Universität Duisburg - Essen

Ein Modellierungsframework für die technologieübergreifende Verwaltung von Funkressourcen in mobilen Kommunikationssystemen

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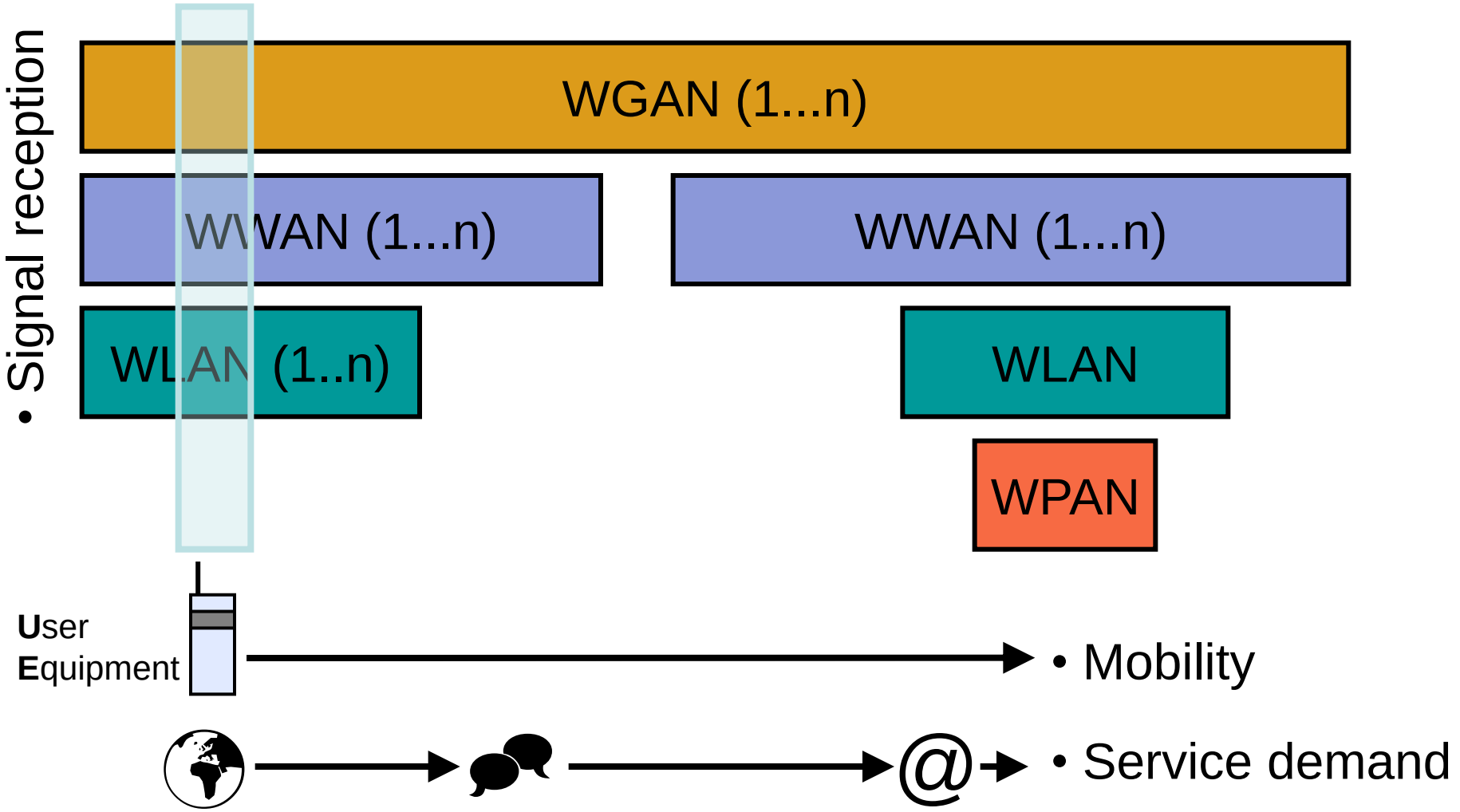
Outline

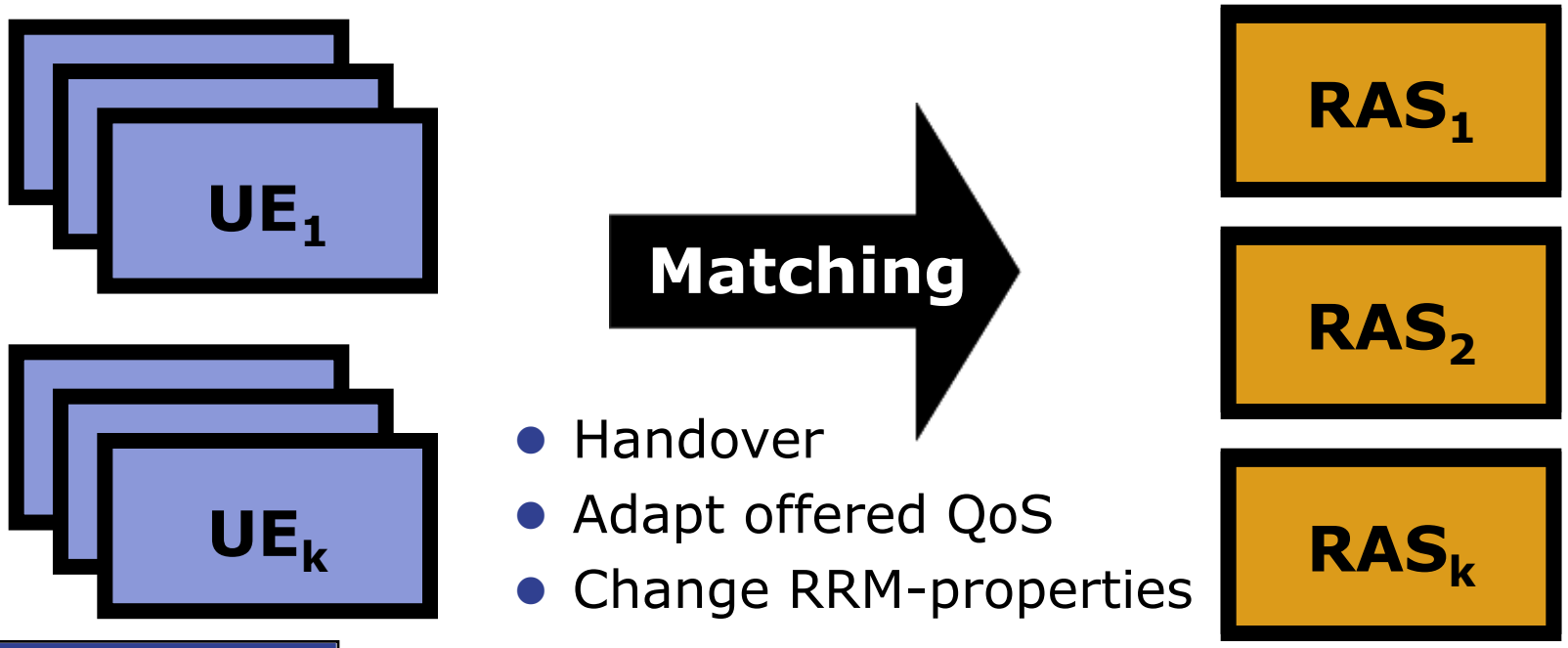
- Motivation
- Basic Structure of CRRM
- Model Framework
- Simulation Framework
- Some Results
- Summary

UE in a Changing Environment



CRRM Problem

- **Set of UE**
  - QoS demand
  - Resource consumption
  - Supported RAT/Provider
  - Available RAS…
- **Set of RAS**
  - QoS offered
  - Availabe Resources
  - Coverage
  - RAT/Provider…



- Handover
- Adapt offered QoS
- Change RRM-properties

What can CRRM achieve?

- **Trunking efficiency gain**
  - Shared use of (randomly) free resources
  - Redundancy (e.g. coverage)
- **Service assignment gain**
  - Exploitation of different service and wireless system characteristics

Problems & Tasks of this Thesis

- **CRRM is complex due to dynamics in the system and many influencing factors**
  - Properties of wireless system and user equipment
- **Development of modeling framework**
  - Versatile scenarios
  - Transfer of solutions for multi-objective optimization problems
- **Development of simulator**
  - Aim: Implementation/test of algorithms
  - Computing power and time restrictions

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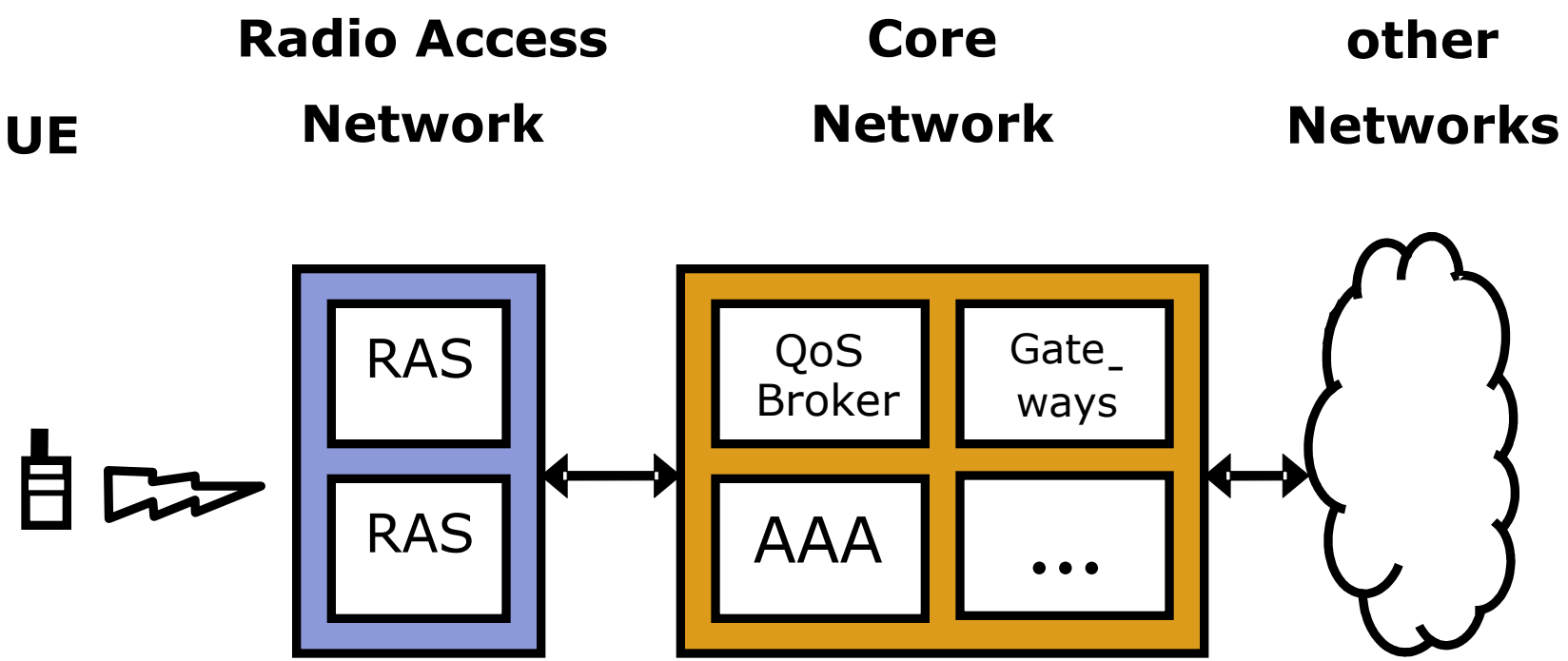
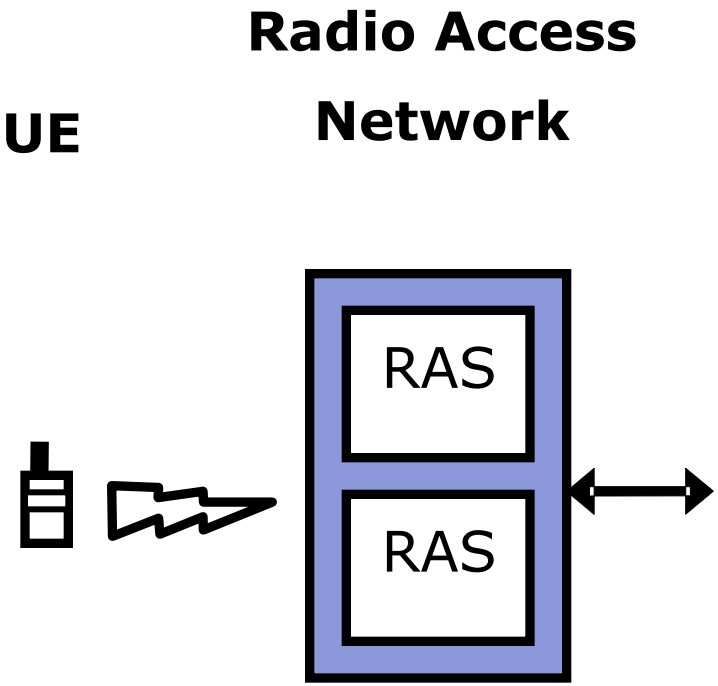
Common RAT Architecture



Common RAT Architecture (II)

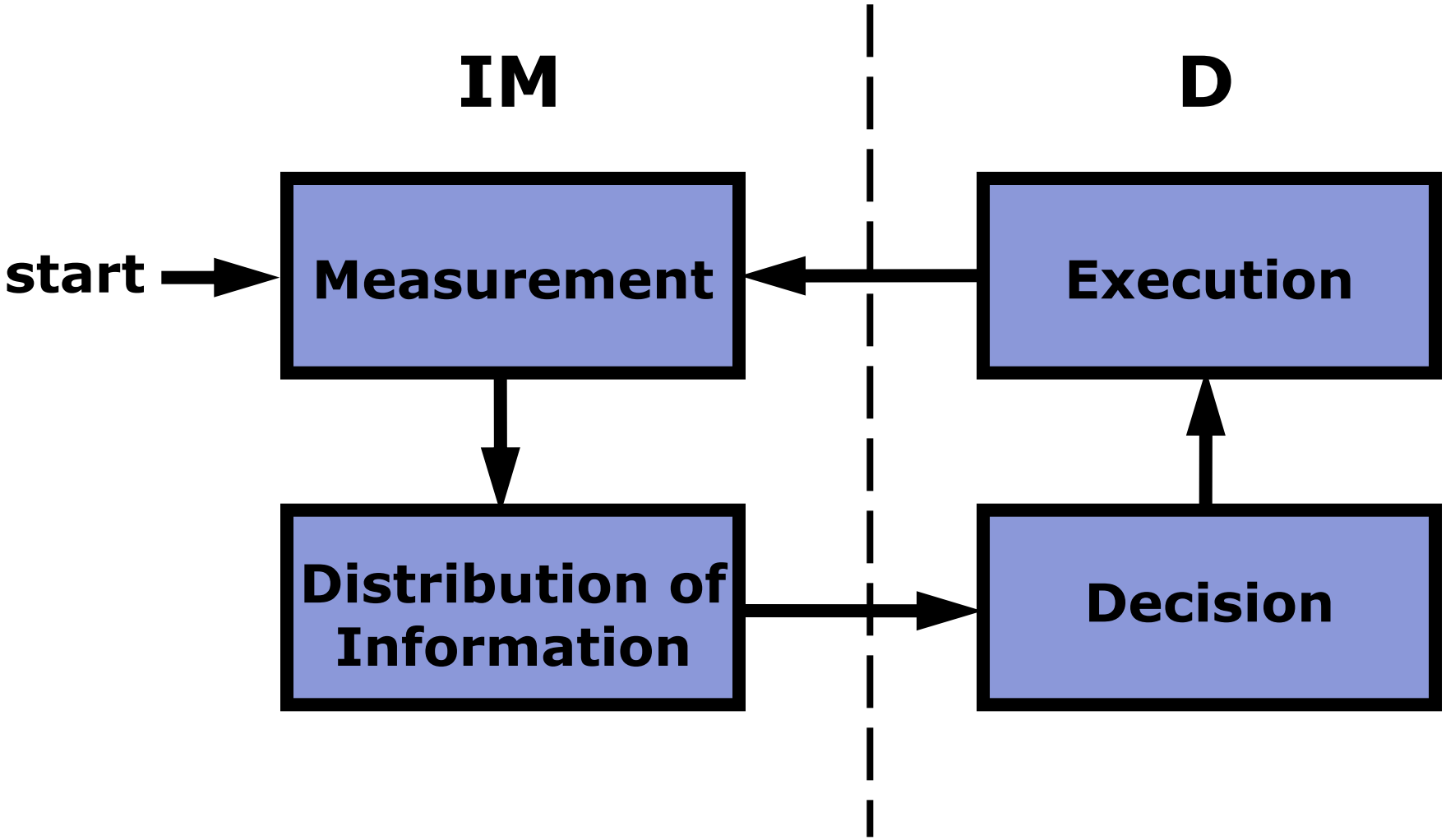


Assumptions:

Core Network supports RAS features

RAS is bottleneck due to unreliable wireless links

CRRM Control Loop



CRRM – Manifold Options

- Information management (**IM**) and decision (**D**) model
  - Level A (RAS), Level B (RAT), Level C (Provider)
  - Integration levels
    - High scale, medium scale, low scale
  - System structure
    - Centralized, hierarchical, decentralized
- Different **time horizons**
- Different **amounts of information**
  - Transferred
  - Usable

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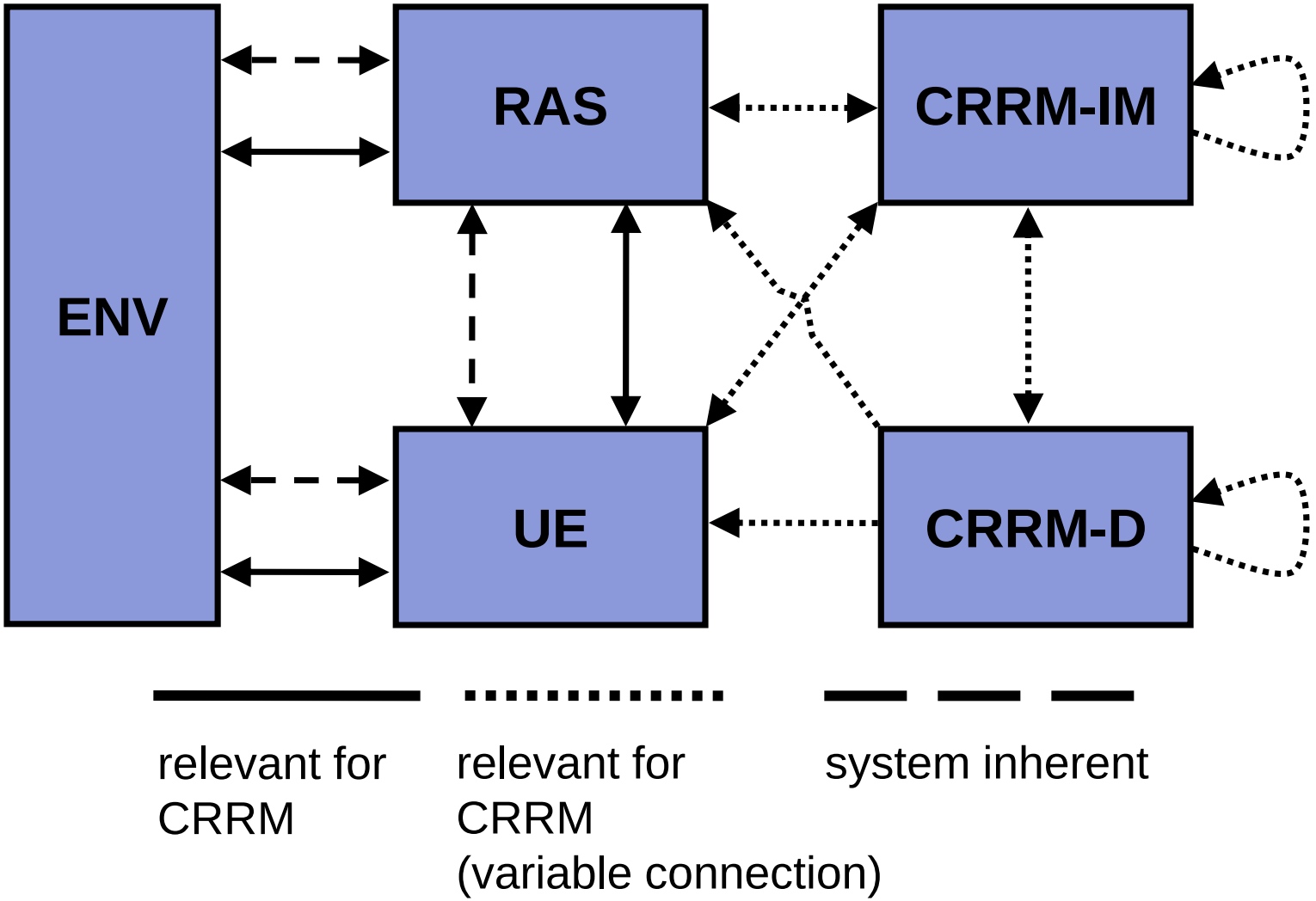
Model Components & Connectivity



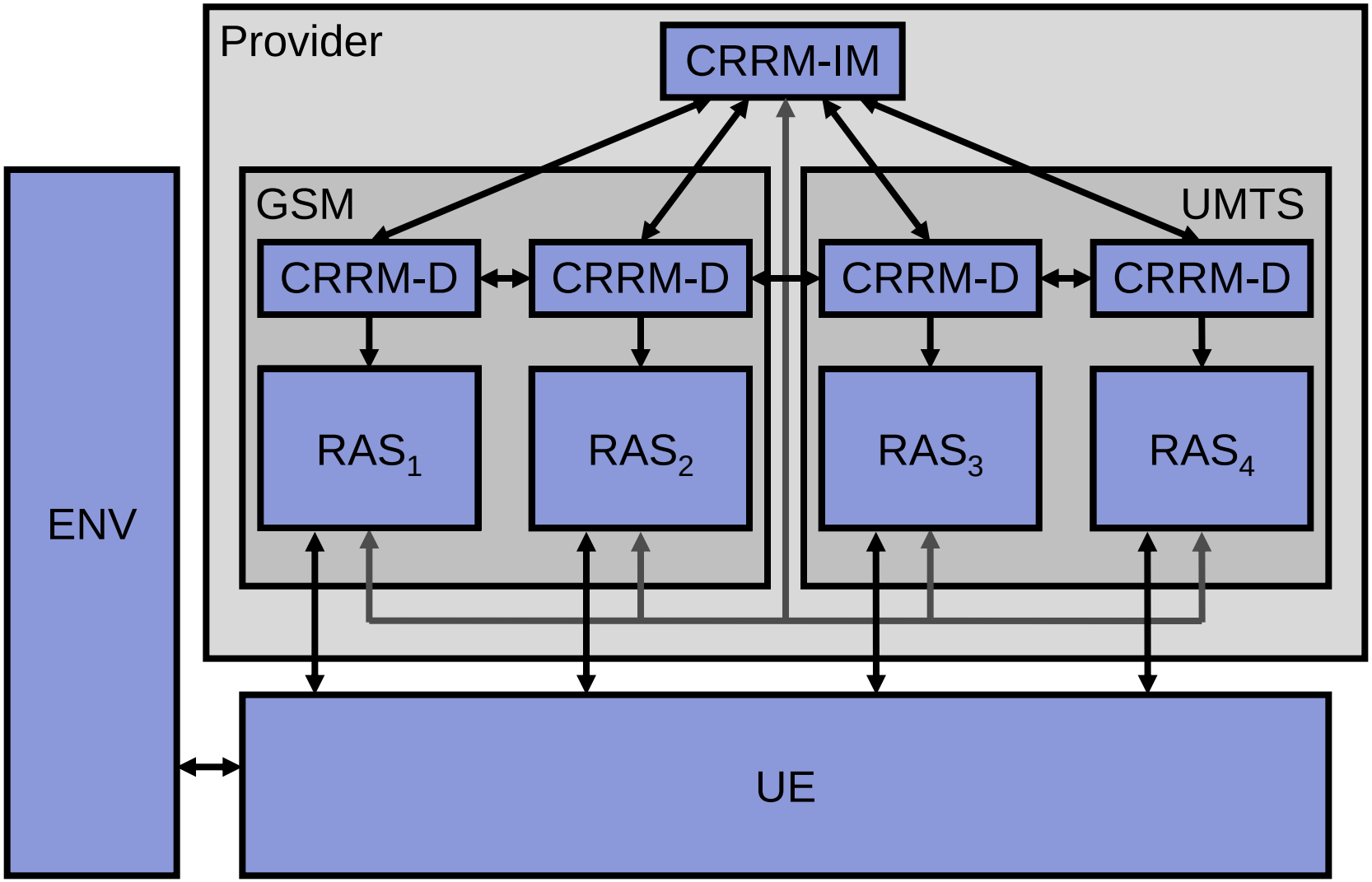
Component Connection – Information Transfer

- **Message routes definable**
- **Different types of messages definable**
  - Message costs (abstract or time)
    - Messages accumulate abstract costs
    - Messages can be delayed at components
  - Component-wise definition of costs
- **Components register at components to receive messages**
  - start load threshold
  - min load difference
  - min time difference
- **System inherent information transfer via messages without costs**

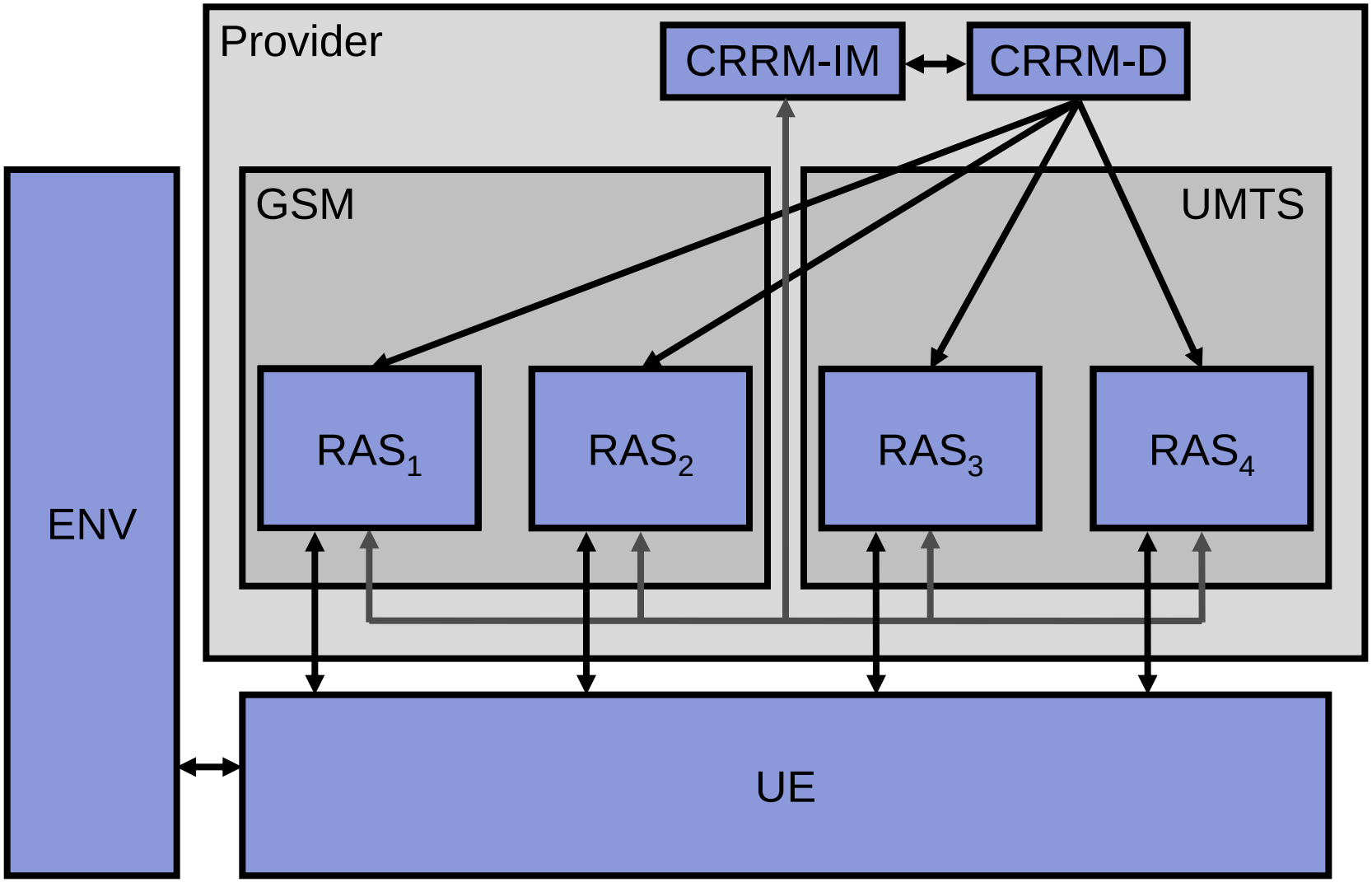
Scenario Definition

- **Definition of CRRM level and system structure**
  - Via components and connections
- **Definition of CRRM integration levels**
  - Task assignment via registration for message types

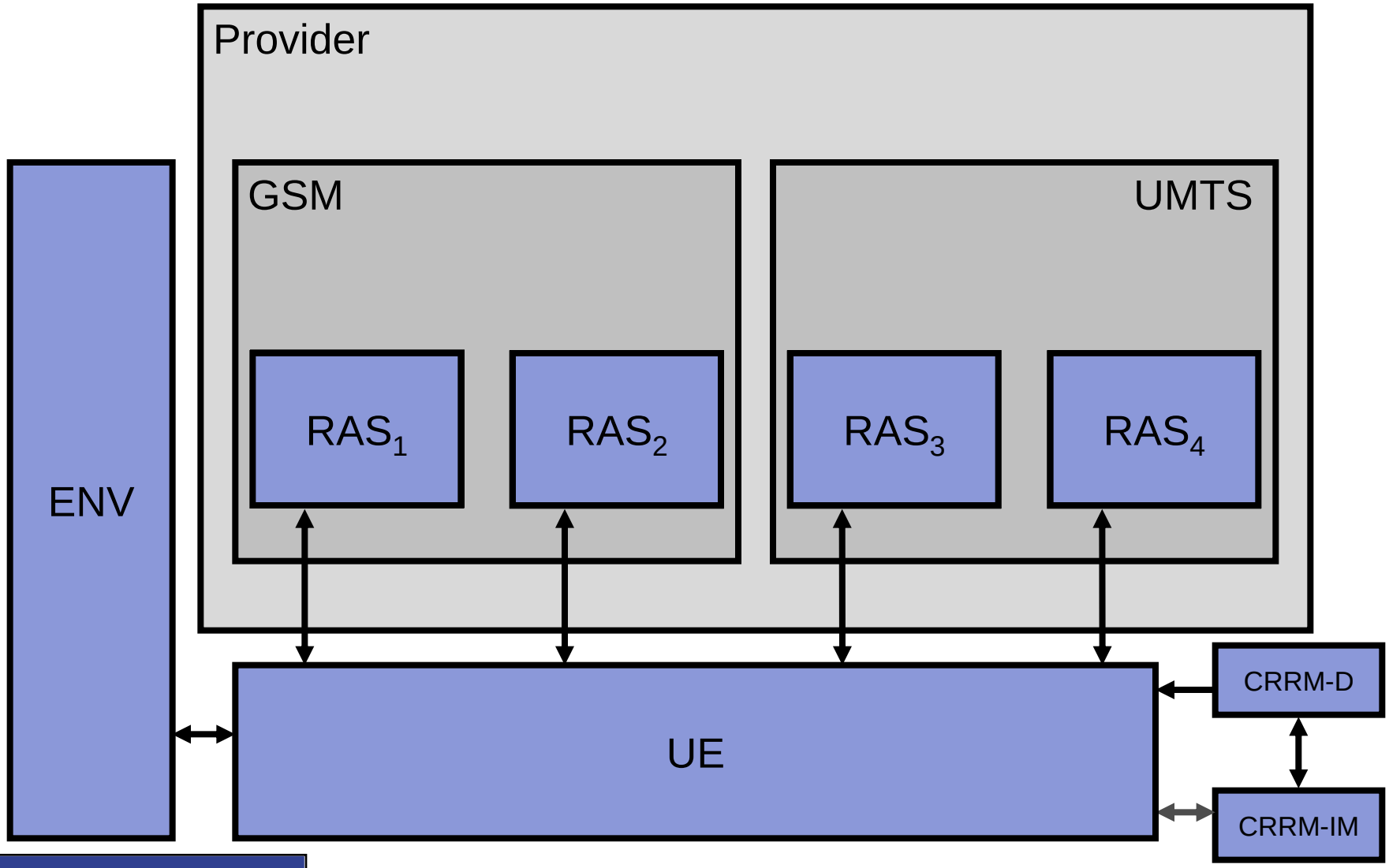
Level B Scenario Example – de/centralized NI-CRRM



Level B Scenario Example – centralized NI-CRRM



Level B Scenario Example – decentralized MI-CRRM

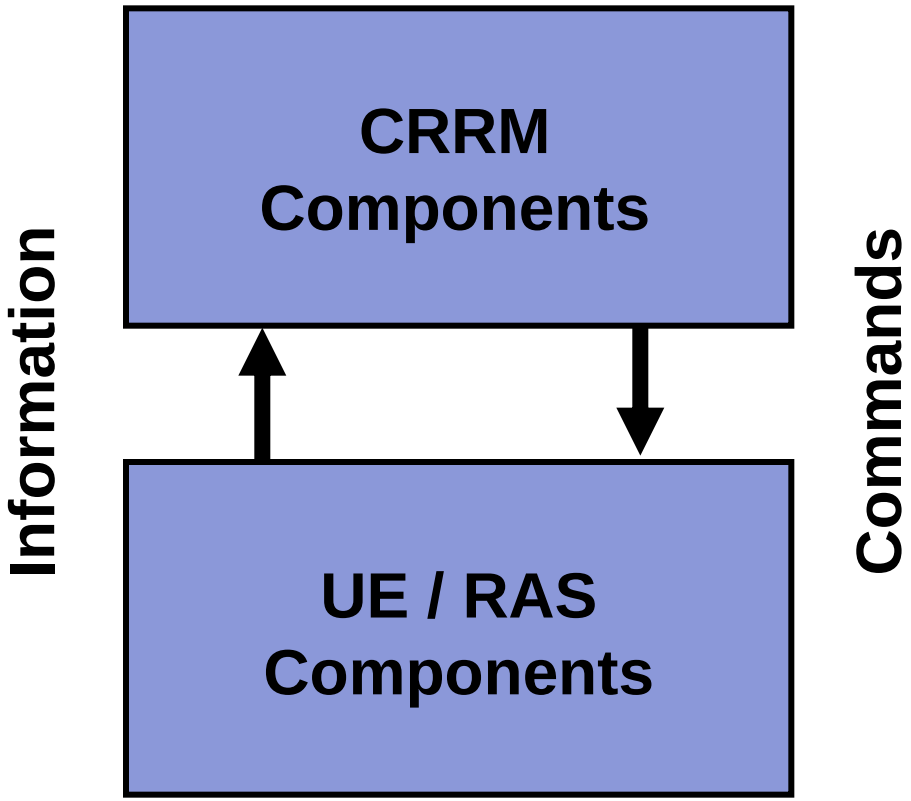


Definition of Integration Level

Tasks

- Initial RAT selection
- Intersystem Handover
- Intrasystem Handover
- Admission control
- Congestion control
- Scheduling
- Power control

Task assignment



Model supports CRRM Control Loop

- **Information Management**
  - No full system overview
    - Start/stop measurements
    - Transfer of measurement results
    - Save/manage results
  - Costs (abstract or time) definable
  - Structure/ integration level definable
- **Decision**
  - Information lookup
  - Transfer of decisions
  - Costs (abstract or time) definable
  - Structure/ integration level definable

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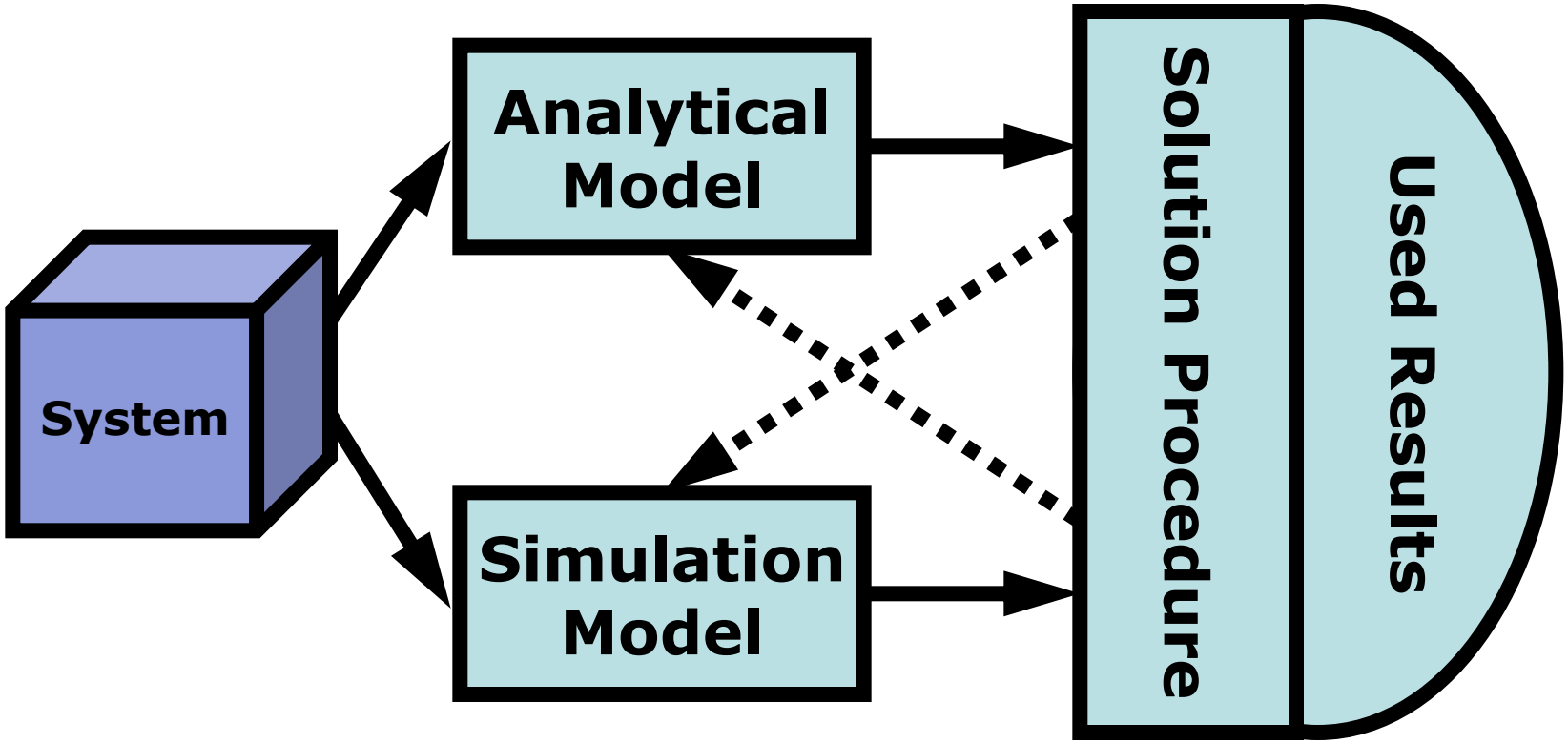
Simulation Framework – Overview

- **Simulator named HEKATE**
  - goddess of doorsteps, portals and crossroads
- **Discrete event simulator**
  - Based on OMNeT++
- **Hybrid simulation model**
  - Flow level of connections is modeled via discrete event simulation
  - Packet arrival/transfer process is considered via analytical models

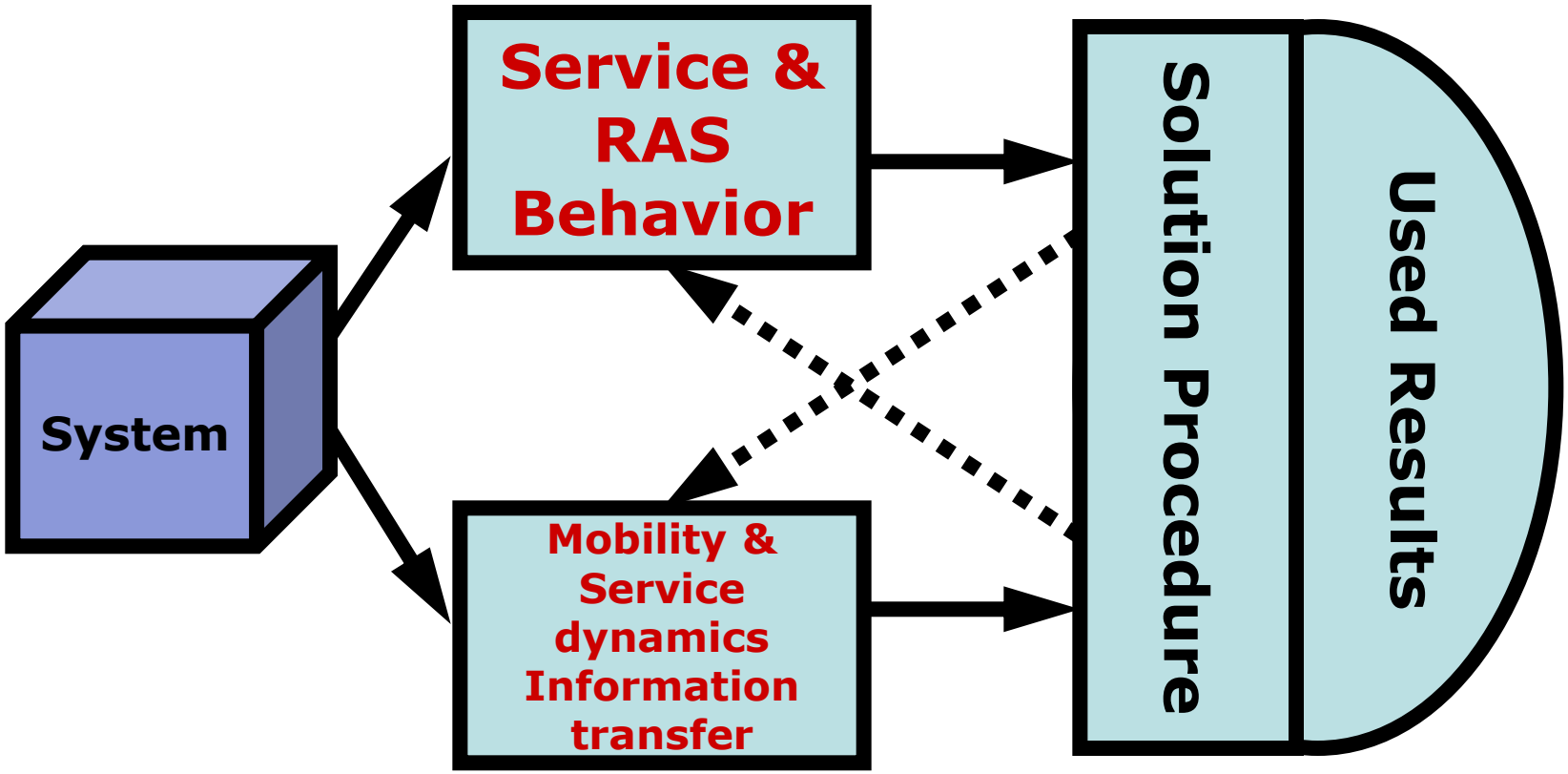
Hybrid Simulation Concept

- **Class II hybrid simulation model** (Shanthikumar, Sargent - 1983)

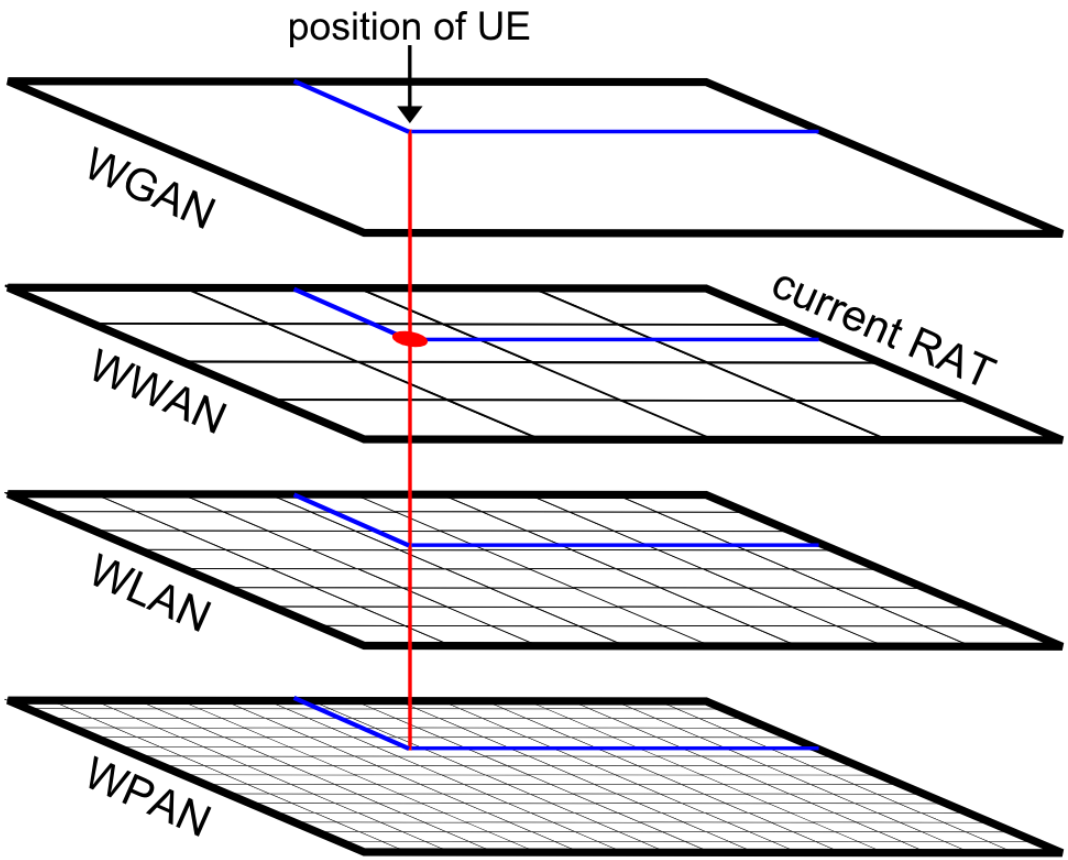


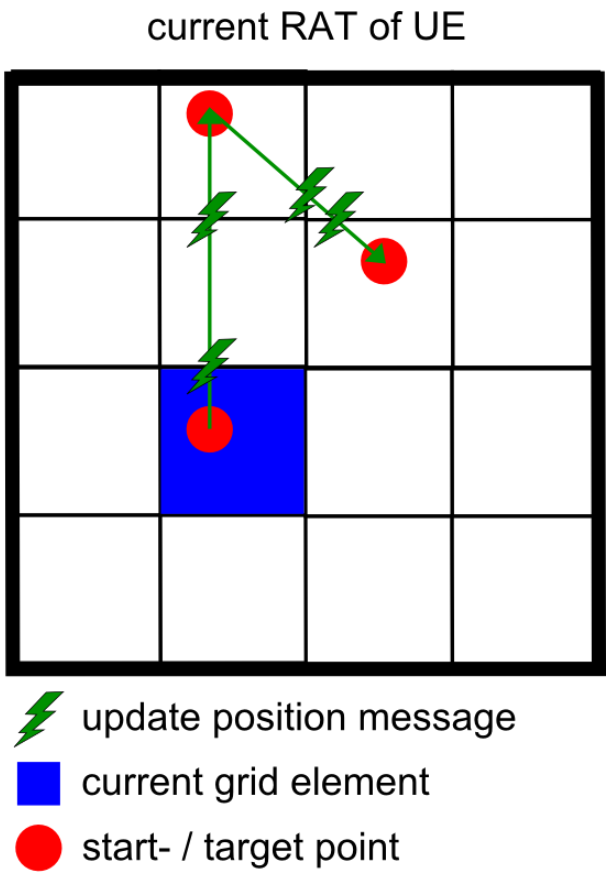
Hybrid Simulation Concept (2)

- **Class II hybrid simulation model** (Shanthikumar, Sargent - 1983)



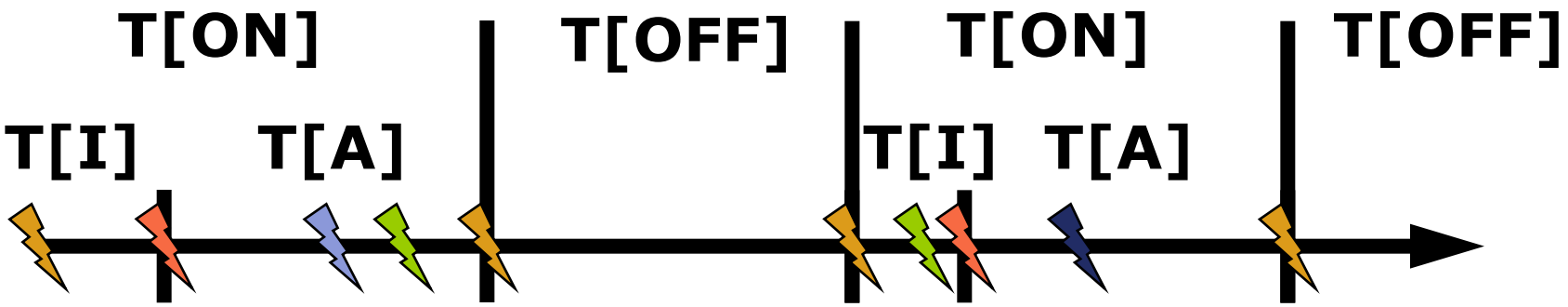
ENV Model – Grid/Layer





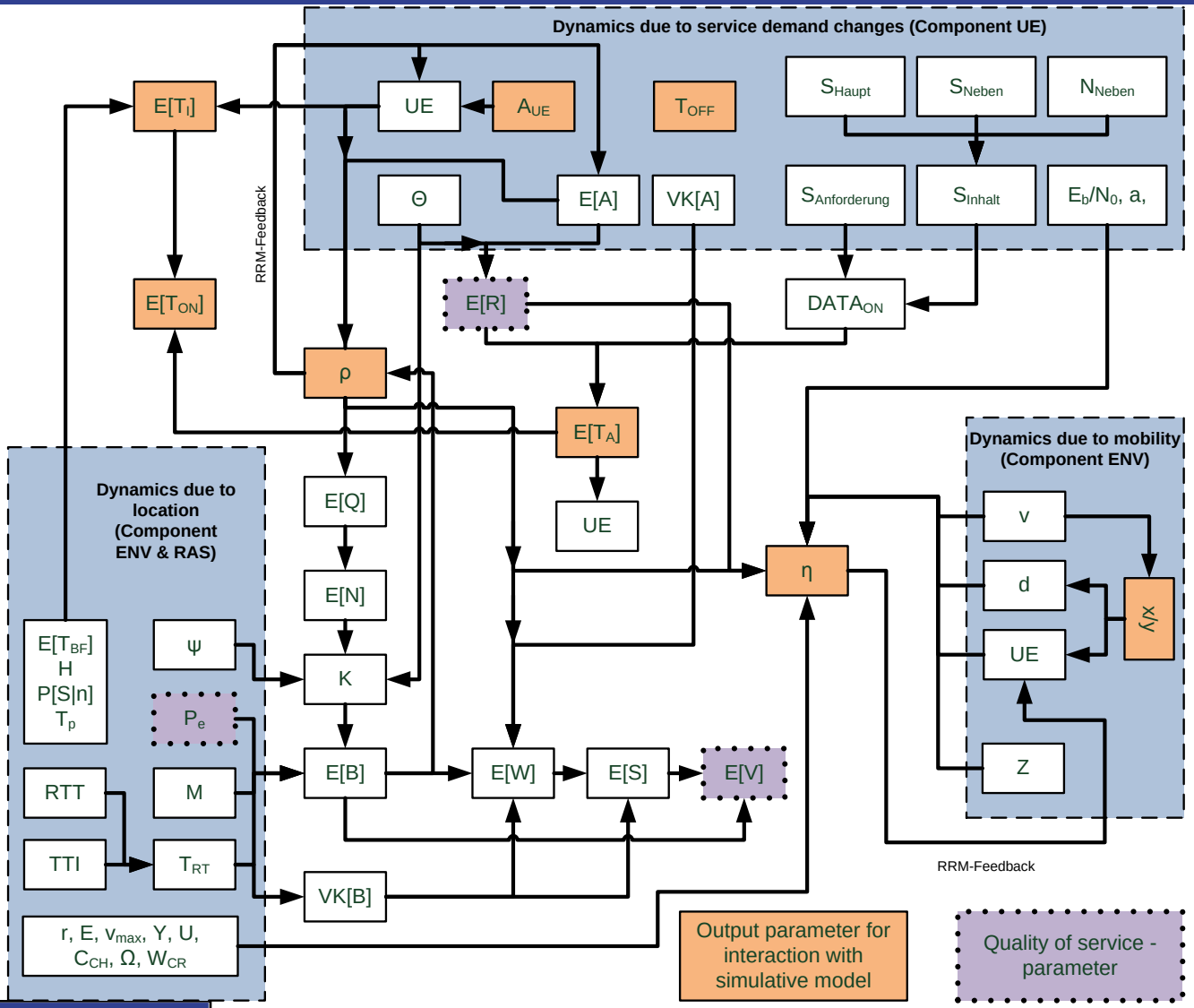
UE Model – Service Lifetime and Update Events

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



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

UMTS/GSM RAS Model – Analytical Model Dependencies



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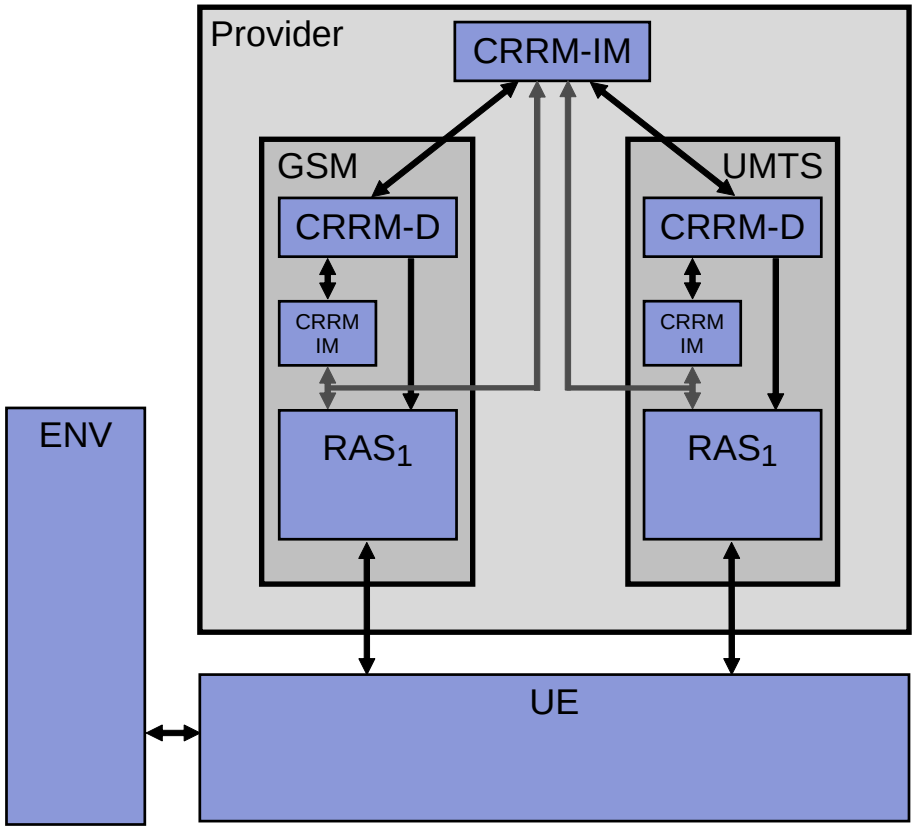
Scenario Parameters

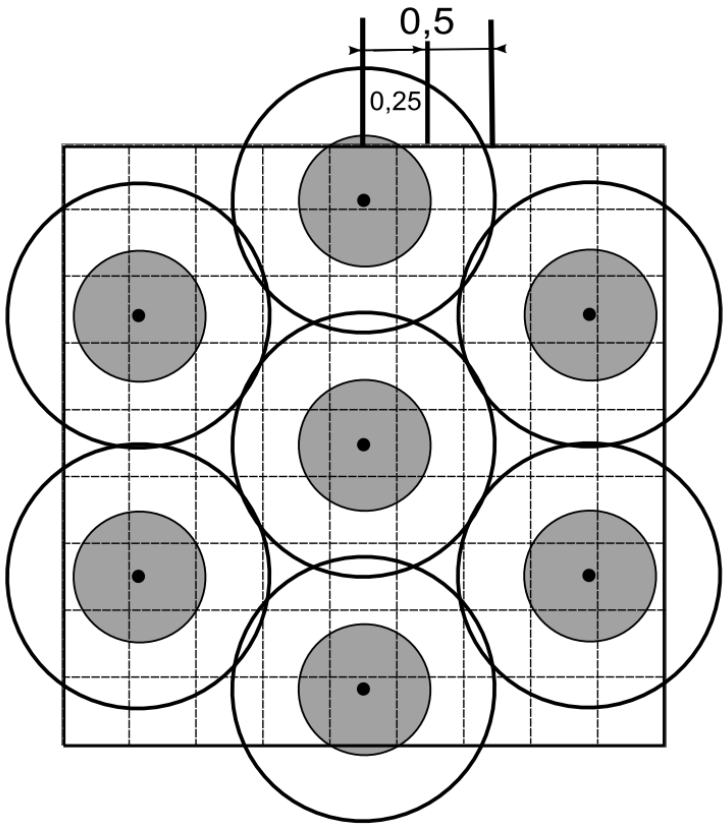
- Test of group based multiple knapsack – GMKP – algorithm for CRRM
- Scenario parameters are based on IST EVEREST scenarios
- Service parameters for conversational real time service and non real time web-service

CS – conversational	PS – web-service
■ 10 calls/h per user (exp) ■ 3 min call duration (exp) ■ 12,2 kbit/s	■ 24 sessions/h per user ■ Mean session size 60 kbyte (geo) ■ Mean page size 12 kbyte (geo) ■ Mean packet length 897 byte (const) ■ Reading time 30 s (exp) ■ 12-128 kbit/s (exp)

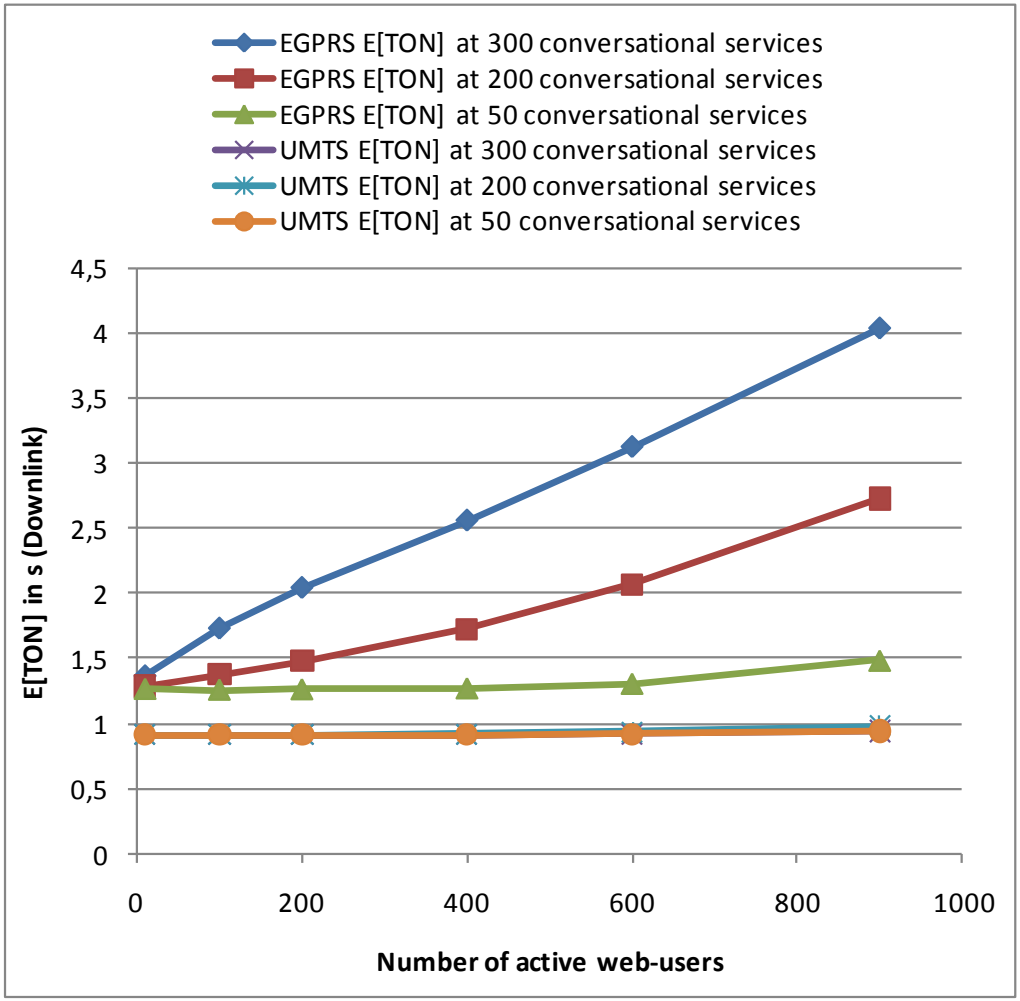
Scenario Layout

- CRRM Level B, low scale integration, decentralized decision



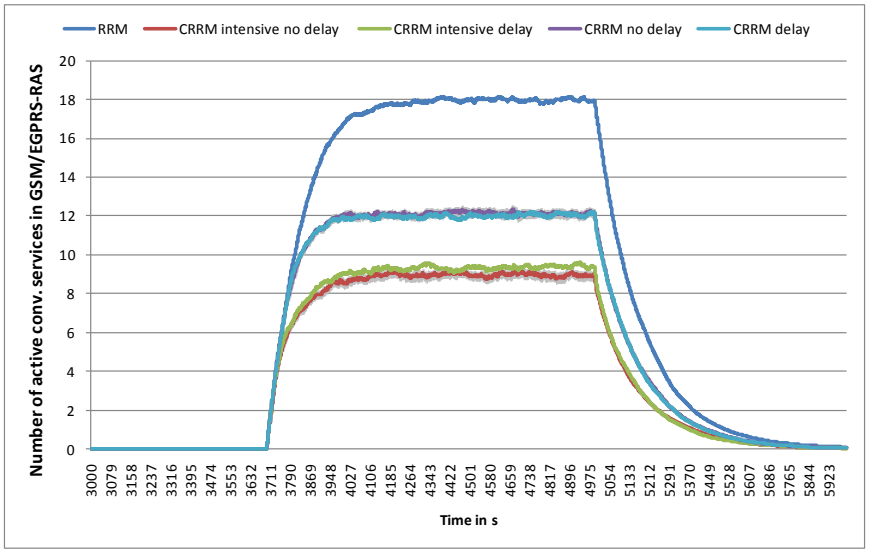


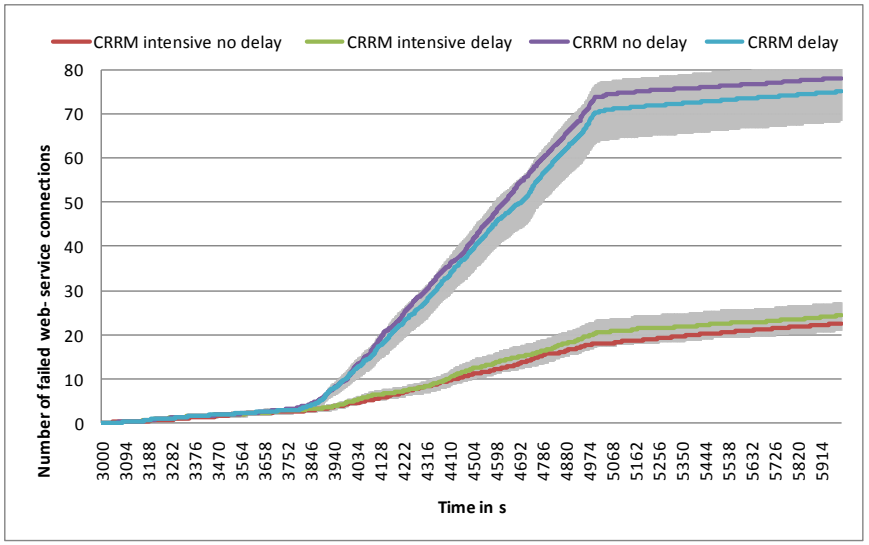
Example - Stationary Simulation Results



- UMTS
  - Dedicated channel
- EGPRS
  - Shared channel
  - Conversational services are displacing web services
- EGPRS is impaired by conv. background traffic
  - No CRRM
- Simulation properties
  - Simulated time interval 7 h
  - mean of 6 runs
  - Runtime 20 min per run (with 1200 user)
  - Memory usage 23 Mibyte

Example - Transient Simulation Results

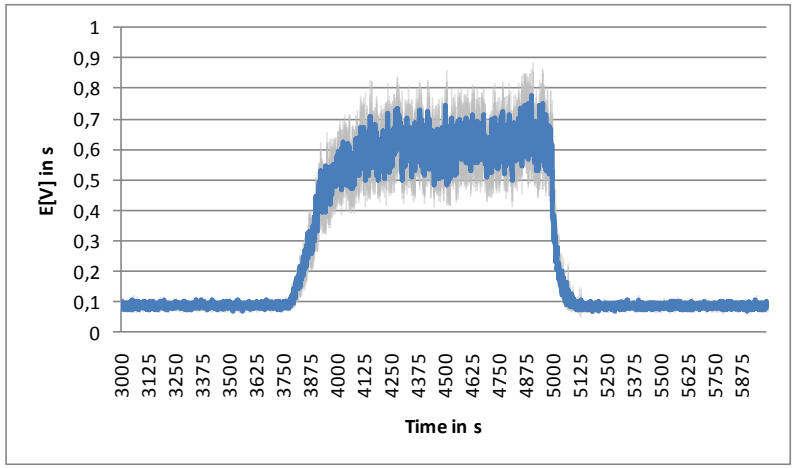




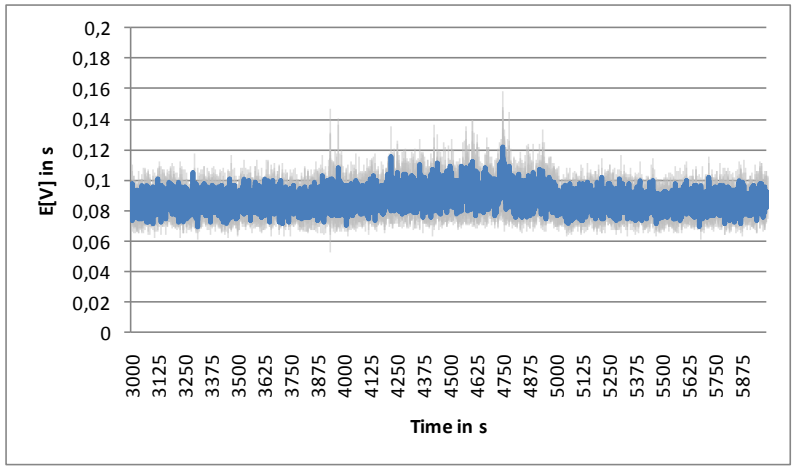
- GMKP is active
  - Otherwise 1040 web and 146 conv. services unsuccessful
- Handover of conv. services to UMTS-RAS
- Intensive CRRM:
  - Start at 30 % load (instead of 60 %)
  - Resolution 1 % (instead of 10 %)
- Delay in CRRM:
  - Information transfer takes 5 s (instead of 0.01 s)

Example - Transient Simulation Results (2)

No CRRM



Active CRRM (intensive, no delay)



- SDU delay (E[V]) is higher at high system utilizations
- GMKP is able to decrease delay in EGPRS-RAS
- Simulation properties
  - Simulated time interval 6000 s
  - mean of 70 runs
  - Runtime 30 s per run (with 500 user)
  - Memory usage 10 Mibyte

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Summary

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  - Actions: Handover (intra/intersystem), adapt offered QoS, change RRM-properties
- **Model framework:** Five components (ENV, UE, RAS, CRRM-IM, CRRM-D)
  - Supports a wide variety of CRRM scenarios (CRRM structures & integration levels)
  - Supports CRRM control loop and cost-benefit analysis
- **HEKATE simulator:** hybrid simulation saves computing resources.
  - Based on discrete event simulator OMNeT++
  - Analytical models for UMTS & GSM/EGPRS
  - Straightforward integration of new RAT models
- **Applications:** Test of new CRRM algorithms (incl. IM)
  - Multi-objective optimization
  - Fast investigation of parameter variations

End of Presentation

Thank you very much for your attention!

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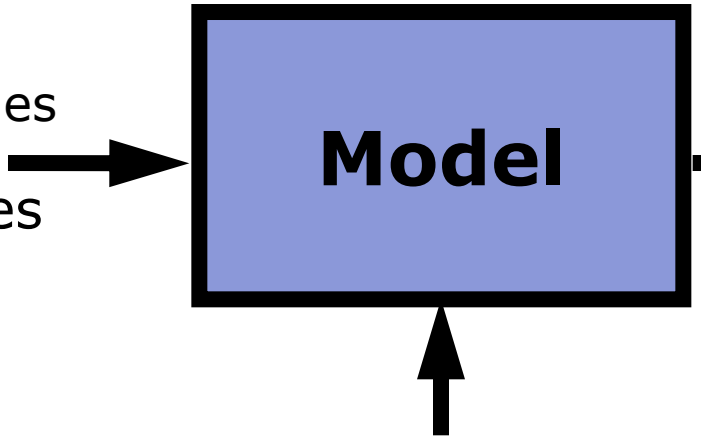
RAS Model – Analytical Model Input/Output

- Number of UE
- UE properties
  - Mobility
  - Tech. capabilities
- Service properties
  - PS/CS
  - Packet arrival process
  - Priority



- Resource consumption
- Offered QoS
- T[I] - Init
- T[A] - Active

- Server properties (per grid element of UE)
  - Signal quality
  - Load in neighboring cells
  - Coding schemes
  - Frequency bands

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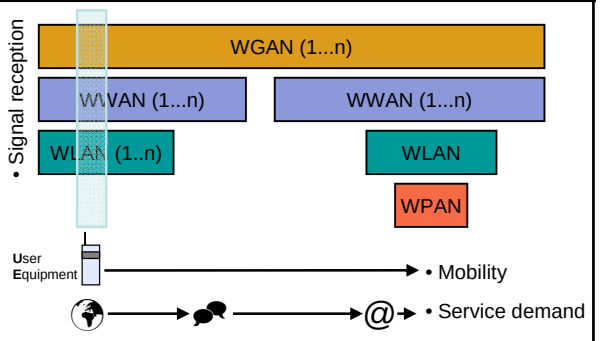
UE in a Changing Environment



UE in a Changing Environment – Information

- **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), UMTS-LTE (326 Mbit/s - 1 Gbit/s), GSM-GPRS (171,2 kbit/s), GSM-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)

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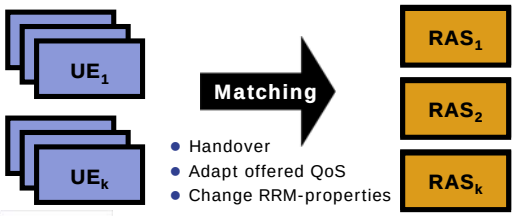
CRRM Problem

- **Set of UE**
  - QoS demand
  - Resource consumption
  - Supported RAT/Provider
  - Available RAS...
- **Set of RAS**
  - QoS offered
  - Availabe Resources
  - Coverage
  - RAT/Provider...



- Handover
- Adapt offered QoS
- Change RRM-properties

CRRM Problem – Information

- **C**ommon **R**adio **R**esource **M**anagement **(CRRM)**
- **U**ser **E**quipment (**UE**)
  - e.g. Mobile, netbook, car communication system
- **R**adio **A**ccess **S**ystem (**RAS**)
  - Autonomous local radio resource management
  - e.g Satellite, Wi-Fi cell, micro/macro cell layer
- **R**adio **A**ccess **T**echnology (**RAT**)
  - e.g UMTS/HSPA, GSM/EGPRS, 802.11

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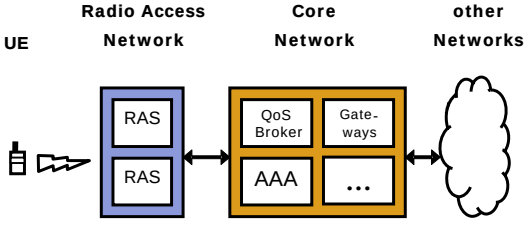
Common RAT Architecture



Common RAT Architecture – Information

- **Q**uality **o**f **S**ervice (**QoS**)
  - e.g. data rate, delay, jitter, security
- **A**uthentication **A**uthorization **A**ccounting (**AAA**) services
  - Authentication: Who wants to establish a connection?
  - Authorization: What is s/he allowed to do?
  - Accounting: What do we charge for it?

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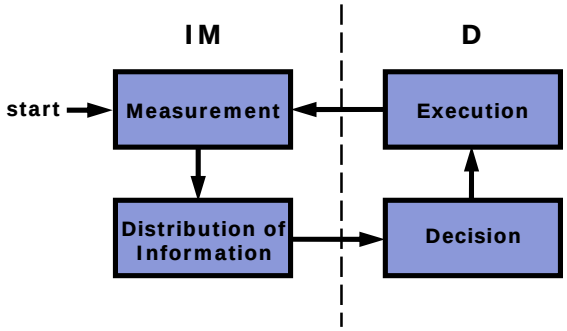
CRRM Control Loop



Basic Structure of CRRM

CRRM Control Loop – Information

- **I**nformation **M**anagement (**IM**)
  - Start/stop measurements, transfer & save results, provide information
- **D**ecision (**D**)
  - Evaluate information, solve multi-objective optimization problem, schedule/start adaptation (handover, QoS adaption…)

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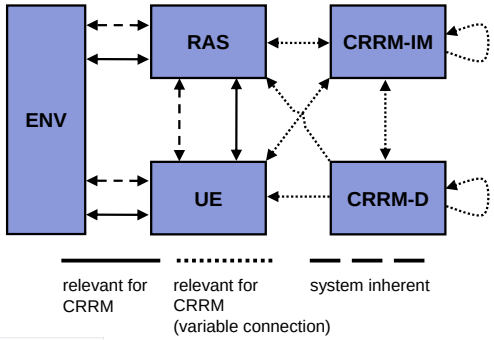
Model Components & Connectivity

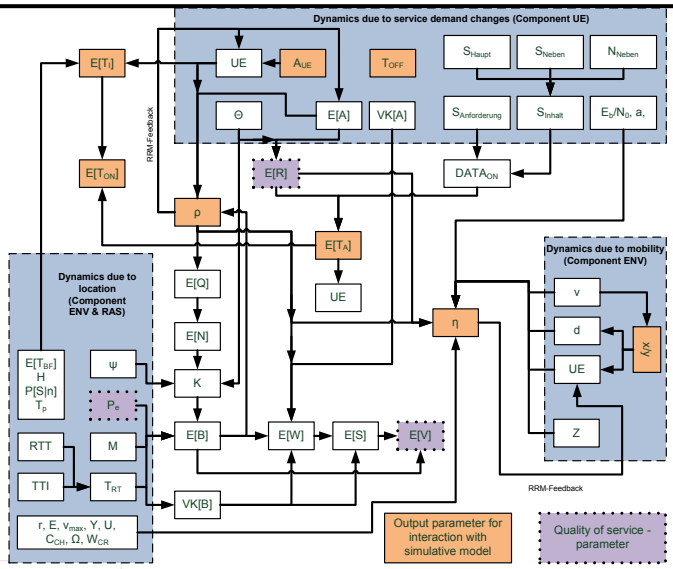


Model Framework

Model Components & Connectivity – Information

- **U**ser **E**quipment (**UE**)
  - Models technological capabilities and service demand dynamics of different UE classes
- **R**adio **A**ccess **S**ystem (**RAS**)
  - Models different RATs and processes service demands of UE
- **E**nvironment (**ENV**)
  - Models dynamic behavior regarding mobility
- **CRRM I**nformation **M**anager (**CRRM-IM**)
  - Models collection, distribution and storage of CRRM information
- **CRRM D**ecider (**CRRM-D**)
  - Models CRRM decision algorithm

UMTS/GSM RAS Model – Analytical Model Dependencies



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Simulation Framework

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UMTS/GSM RAS Model – Information

- **E[V]** – Mean residence time
  - SDU Delay on wireless channel for service
- **E[R]** – Mean data rate
  - "Goodput" on wireless channel for service
- **P_e** – PDU Error Probability
  - Input parameter (based on position and coding scheme)
- **E[T_i]** – Mean accessing time
  - For allocating resources for data transfer of service
- **E[T_A]** – Mean data transfer time
  - For transferring data of the service's ON-Phase
- **E[T_{ON}]** – Mean duration of ON-Phase
  - ON-Phase on flow level of service
- **E[T_{OFF}]** – Mean duration of OFF-Phase
  - OFF-Phase on flow level of service
- **η** – Resource utilization
  - Consumption of RAS/cell resources by service
- **ρ** – Channel utilization
  - Usage of channel capacity for data transfer by service
- **A_{UE}** – Arrival process of new connections
- **x / y** – Position of user equipment

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