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Digital On-Demand Computing Organism for Real-time Systems

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SPP OC Kolloquium

DFG SPP 1183 “Organic Computing”

Zürich, September 17/18, 2008

Talk Overview

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- ►**Project Motivation and Overview**
- ►**DodOrg: Interaction of the System Components**
- ►**Assembly and Results of Main Components:**
  - Organic Monitoring
  - Organic Middleware
  - Organic Low Power Management
  - Organic Processing Cells
- ►**Conclusion and Phase III Outlook**

Phase II: Refined Layer Model

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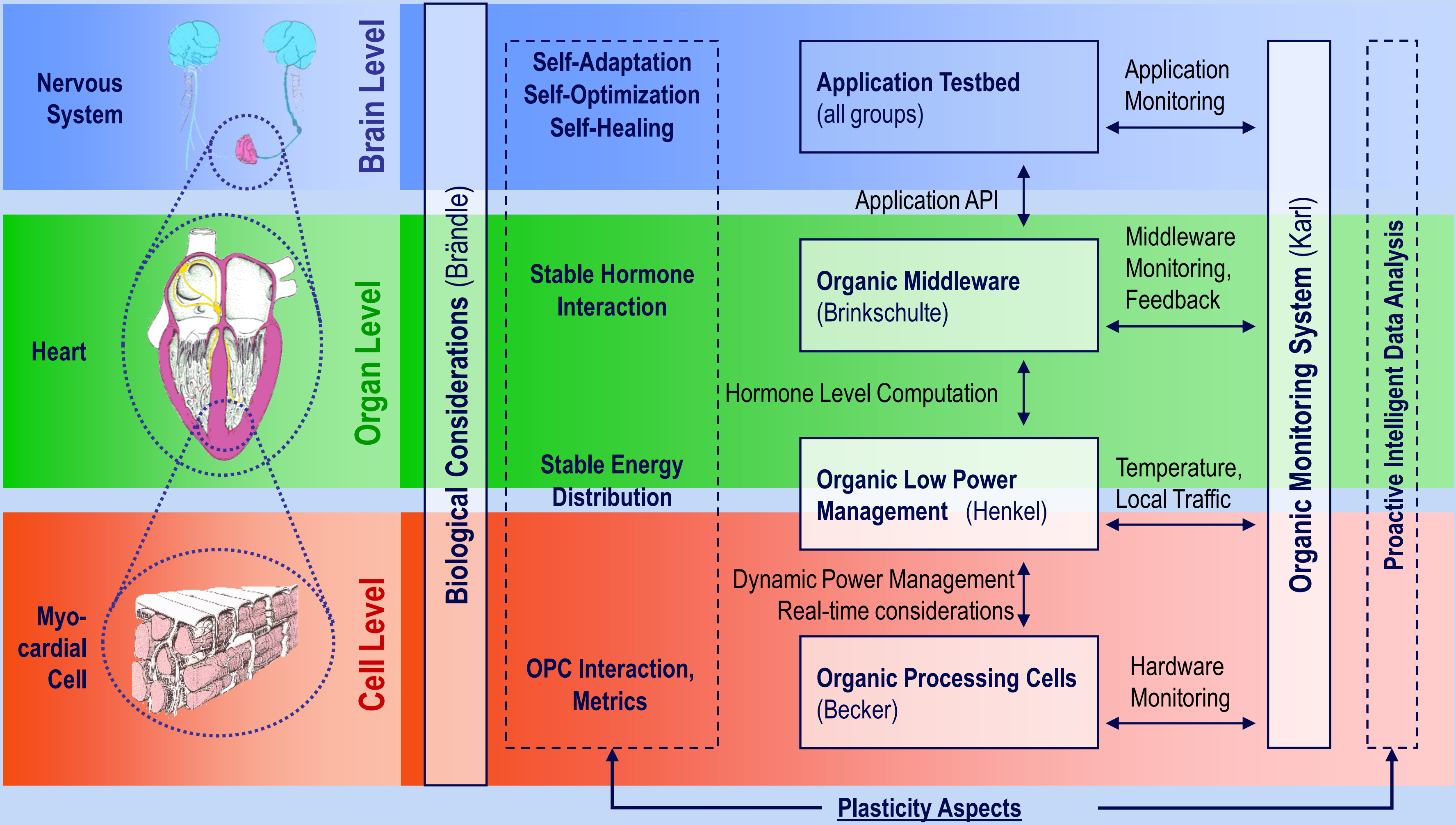

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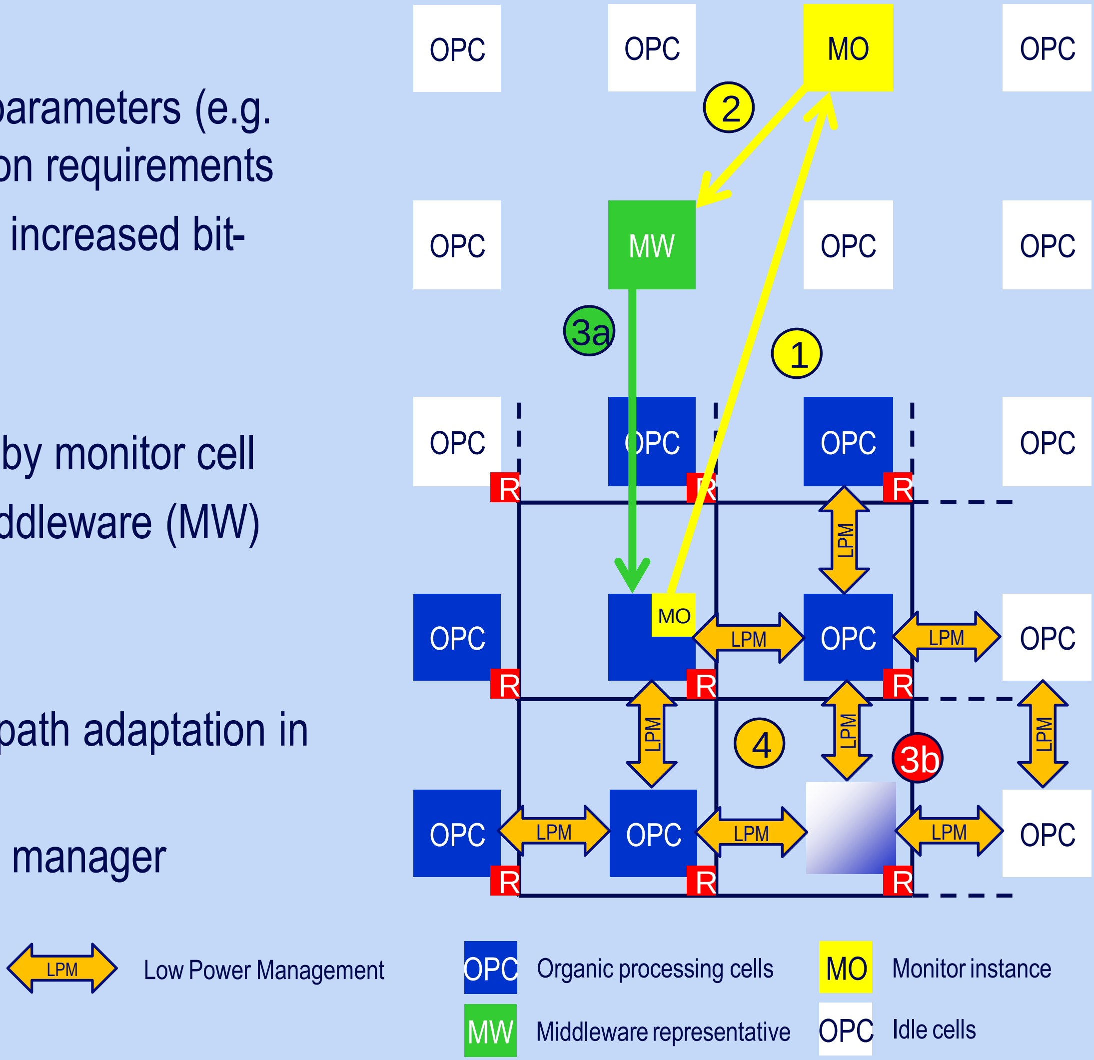
Situation detection

- Cause: Change in local system parameters (e.g. on-board temperature), application requirements
- Indication: Monitored errors (e.g. increased bit-error rates), hormone levels

Dynamic reaction:

1. Cell emergency event picked up by monitor cell
2. Monitor cell decides to inform middleware (MW)
3. Task migration
   a. Initiated by MW
   b. Cell configuration and data path adaptation in NoC
4. Energy adjustment by low-power manager
5. System settling



Organic Monitoring: Overview
(Prof. Karl)

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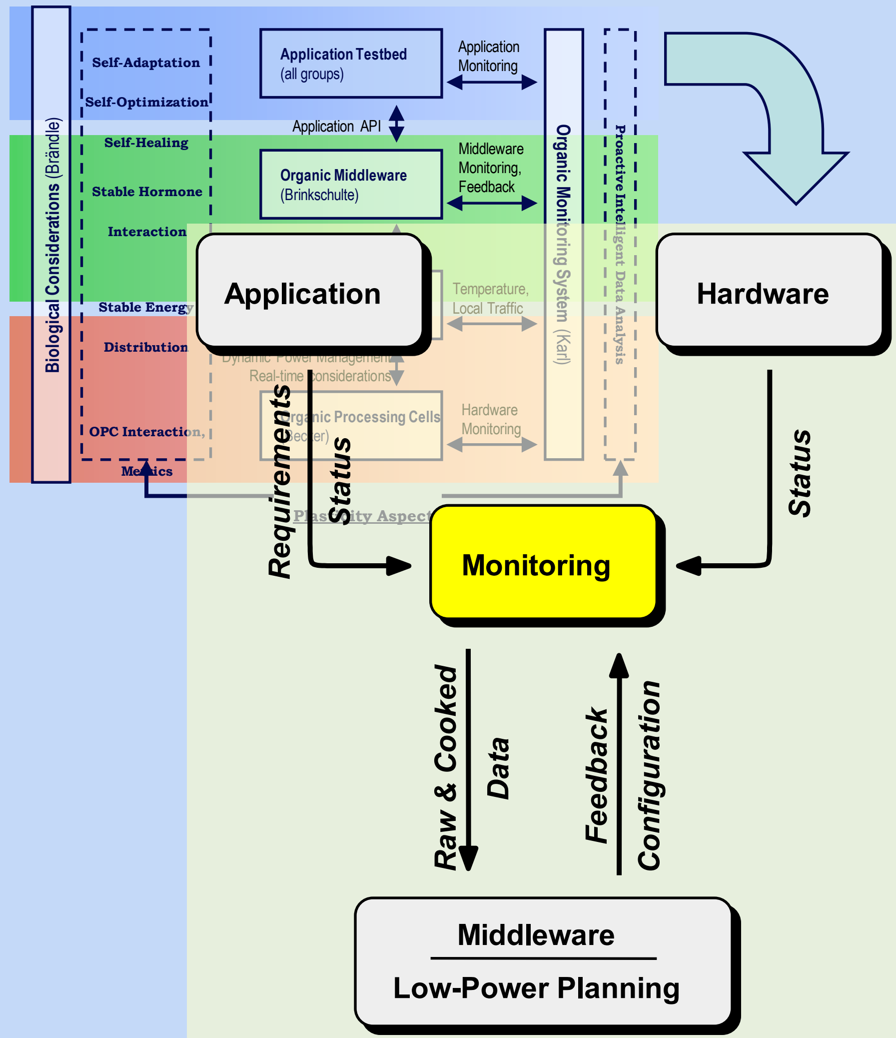
► Aim

- Enable and support Self-X capabilities
- Focus on increased self-awareness

► Requirements

- Sustained system monitoring
- Real-time analysis and evaluation
  - Correlation of (many) events
  - Identification of problems/causes
- Semantic data compression
  - Processing at the source of data
  - Generation of meta-data
- Adaptivity (reconfiguration)
- Interfacing



Organic Monitoring: Events and Event Spaces
(Prof. Karl)

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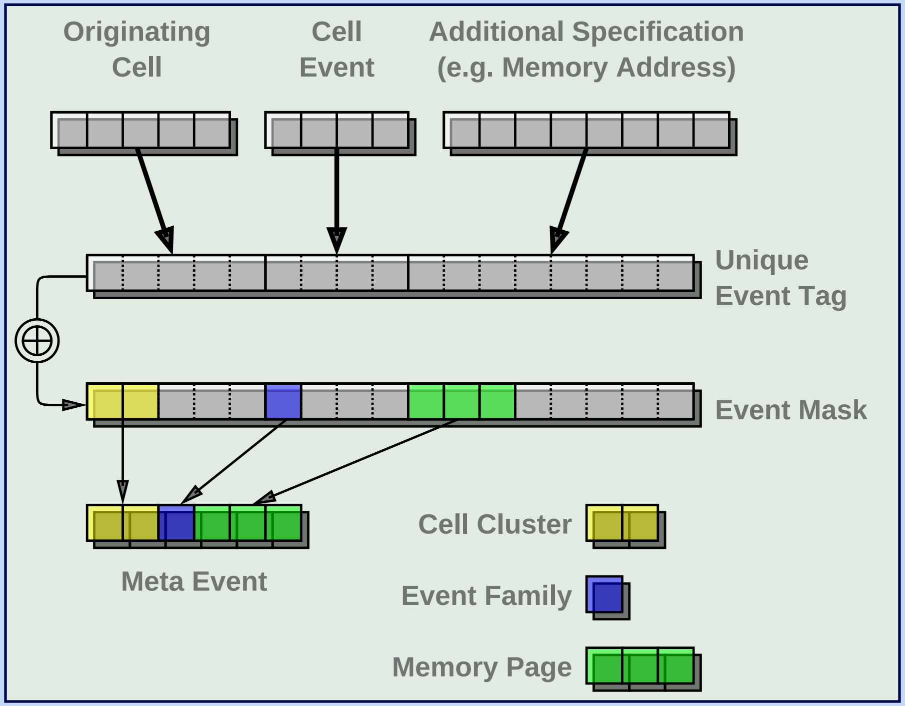
►Events and Event Spaces

- Conventional monitoring and evaluation relies on well-defined individual events and rules
- Hard to maintain in dynamic environments
  - Changing Event Types
  - Changing Event Quality
  - Adaption of Rule-set required
- Event Spaces required
  - Consider Event Spaces, not individual Event
  - Enables Classification and Scaling
- Concept of “Event Resolution”
  - Scale Resolution as required
  - Use entire Event or only Partial Information
- Matches Hormone Messenger Concept
  - Receiver decides if and how to react
- Interfaces well with Correlation Algorithms



Rainer Buchty, David Kramer, Wolfgang Karl: *An Organic Computing Approach to Sustained Real-time Monitoring*. Proceedings of WCC2008/BICC (IFIP Vol.268), pp.151-162, Springer, ISBN 978-0-387-09654-4

Organic Monitoring: Event Monitoring (Prof. Karl)

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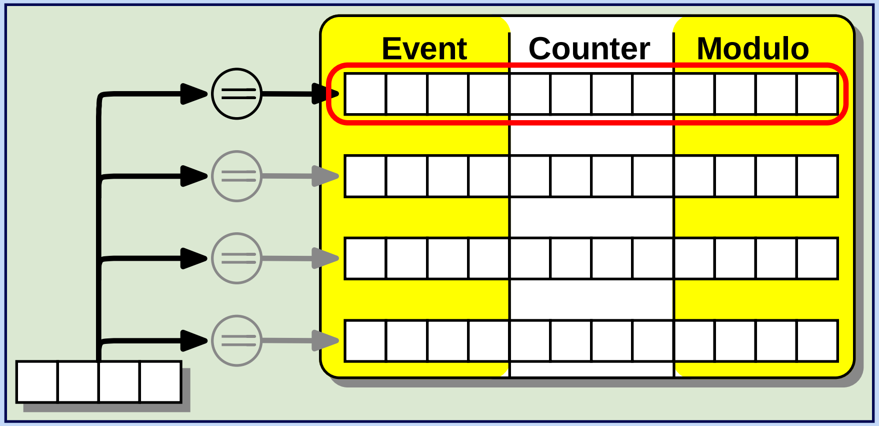
► Event Monitoring

- Autonomous receiving and processing of events
- Associative Counter Arrays
  - Association of events to counters
  - Cache principle (replacement)
  - Event transmision upon overflow or replacement
  - Semantic compression
- Layered monitor concept
  - Low-level monitoring: ACA built into every cell
  - High-level monitoring: dedicated ACA units
  - Scalable
- Event message anatomy
  - Originating cell
  - Cell type
  - Reason (overflow, replacement, forced read)
  - Event type
  - Counter value and modulo



► Implementation Test Cases

- HyperTransport memory access monitor
  - Usability and hardware performance study
- Self-aware Memory monitoring infrastructure
  - Control information
  - Protocol verification and evaluation

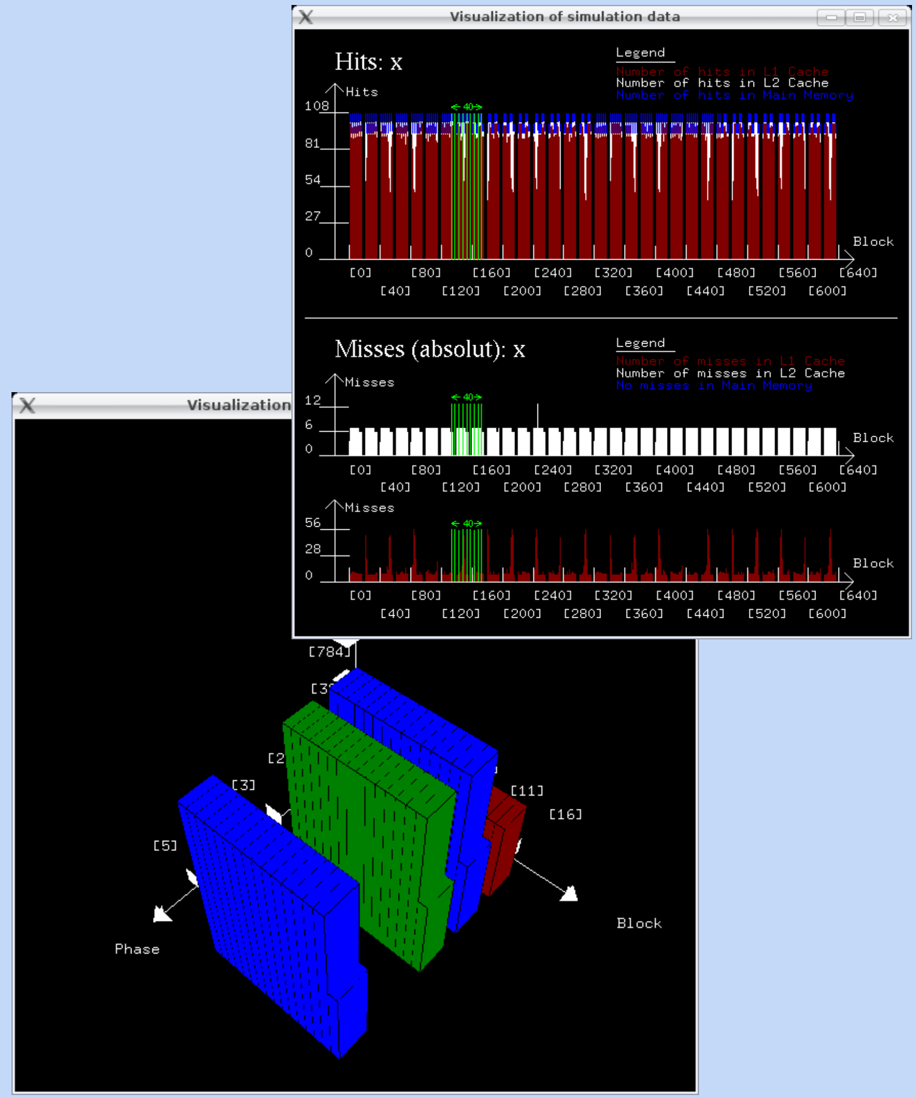
Rainer Buchty, Oliver Mattes, Wolfgang Karl: *Self-aware Memory: Managing Distributed Memory in an Autonomous Multi-Master Environment*. Proceedings of ARCS 2008 (LNCS 4934), pp.98-116, Springer, ISBN 978-3-540-78152-3

Rainer Buchty, Wolfgang Karl: *Design Aspects of Self-Organizing Heterogeneous Multi-Core Architectures*. to appear in: it – Information Technology, issue 5/2008, Oldenbourg Wissenschafts-verlag

Organic Monitoring: Intelligent Data Analysis and Proactivity
(Prof. Karl)

▶ Proactivity through Intelligent Data Analysis

- Rule-sets hard to maintain in dynamically changing systems
  - Availability of event types & quality
- Rule-sets rely on profiling
  - Determine application behavior (phases, hot-spots) and define according rule-set(s)
  - Not suitable for transient or data-driven events
  - Profiling impossible for dynamically changing systems
- **Intelligent data analysis techniques required**
  - Improved self-awareness through auto-correlation and –evaluation of events
  - Only basic, simple, and generic rules remain
  - Introduce proactivity: actively avoid potential conflicts by timely adaptation



Organic Middleware: Artificial Hormone System
(Prof. Brinkschulte)

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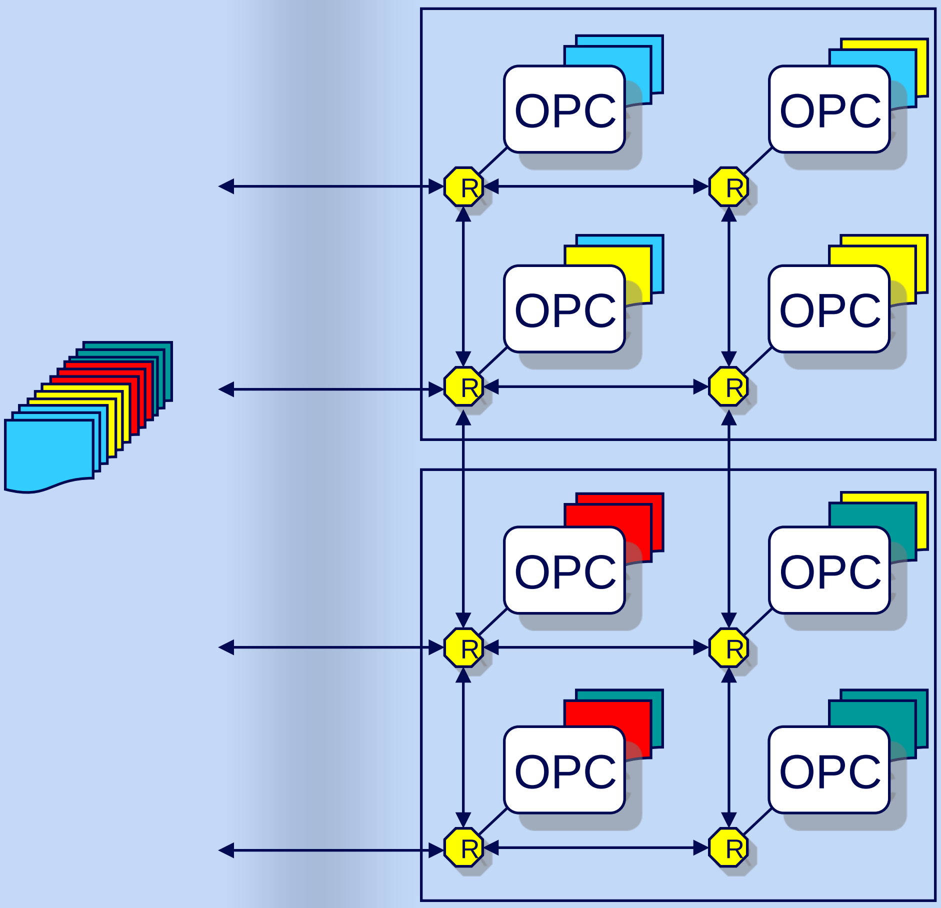
► **Aim:**

- Mapping tasks on Organic Processing Elements (OPC)
- Providing the system with Self-X properties on the middleware layer:
  - Self-Configuration
  - Self-Healing
  - Self-Optimization
- Achieving a good mapping with regards to
  - Requirements of each task
  - Relationships of the tasks
  - Condition of each cell and its neighborhood
- Reacting and adapting to changes (plasticity)
  - e.g. increased bit-rate errors
- Reaching stable mapping conditions

► **Requirements**

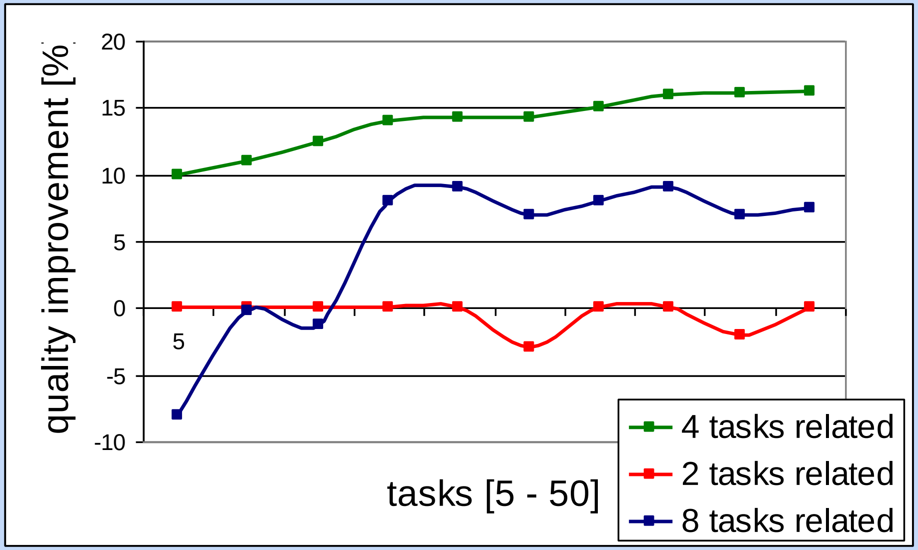
- Receive tasks and details from the application
- Information from Monitoring and Low-Power-Management



►Quality Analysis of the Artificial Hormone System

- Quantitative measure for the task assignment quality

- Merge different aspects:
  - Cell suitability for the mapped tasks
  - Communication distance
  - Cell workload



$$QU_{i\gamma} = \frac{w_{SH} \cdot SH_{i\gamma} + w_{EV} \cdot EV_{i\gamma} + w_{CD} \cdot CD_{i\gamma}}{w_{SH} + w_{EV} + w_{CD}}$$

$$QU = \frac{\sum_{PE_\gamma \in \Omega} \sum_{T_i \in E_\gamma} QU_{i\gamma}}{m} = \frac{\sum_{PE_\gamma \in \Omega} e_\gamma \cdot QU_\gamma}{m}$$

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- **Finding suitable hormone settings and improving mapping results**
- **Direct the Artificial Hormone System towards intended behaviour**

- **Methods:**
  - Genetic Algorithm: Measurements of the hormone configuration quality in order to produce a set of optimal hormone configurations.
  - Kalman Filter: Predicting optimal hormone values for unmeasured configurations
  - Support-Vector Regression: Estimating the drift function as required by the Kalman filter

Organic Middleware: Work in progress - Network
(Prof. Brinkschulte)

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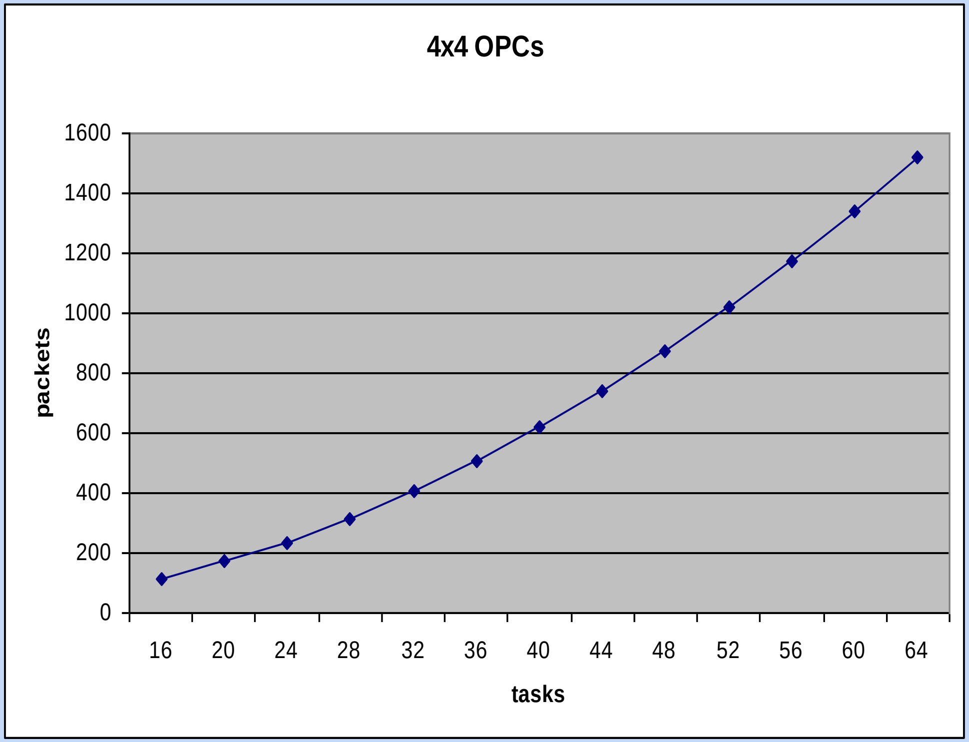
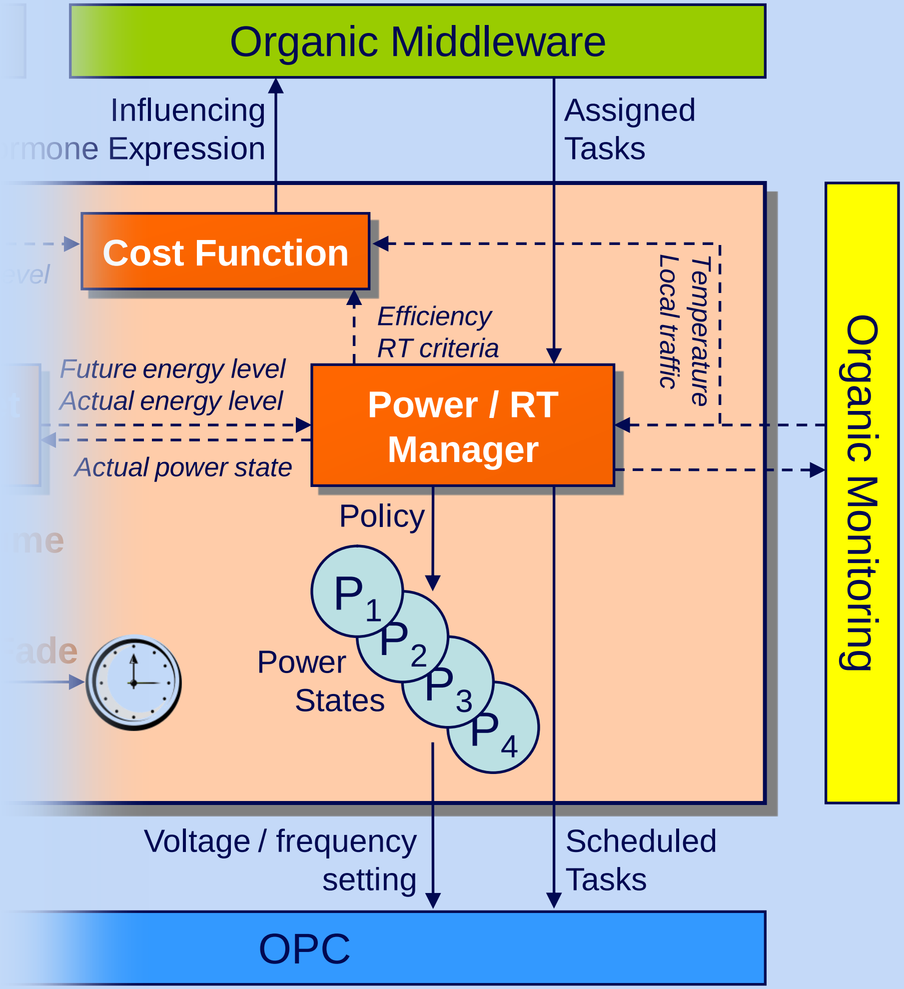
- Investigation of minimal requirements
- Improving network behavior
- Minimalizing AHS-related traffic

- Network behavior analysis
  - Network load
  - Overhead
  - Timing and latency
  - Effect of different routing algorithms
- Network protocol design and analysis
  - Header
  - Hormone Scale and Resolution
  - CRC / Parity check



Organic Low Power Management: DodOrg Interfaces
(Prof. Henkel)

- **Organic Middleware**
  - Cost Function
    - Used for computation of local eager values
- **Organic Monitoring**
  - External cost function parameters
    - Used to select apt power management policy
- **OPC**
  - Configure power state



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Organic Low Power Management: Managing Energy-Distribution
(Prof. Henkel)

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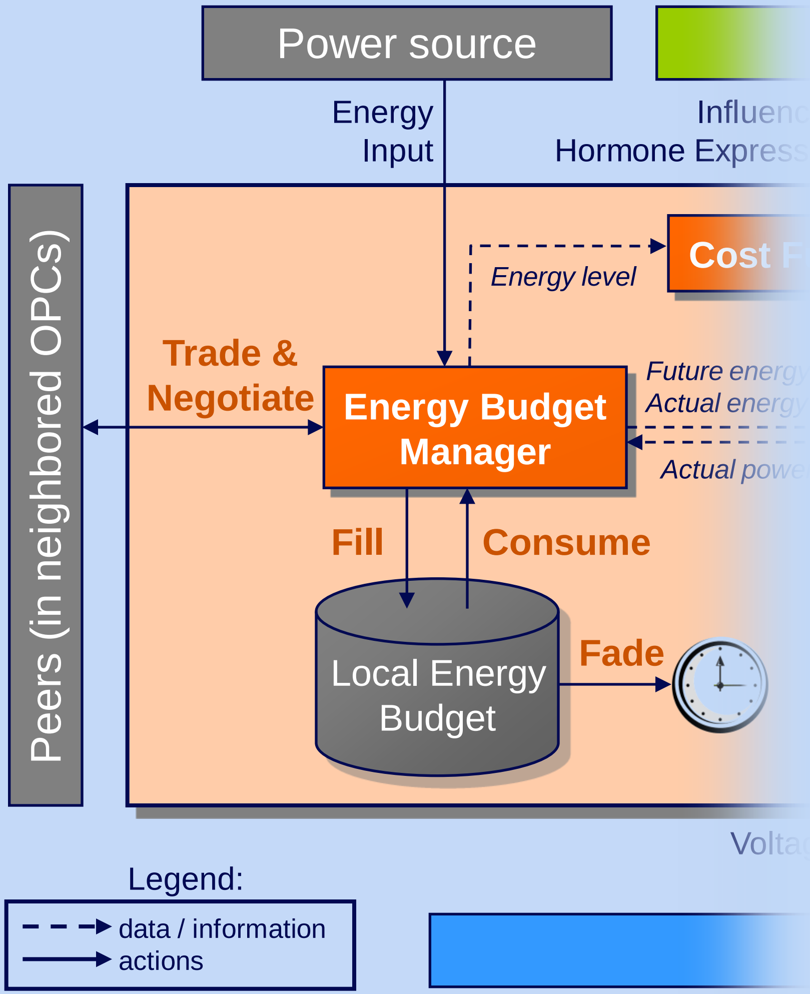
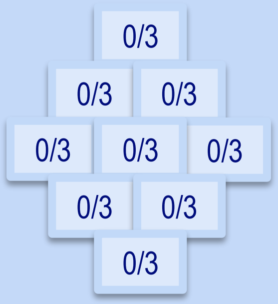


Energy Distribution: goals

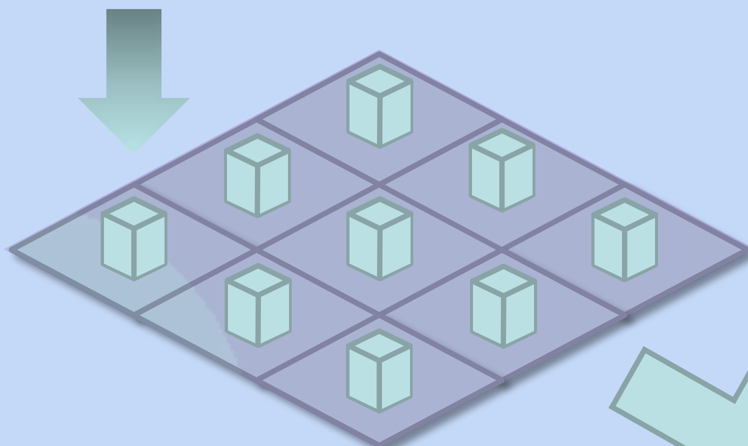
- Low energy consumption
- Avoidance of local thermal hot-spots
- Convergent system behavior (plasticity)

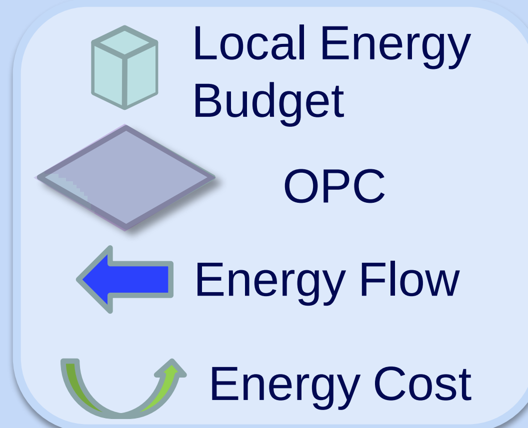
Energy Distribution: main concept

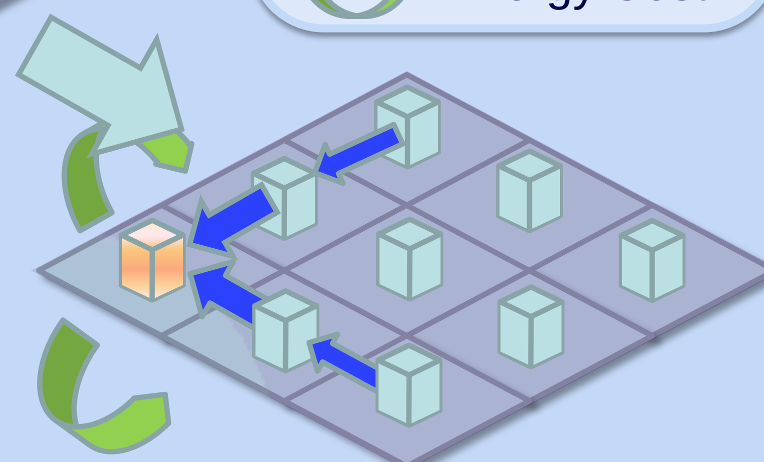
- Each OPC has a local energy budget
  - Simulates the locally available energy
- Energy Budget Manager
  - Agent controlling local energy budget
  - Negotiates & trades energy budget with neighboring OPCs
  - Influences Power/RT Manager policies
- Global Power Source
  - Assigns energy budgets to OPCs (pulse-based)
  - Depending on e.g. state of charge



Energy units used/available

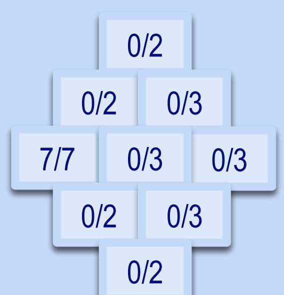






OPC requires energy to run demanding task

OPC negotiates energy budget with neighbors using cost function based on supply and demand



Energy units used/available

Organic Low Power Management: Agent Negotiation

(Prof. Henkel)

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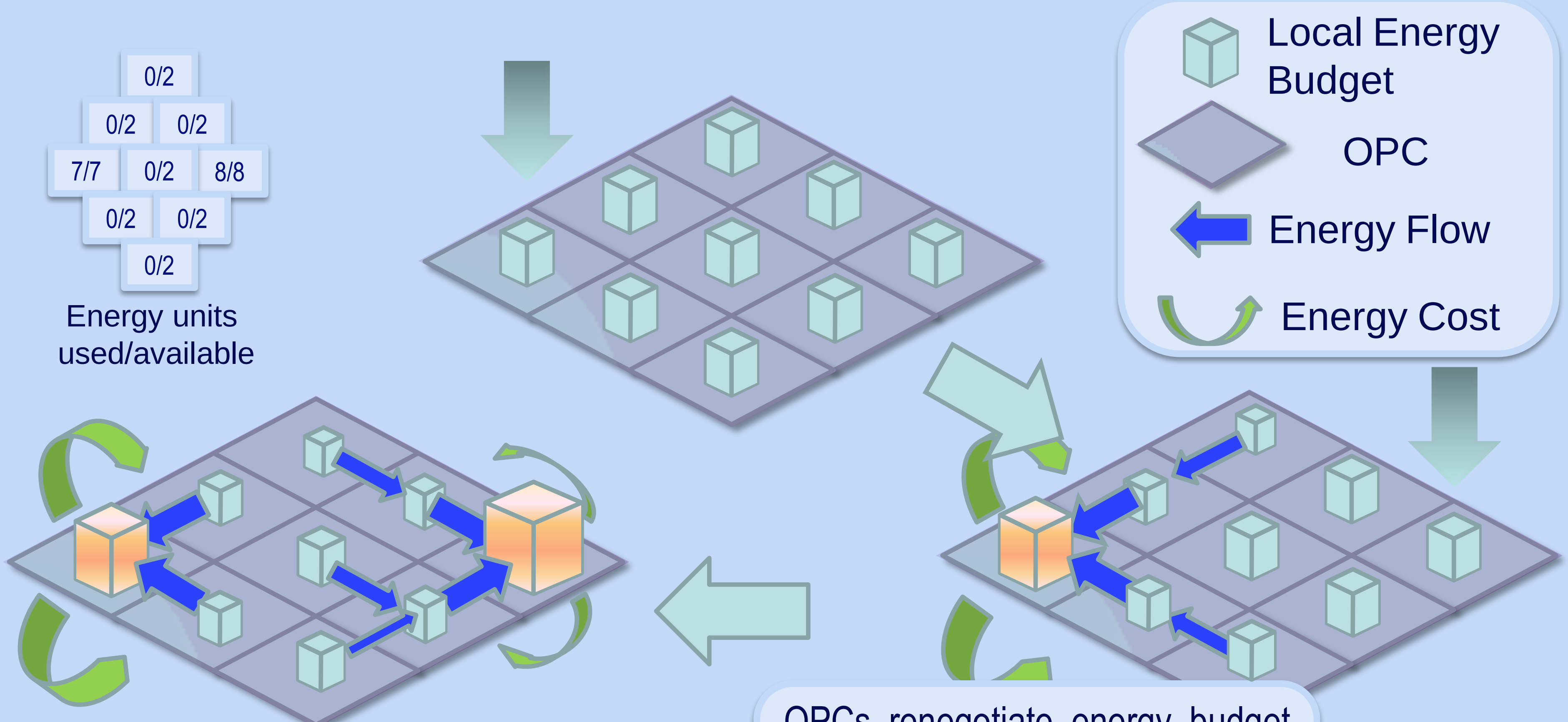

High priority task mapped to a second OPC

OPCs renegotiate energy budget with neighbors. Cost function is influenced by priority (high priority reduces cost)

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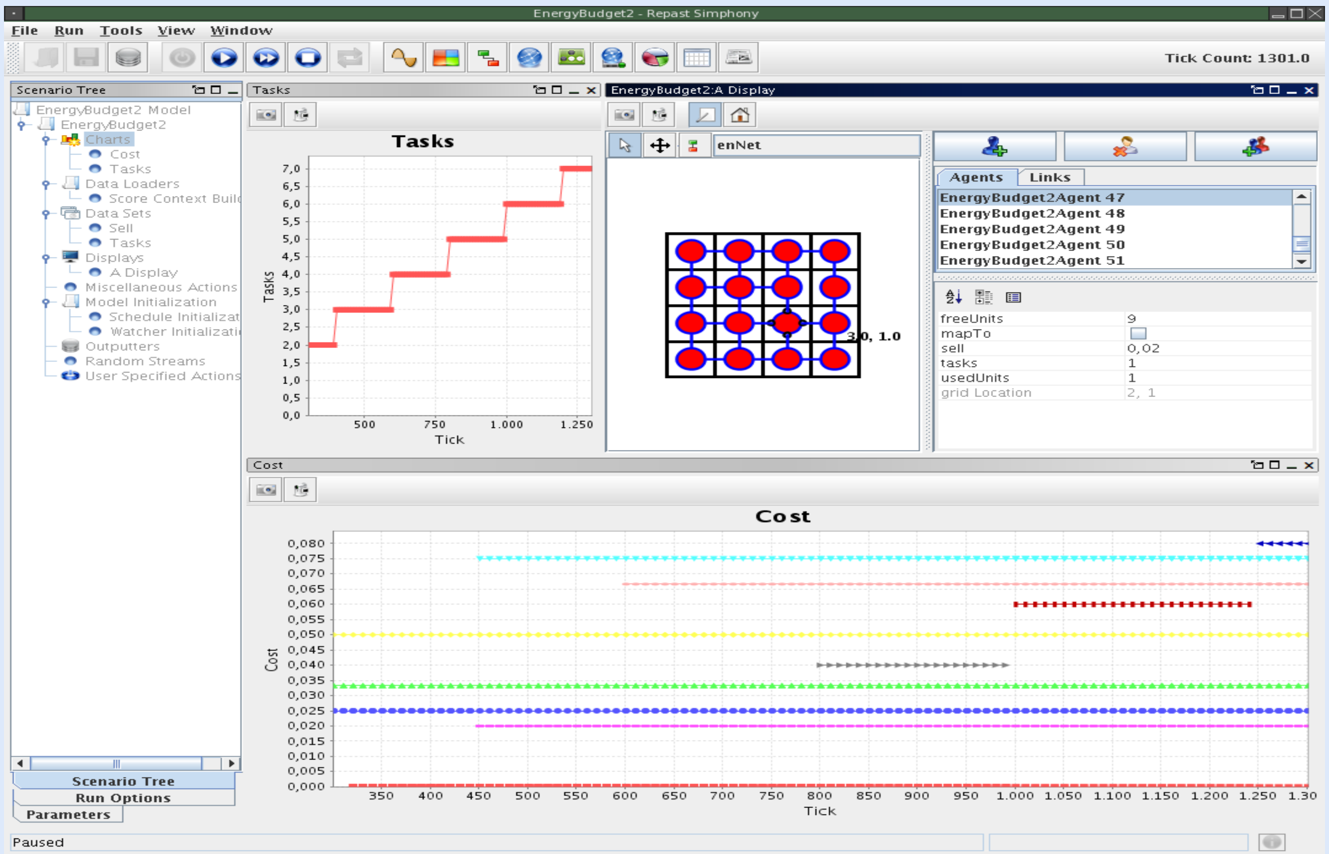

Repast: Simulation of agent negotiation

Organic Processing Cells: Hardware Overview (Prof. Becker)

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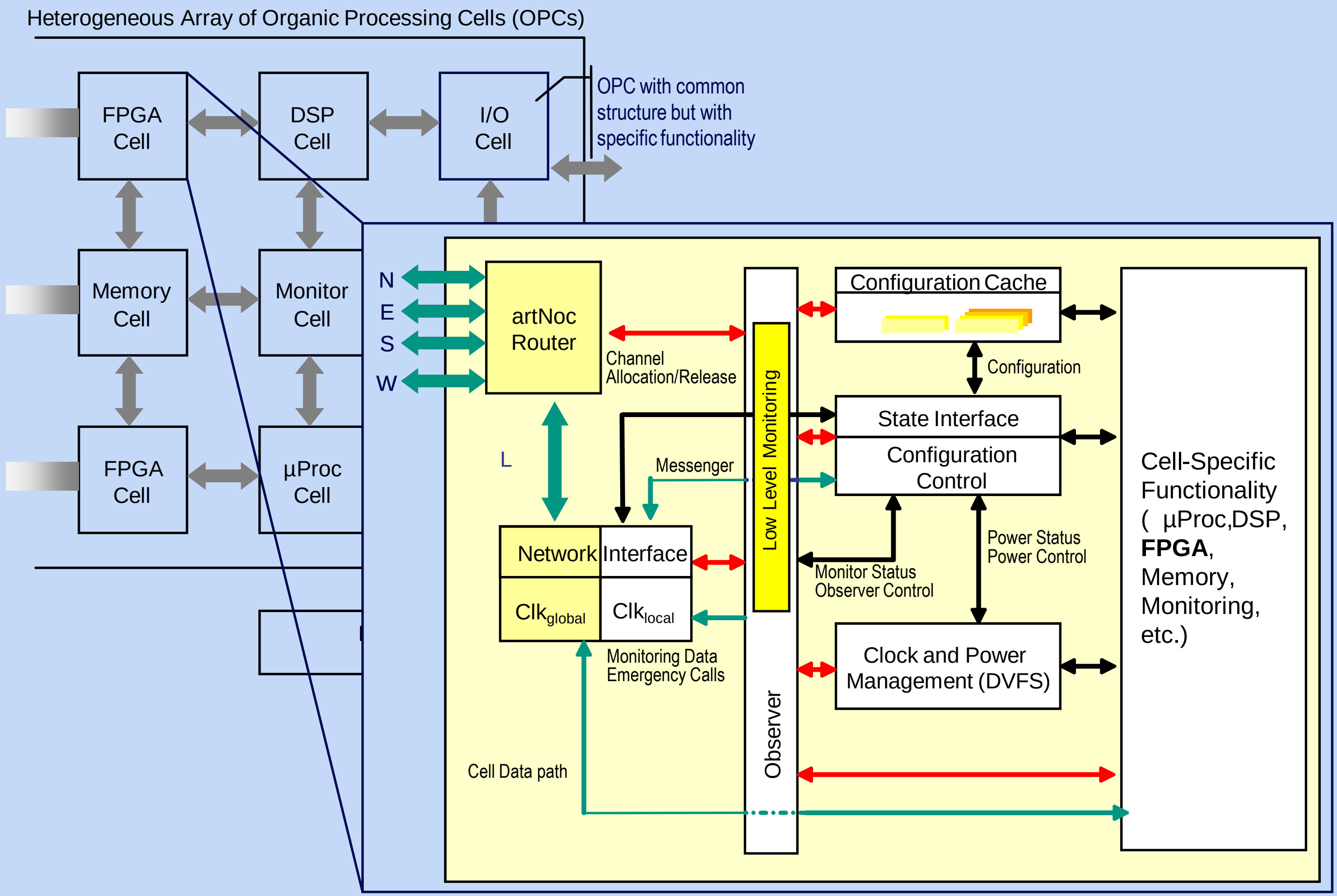
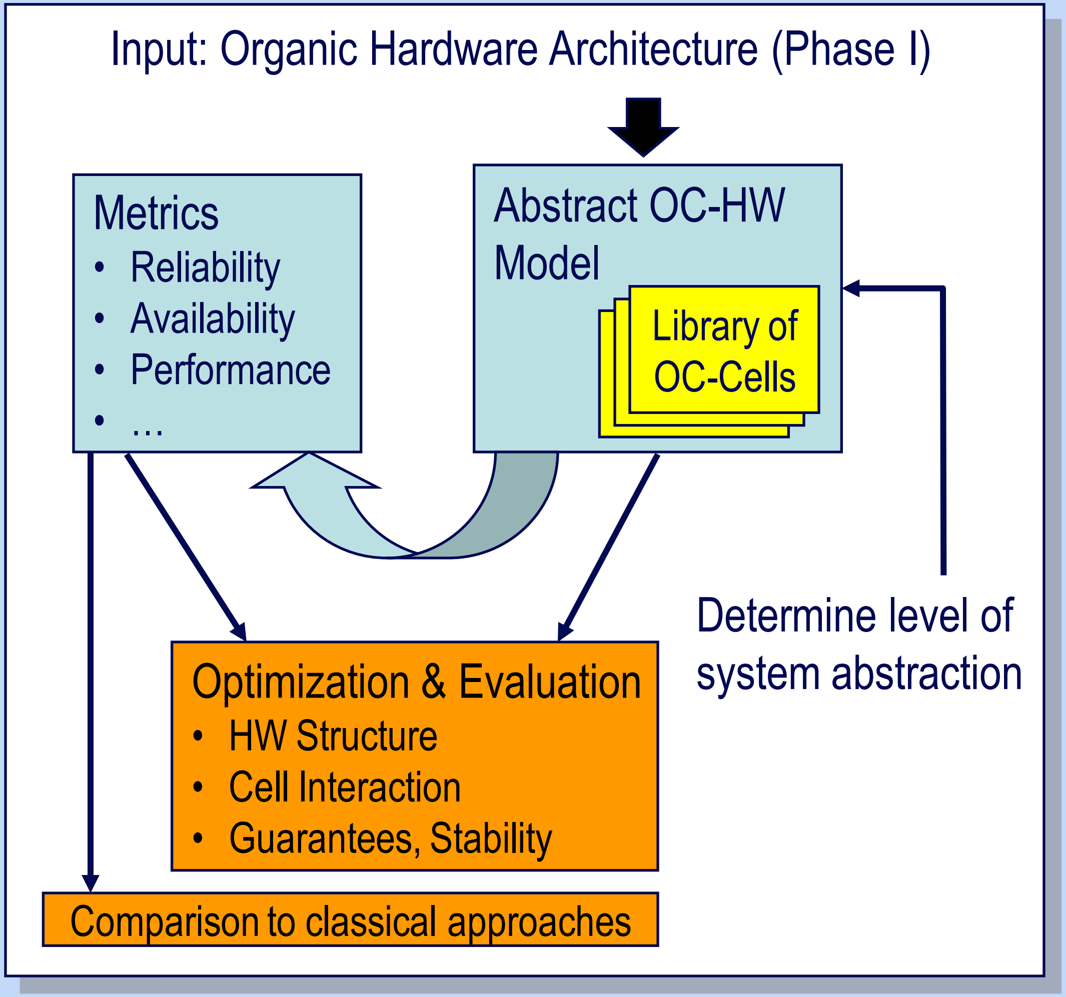


Organic Processing Cells: Close Control Loop Effects, Metrics, Cost Functions
(Prof. Becker)

▶ Foundation laid by
- DNA-configuration control
- Fault-tolerant/adaptive routing
- Automated test system
- Hardware prototype

▶ Challenges
- Dynamics of cell interaction
- Interference with Middleware/ Low-Power Management

▶ Research Goals
- Metrics
- Optimization
- Plasticity



Organic Processing Cells: Close Control Loop Effects, Metrics, Cost Functions
(Prof. Becker)

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► Distributed Power Management

- Hardware costs
- Switching speed, wakeup time
- Power savings
- Online task throughput synchronization / stabilization

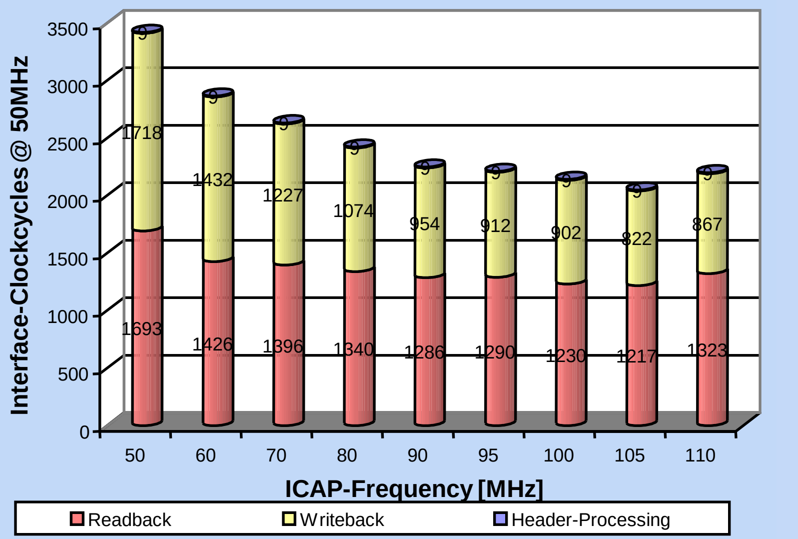
► Reconfiguration of data path

- Reconfiguration speed / execution time
- Configuration stream size / flexibility
- Self-repairing capabilities / potential

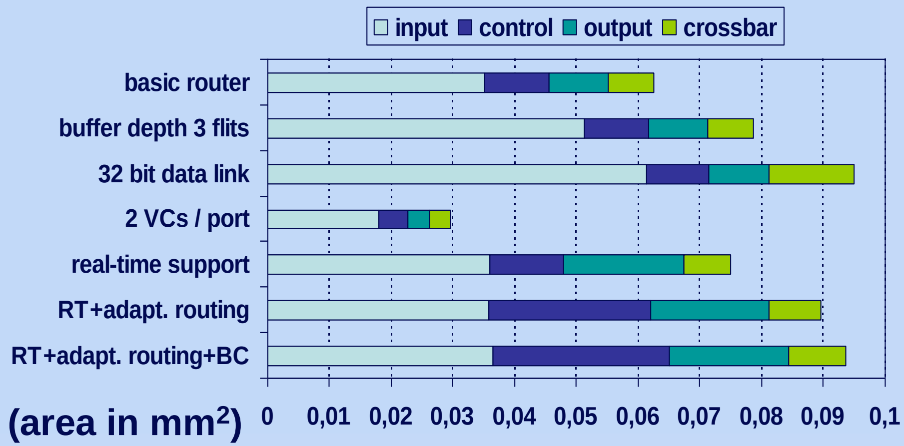
► Secure Packet Transmission

- Deadlock, Livelock, Starvation
- Adaptive routing
- Recovery mechanism

Reconfiguration Performance: Frame RMW Processing on Virtex2VP30



Hardware Cost: Router



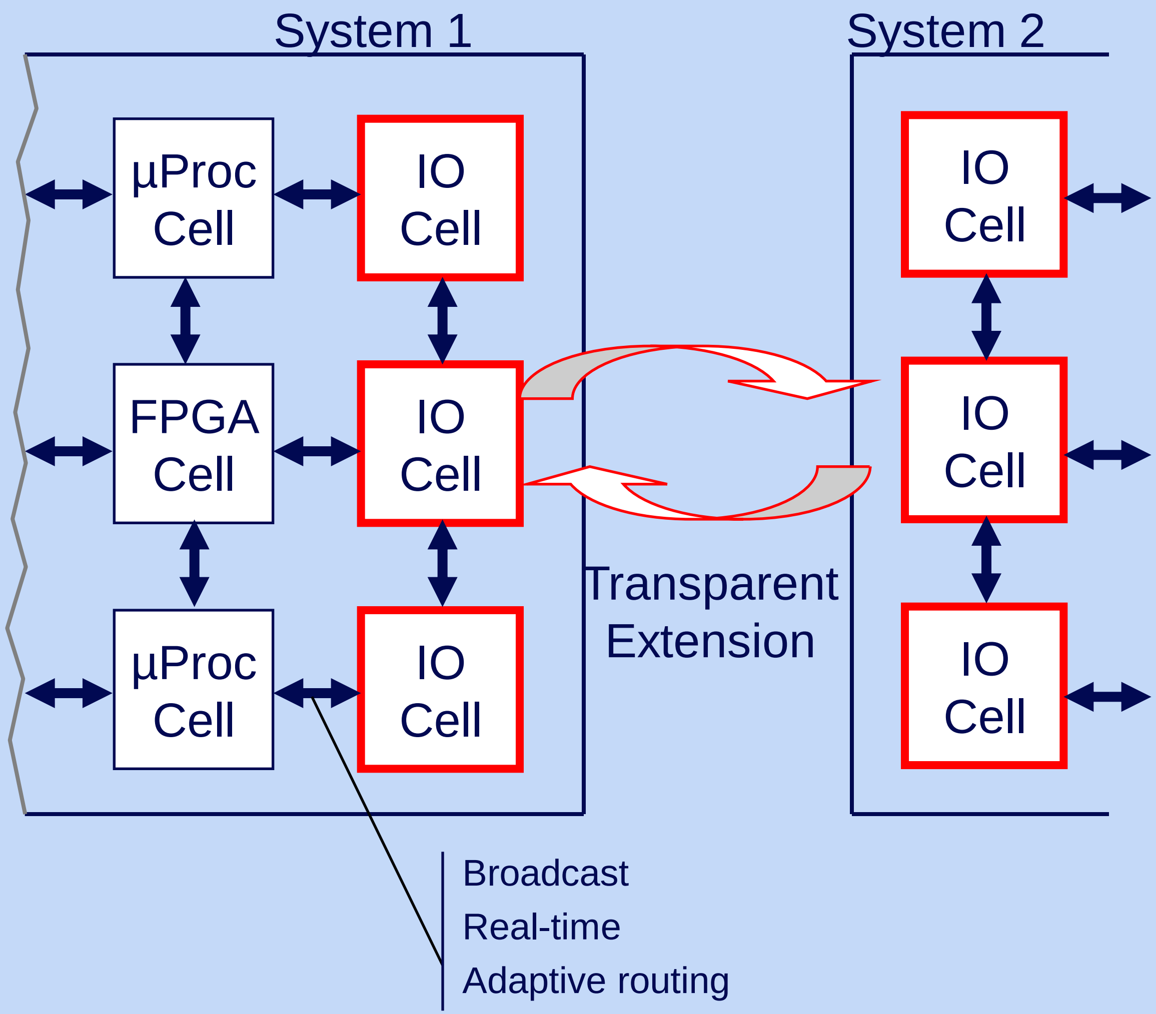
Organic Processing Cells: Transparent System Extension
(Prof. Becker)

▶ Challenges

- Generalization of generic hardware model
- Transfer of network services
- Removing/adding individual OPCs

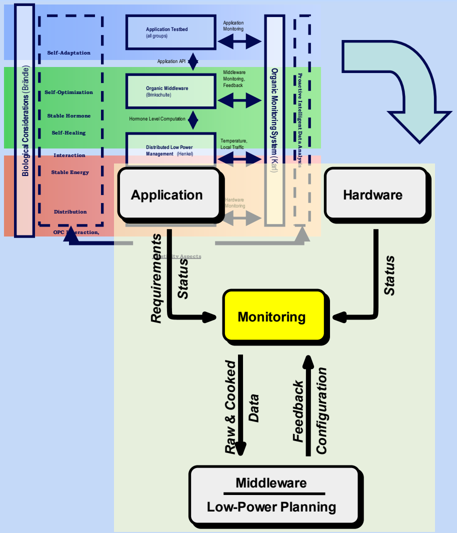
▶ Research Goals

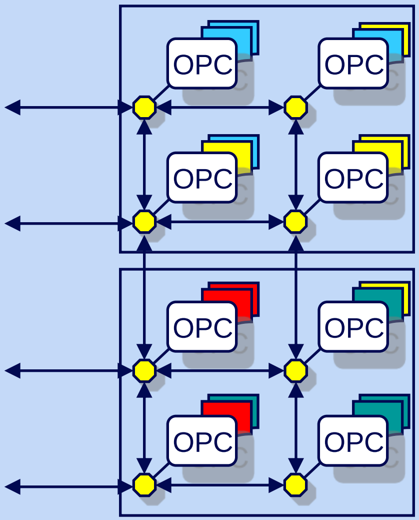
- Communication mechanisms of IO-cells
- Adaptation of address space through use of DNA Configuration Management
- Achieving true modularity

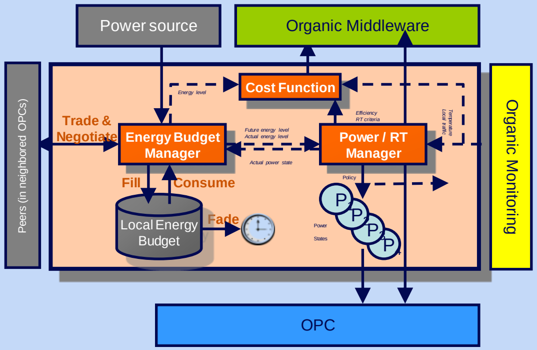


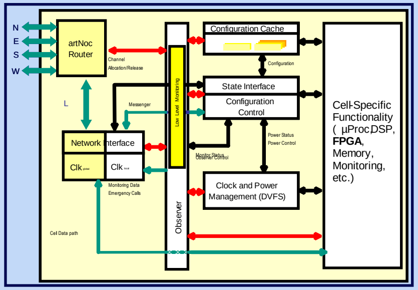
Conclusion

- **Current status of the DodOrg project:**
  - Concepts individually tested and applicability proven
  - **Monitoring:** hormone-inspired associative event coding and use of associative counters
  - **Middleware:** reaching stable hormone and mapping situations while still being able to react to changes (plasticity)
  - **Low-Power-Processing:** local agent-based energy budget distribution
  - **Processing Cells:** abstract OC-hardware model and evaluation of metrics and cost-functions









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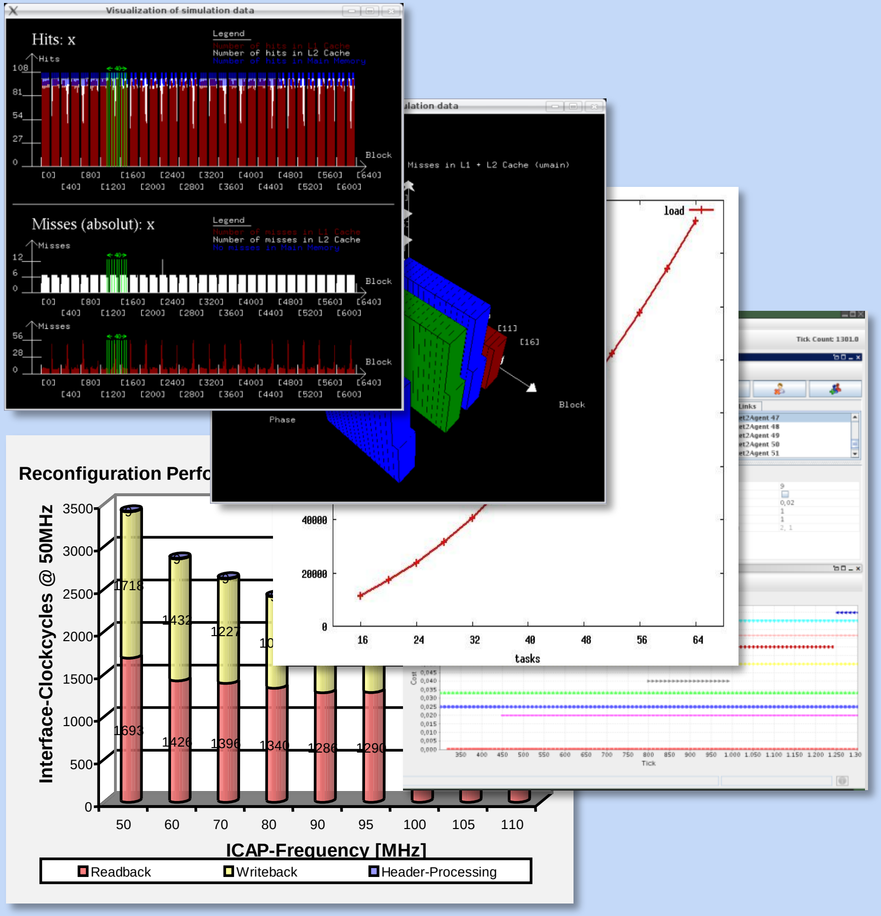
- **Remaining Phase II tasks** (approx. 9 months)
  - Stability and robustness
  - Intelligent data analysis techniques
  - Local energy-distribution management
  - Closed control-loop effects
- **Phase III**
  - Self-optimization scenarios
  - Conflict avoidance through proactivity
  - Cell-level low-power issues and interaction
  - Off-chip communication
  - Prototype implementation: application phase detection and fault-tolerance



Thank you for your attention!

Questions?