Digital On-Demand Computing Organism for Real-time Systems
DodOrg

SPP OC Kolloquium
DFG SPP 1183 “Organic Computing”
Nürnberg, September 15/16, 2011

Talk Overview

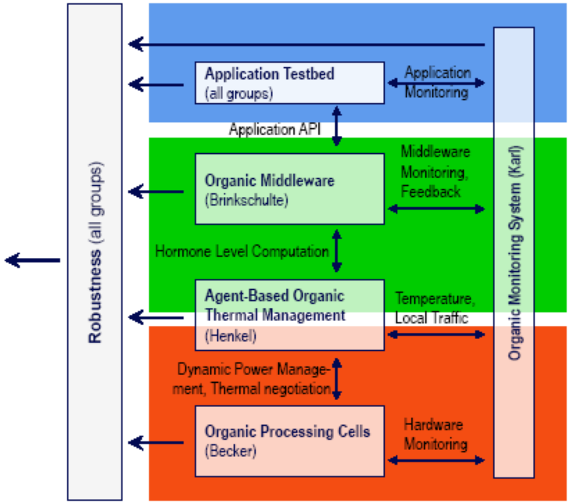
- Motivation and Overview
- Current Work Phase III:
  - Organic Hardware
  - Organic Monitoring
  - Organic Low Power Management
  - Organic Middleware
- DodOrg Demonstrator Platform
  - Interaction and Overview
  - Scenarios and Results
- Conclusion

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 …)

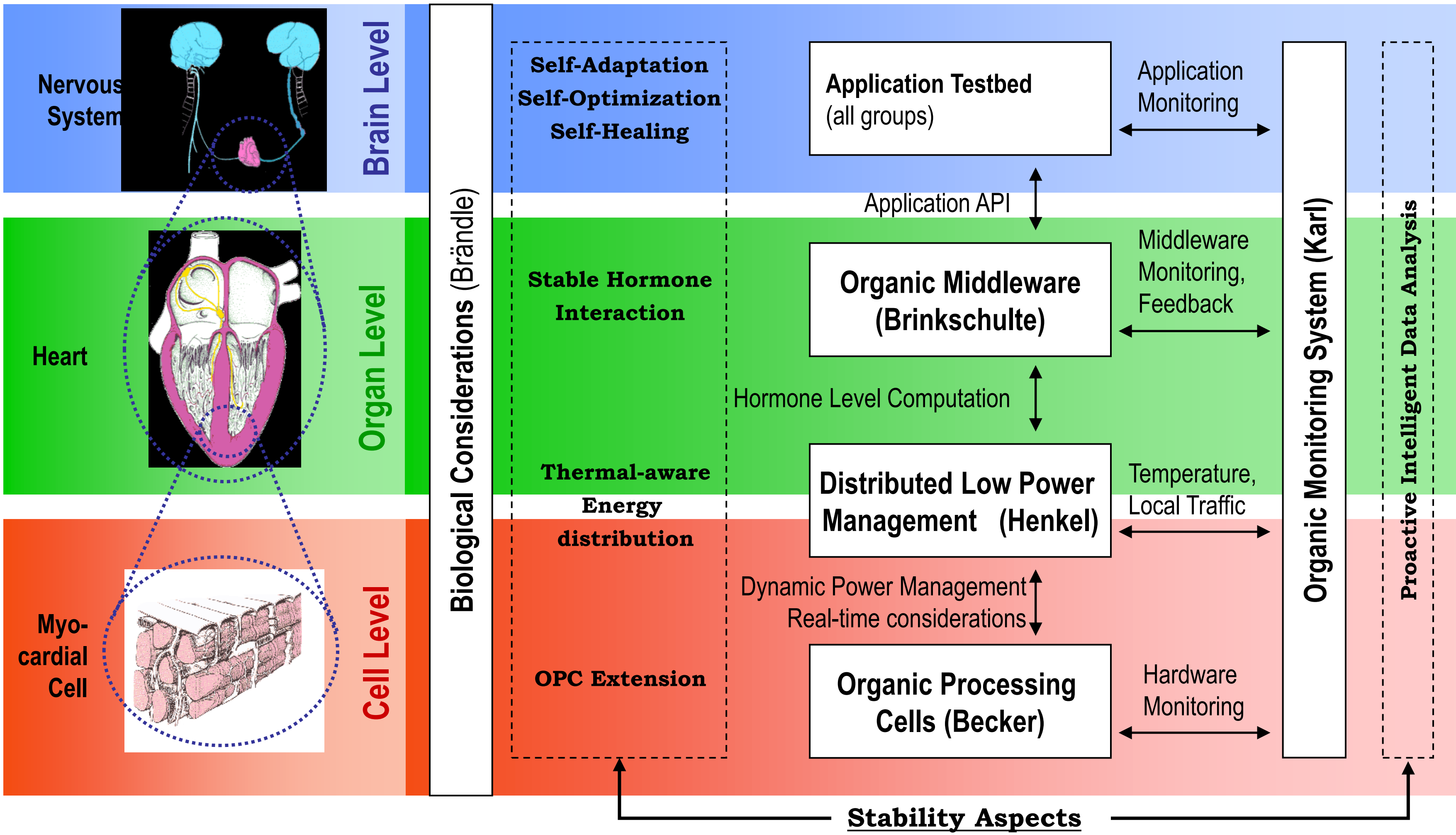
Demonstrator platform



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)

DodOrg: Refined Layer Model



Phase III: Project Objectives

Stability
The ability of the system to provide the required service while reacting upon external and internal events.

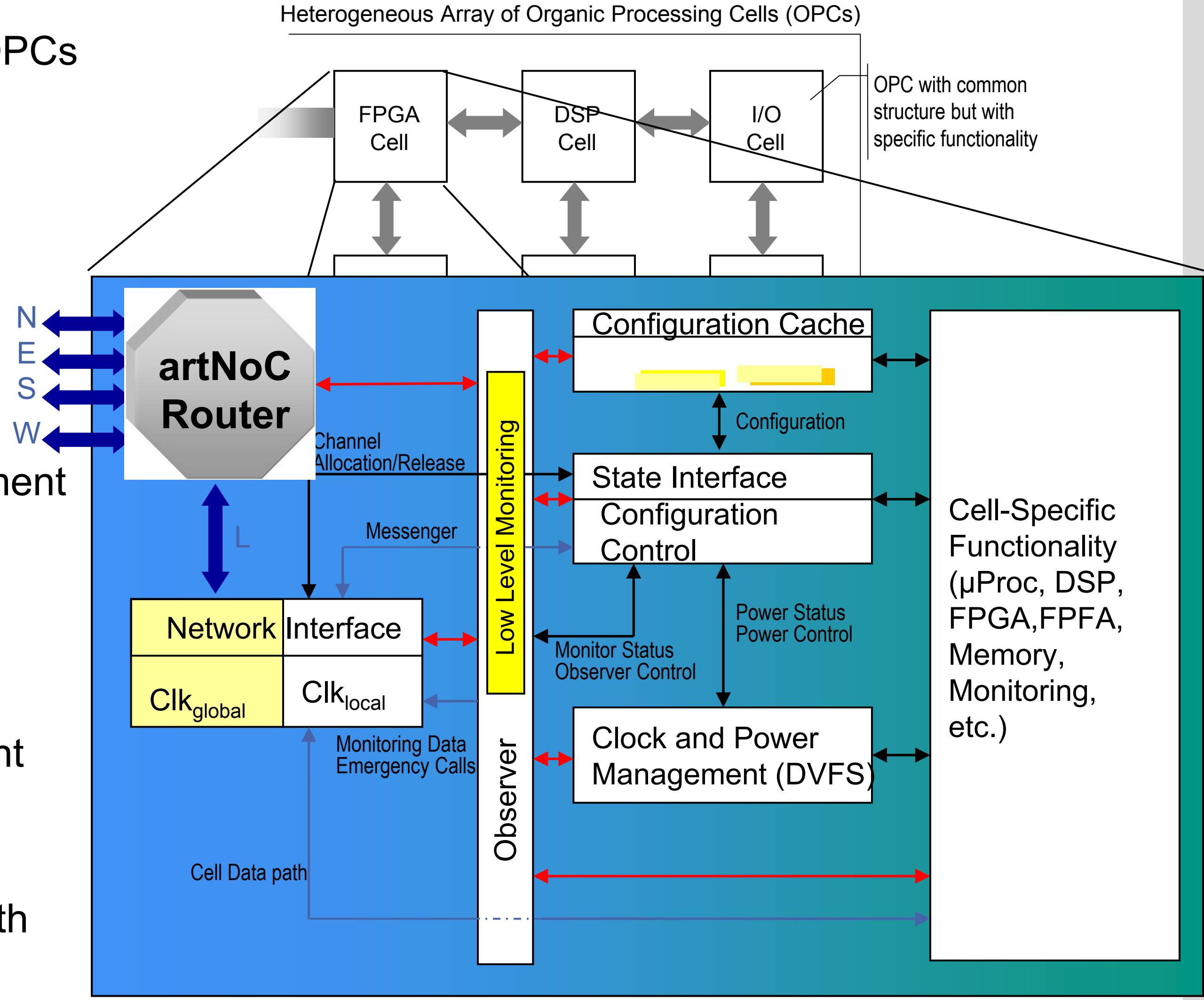
Robustness
Extending the stable system property towards more serious system changes .

- \+ Oscillation avoidance
- \+ Normal operating conditions
- \- Faulty components

- \+ Fault resistance
- \+ Increased tolerance
- \- Increased overhead

Organic Hardware Approach (Prof. Becker)

- Modularity
  - Same blueprint for all OPCs
  - Common infrastructure
  - Cells easily replaceable
- Local intelligence
  - artNoC Router
  - Power-Management
  - Monitoring
  - Configuration-Management
- Interfaces
  - Monitoring
  - Middleware
  - Low Power Management
- Flexibility
  - Reconfigurable data path



Organic Processing Cells: Robustness (Prof. Becker)

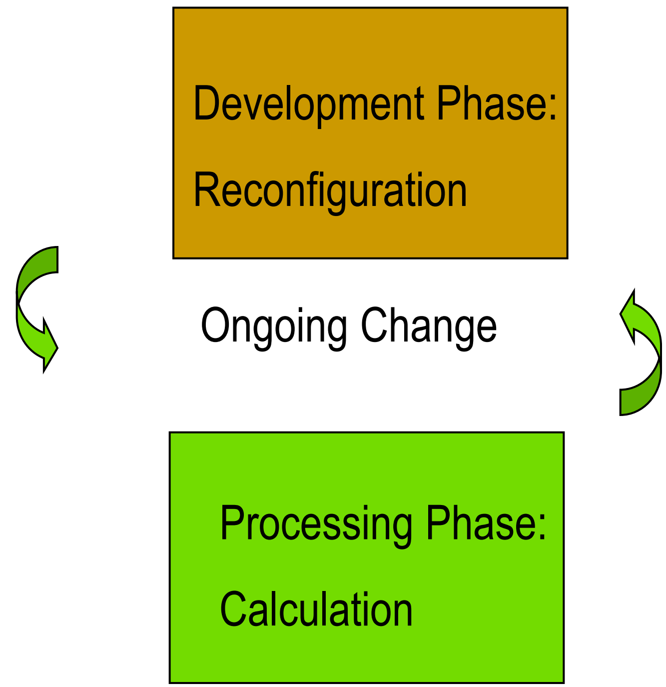
Robustness during development phase

- Scope
  - Loading new configuration
  - Establish-inter-cell-data path
  - Power up/down cells
- Method:
  - On-demand hardware monitoring
  - Blank configuration pattern

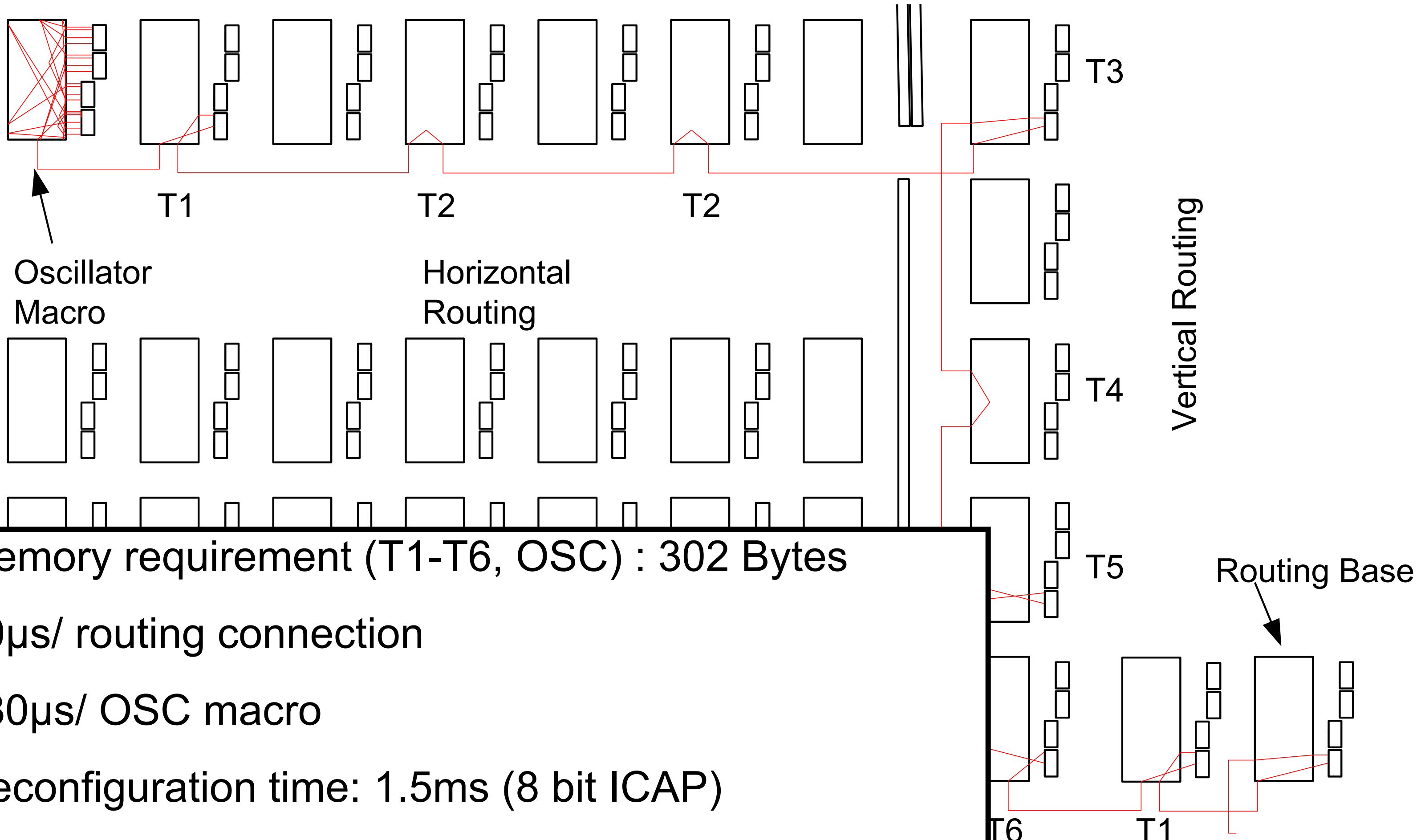
Robustness during processing phase

- Scope
  - OPC-data path (packet sender)
  - OPC to OPC communication path (artNoC-Network)
- Goal: hardware support for cell immune system
- Method:
  - artNoC header packet protection
  - Channel auto release

OPC-Lifecycle



On-Demand Hardware Monitoring
(Prof. Becker)

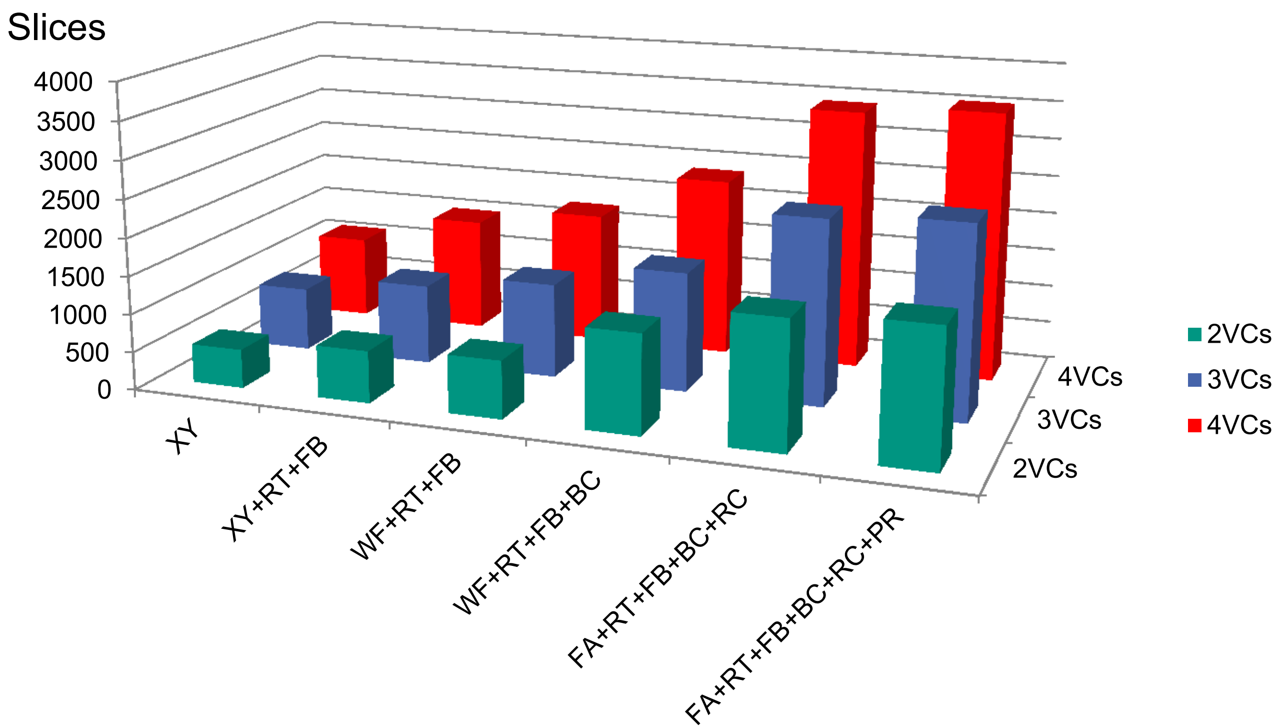


- Memory requirement (T1-T6, OSC) : 302 Bytes
- 80µs/ routing connection
- 880µs/ OSC macro
- Reconfiguration time: 1.5ms (8 bit ICAP)
- Suitable to monitor large areas

Organic Processing Cells: Robustness (Prof. Becker)

- Challenge: Fault introduced communication deadlock
- OPC-2-OPC communication: Wormhole Flow Control
  - Flexible
  - Low buffer requirements
  - Packet spread across several routers
  - Failure/attack affects several routers
- Protect control flits:
  - Corrupted header-flit → misrouting of packets
    - Checksum
  - Missing tail/header-flit → blocked virtual channels
    - If downstream cell – release channel via feedback line
    - If upstream cell – inject tail flit to release channel with error code

Synthesis Result: ArtNoC Router on Xilinx FPGA (Prof. Becker)



RT: Real-Time
FB: Feedback Channel
WF: West-First Routing
BC: Broadcast
FA: Full adaptive Routing
RC: Packet Recovery
PR: Control-Flit Protection

- ca. 110 additional Slices for Control-Flit Protection
- Avoidance of blocked Virtual Channels (VCs)
- Avoidance of misrouting packets

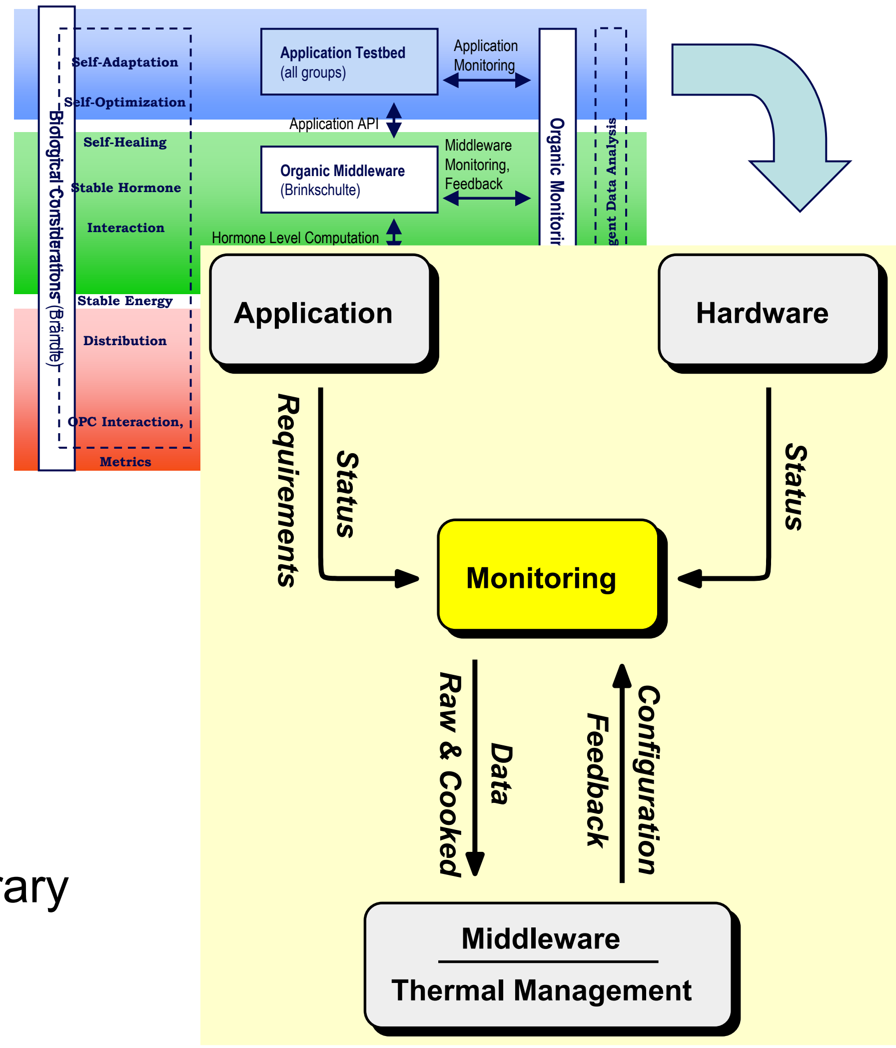
Organic Monitoring (Prof. Karl)

Objectives

- Coordinated, cooperative and system-wide monitoring
- Fundamental for self-organizing systems
- Providing monitored data to Organic Middleware and Thermal Management for further analysis
- Providing self-awareness

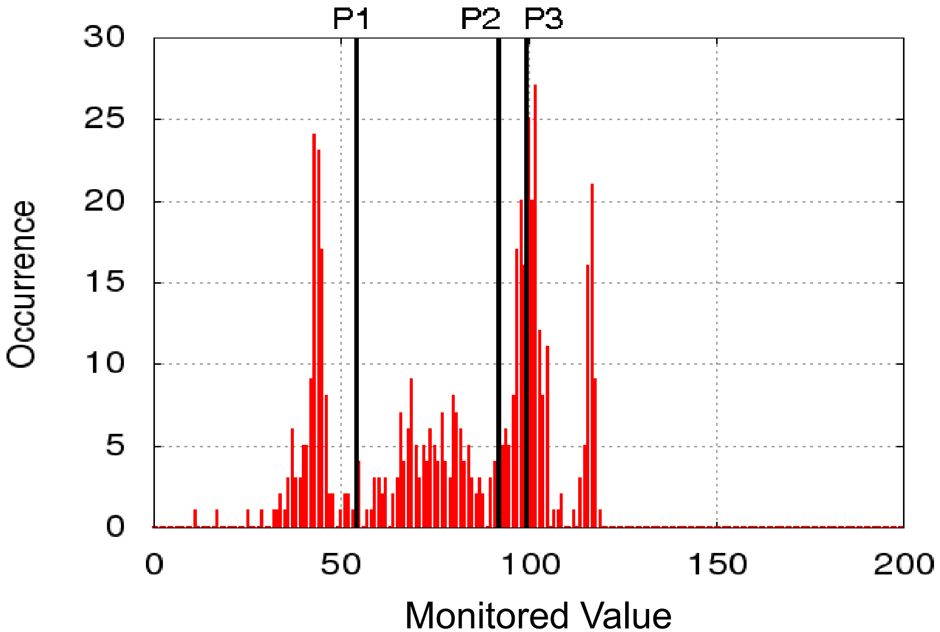
Self-Awareness

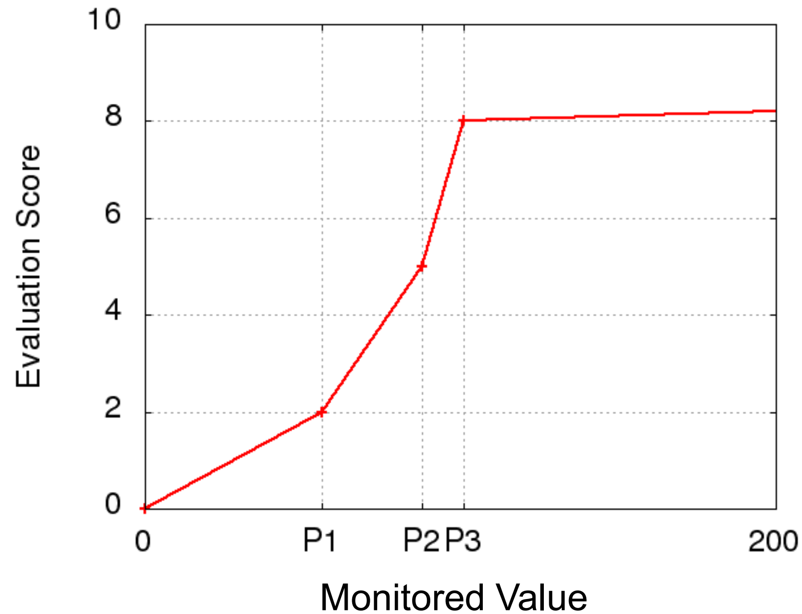
- Prerequisite for all self-X features
- Ability of system state determination
- Ability of system state classification
- Permitting the comparison of two arbitrary system states



Organic Monitoring: State Evaluation (Prof. Karl)

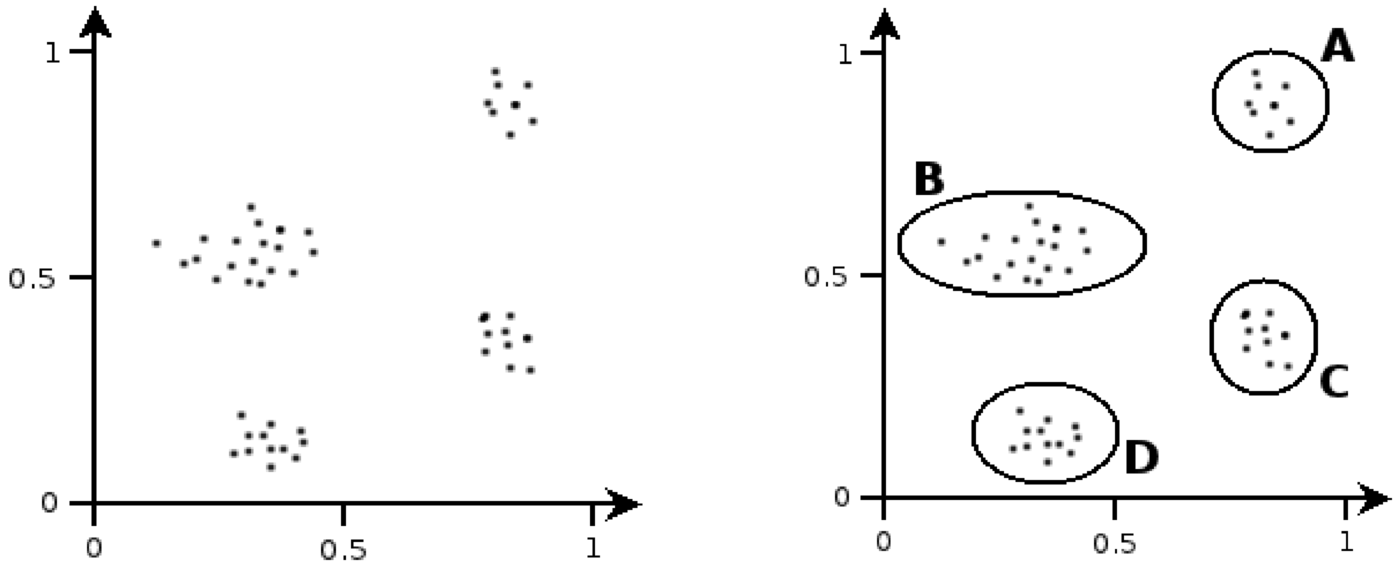
- Using a rule-based approach
  - Learning evaluation rules in a dedicated training phase
  - Defining a normal system state
  - Comparison of further system states with the normal state
- Properties
  - Rules convert an occurrence ratio of an event into a fitness value
  - One rule per event / hormone
  - Weighted arithmetic mean for determ-ining the fitness value for the system
  - Different states then can be compared by comparing the fitness values





Organic Monitoring: State Classification
(Prof. Karl)

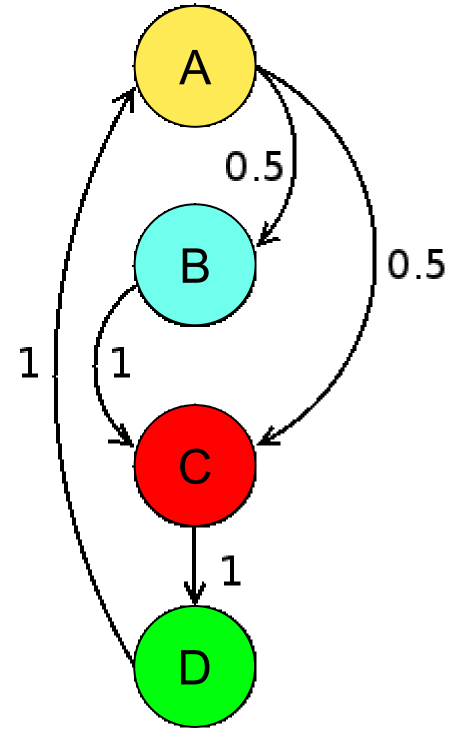
- Using k-means clustering for definition of individual system state at runtime
- Treating all available event occurrences as a point in a n-dim space
- Clustering of close points within this space
- Using euclidean distance for online state detection



Organic Monitoring: Phase Detection and Prediction (Prof. Karl)

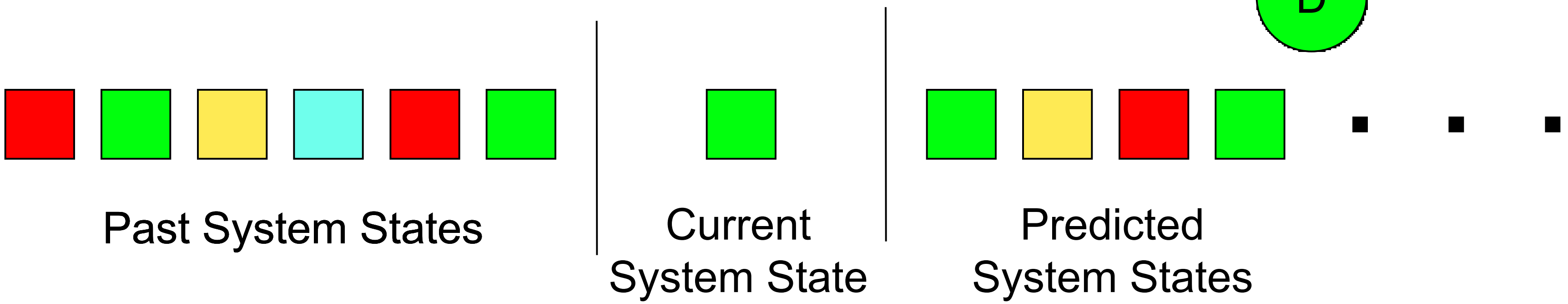
Goals:

- Prediction of future system states
- Identification and avoiding of potentially harmful system states

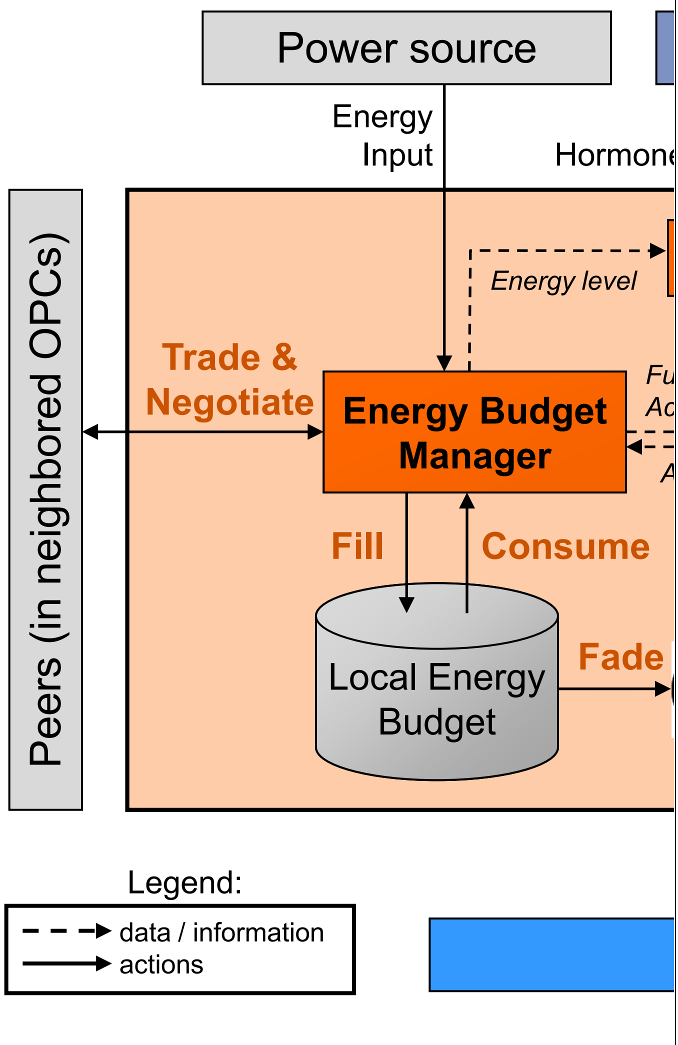


State Prediction:

- Using a runlength-encoded Markov chain as predictive model
- Trained in a dedicated learning phase using the previously classified system states



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

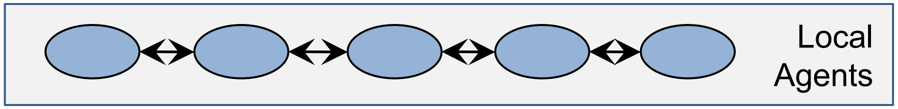


- Energy distribution: goals
  - Low energy consumption
  - Avoidance of local thermal hot-spots
- Energy distribution: main concept
  - Each OPC has a local energy budget
    - Determines the local available energy
  - Global power source
    - Assigns energy budgets to OPCs (pulse-based)
  - Energy budget manager
    - Agent controlling local energy budget
    - Receives temperature data each pulse
    - **Negotiates & trades energy budget with neighboring OPCs**
    - Influences power manager policies

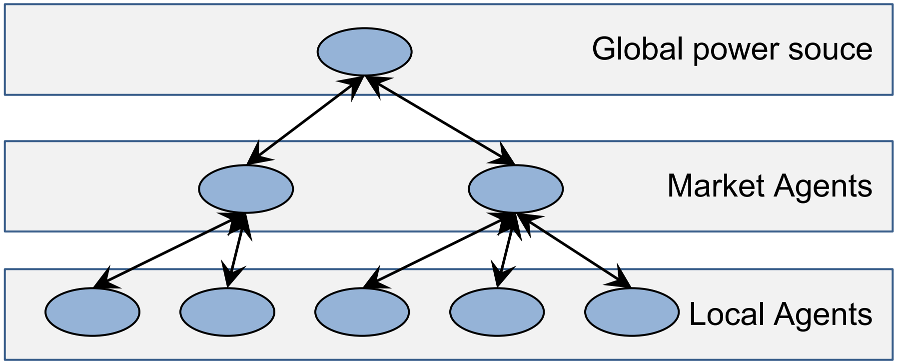
Organic Low Power Management: Agent Negotiation (Prof. Henkel)

Two types of agent negotiation based on simple economic principles

- Fully distributed [ICCAD 09]
  - Trading based on supply & demand
  - Temperature incorporated as a negotiation penalty
  - Agents only trade with their direct neighbors

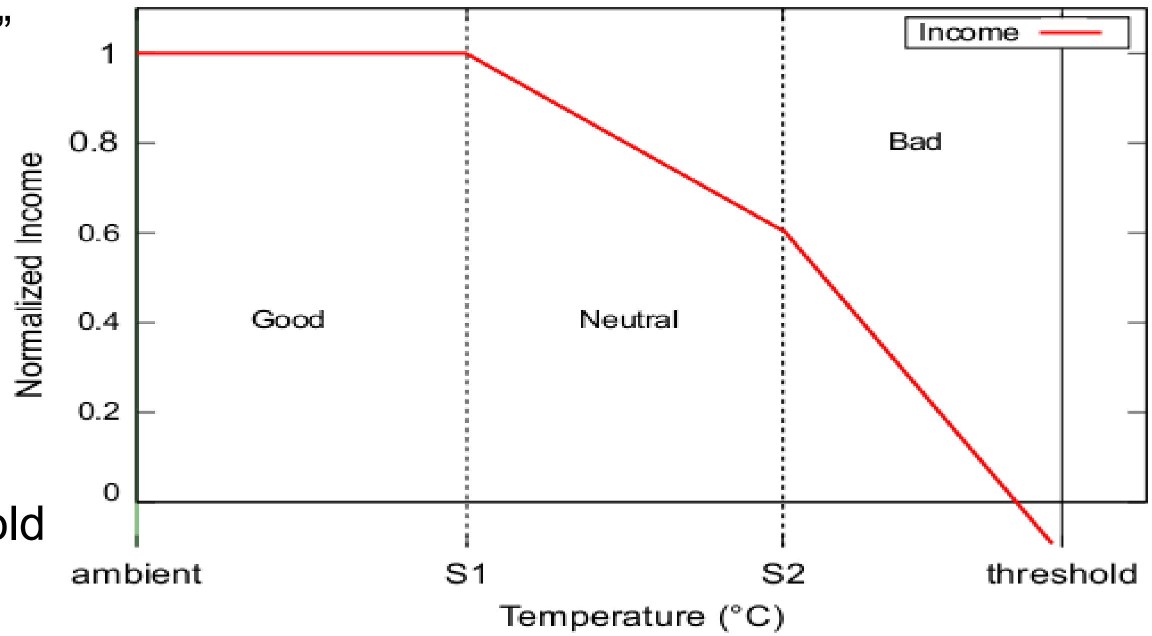


- Hierarchical [CODES 11]
  - Local agents make bids to higher level market agents
  - Market agents make requests to global power source
  - Local agent has income based on current temperature



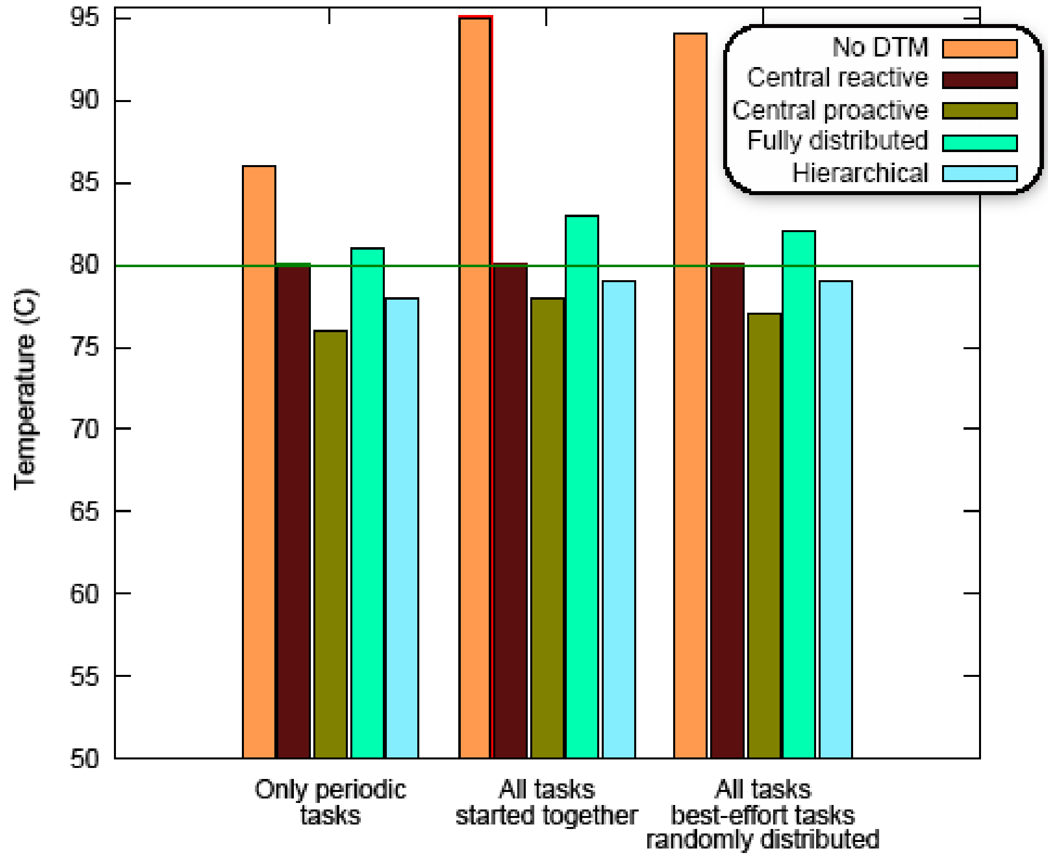
Organic Low Power Management:Thermal Management (Prof. Henkel)

- Thermal state of core classified as good, neutral, or bad
  - Special case of monitoring state evaluation
  - State determines current core power budget, i.e. local agent income dependent on state
- Budget trading resulting in state transitions to a "better" state are reinforced → Shift of S1 & S2 to higher temperatures
- Trading resulting in "worse" state are penalized → Shift of S1 & S2 to lower temperatures
- In good state, no suppressors are released to the AHS allowing other optimizations (e.g. communication/performance)
- When approaching threshold in bad state, thermal suppressors become dominant



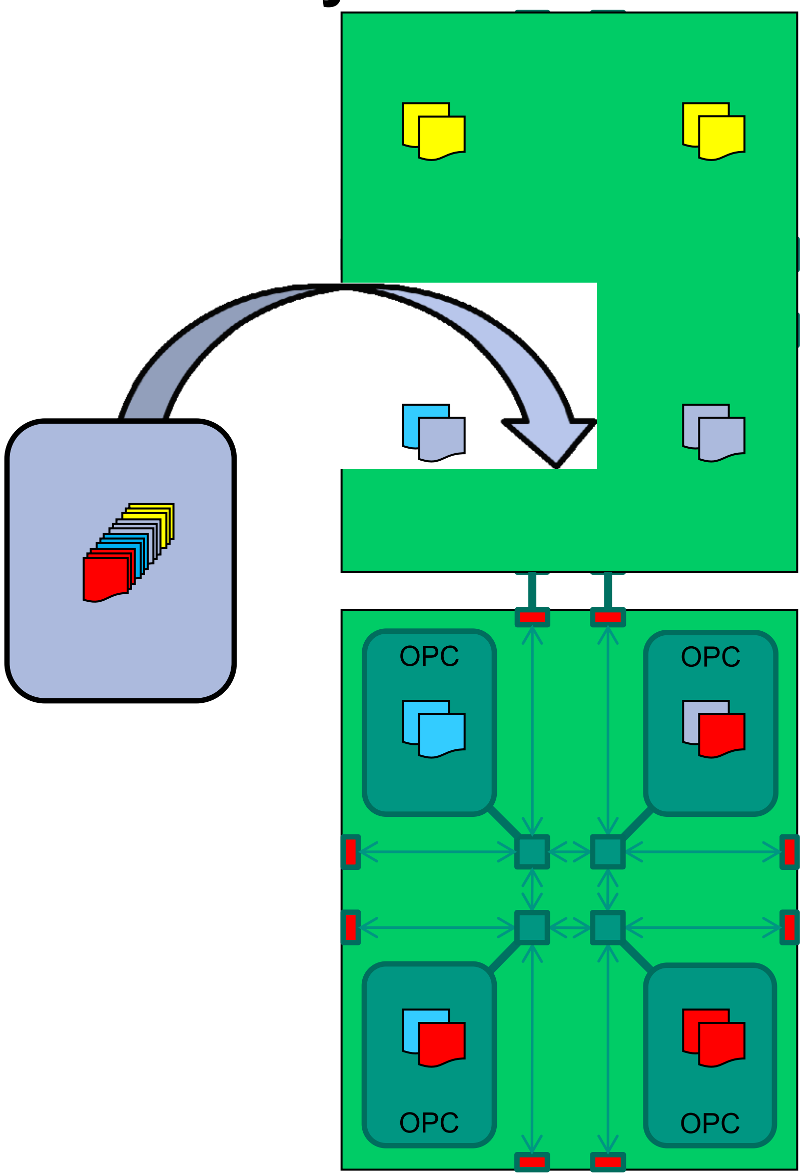
Organic Low Power Management: Peak Temperatures (Prof. Henkel)

- Central approaches benefit from global knowledge
  - Can achieve lowest peak temperatures
  - But: do not scale and have central point of failure
- Distributed and hierarchical approaches both succeed in lowering peak temperature
- Hierarchical approach sacrifices some scalability in order to achieve lower temperature peaks



Organic Middleware: Artificial Hormone System
(Prof. Brinkschulte)

- Task mapping
- Providing self-X properties:
  - Self-configuration
  - Self-healing
  - Self-optimization
- Good mapping regarding
  - Requirements of each task
  - Relationships of the tasks
  - Condition of each cell
    and it's neighborhood
- Reacting and adapting to changes
  - e.g. increased bit-rate errors
- Reaching stable mapping conditions
  - Oscillation avoidance



Organic Middleware: Implementation of the AHS for µCs (Prof. Brinkschulte)

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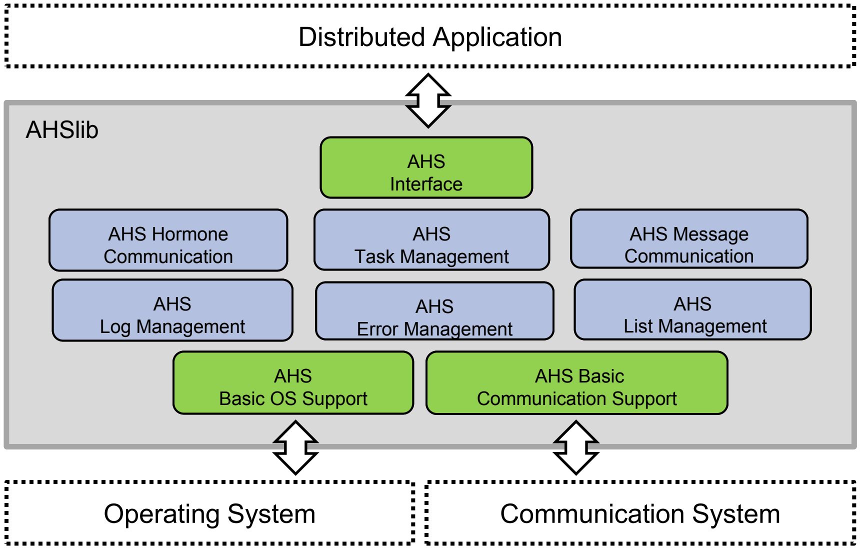
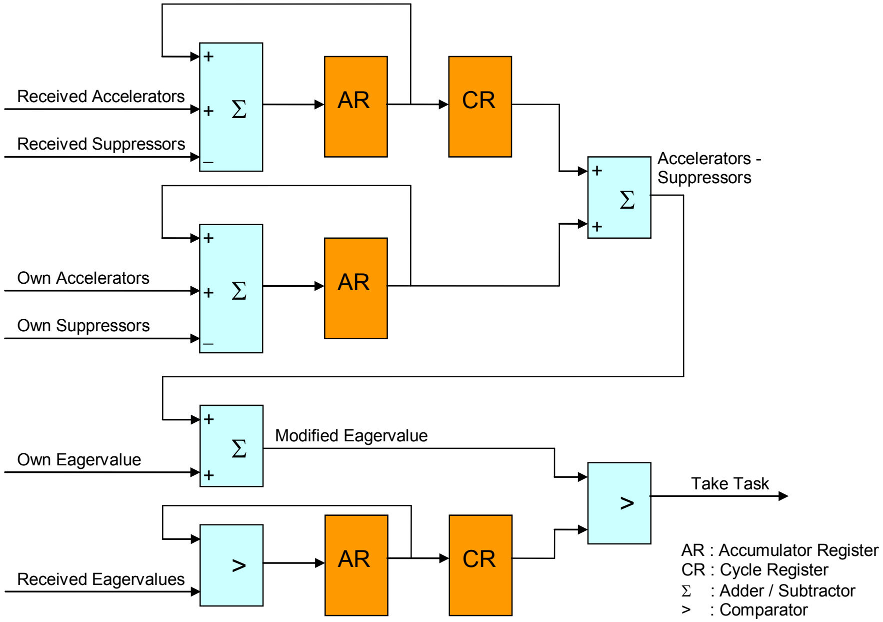
AHS Library:

- AHSlib in pure ANSI C for deployment in environments from small µCs to large PCs
- Abstraction layers:
  - “AHS Basic OS Support” – simple exchange of underlying OS
  - “AHS Basic Communication Support” – easily interchangeable network layer and protocol



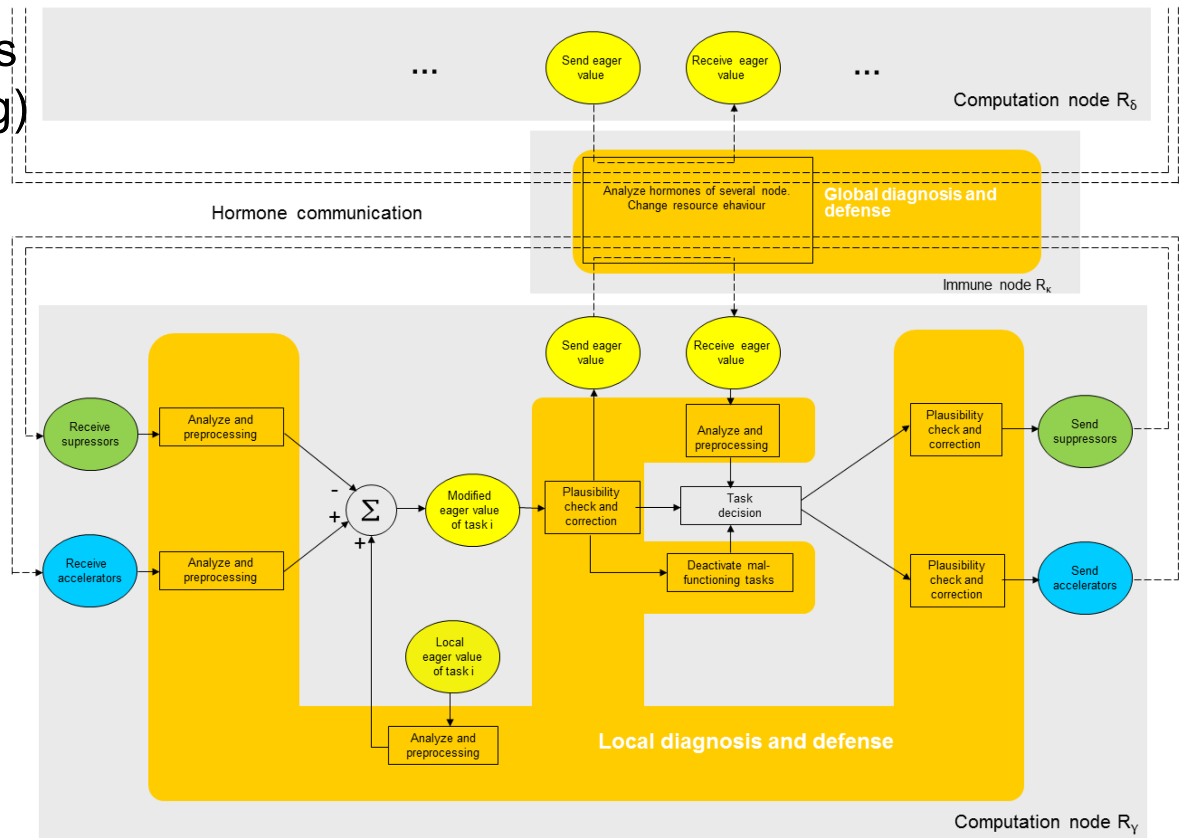
AHS in Hardware:

- Simplified, light-weight implementation
- Self-synchronization method
- Less data to store
- Less computational work to do
- Perfect for running the AHS on a µC-platform or real hardware



Organic Middleware: Immune System
(Prof. Brinkschulte)

- Immune mechanisms for advanced self-healing and self-protecting aspects to increase robustness
  (together with the Organic Processing Cell capabilities and the Organic Monitoring)
- Robustness against mal-behaving internal/ external components (comparable to illness in a biological system)
- React to „ill“ OPCs
- Counter-measures against malicious attacks
- Global and local verification



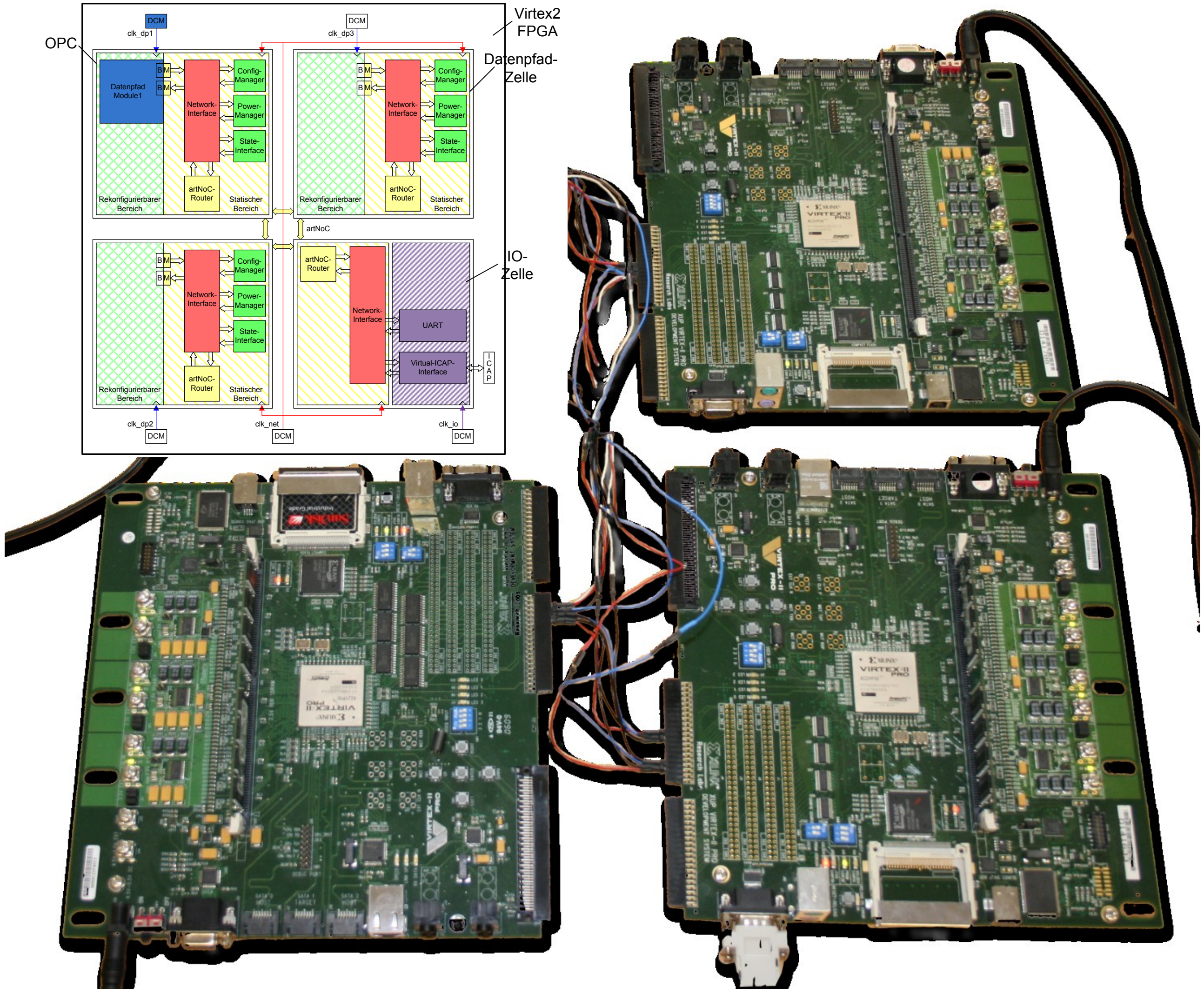
Prototype:
Interaction of HW, Mon, MW and TM

HW-Interfaces:

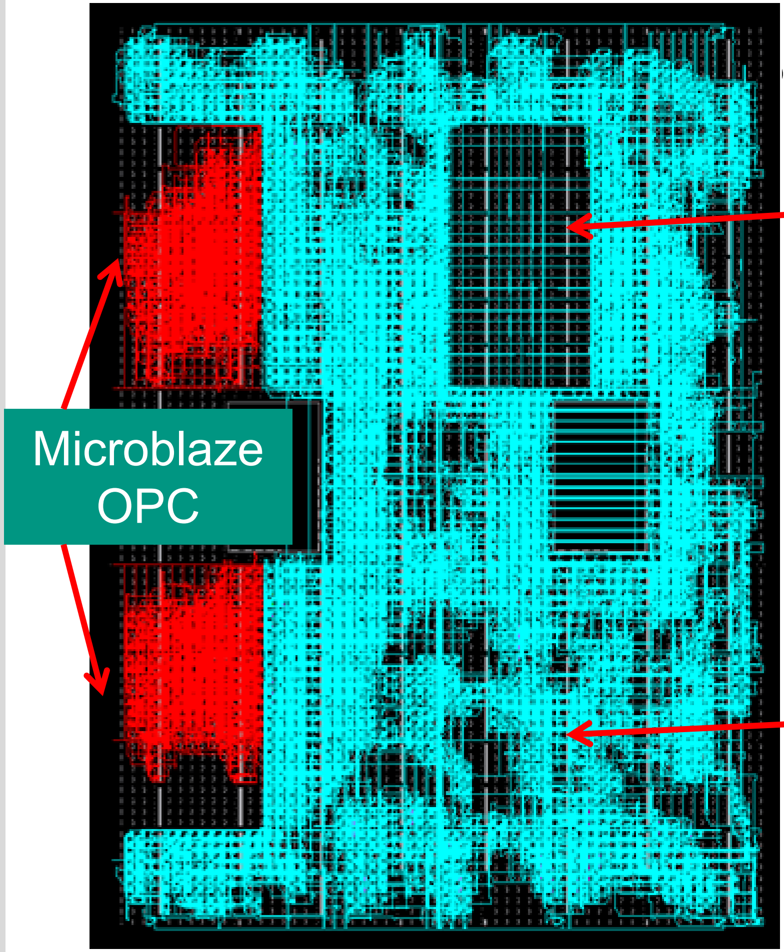
- Networking via HW-Interface
- Config-Manager via HW-Interface
- Energy Budget via Interface MW/Mon
- System Status MW/Thermal

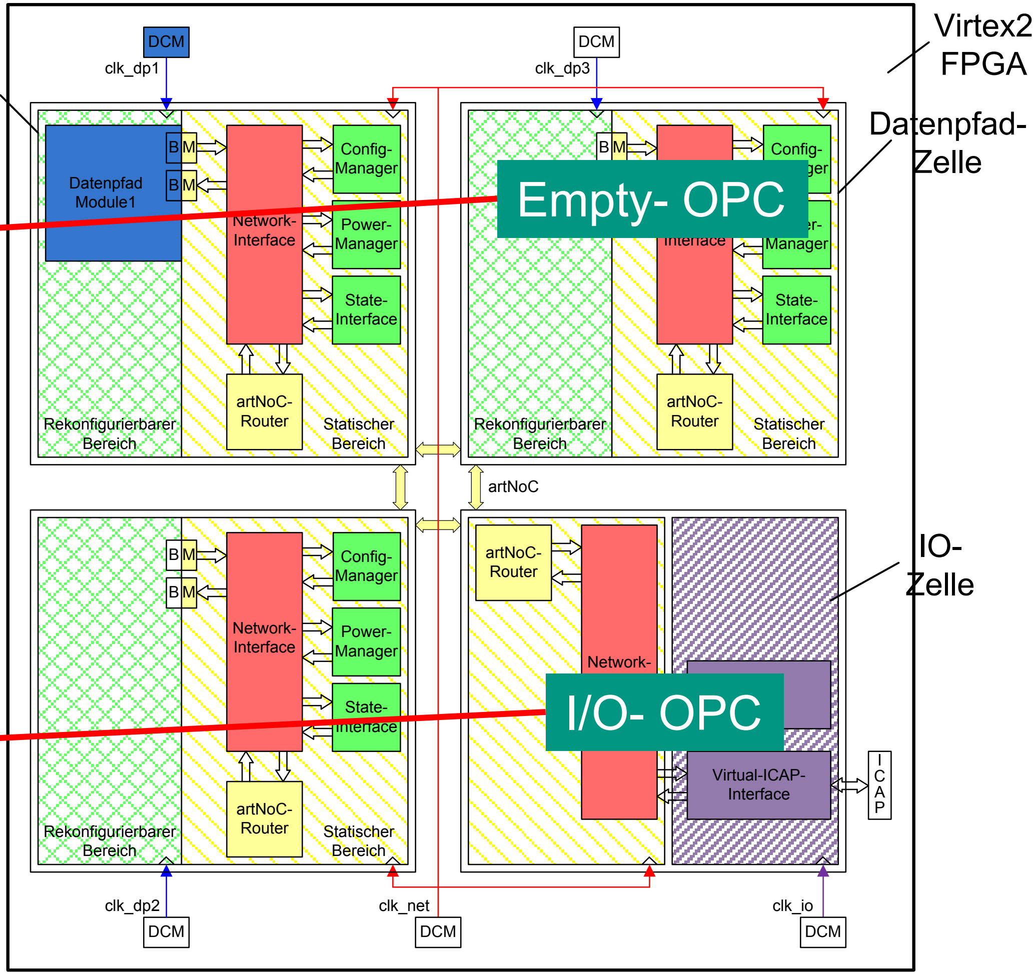
Developed Protocols:

- Output
- Ranges
- Packet Formats



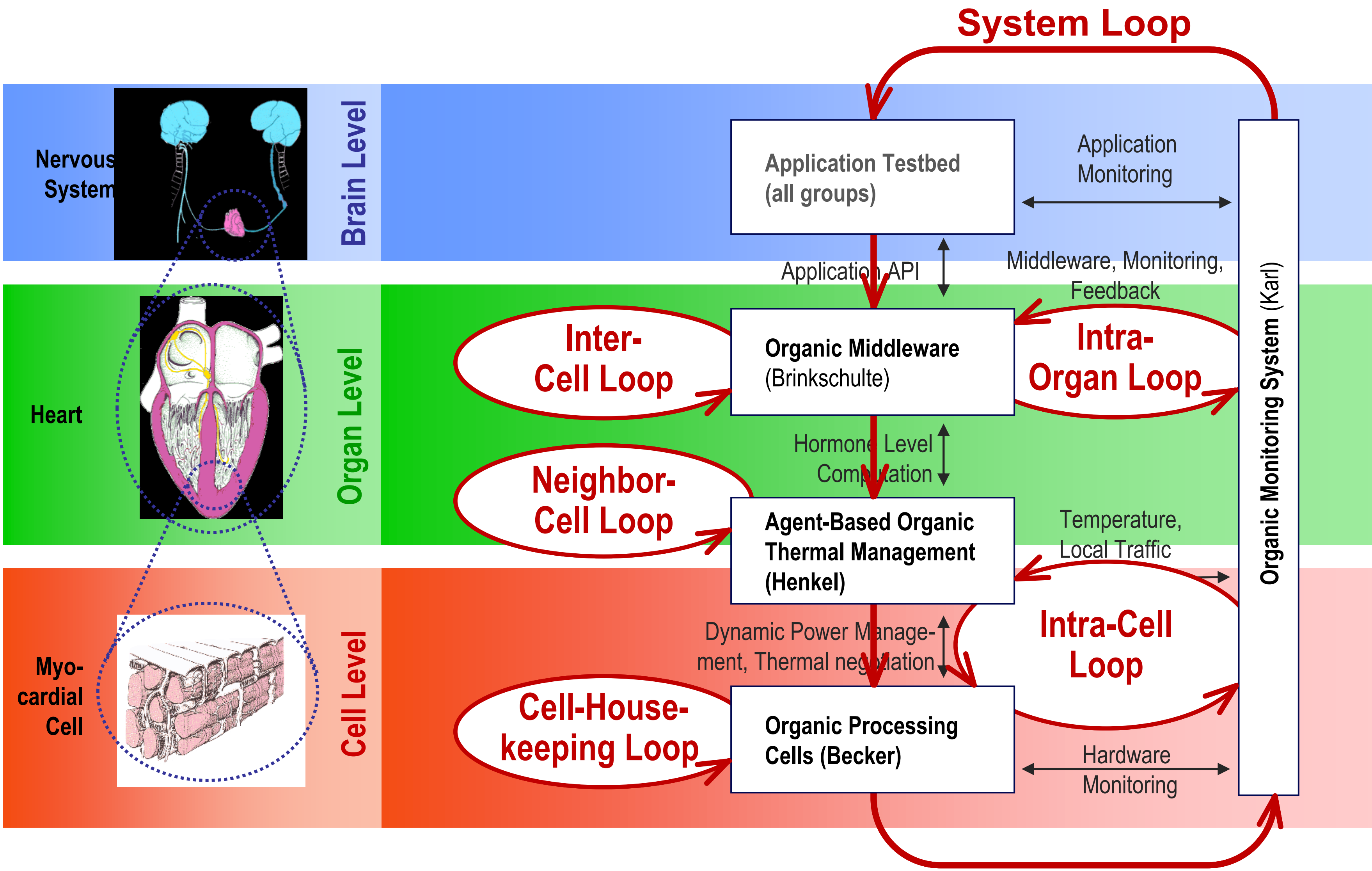
Demonstrator Hardware Floorplan





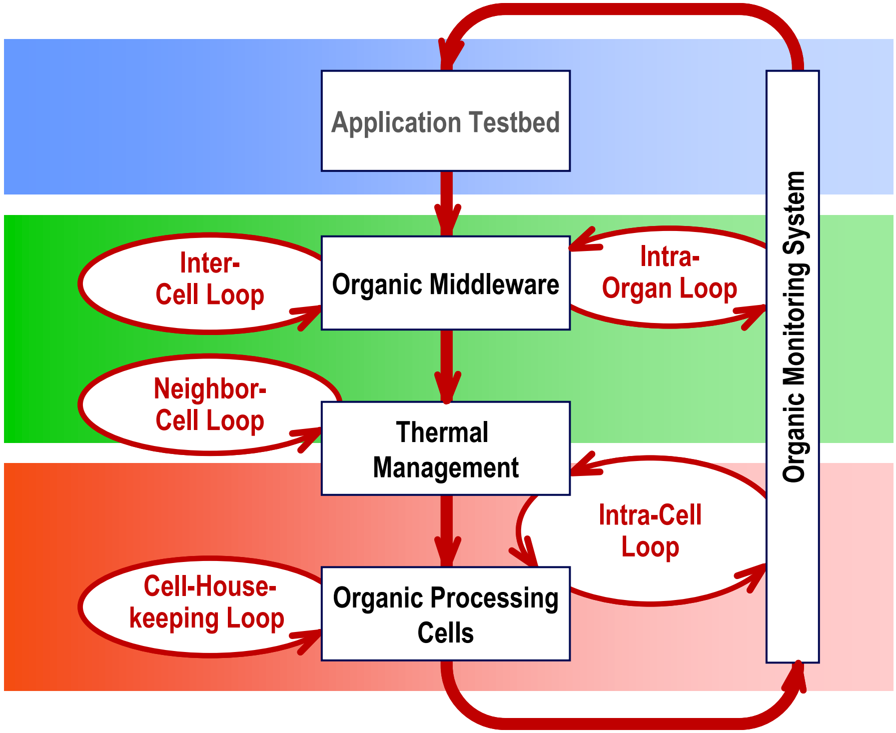
design flat; except OPC reconfigurable data path

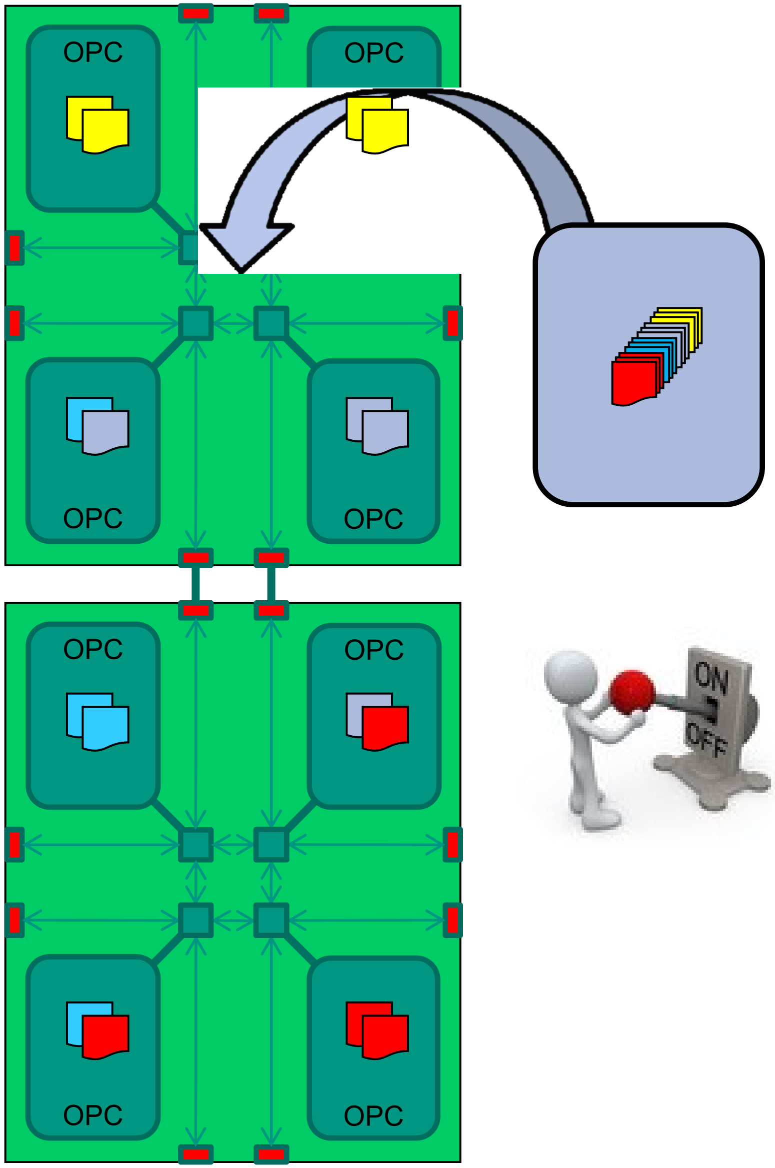
Coordination of the Decentralized Control Loops



DodOrg Demonstrator Scenarios

- Providing self-X properties:
  - Self-configuration
  - Self-healing
  - Self-optimization





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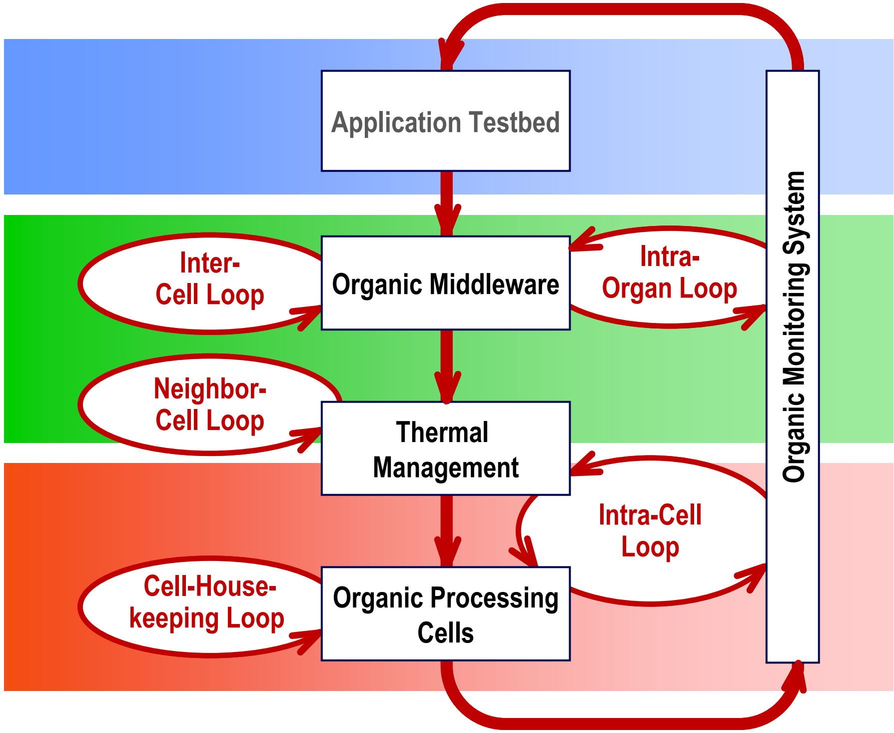

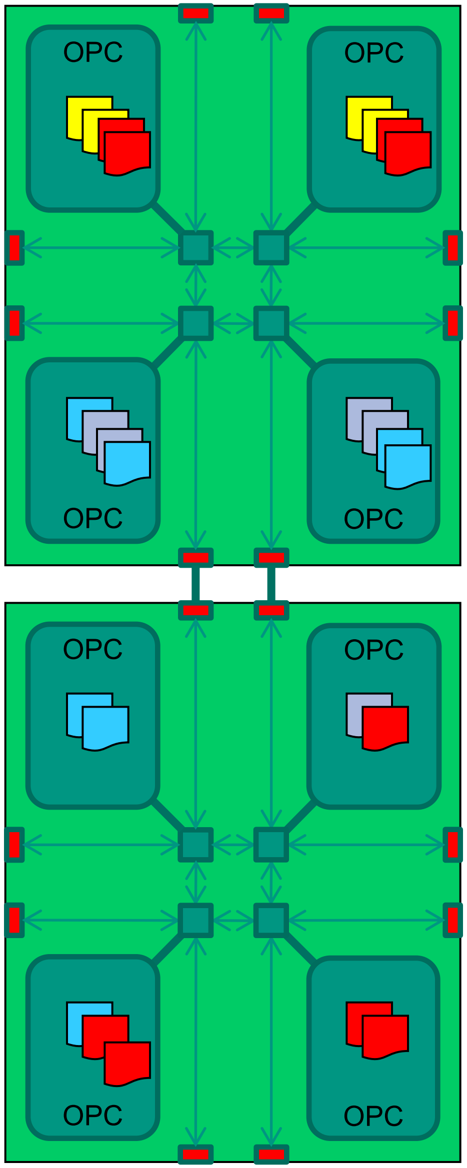

DodOrg Demonstrator Scenarios

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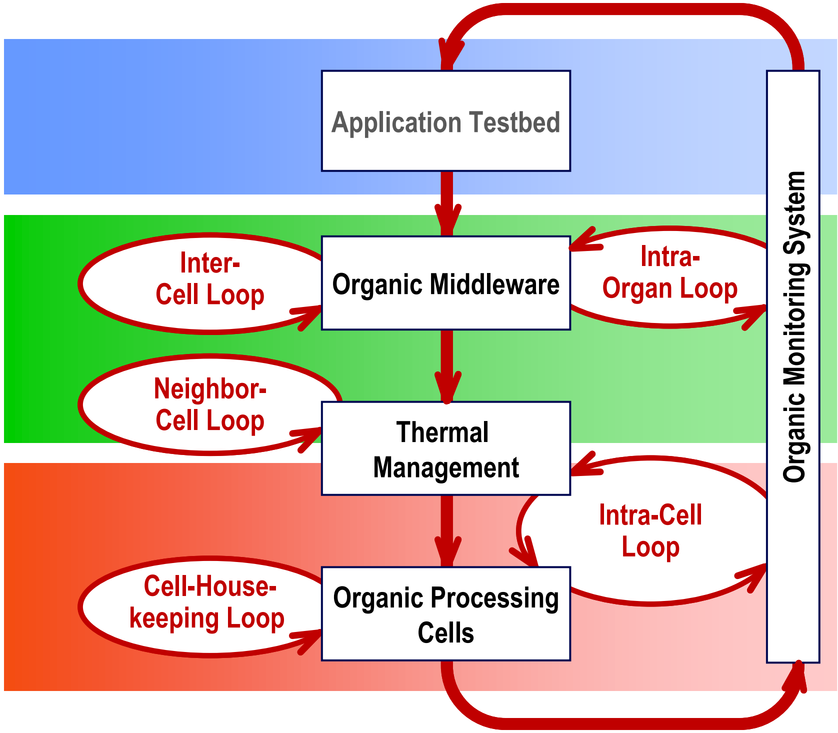

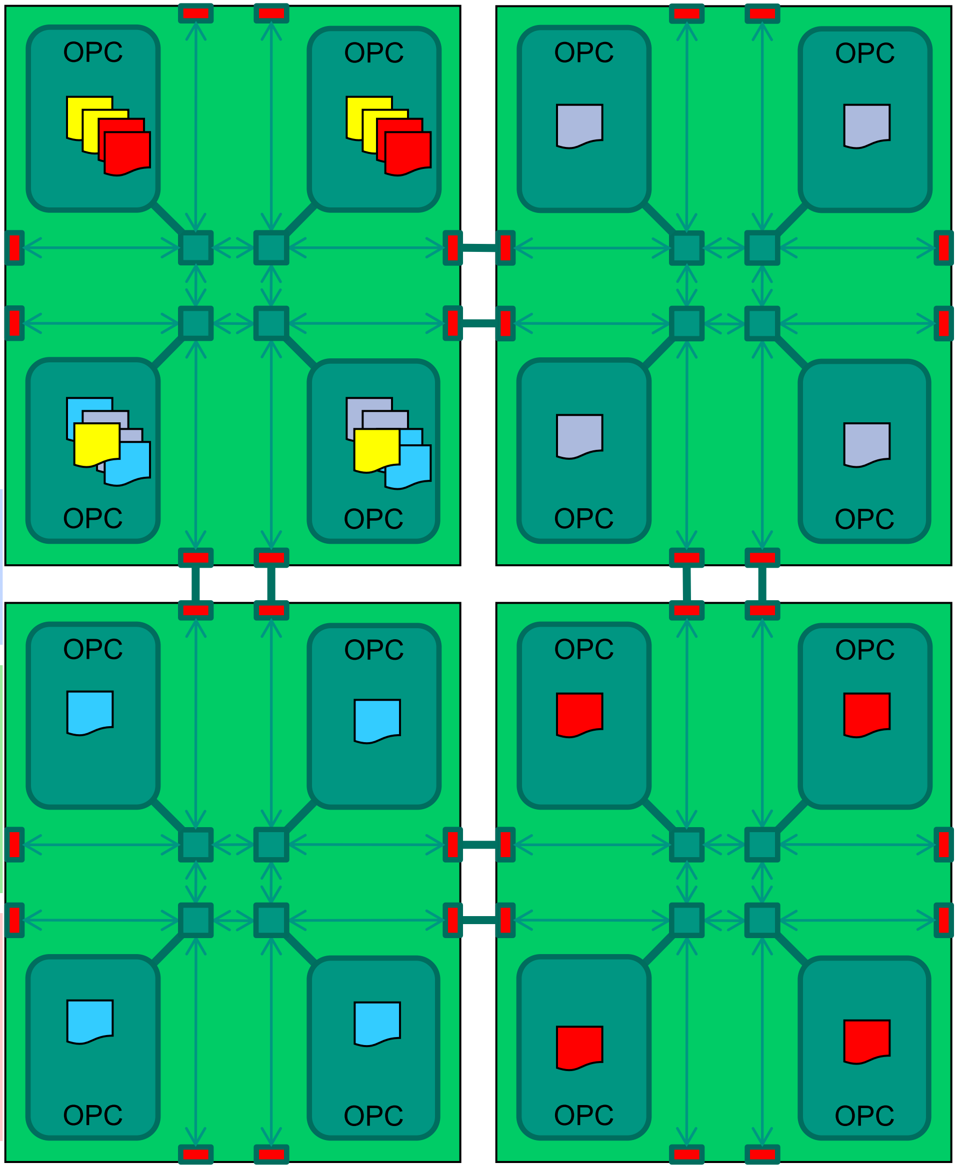

DodOrg Demonstrator Scenarios

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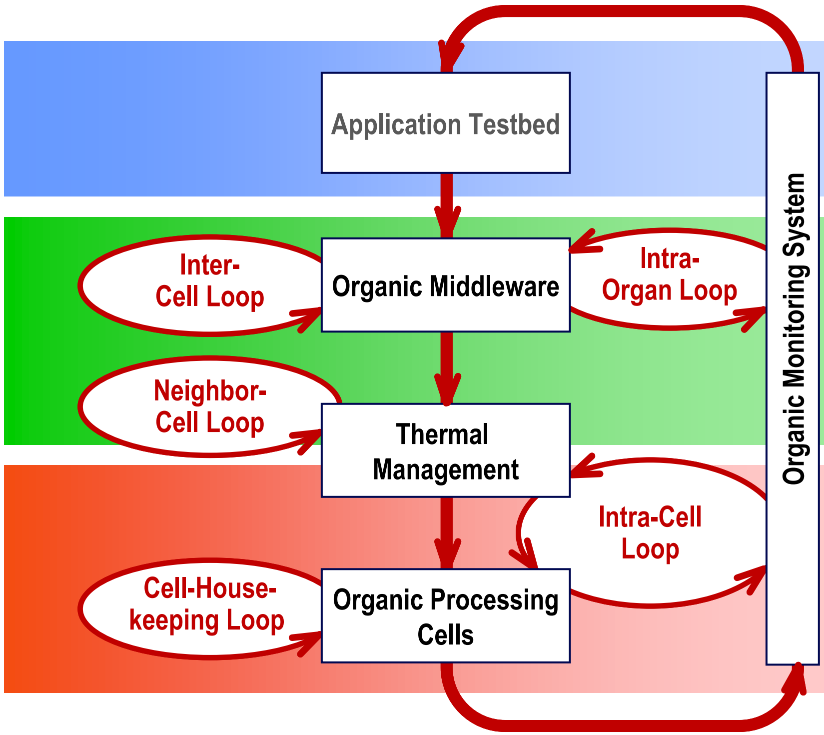
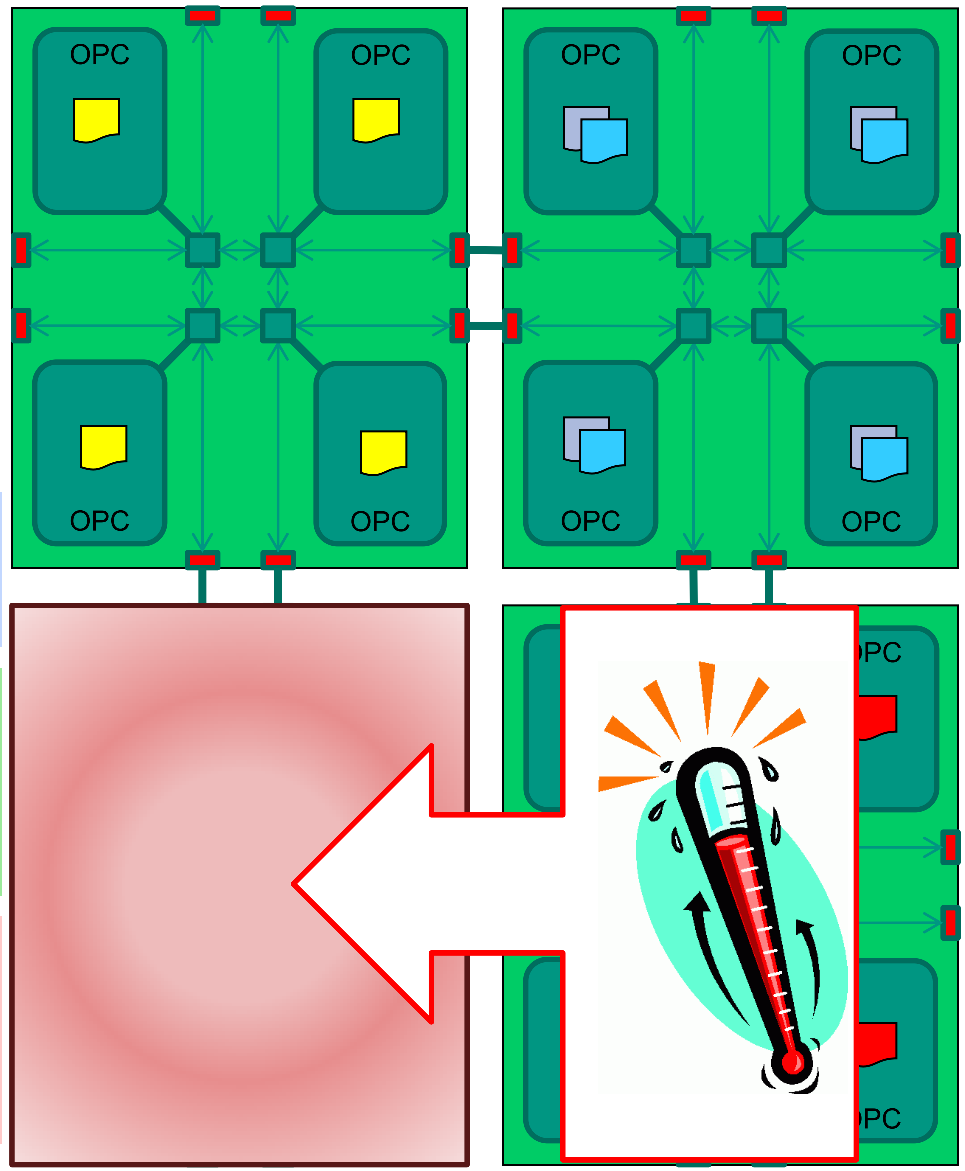
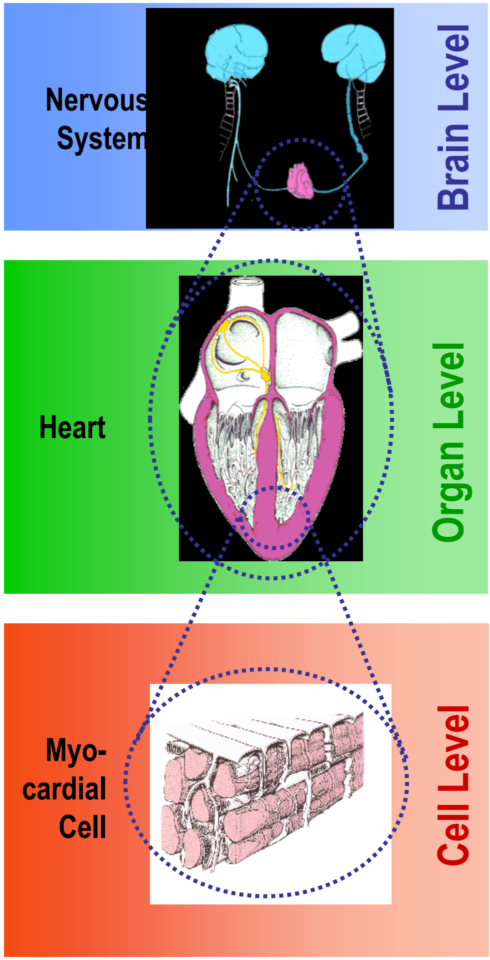




Conclusion

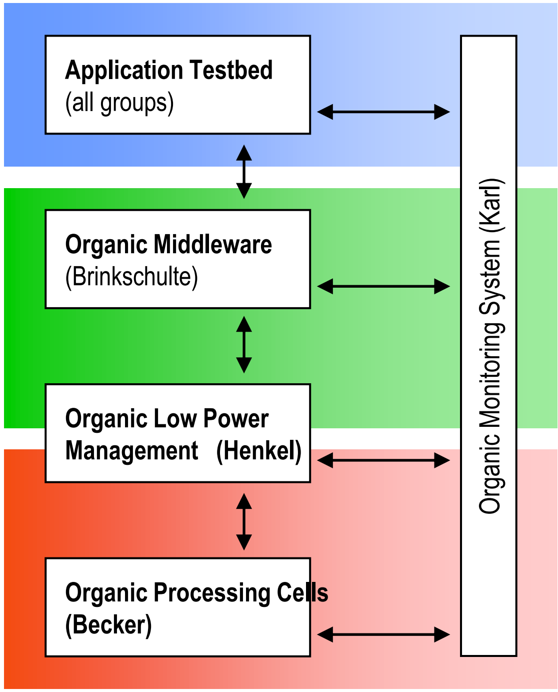
- DodOrg:
  - New scalable system design
  - Biologically inspired, reconfigurable many-core computer architecture
  - Adaptation through decentralized control loops
  - Modular, re-usable system components
  - Autonomous
  - Robustness and plasticity (dynamic stability)

  - Provides the foundation for research in the area of self-organizing computing systems
  - Motivates further and future research



Thank you for your attention!

- Questions?



List of Publications:

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KIT Karlsruhe Institute of Technology

- 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
- T.Ebi, D. Kramer, W. Karl, and J. Henkel, "***Economic Learning for Thermal-aware Power Budgeting in Many-core Architectures***", *CODES 2011*
- 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
- 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