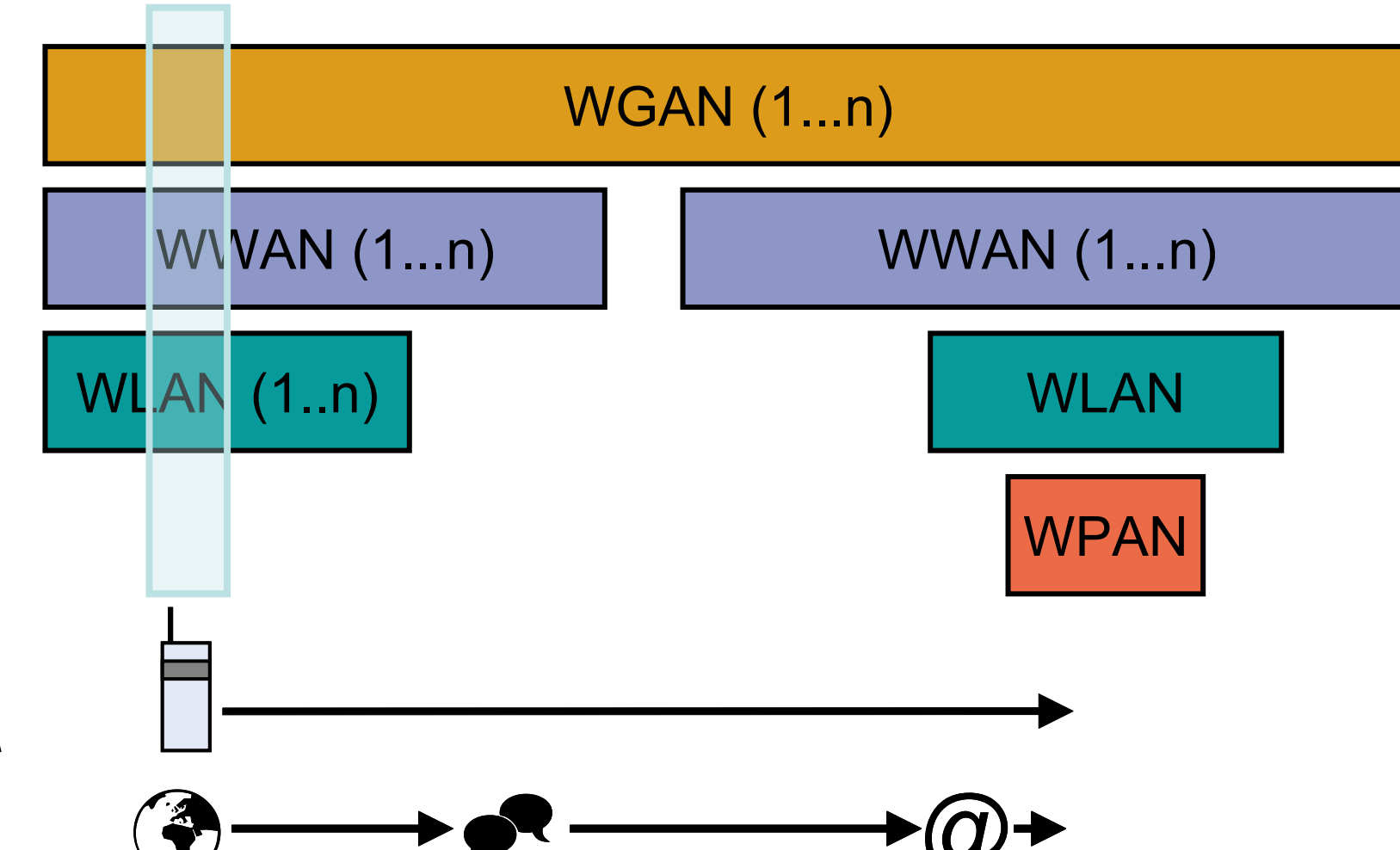
- **Set of User Equipment**
  - QoS demand
  - Resource consumption
  - Supported RAT/Provider
  - Available RAS ...

UE₁ ... UEₖ
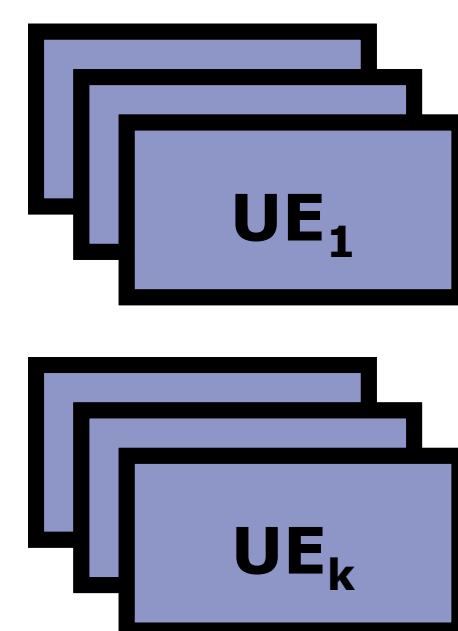
Matching →

- **Set of Radio Access Systems**
  - QoS offered
  - Available Ressources
 - Coverage
  - RAT/Provider ...

RAS₁ / RAS₂ / RASₖ

- **Aim: optimal distribution of services (UE) to available radio access systems**
  - Satisfied users, minimal costs
- **Possible actions to meet this aim:**
  - Handover (intra-/intersystem), adapt QoS, change RRM-properties (e.g. allocate additional frequencies)
- **Complex task due to dynamics in the system and many influencing factors**
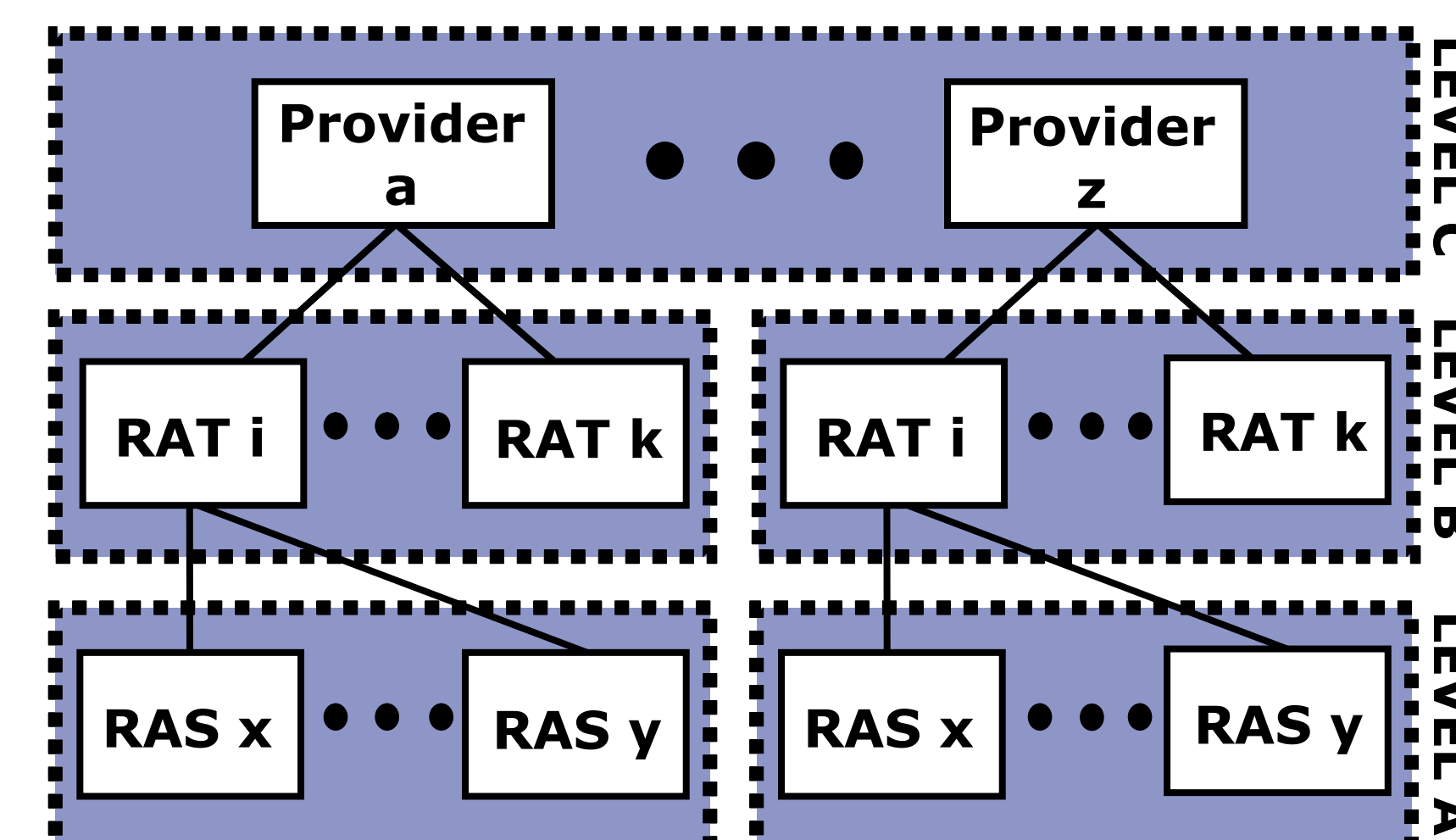 - Heterogeneous wireless systems and user equipments

Systematic View

Assumption:
- Core Network supports RAS features
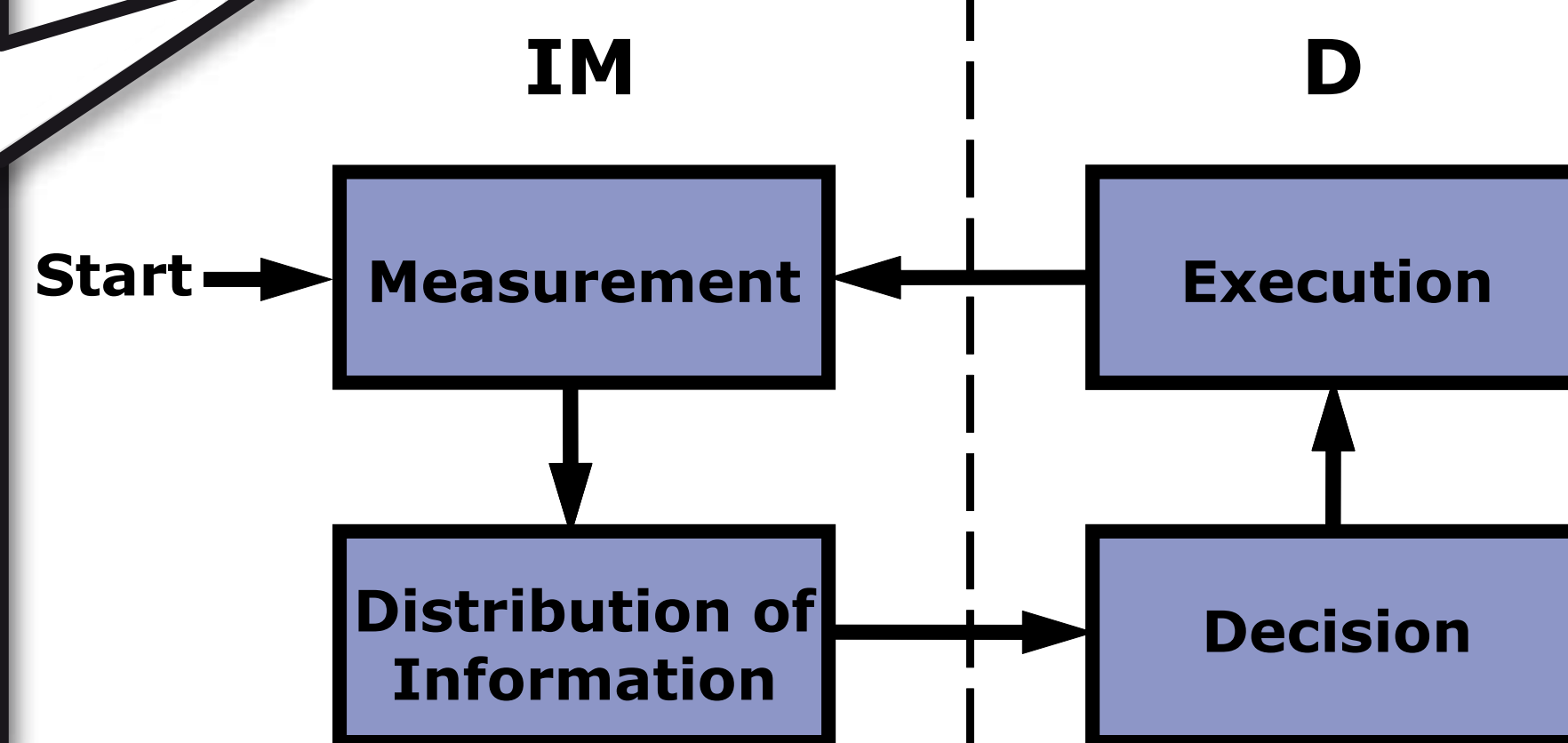- RAS is bottleneck due to unreliable wireless links

Common RAT Architecture

UE — Radio Access Network — Core Network — other Networks

RAS / RAS / QoS Broker / Gateways / AAA / ...
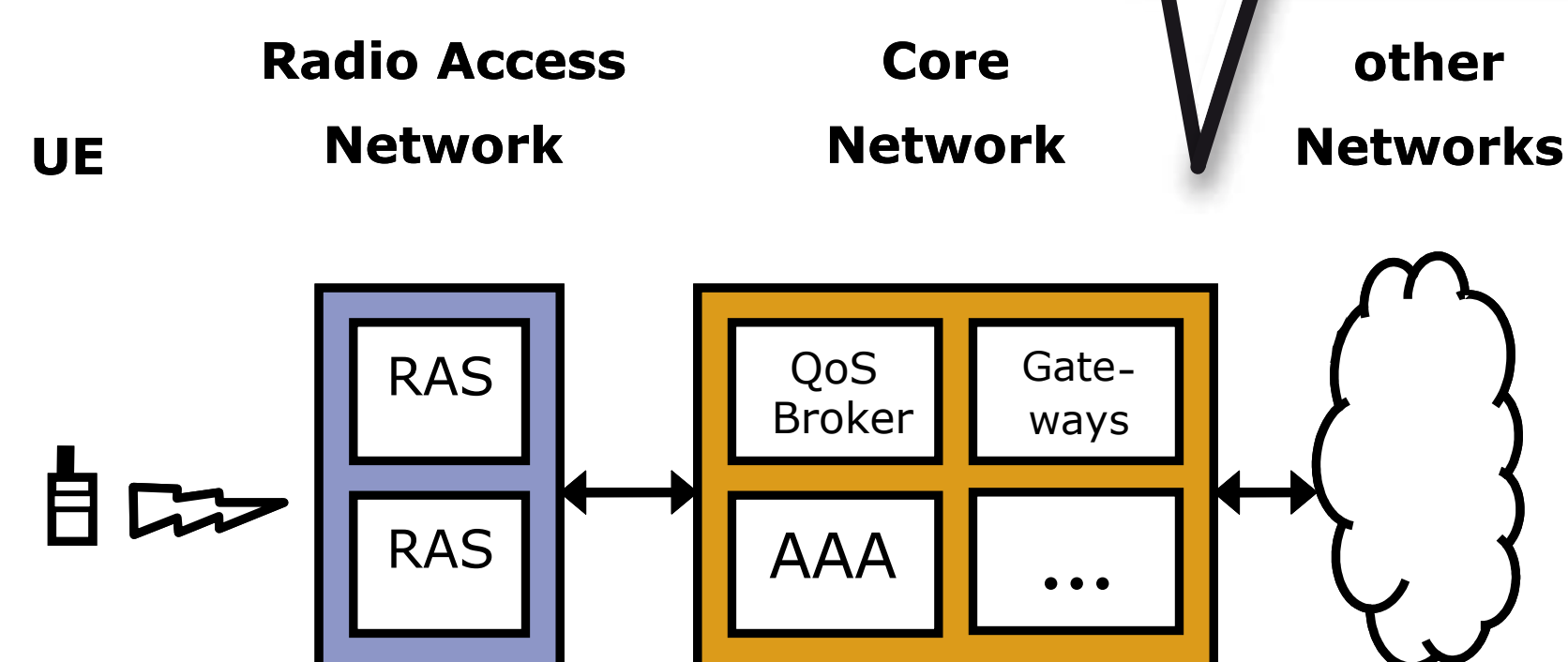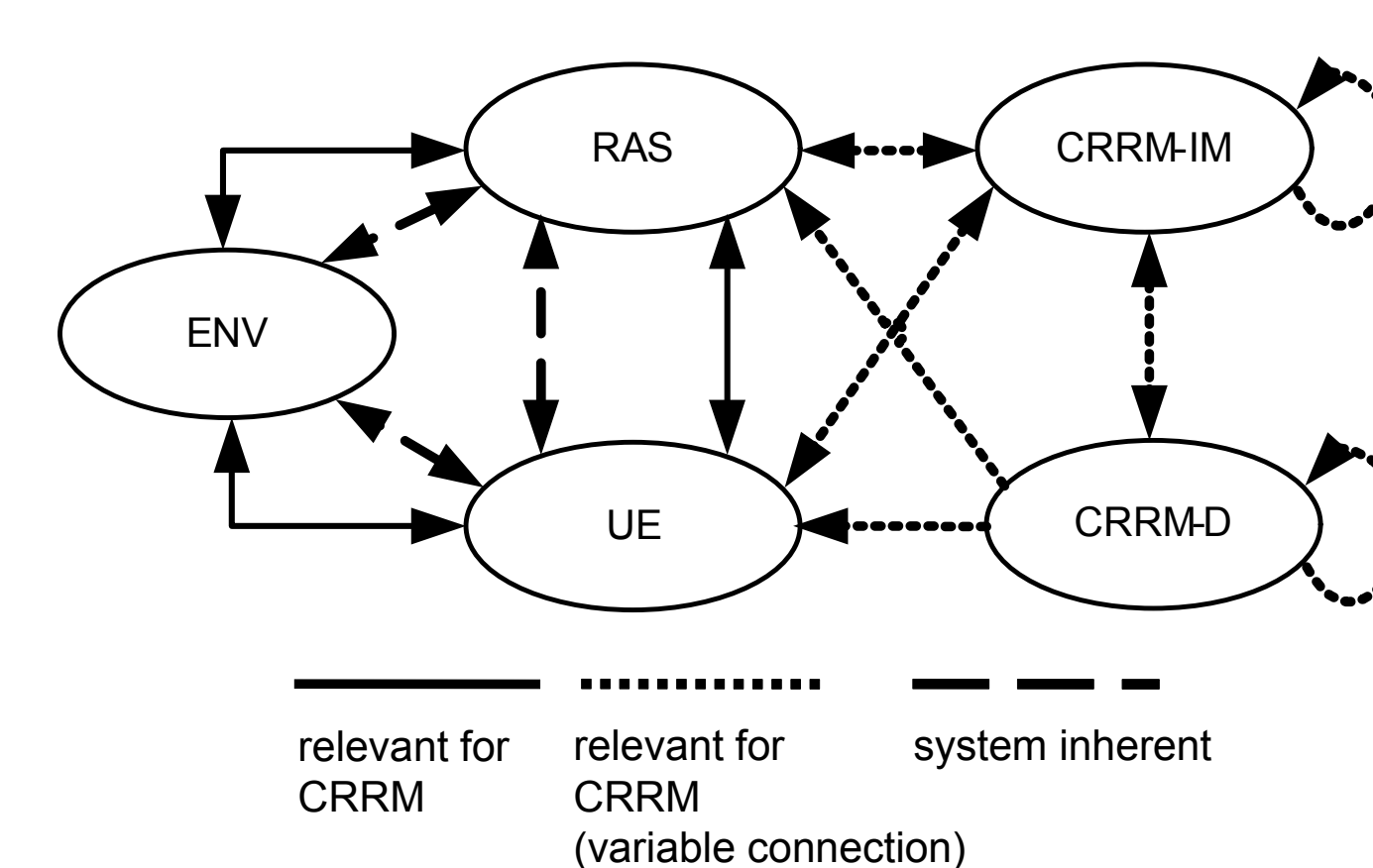

CRRM Control Loop

- **Main tasks of CRRM are Information Management and Decision**
  - Suitable protocols and communication connections for measurements and command execution are needed
- **Close relationship to Load Sharing Algorithms**
  - Categorization: system -, transfer -, information distribution -, coordination model, time horizon, stability control, adaptivity

IM / D

Start → Measurement → Execution
Measurement → Distribution of Information → Decision → Execution

Different CRRM Levels

LEVEL C: Provider a • • • Provider z
LEVEL B: RAT i • • • RAT k   RAT i • • • RAT k
LEVEL A: RAS x • • • RAS y   RAS x • • • RAS y

- **Each RAS has an autonomous local radio resource management**
  - Residing either close to the wireless transceiver or partly in the CN.
  - The RAS can be a satellite in case of a WGAN, a cell layer in case of a cellular WWAN system like UMTS, or even a single cell in case of a WLAN system or other UE in case of ad-hoc networks.
- **Providers usually support more than one Radio Access Technology**
  - f.i. GERAN together with UTRAN
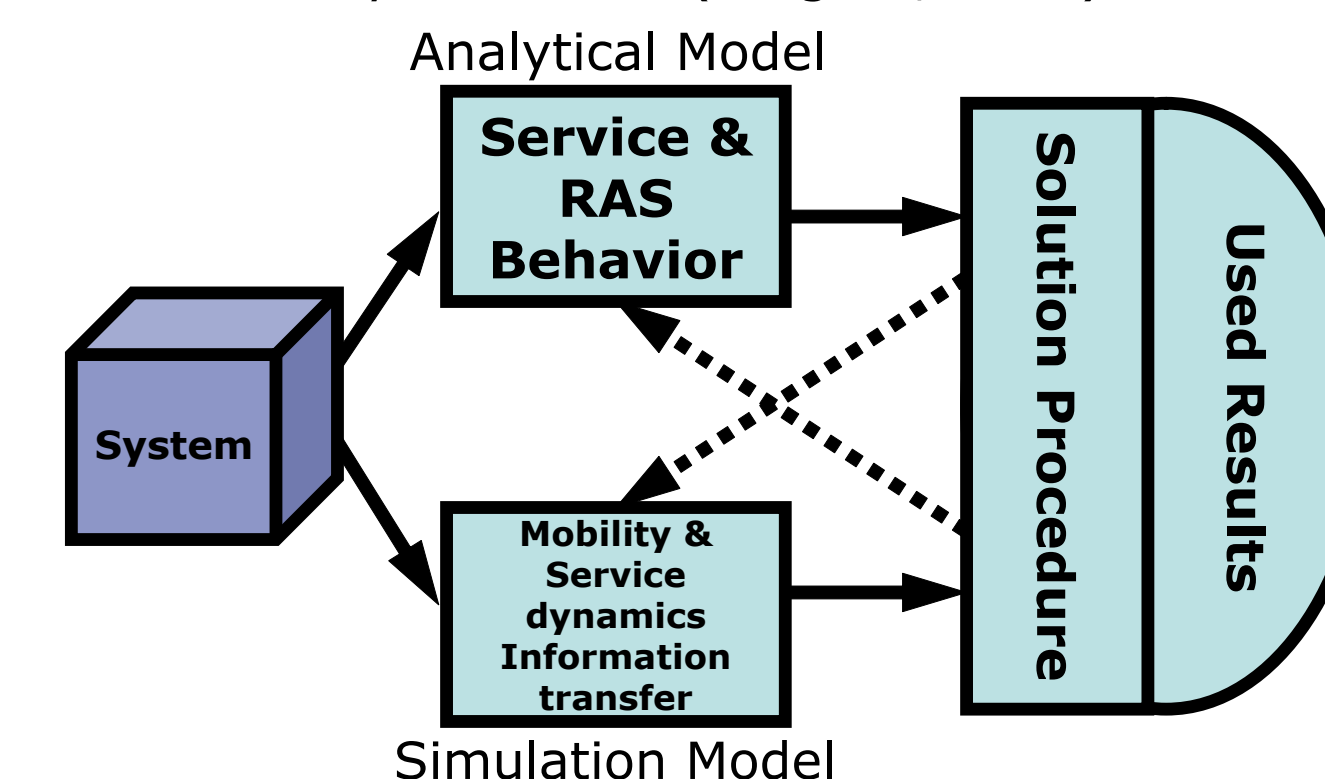- **Providers can have roaming agreements**

Modeling and Simulation
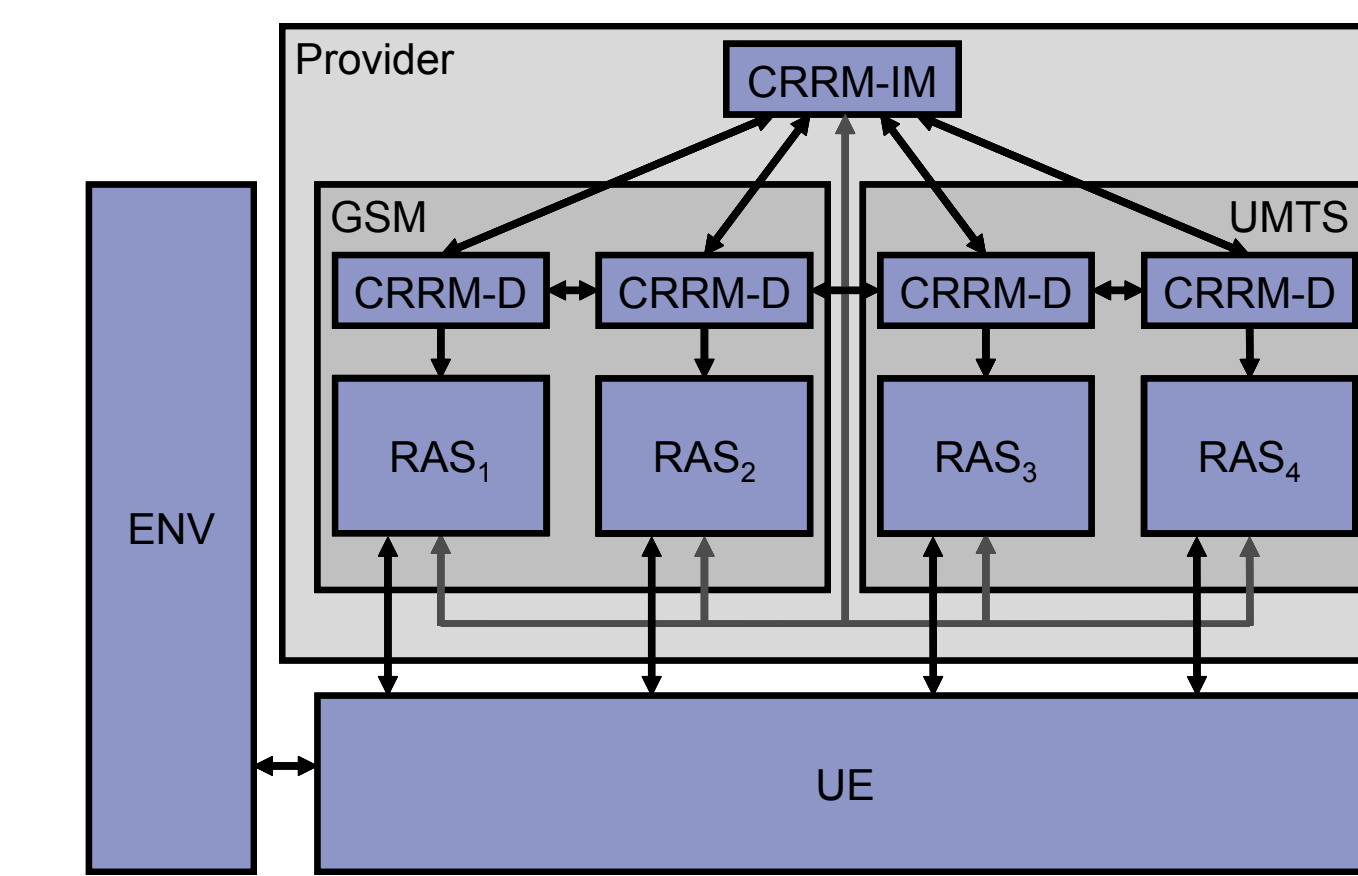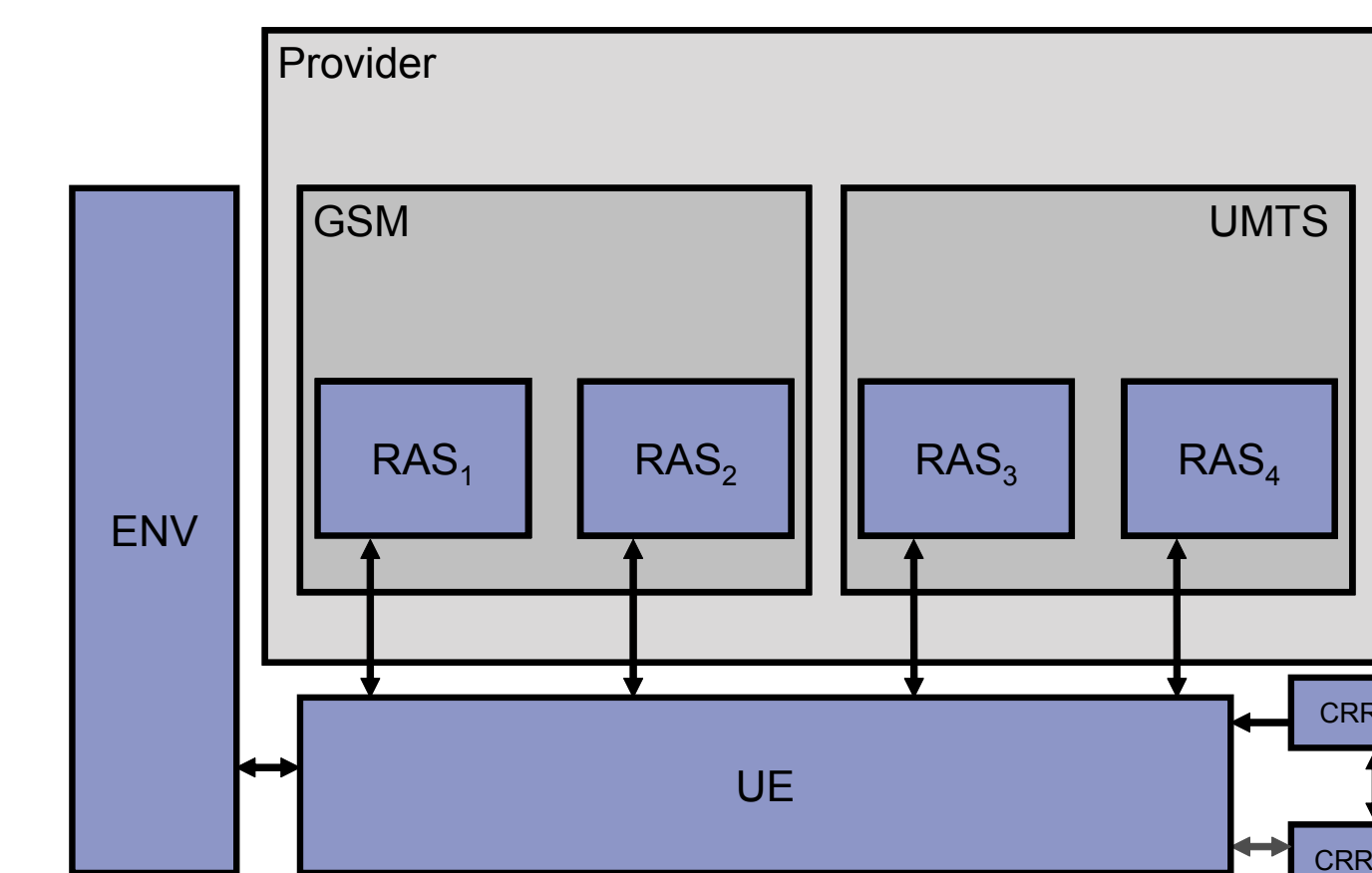
Component Connectivity in Model Framework

ENV / RAS / CRRM-IM / UE / CRRM-D

relevant for CRRM (solid) — relevant for CRRM (variable connection) — system inherent

Scenario Example: UMTS/GSM (NIHO)
centralized IM, decentralized D

Provider / CRRM-IM / GSM / UMTS / CRRM-D / RAS₁ RAS₂ RAS₃ RAS₄ / ENV / UE

Scenario Example: UMTS/GSM (MIHO)
decentralized IM & D

Provider / GSM / UMTS / RAS₁ RAS₂ RAS₃ RAS₄ / ENV / UE / CRRM-D / CRRM-IM

Hybrid Simulation Concept

- Class II hybrid model (Sargent, 1994)

System → Analytical Model: Service & RAS Behavior → Solution Procedure → Used Results
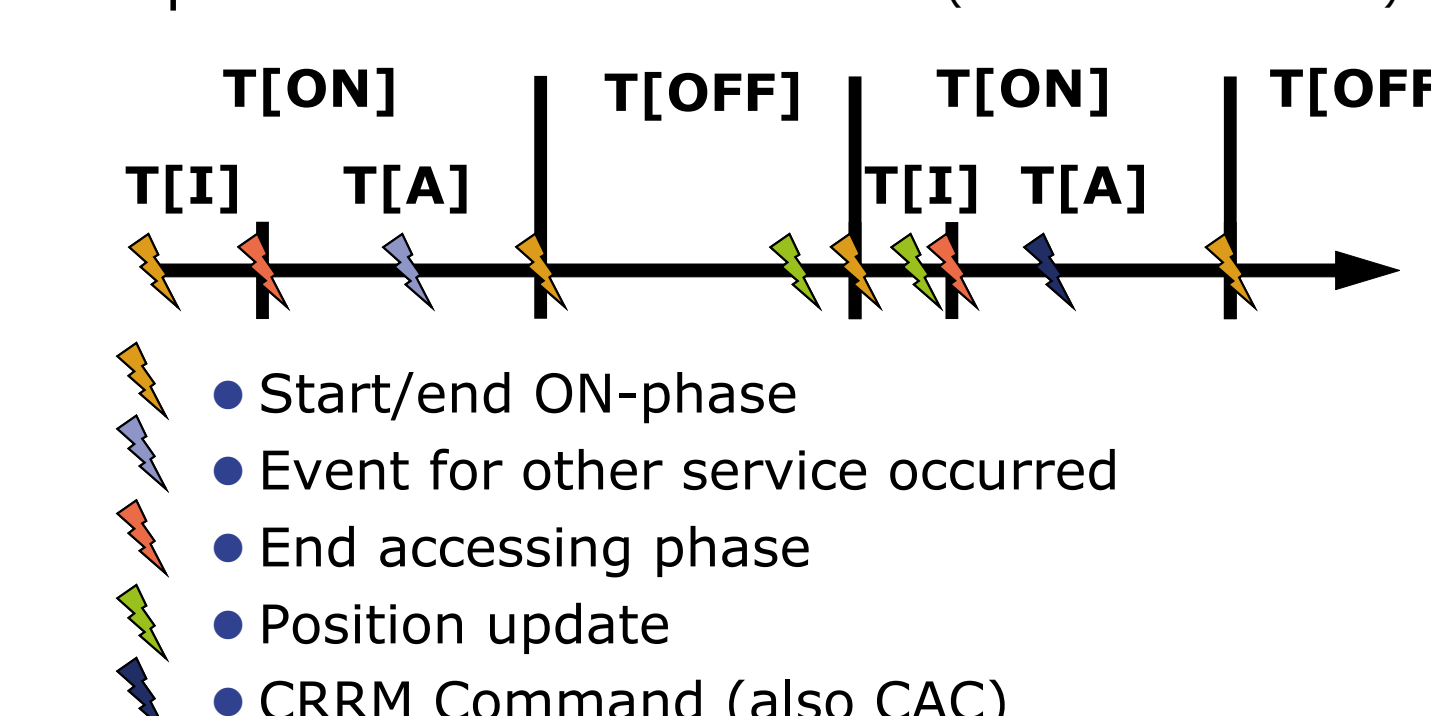Simulation Model: Mobility & Service dynamics Information transfer

Grid/Layer Structure of Environment

position of UE / WGAN / WWAN / WLAN / WPAN
current RAT of UE / current RAT
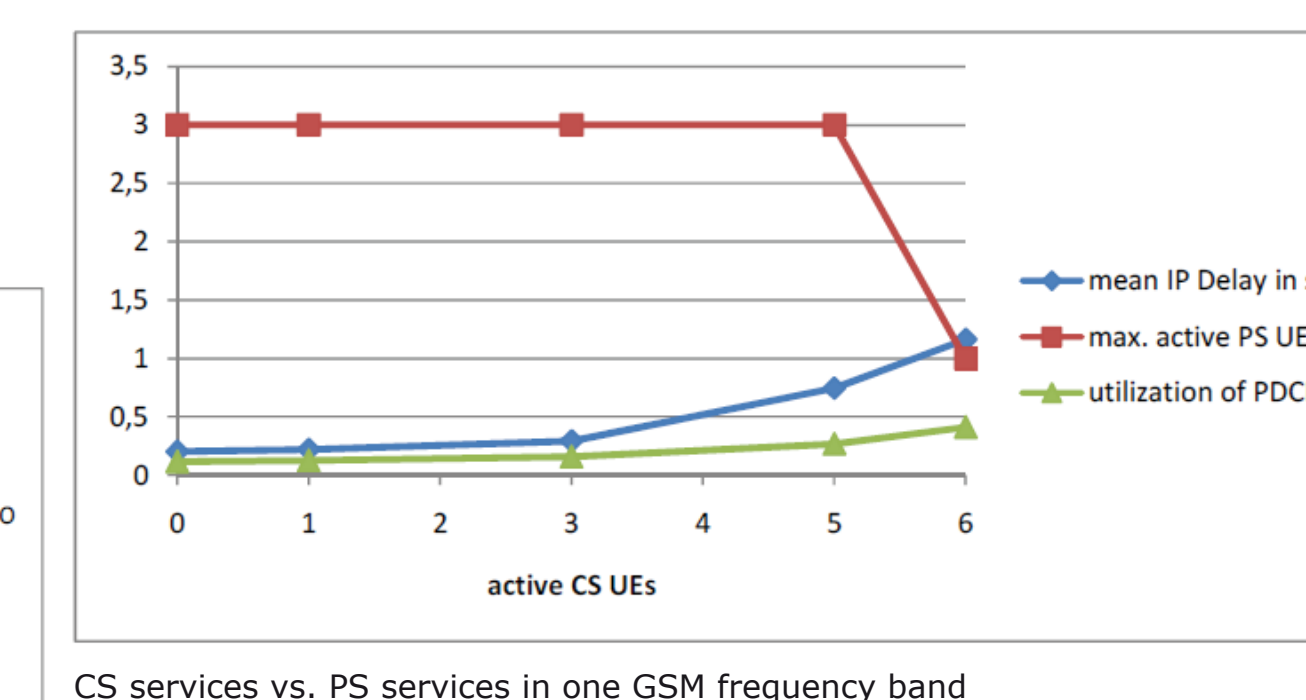update position message / current grid element / start- / target point
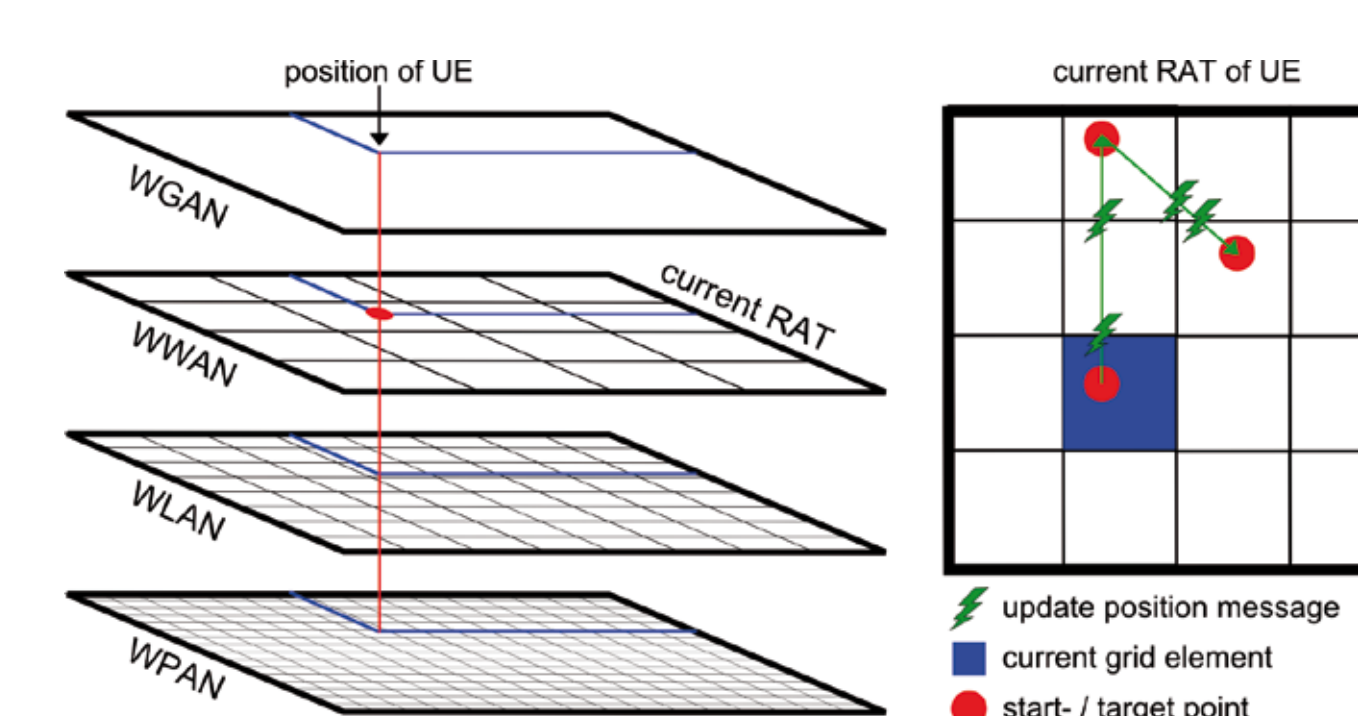
Service Lifetime and Update Events

- Update events for services (in one cell of a RAS)

T[ON] T[OFF] T[ON] T[OFF]
T[I] T[A]

- Start/end ON-phase
- Event for other service occurred
- End accessing phase
- Position update
- CRRM Command (also CAC)

What did we achieve? What is the work ahead?

CS services vs. PS services in one GSM frequency band

Ratio of normally ended to overall created calls in a UMTS/GSM scenario

Number of ISHO and connection retrials

IP delay over time in a GSM scenario with load impulse
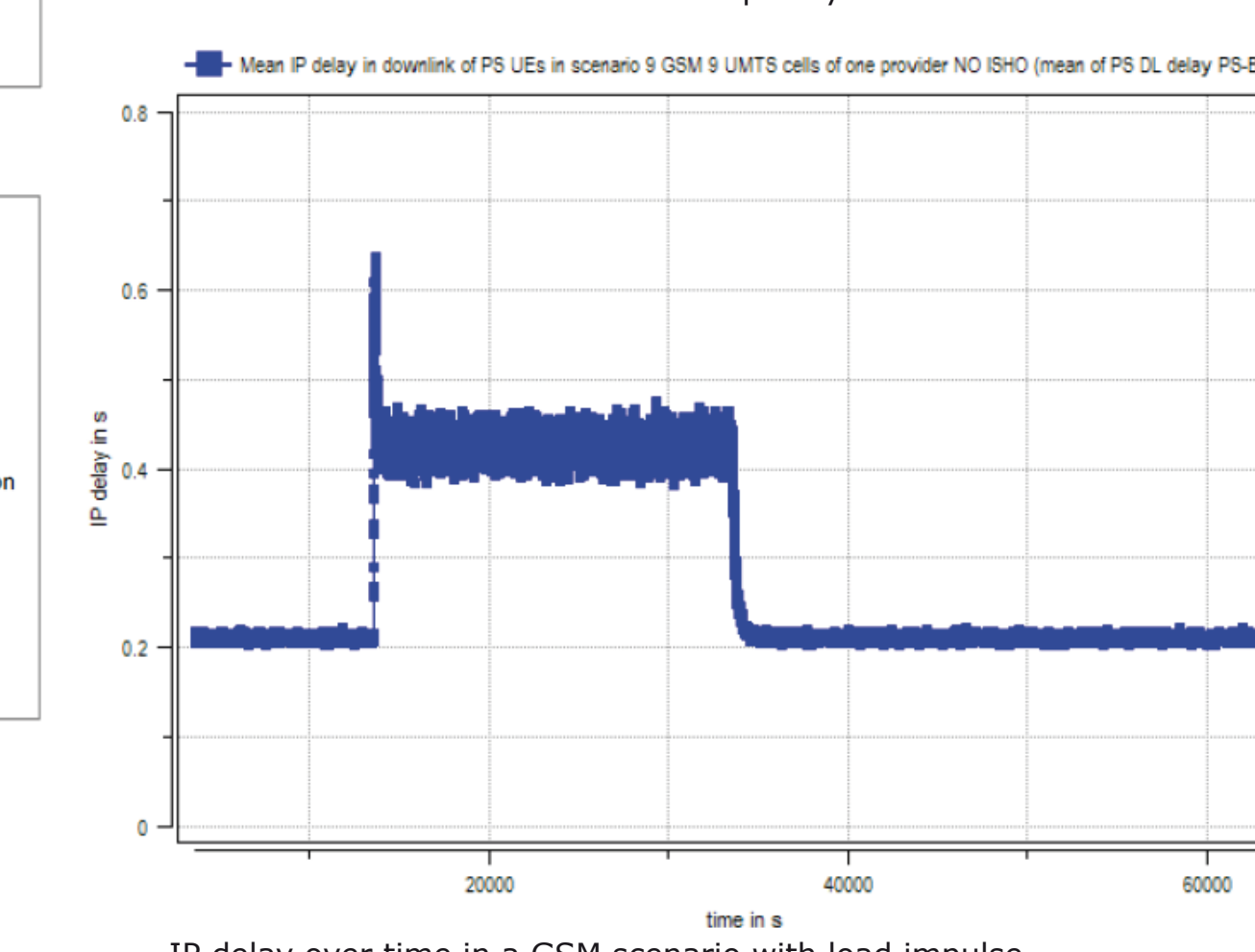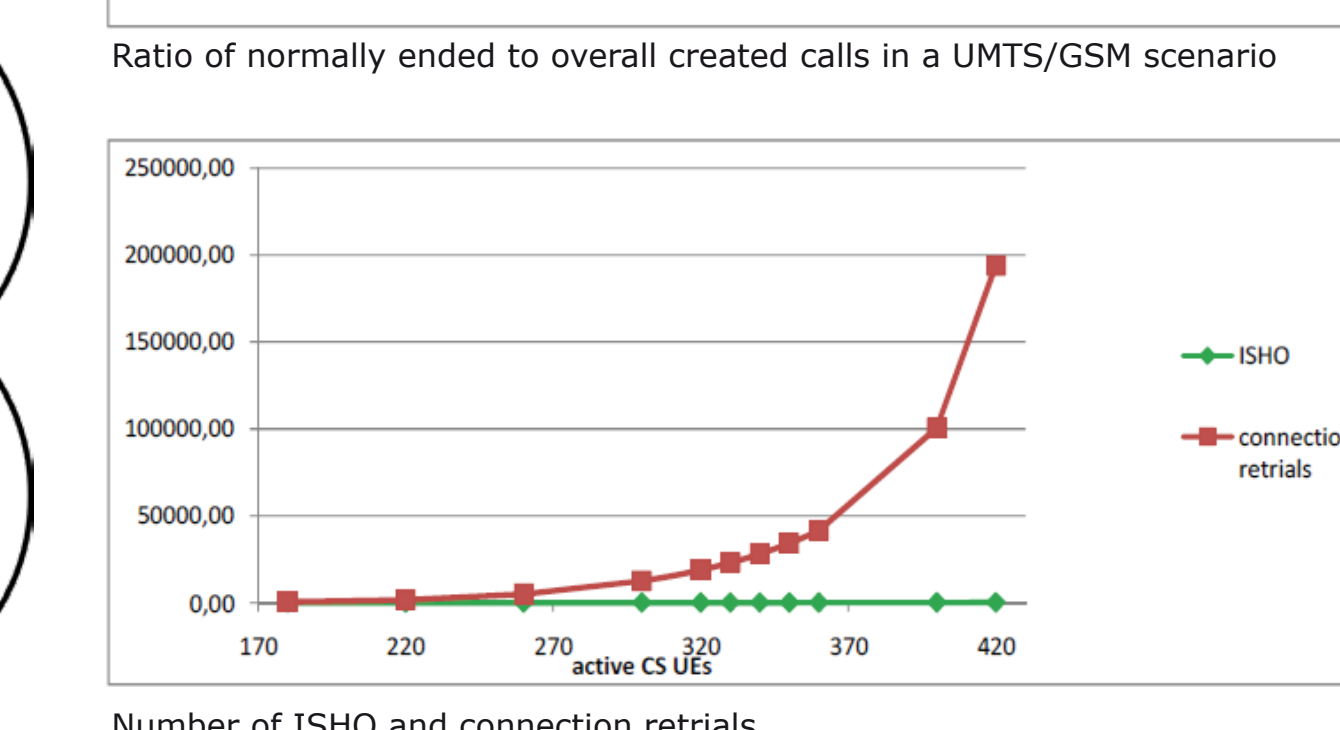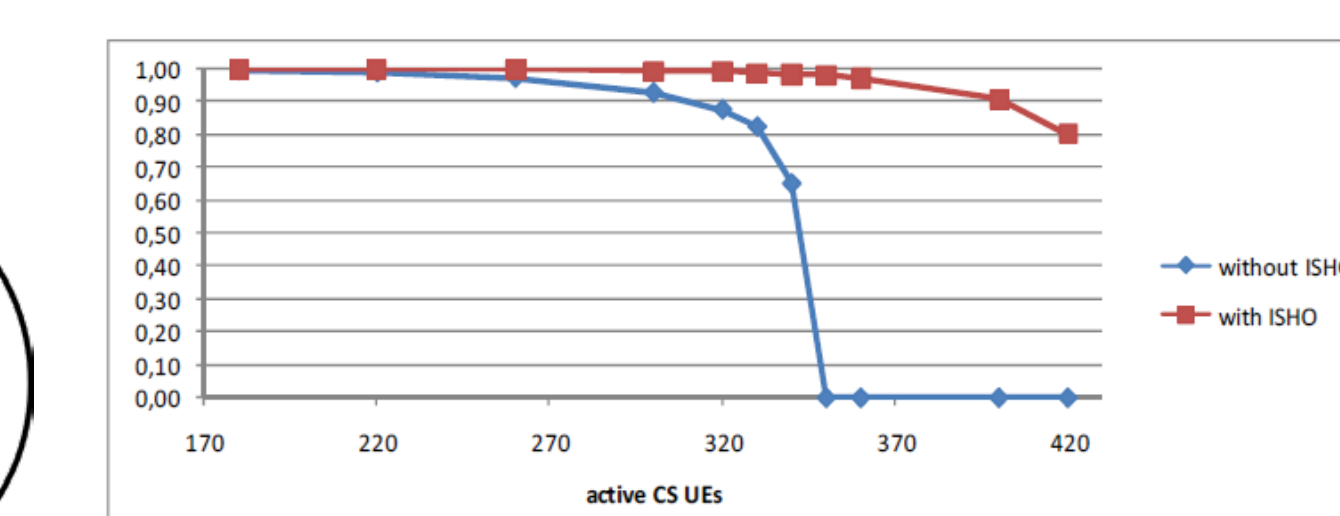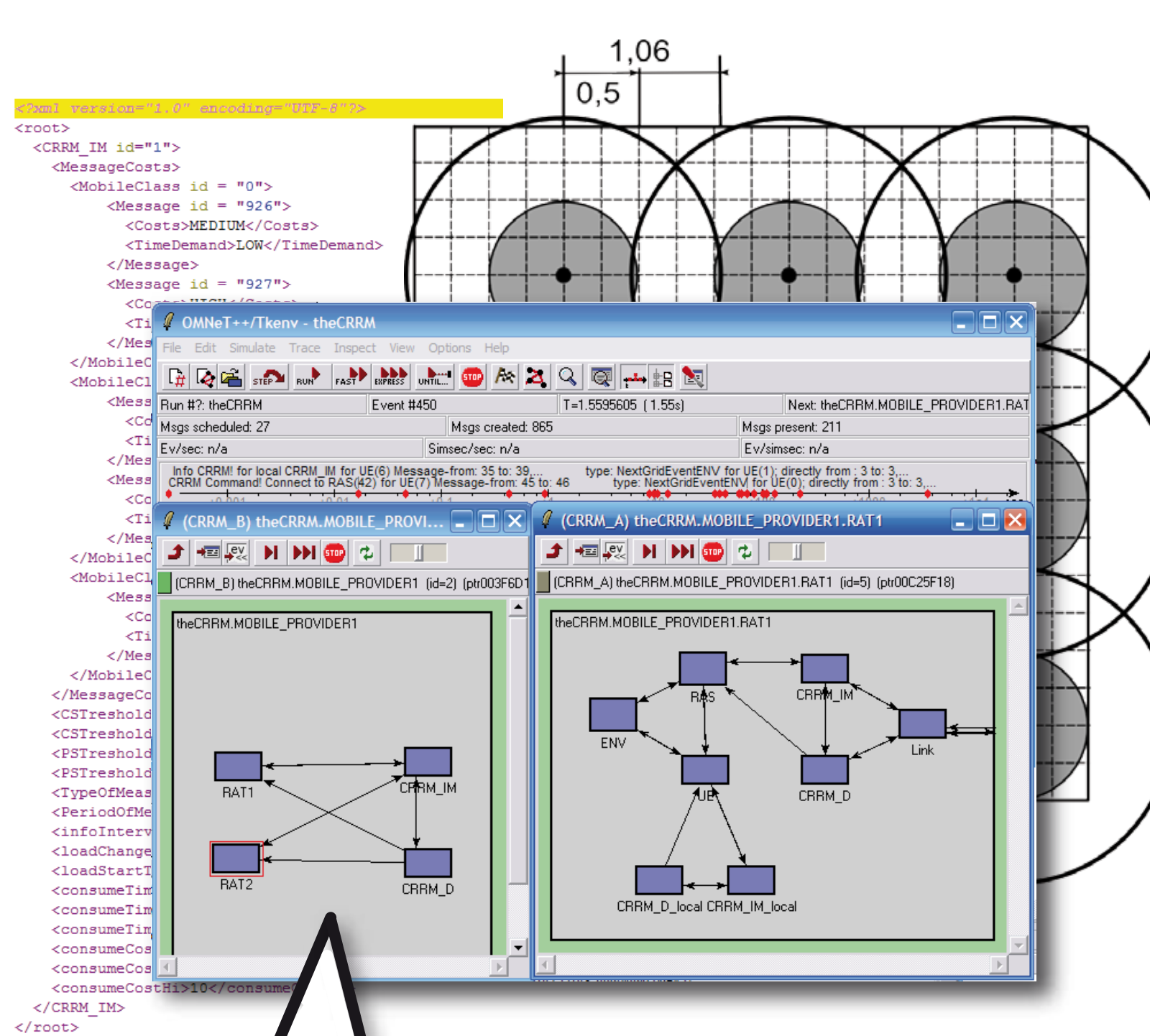
- **Variable model framework**
  - Covering a wide variety of scenarios
- **Starting point for development/evaluation of CRRM algorithms**
  - CRRM entities have to measure and fetch information
  - Possible conflicts in CRRM hierarchies
- **Cost-Benefit analysis is possible**
  - Event counters and action related costs
- **Influence of time is considered**
  - Refresh period of information
  - Transport time delays
- **Hybrid simulation model**
  - Fast simulation
  - Convenient integration of new RAT / Service models

Work Ahead!

- **Suitability assessment of different CRRM algorithms for diverse CRRM scenarios**
  - Multi-criteria optimization (game theory, theory of evolution, fuzzy-neural controller, policy based, multi-agent based – algorithms for knapsack problems or load balancing)
  - Stability against information aging
  - Robustness against erroneous information
  - Suitability of decentralized/ hierarchical/ centralized information or decision management
    - Influence of mobility and service dynamics
- **Integration of analytical models for UMTS/HSDPA-HSUPA and IEEE 802.11 networks**