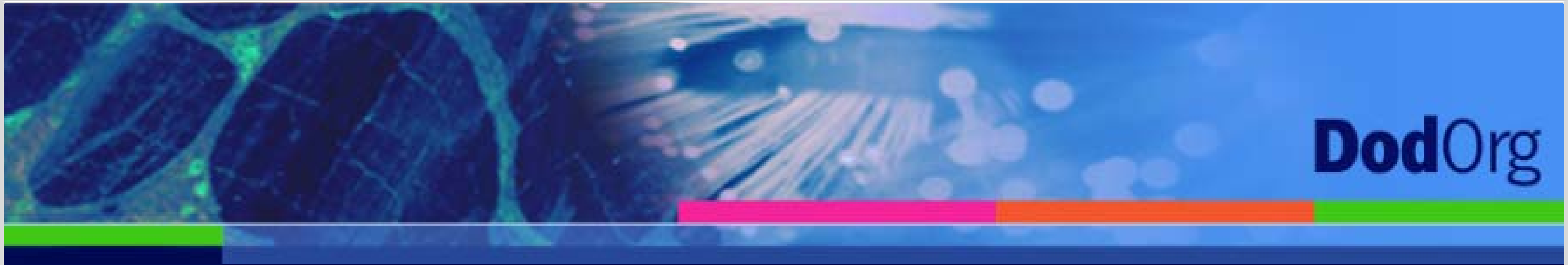
Karlsruhe Institute of Technology

Digital On-Demand Computing Organism - **Dod**Org

SPP OC Kolloquium
DFG SPP 1183 “Organic Computing”
Augsburg, September 21/22, 2009



Talk Overview

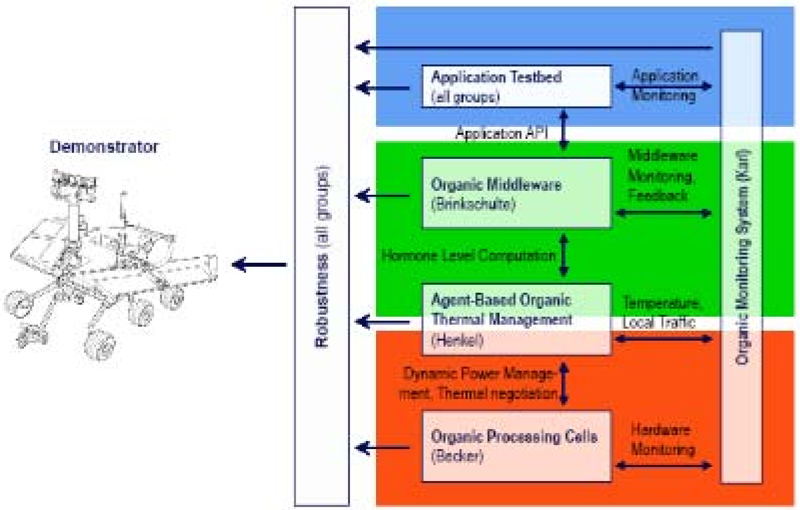
- ►Project Motivation and Overview
- ►DodOrg: Plasticity and Dynamics
- ►Results of third year:
  - Organic Monitoring
  - Organic Middleware
  - Organic Low Power Management
  - Organic Hardware
- ►Conclusion Phase II
- ►Research Goals for Phase III
  - Stability
  - Robustness
- ►Phase III Summary

DodOrg Motivation

Classic Scenario:

► Only those scenarios can be handled
- that were considered in advance,
- where the cause can be detected,
- where the corresponding reaction had been explicitly programmed.

► Lack of adaptation leads to insufficient reactions (e.g. shutdown …)



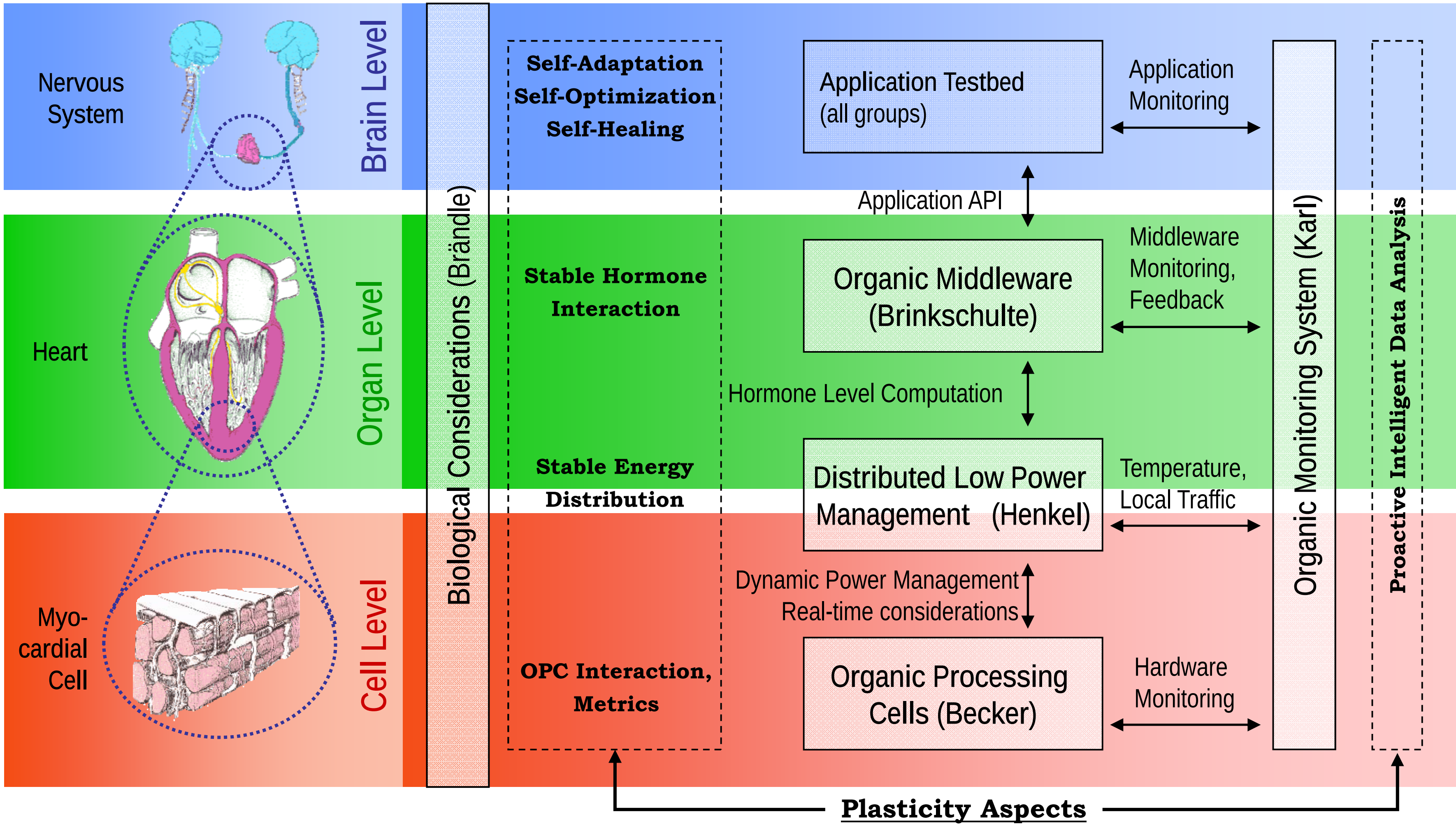
DodOrg Scenario:

► System reaction based on indications (higher level of abstraction)
- e.g. CRC/bit error rate, network bottleneck, environmental change or change on application level

► Proper reaction possible even if
- Scenario was not considered in advance.
- Cause was not detected,
- Reaction was not explicitly programmed.

► Flexible response to changed environmental situation
- Scenario detection: recognize that something is different
- Adapt to changed requirements either by known path or gradual process of rearrangement (optimization, healing)
- Plasticity: Stabilization but not “petrification”

Phase II: Refined Layer Model



Phase II: Project Objectives

Dynamics
The ability of the system to react according different parameter changes (external, internal).

+ Improved performance
+ Immediate reaction
- Danger of oscillation
- Unstable behavior

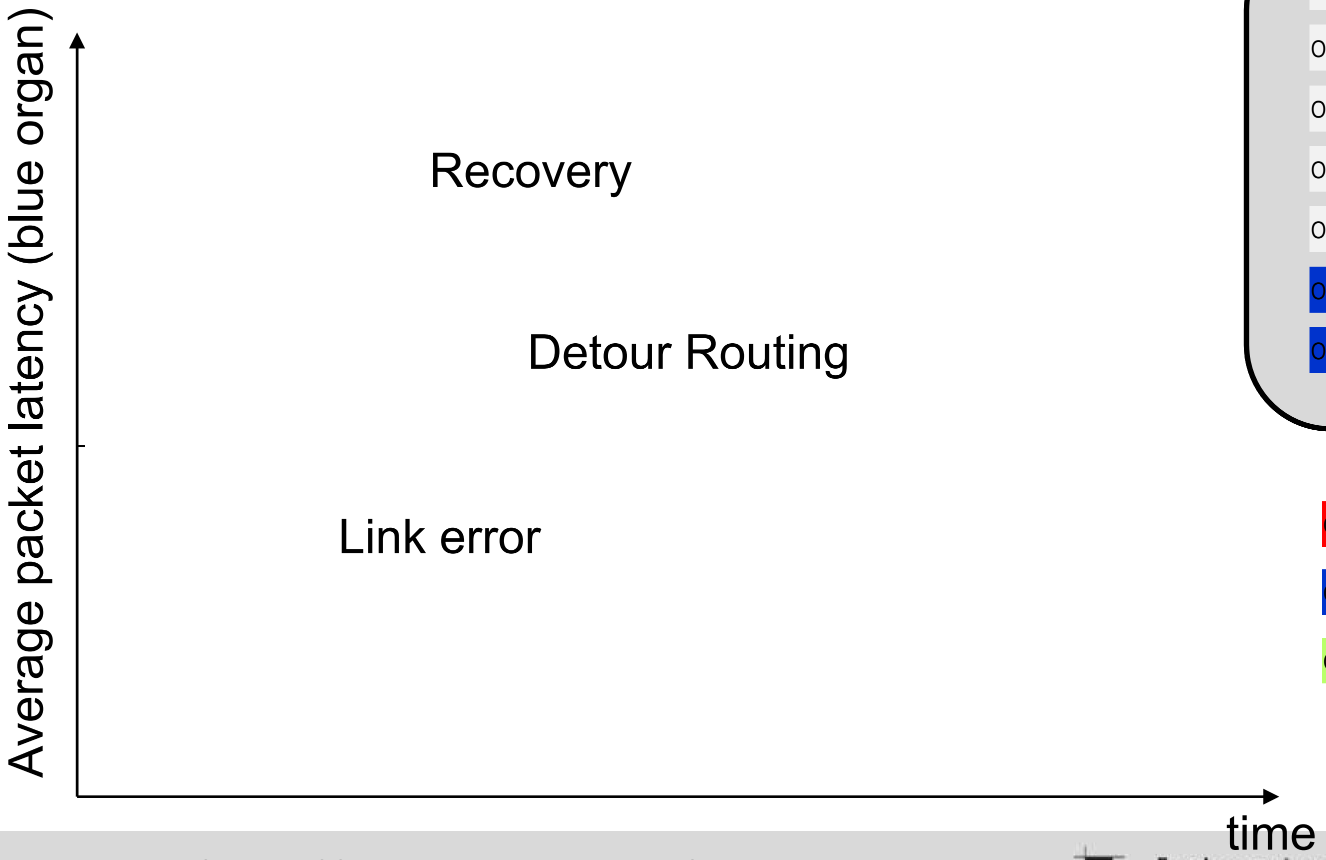
Plasticity
Narrowing the dynamic properties.
The ability of the system to leave a stable state in order to adapt to larger environmental changes.

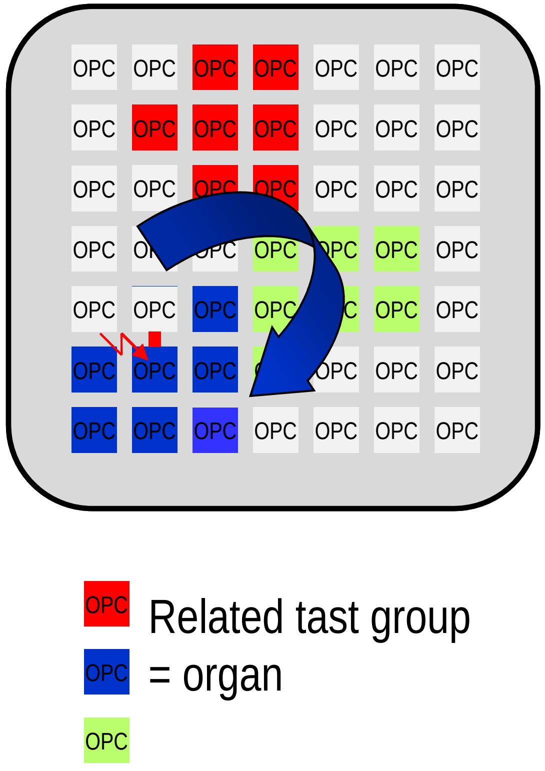
+ Decreased power consumption
+ Oscillation avoidance
+ Overhead reduction
+ Reduced complexity
- Delayed reaction

Example of Plasticity

- Scenario
  - ► Link Failure → Packet Deadlock
  - ► Recovery Broadcast to deliver stuck packet
  - ► Implications
    - Hormon cycle
    - Network topology because of broken link → neighbor relationship changes
  - ► MW redistribution of task
  - ► Different Link Workload
  - ► Power Management Regulation of new Power Situation

Scenario


Average packet latency (blue organ)
Recovery
Detour Routing
Link error
time


OPC
Related tast group
= organ

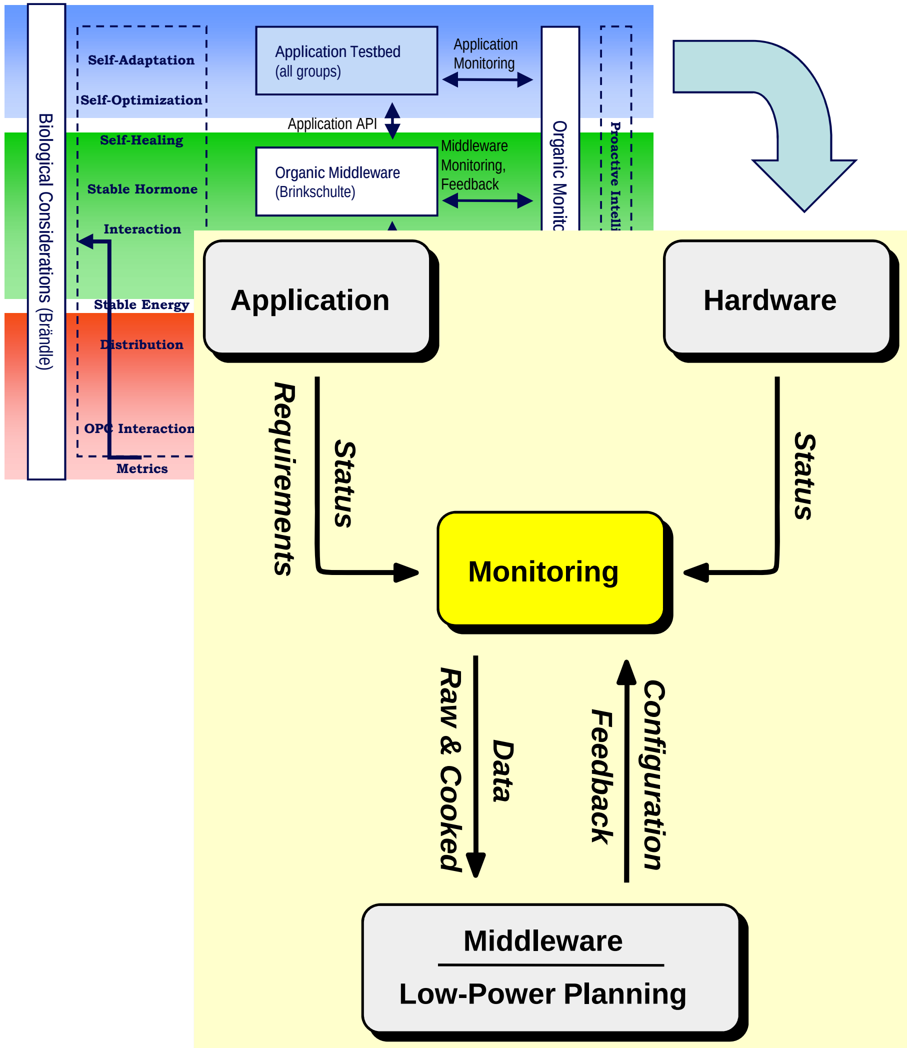
Organic Monitoring: Overview
(Prof. Karl)

▶ Aim

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

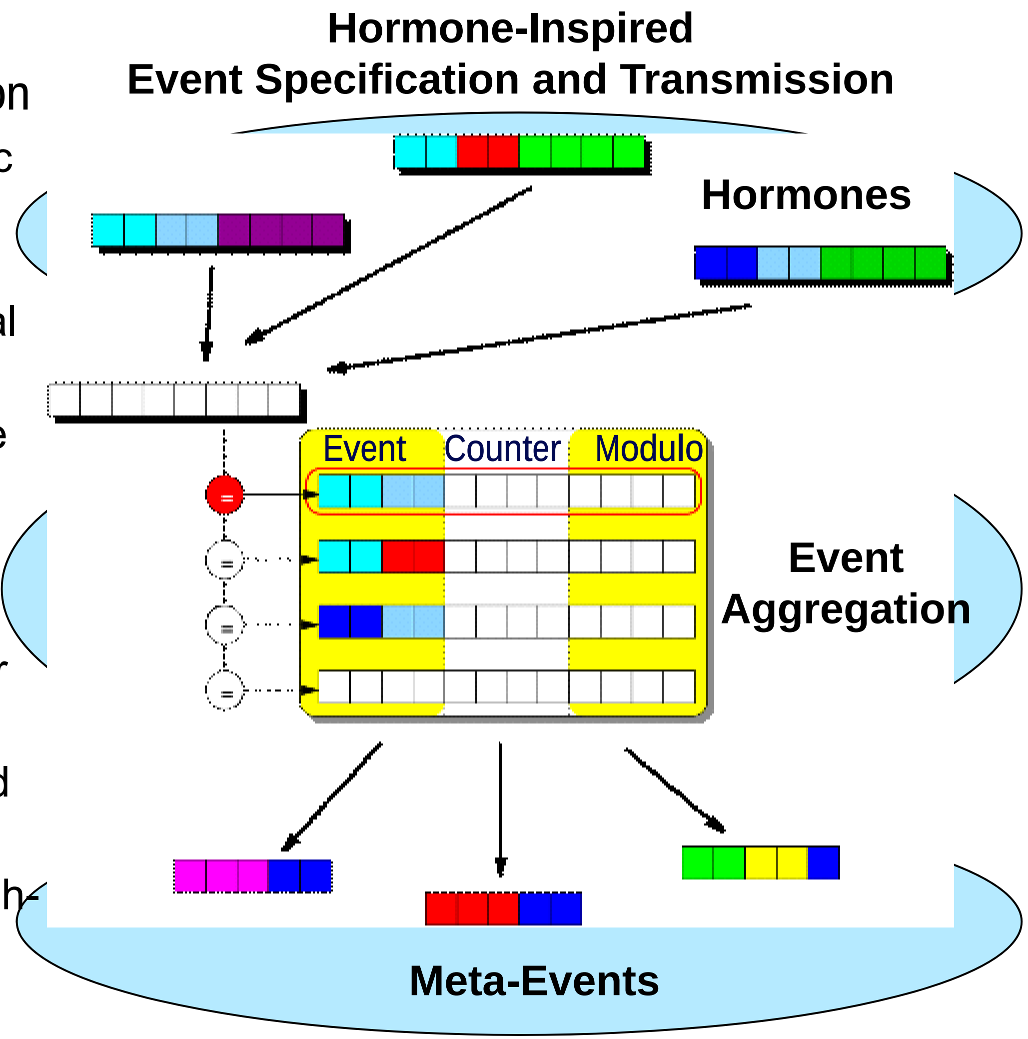
▶ Requirements

- 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
- Scalability



Organic Monitoring: Event Monitoring and Aggregation
(Prof. Karl)

▶ Decentral Event Monitoring and Aggregation
- Based on the hormone concept, Organic Monitoring Modules (MM) monitor the hormone concentration in each OPC
- Each hormone is treated as an individual event
- Events are aggregated in an Associative Counter Array (ACA)
  - Association of events to counters
  - Cache principle
  - Event transmission upon overflow or replacement
- Events transmitted are forming so-called Second Messenger or Meta-Events
- Meta-Events are then transmitted to High-Level instances for data analysis



Organic Monitoring: Intelligent Data Analysis Techniques
(Prof. Karl)

► State Classification in High-Level Monitoring

- Several High-Level Monitoring Units (HLM) operate on Meta-Events generated by several Organic Monitoring modules
- Incoming Meta-Events are stored in so-called Event Lists which are sorted by hormone type
- State Classification algorithms are using one or more Event Lists to classify the state of the (sub-) system as good, neutral or bad
- If necessary, appropriate actions are triggered by HLM instances

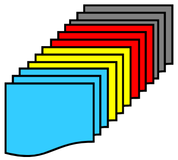
► Application Scenario – Power Consumption

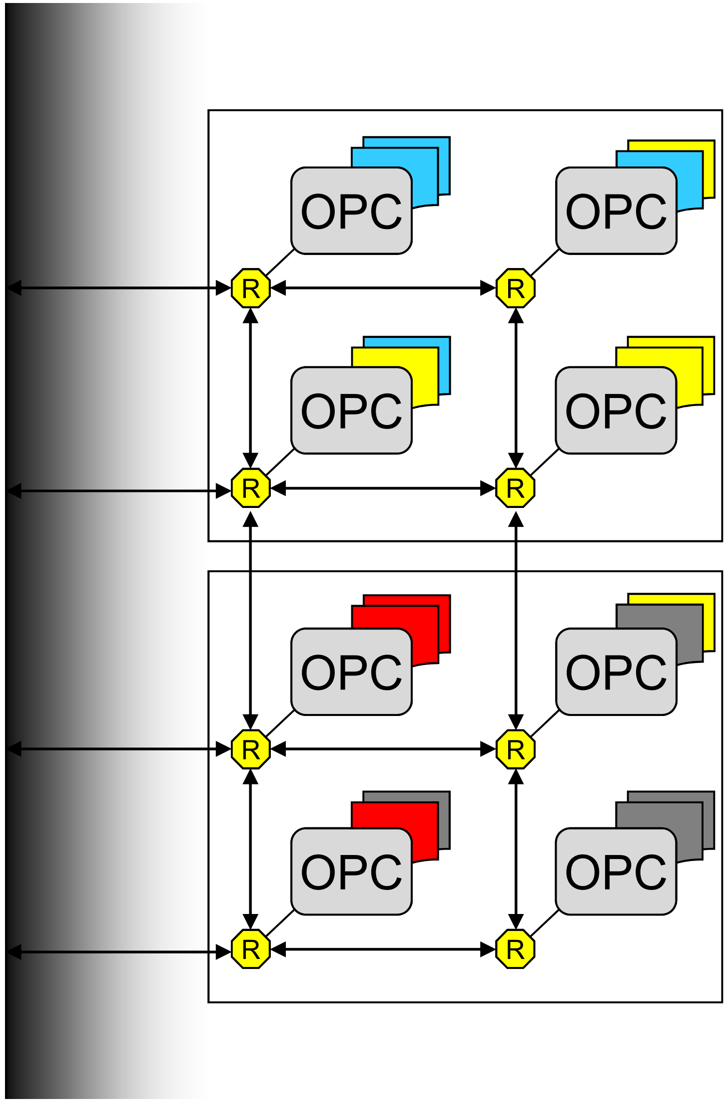
- The power consumption of OPCs is monitored by dedicated hardware sensors
- Scenario: encoding of a wav-file using lame
- A hormone is generated each time 10 mW are consumed by the CPU
- State Classification every 16 Meta-Events
- Simulation time: ~ 4 Billion Cycles
  - ~ 300 Mio. Hormones
- Training Phase: 1 000 000 Cycles
- Results: 282,292 state classifications
  - Used for Training: 76
  - Good: 242,590
  - Neutral: 35,096
  - Bad: 4,530

Organic Middleware: Re-Intruduction of the Artificial Hormone System
(Prof. Brinkschulte)

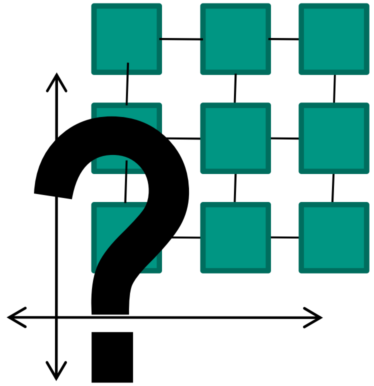
► Aim:

- 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 in regards to
  - Requirements of each task
  - Relationships of the tasks
  - Condition of each cell and it's neighborhood
- Reacting and Adapting to changes (plasticity)
  - e.g. increased bit-rate errors
- Reaching stable mapping conditions





Organic Middleware: New Challenges of the Second Phase
(Prof. Brinkschulte)



Hormone Concept - Evaluation and Refinement:

- Analyzing the network load in the system
- Generating hormone configurations with evolutionary algorithms

Stability:

- Stability of the system of individual OPCs with Hormone Cycles
  - a bounded input (configuration + measured data) results in an bounded output
  - no oscillation of tasks and no unnecessary task allocations

Examination of Stability & Robustness:

- Finding limits of systems:
  - How many tasks/jobs are suitable for a given number of OPCs
- Calculating minimum requirements of the system:
  - How many OPCs will be needed for a given scenario (at a minimum)

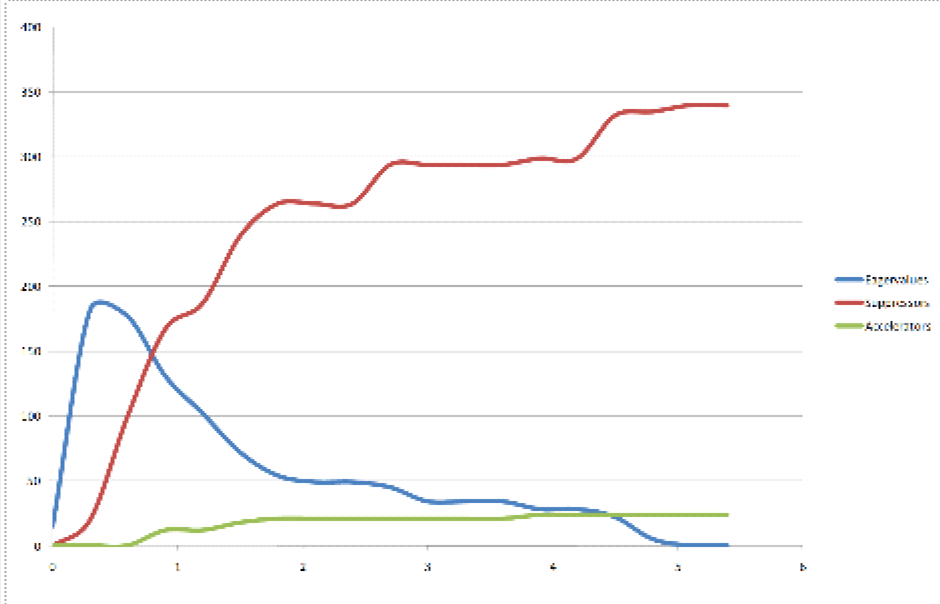
Organic Middleware: Phases of the Configuration
(Prof. Brinkschulte)

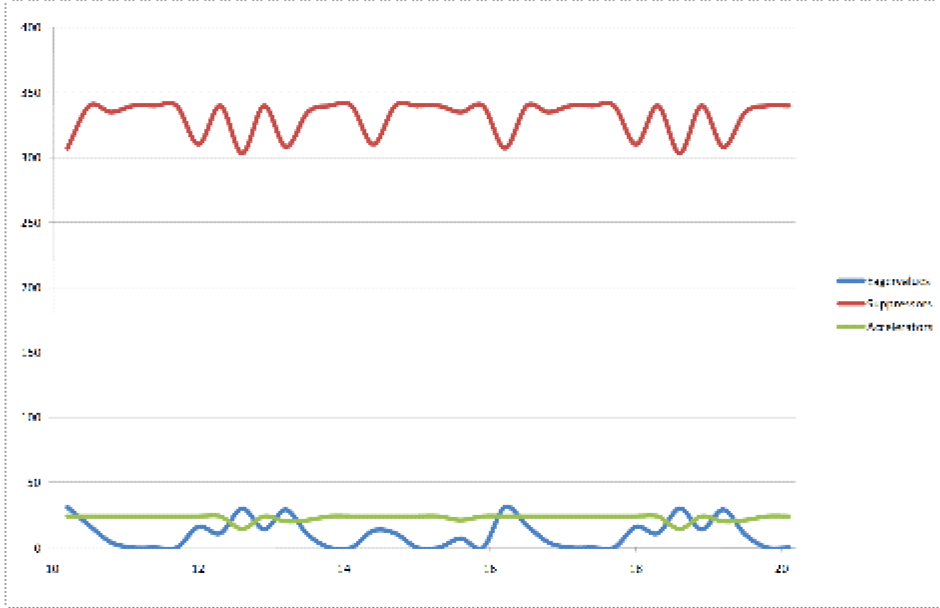
Phase 1:

- Strong Eagervalues, weak Suppressors and weak Accelerators
  → every cell wants to execute tasks
- Suppressors rise when tasks are mapped

Phase 2:

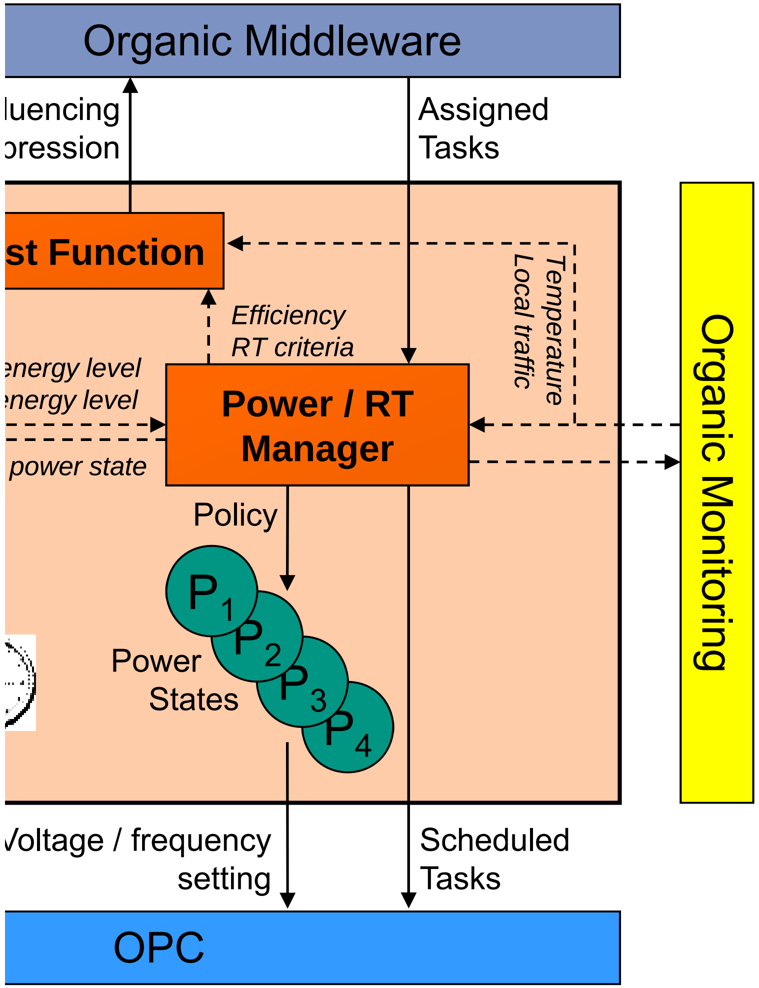
- Strong Suppressors, Eagervalues to zero
  → System will remain in a stable state
- Reconfiguration and Self-Optimization (fluctuation of the hormones)



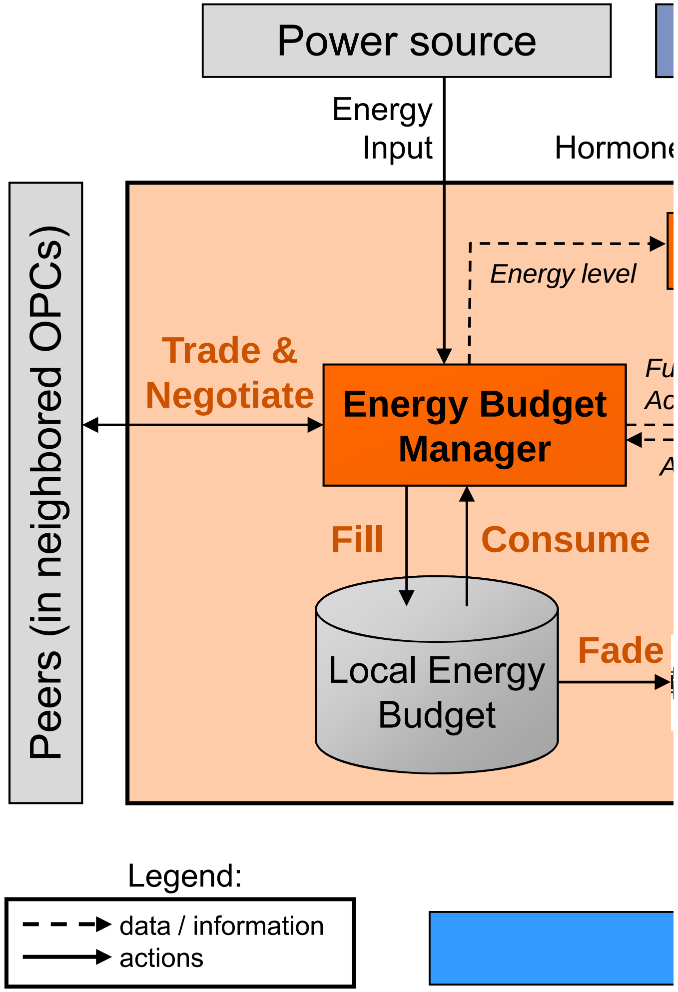


Organic Low Power Management: DodOrg Interfaces
(Prof. Henkel)

- **Organic Middleware**
  - Cost Function
    - Used for computaion of local eager values
- **Organic Monitoring**
  - External Cost Function parameters
    - Used to select apt power management policy
- **OPC**
  - Configure Power State

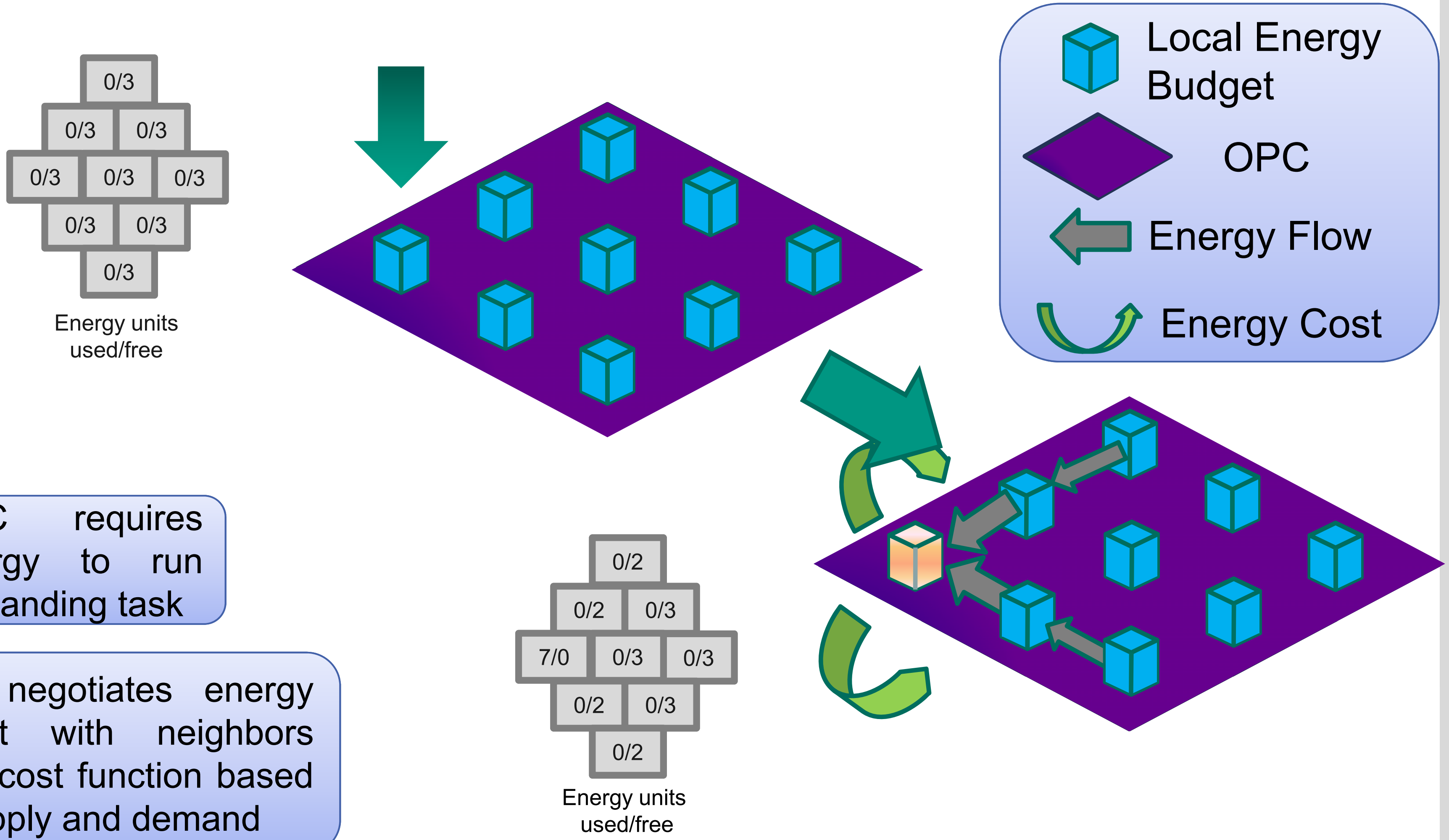


Organic Low Power Management: Managing Energy-Distribution
(Prof. Henkel)



- **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
    - Determines the local available energy
  - Global Power Source
    - Assigns energy budgets to OPCs (pulse-based)
  - Energy Budget Manager
    - Agent controlling Local Energy Budget
    - **Negotiates & Trades energy budget with neighboring OPCs**
    - Influences Power Manager policies

Organic Low Power Management: Agent Negotiation
(Prof. Henkel)



OPC requires energy to run demanding task

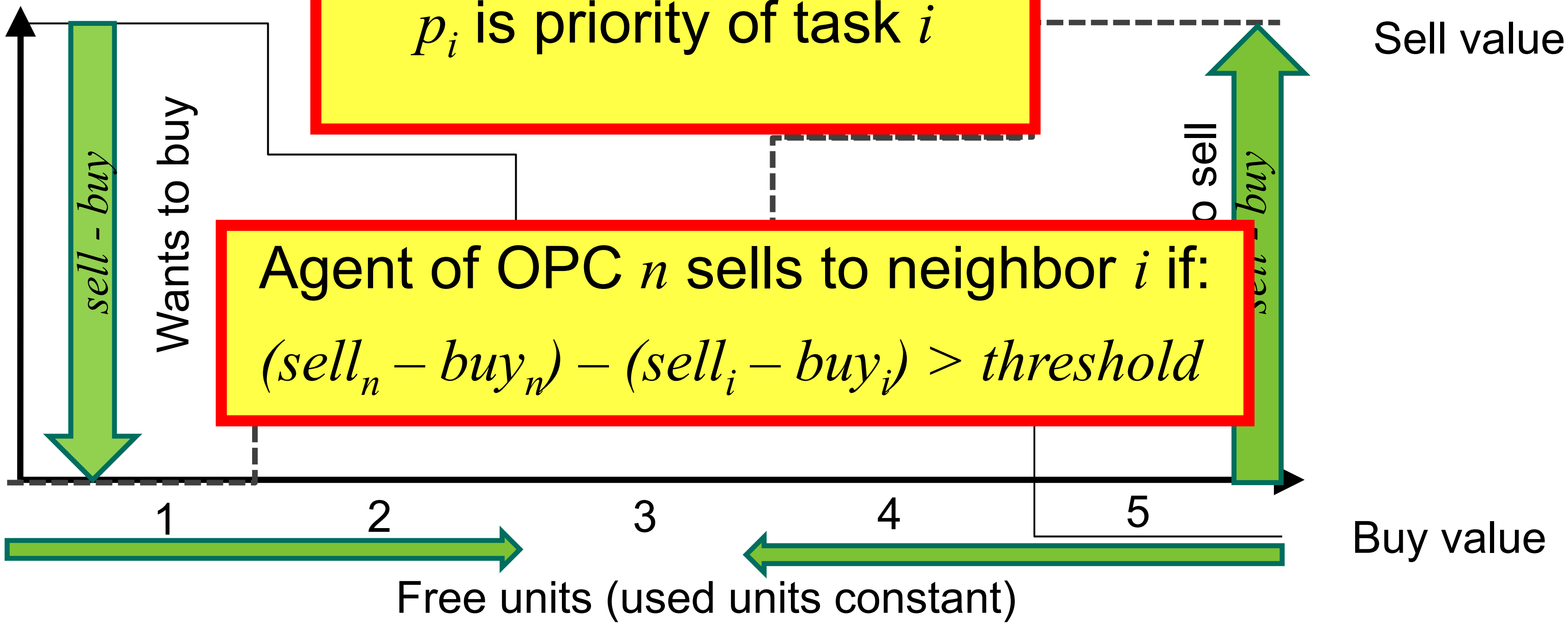
OPC negotiates energy budget with neighbors using cost function based on supply and demand

Organic Low Power Management: Power Trading – Getting *buy* and *sell* Values
(Prof. Henkel)

Weights and γ are dependant on OPC type, total amount of energy units and number OPCs

- ***Sell* value must also consider running tasks:**

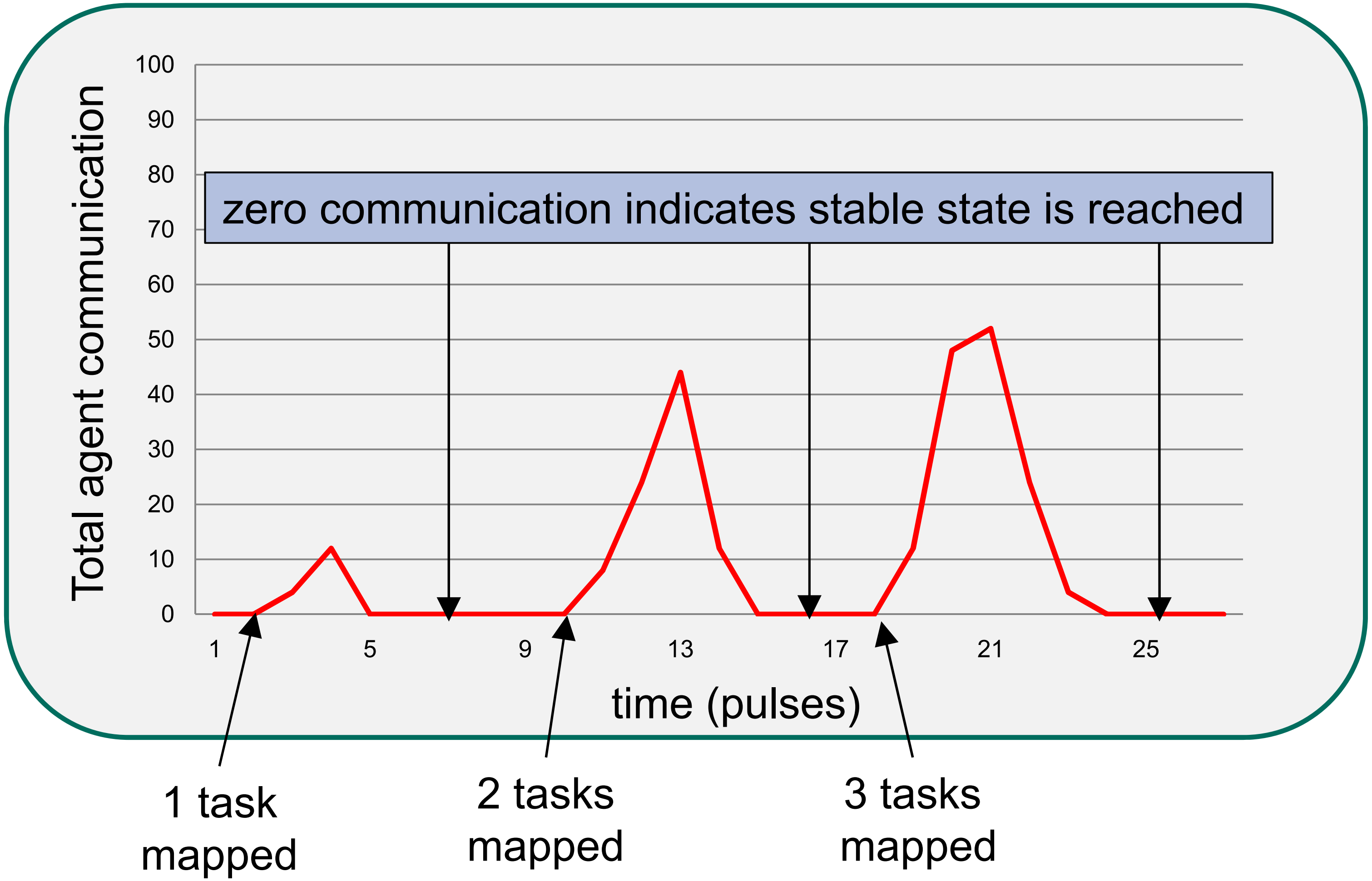
p_i is priority of task i



Agent of OPC n sells to neighbor i if:

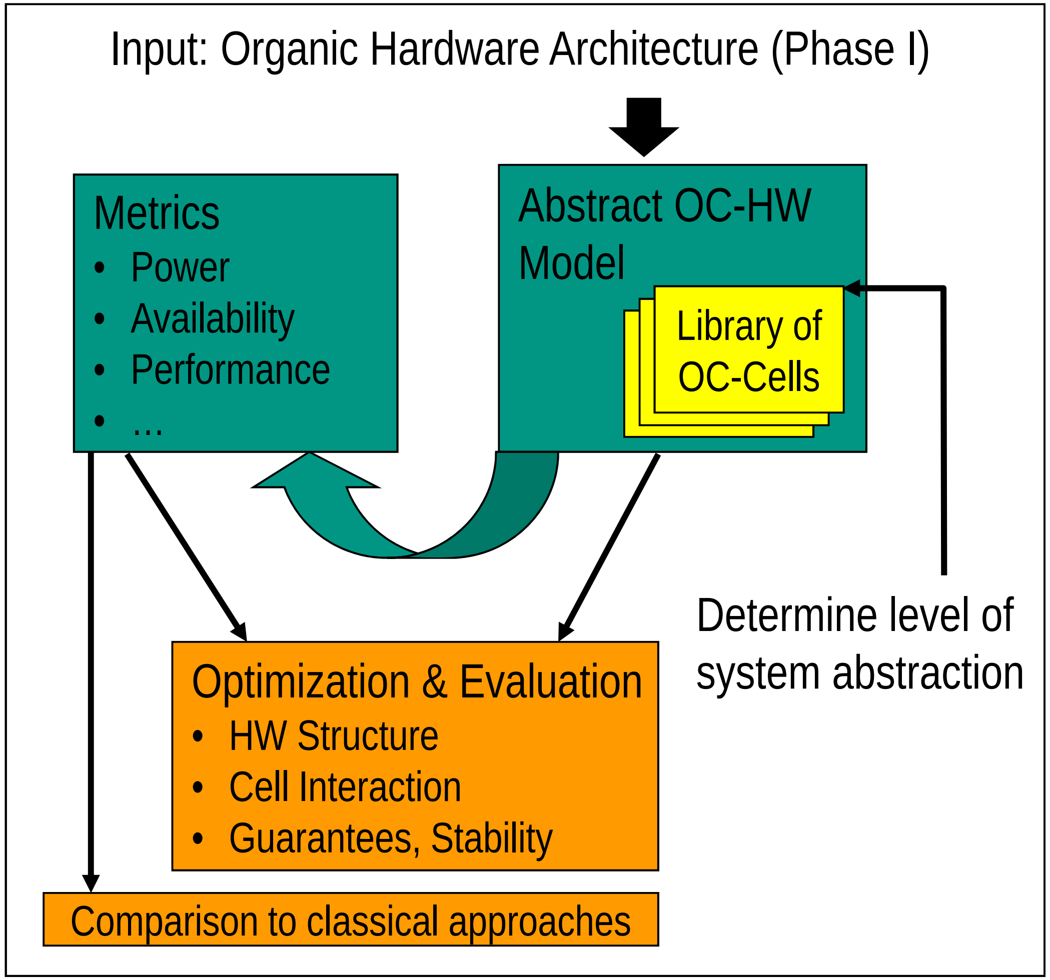
$$(sell_n - buy_n) - (sell_i - buy_i) > threshold$$

Organic Low Power Management: Power Trading – Agent Communication
(Prof. Henkel)



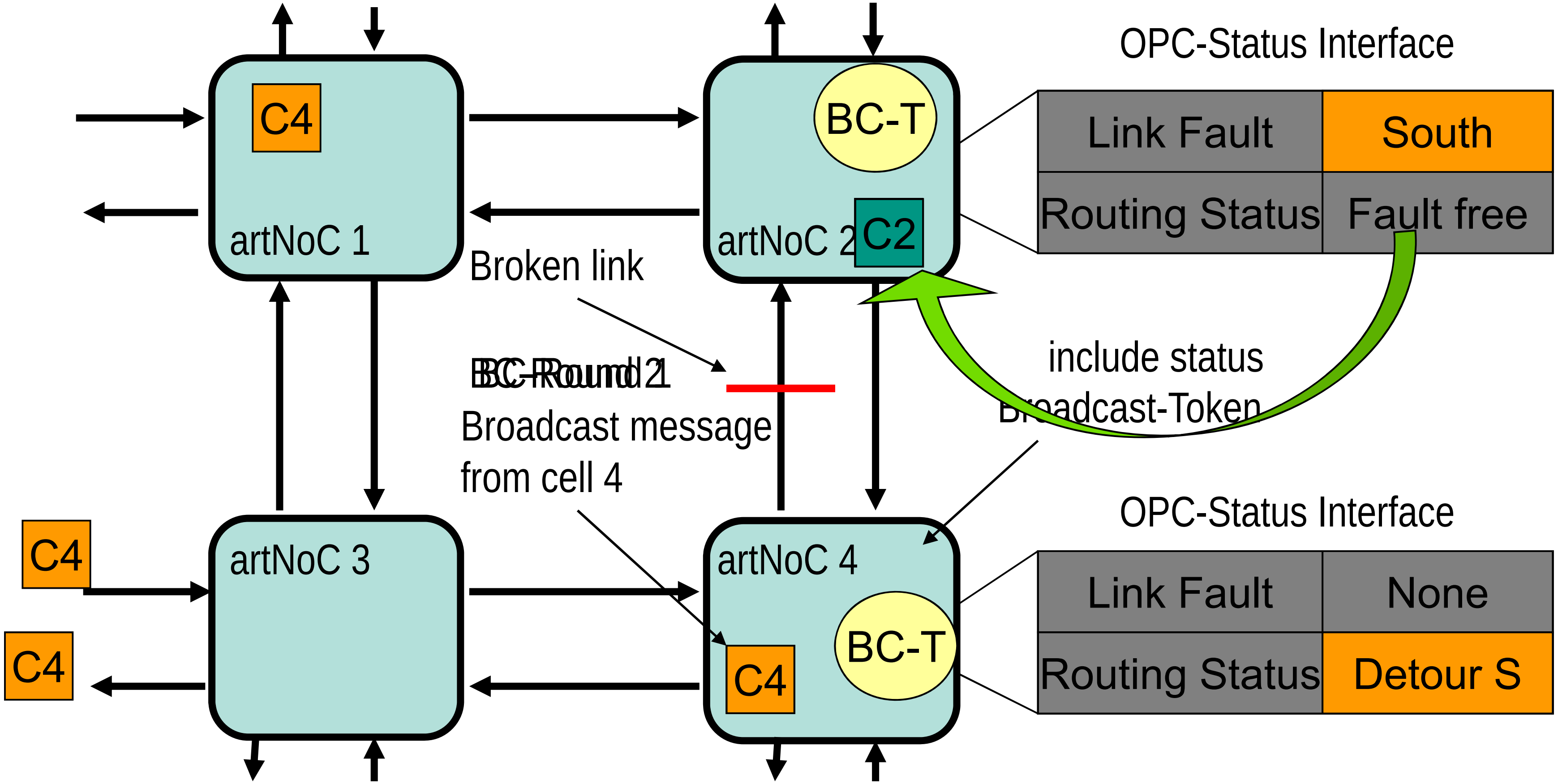
Organic Processing Cells Work plan: Close Control Loop Effects, Metrics, Cost Functions (Prof. Becker)

- Foundation laid by
  - DNA-configuration control
  - Adaptive routing
  - Automated test system
  - Hardware prototype
- Challenges
  - Dynamics of cell interaction
  - Interference with Middleware/ Low-Power Management
- Research Goals
  - Metrics
  - Optimization
  - Plasticity

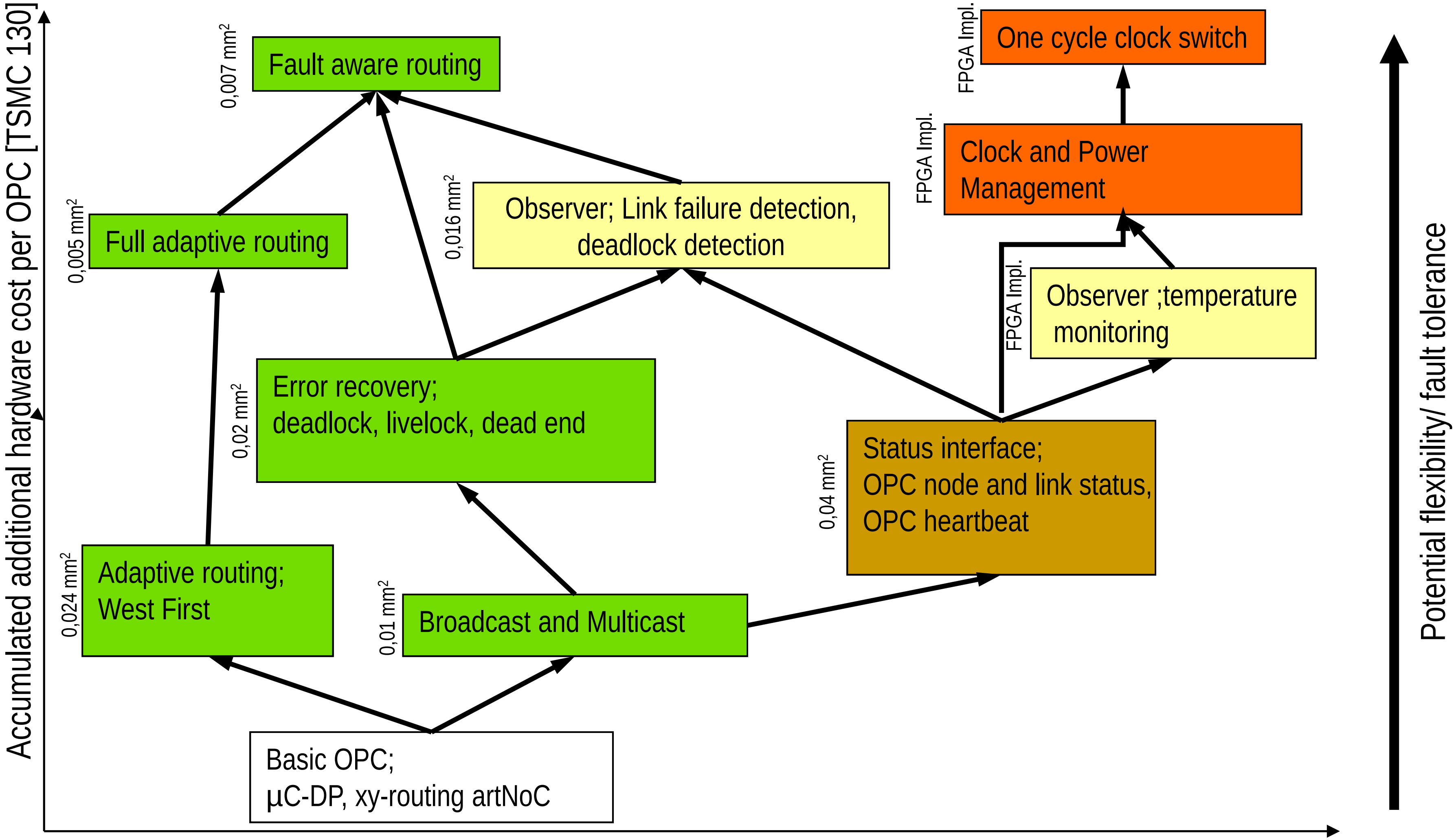


Organic Processing Cells: Close Control Loop Effects: Example Link Fault Detection (Prof. Becker)

- Analysis of neighbor broadcast
  - Broadcast uses flooding
  - Assumption on fault free link: receive neighbor BC over adjacent link



Organic Processing Cells: OPC-Hardware Cost – Synergetic Effects (Prof. Becker)



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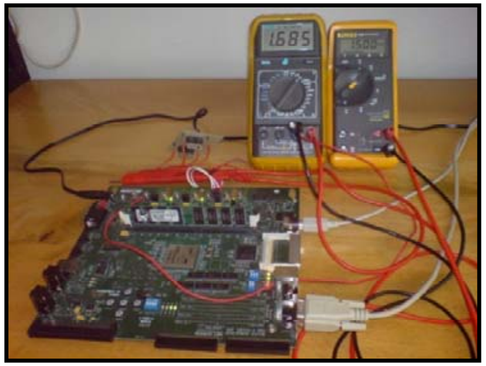
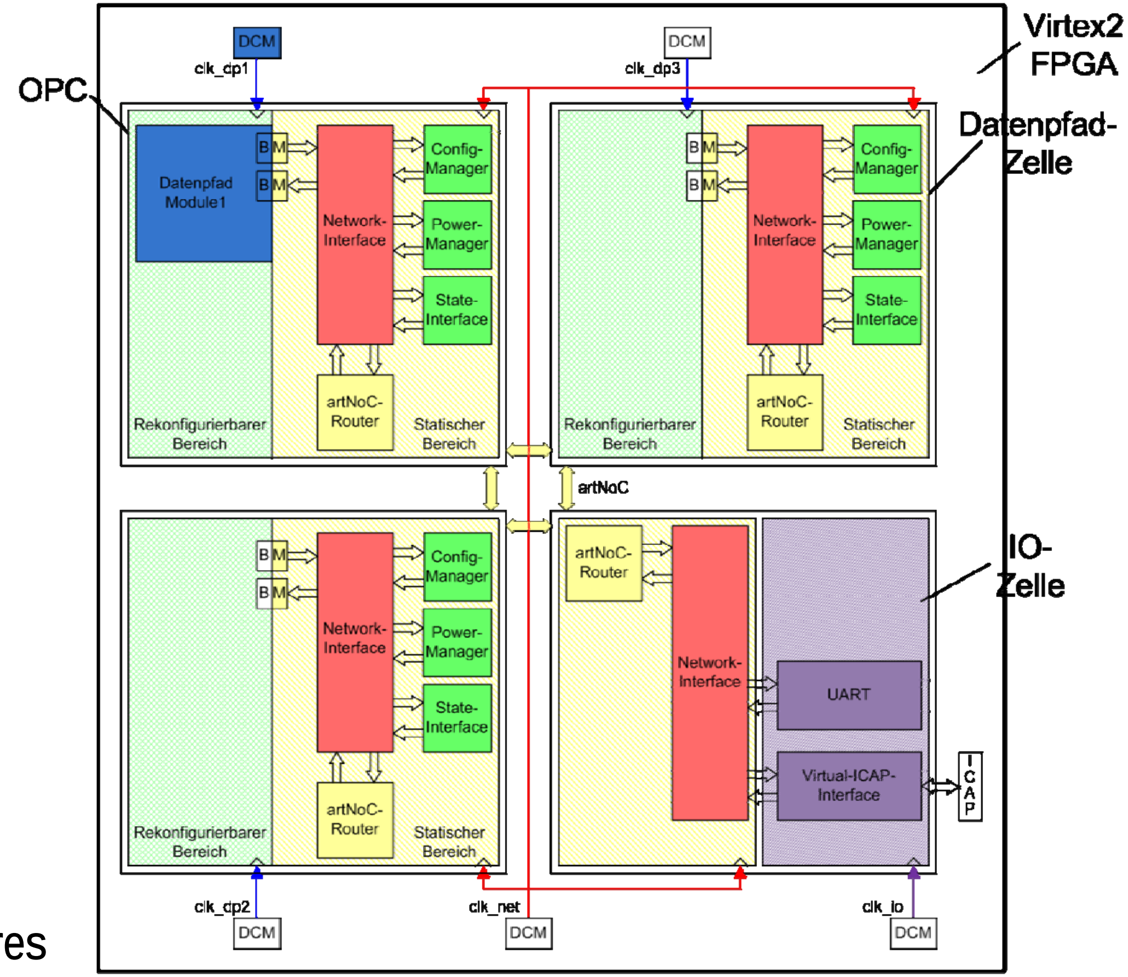
Organic Processing Cells :
Xilinx-Virtex-II Pro Hardware Prototype (Prof. Becker)



Power Measurement Setup



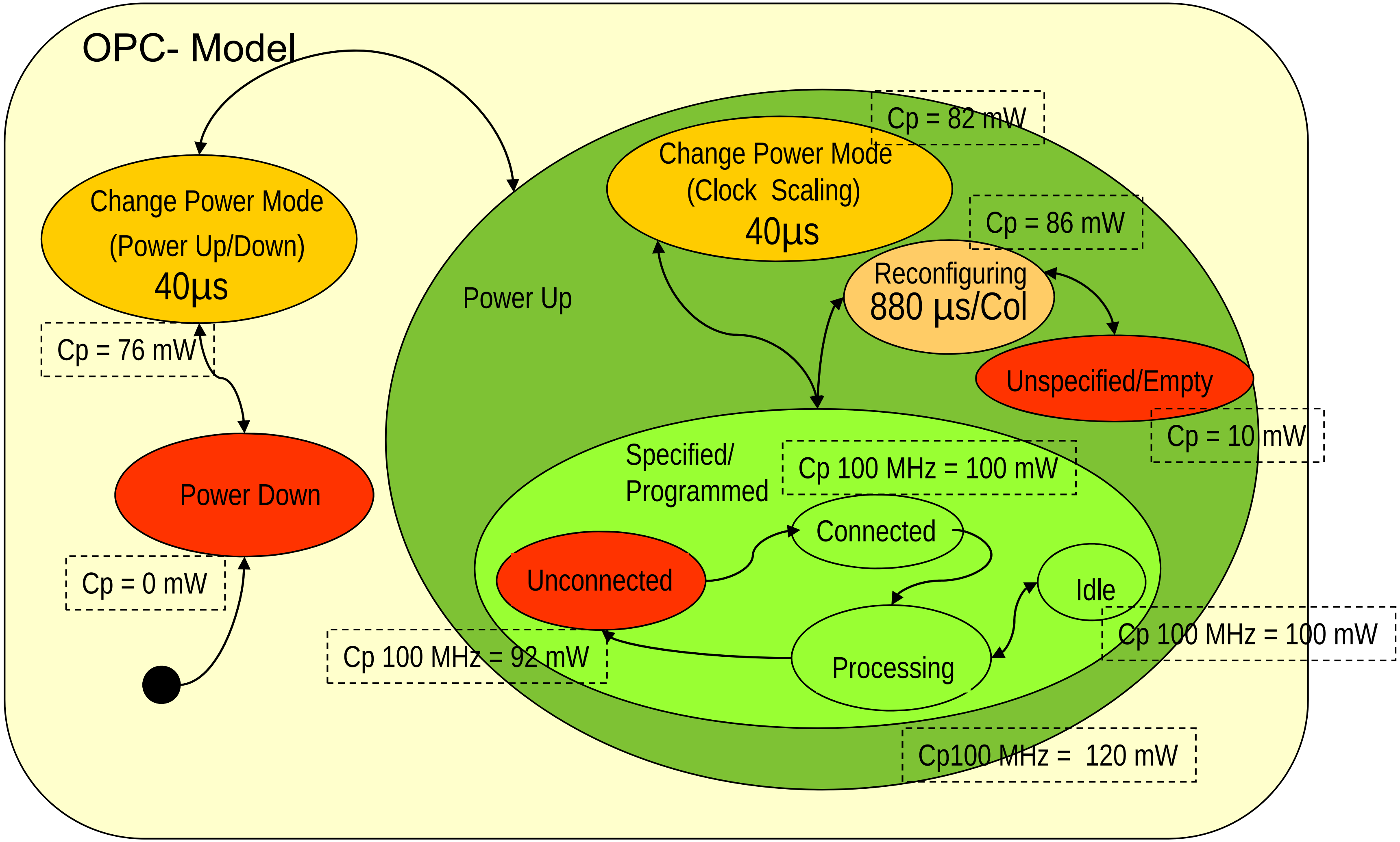
►2D-Partial and dynamic reconfiguration of FPGA-datapath

►OPC-based distributed clk-management

►Core OPC functionality

►Derive cost and performance figures for OPC HW-model

Organic Processing Cells :
OPC Power Model (Prof. Becker)

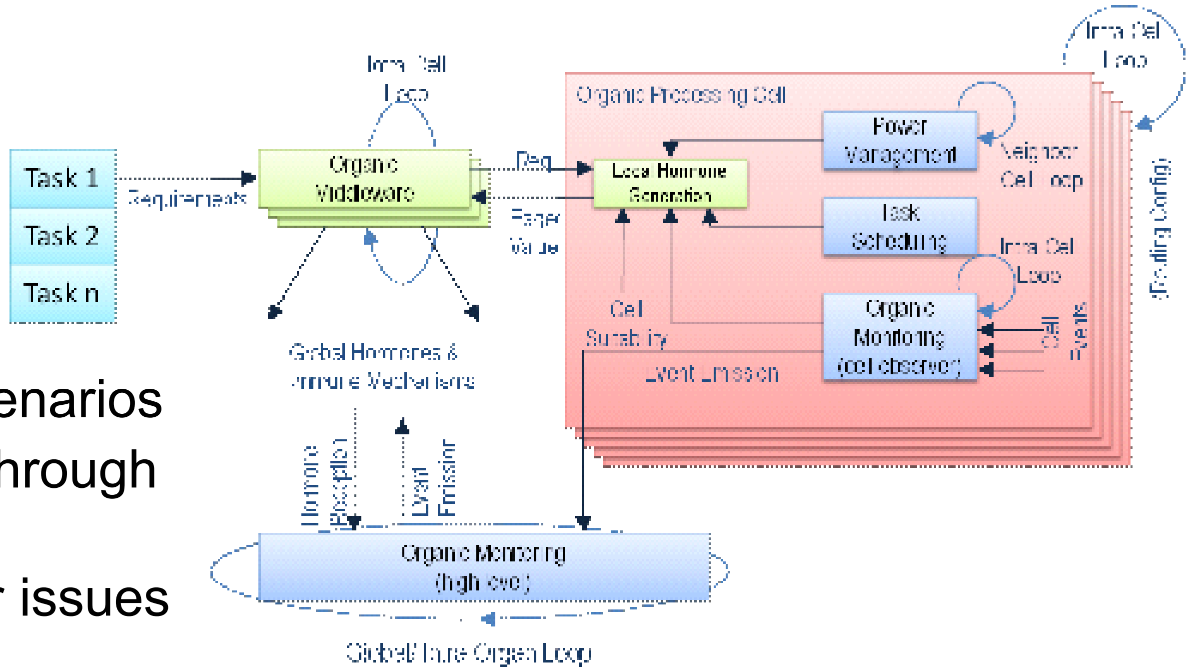


Conclusion and Plans for Phase III

▸ Outcome of Phase II

- 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 cell interaction metrics and cost-functions

Outlook: Stability Phase III



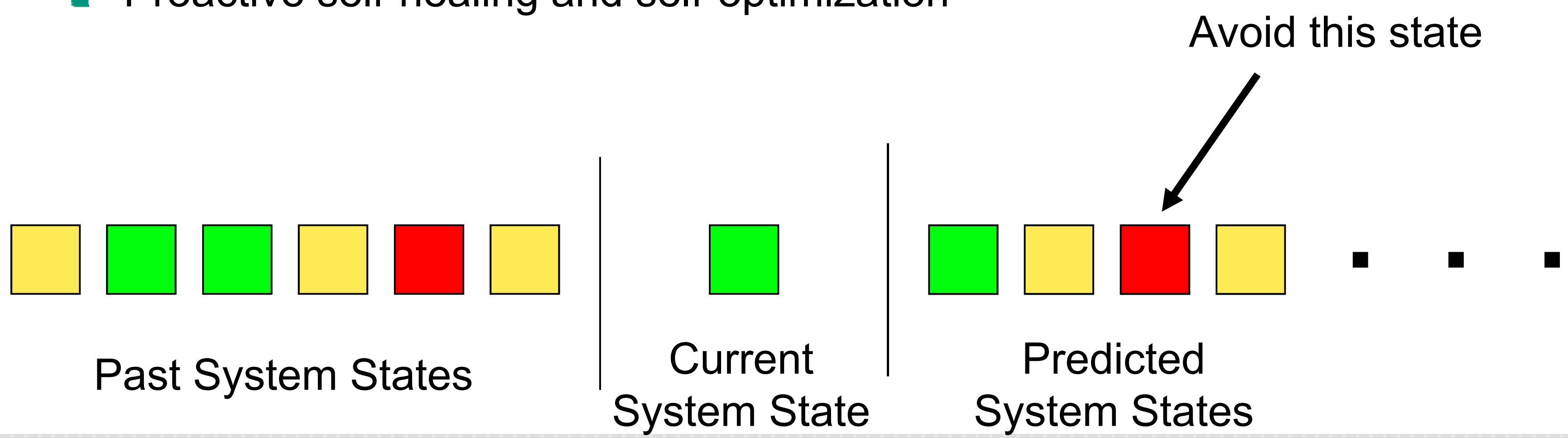
► Phase III

- Self-optimization scenarios
- Conflict avoidance through proactivity
- Cell-level low-power issues and interaction
- Off-chip communication
- Robustness during Development/Processing Phase
- Prototype implementation: application phase detection and fault-tolerance

Organic Monitoring: Outlook
(Prof. Karl)

▶ Trend Detection
- Prediction of future system states
- Identification of potentially harmful system states in advance

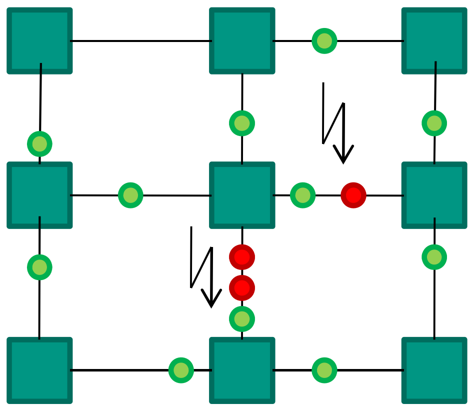
▶ Avoiding Potential Conflicts through Proactivity
- Based upon Trend Detection and Event Correlation
- Initiating required system chances to avoid bad or harmful system states (e.g. high temperature)
- Proactive self-healing and self-optimization



Organic Middleware: Outlook of the Third Phase
(Prof. Brinkschulte)

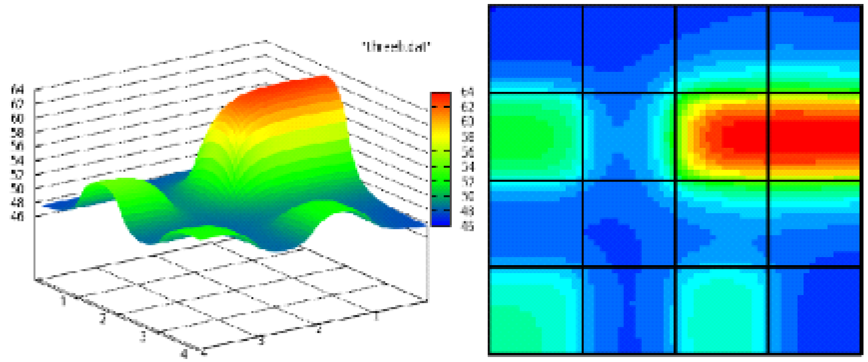
► Robustness and Stability

- Examination of dynamic aspects of task (re-)allocation and operation during normal conditions (also in the presence of internal or external disturbances)
- System changes due to Self-Adaptation and Self-Optimization must lead to new stable conditions
- Robustness against mal-behaving internal/external components (comparable to illness in a biological system)
    - Being able to react to „ill“ OPCs
    - Counter-measures against malicious attacks
- Immune mechanisms for advanced Self-Healing and Self-Protecting Aspects to increase Robustness (together with the Organic Processing Cell Capabilities and the Organic Monitoring)
- Examination and Evaluation of different Self-optimization Scenarios
- Quality Analysis of the Artificial Hormone System



Organic Low Power Management: Outlook
(Prof. Henkel)

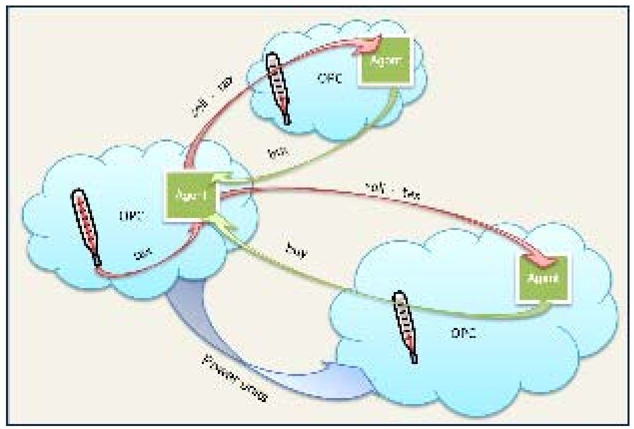
- Thermal issues are a major concern for the robustness of the **Dod**Org System and are directly influenced by the power distribution



Thermal test simulation

⇓

- Thermal models need to be developed and incorporated in the power negotiation process
- Improvement of negotiation process using economic learning



Thermal-aware power negotiation

Organic Processing Cells: Outlook Phase III Stability and Robustness (Prof. Becker)

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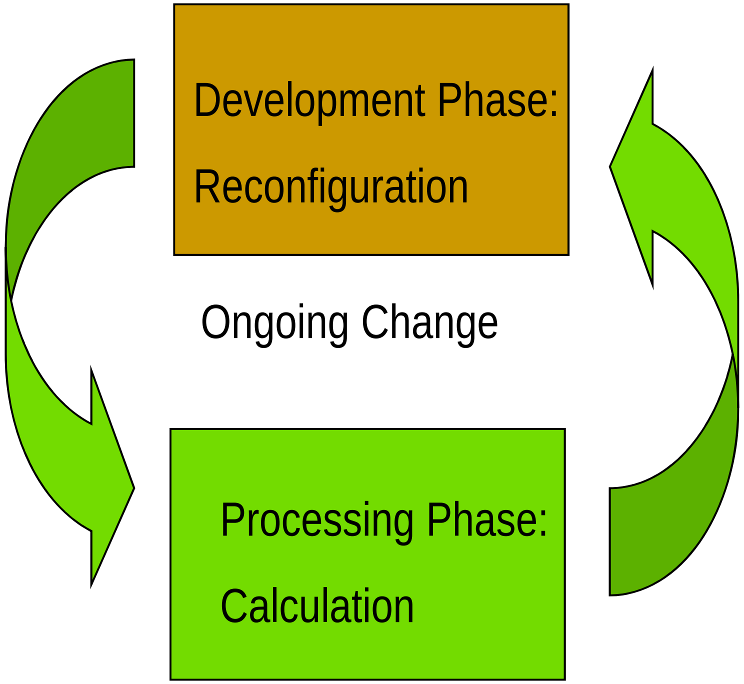
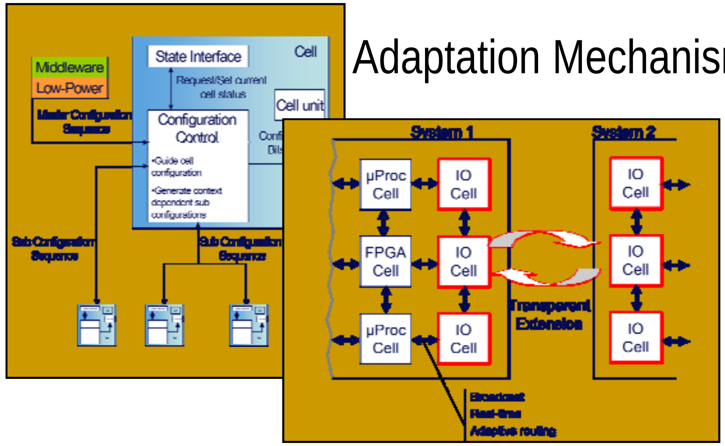
OPC-Lifecycle



Adaptation Mechanisms



Resulting Configurations

Global View: Phases are concurrent within DodOrg Cell-Array

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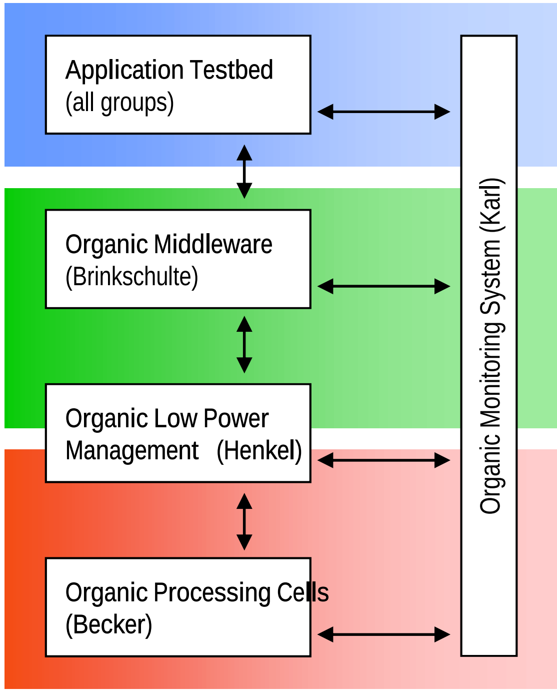
Organic Processing Cells:
Outlook Phase III Goals (Prof. Becker)

- Chip To Chip Communication
  - Seamless and transparent expansion of the on chip communication services
  - Dynamic OPC resource pool →physical growth of the whole DodOrg organism
  - New challenges for all subprojects
- Robustness on hardware-level during development phase
  - Scope
    - Loading new Configuration
    - Establish-Inter-Cell-Datapath
    - Power Up/Down Cells
  - Goal : Reach Fail Safe State after development phase
- Robustness on hardware-level during processing phase
  - Scope
    - OPC-Datapath (packet sender)
    - OPC to OPC communication Path (artNoC-Network)
  - Goal: Cell immune System with Cell-Input/Output-Guidance Mechanism

Thank you for your attention!

- Questions?



List of Publications:

- D. Kramer, R. Buchty, and W. Karl, "***A Scalable and Decentral Approach to Sustained System Monitoring***", ACACES,2009
- R. Buchty and W. Karl, "***Design Aspects for Self-Organizing Heterogeneous Multi-Core Architectures***", IT - Information Technology Journal 5/08, 2008
- R. Buchty, D. Kramer, and W. Karl, "***An Organic Computing Approach to Sustained Real-time Monitoring***", BICC08, 2008
- R. Buchty, O. Mattes, and W. Karl, "***Self-aware Memory: Managing Distributed Memory in an Autonomous Multi-master Environment,***" ARCS, 2008
- R. Buchty and W. Karl, *A Monitoring)* "***Infrastructure for the Digital on-demand Computing Organism (DodOrg)***", IWSOS, 2006
- Hans-Peter Löb, Rainer Buchty, Wolfgang Karl, "***A Network Agent for Diagnosis and Analysis of Real-time Ethernet Networks***", CASES, 2006
- U. Brinkschulte and A. von Renteln, "***Analyzing the Behavior of an Artificial Hormone System for Task Allocation***", ICATC, 2009
- U. Brinkschulte , A. von Renteln, and M. Weiss, "***Examining Task Distribution by an artificial hormone system based middleware***", ISORC, 2008
- U. Brinkschulte, M. Pacher and A. von Renteln, "***An Artificial Hormone System for Self-Organizing Real-Time Task Allocation***", in Organic Computing, 2007
- U. Brinkschulte, A. von Renteln, and M. Pacher, "***Reliability of an Artificial Hormone System with Self-X Properties***", PDCS, 2007
- T. Ebi, M. A. Al Faruque, and J. Henkel, "***TAPE: Thermal-aware Agent-based Power Economy for Multi/Many-Core Architectures***", ICCAD 2009 (accepted)
- M. Shafique, L. Bauer, and J. Henkel, "***REMiS: Run-time Energy Minimization Scheme in a Reconfigurable Processor with Dynamic Power-Gated Instruction Set***" , ICCAD 2009 (accepted)
- M. A. Al Faruque, R. Krist, J. Henkel: "***ADAM: Run-time Agent-based Distributed Application Mapping for on-chip Communication***", DAC 2008
- C. Schuck, B. Haetzer, and J. Becker, "***An Interface for a Decentralized 2d-Reconfiguration on Xilinx Virtex-FPGAs for Organic Computing***", ReCoSoC, 2008
- C. Schuck, M. Kuehnle, M. Huebner, and J. Becker, "***A framework for dynamic 2D placement on FPGAs***" , IPDPS, 2008
- C. Schuck, S. Lamparth, J. and Becker, "***artNoC - A Novel Multi-Functional Router Architecture for Organic Computing***", FPL, 2007