Year 3 Review
Brussels, February 24, 2011

Transversal Activity

Achievements and Perspectives

Design for Adaptivity

Activity Leader : Karl-Erik Årzén

Lund University

Outline

- Structure
- Why adaptivity?
- Objectives and Vision
- Assessment of Year 3
- Project Overview

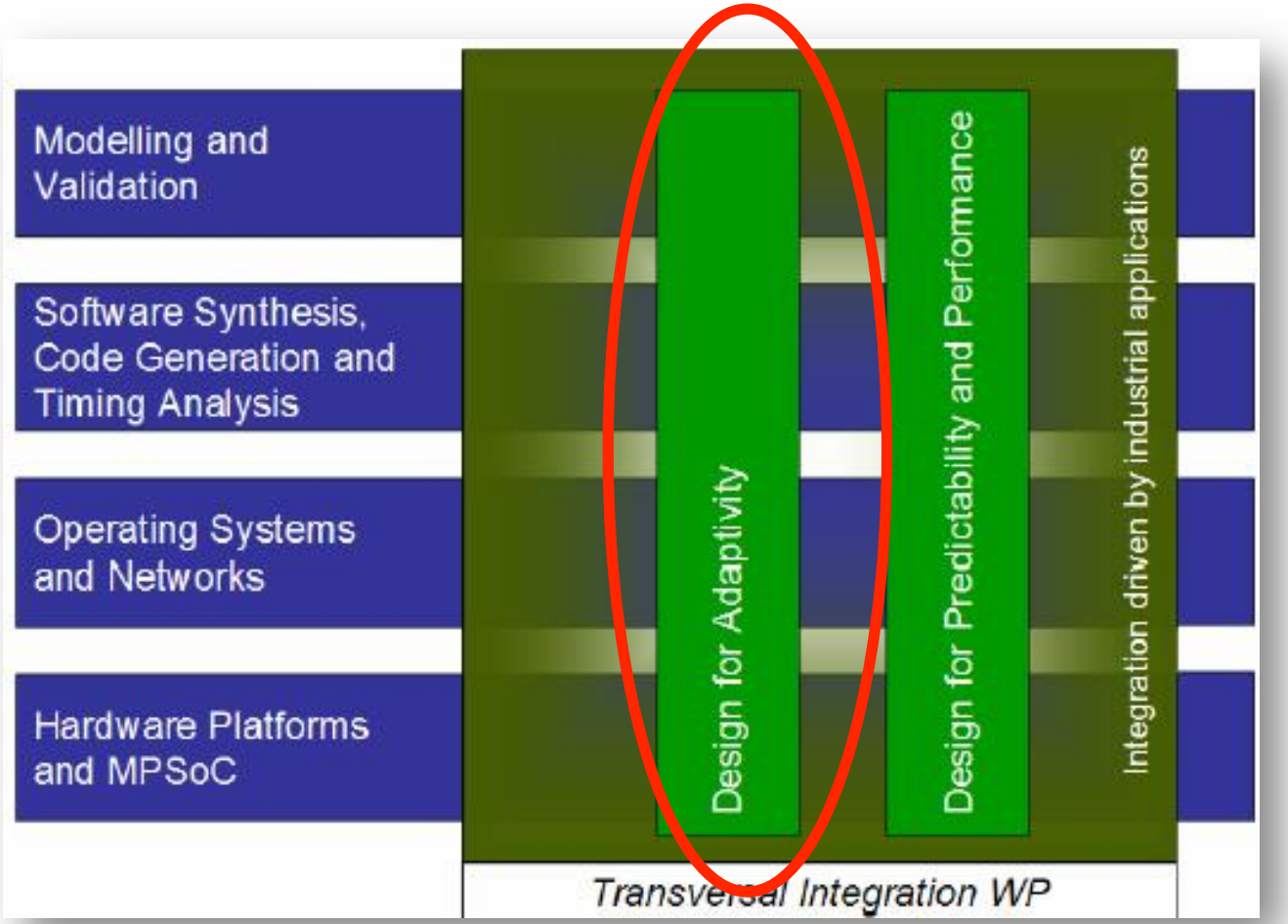
8 minutes

- Scientific Highlights
  - Adaptive Resource Management in ACTORS
  - Demo

10 minutes

- Plans for Year 4 2 minutes

Structure



- Around half the size of a thematic cluster

Involved Partners

Core Partners:

- Karl-Erik Årzén (ULUND)
- Gerhard Fohler (TUKL)
- Giorg
- Luis A
- Luca
- Maja
- Eduardo Tovar (IP Porto)
- Björn Lisper (MdH)
- Alan Burns (York)
- Lothar Thiele (ETH-Z)
- Hamid Brahim (CEA)
- Axel Jantsch & Martin Törngren (KTH)

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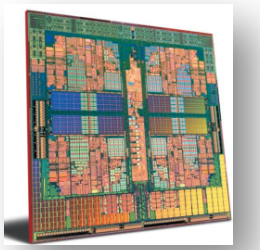
- Alejandro Alonso (UPM)
- Lucia Lo Bello (UCatania)
- Pau Martí (UPC)
- Johan Eker (Ericsson)
- Liesbeth Steffens (NXP)

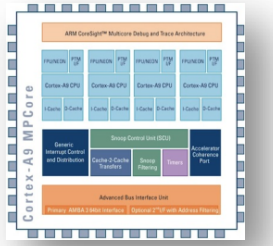
Same partners as last year, some contact persons changed

Motivation for Adaptivity?

- Increasing complexity of embedded systems
  - Higher requirements on autonomous behaviour
- Increasing uncertainty in use cases and re ements
  - Designs based on worst-case prior inf ble
- Hardware development m ty a possibility
  - Reconfigurable h
  - Power s gies
- Hardw opment increases the need for adaptivity
  - Multi- & many-core platforms
  - Variability of 10-20 nm chips
- Hardware development makes adaptivity more complicated
  - High performance on, e.g., multi-cores, for communication-heavy applications requires careful optimization and complicates on-line modifications

Same as last year





Objectives for Adaptivity

- Cope with uncertainties resource requirement[illegible]PUs, network)
  - Unknown resource requirements
  - Varying resource require[illegible]
  - Changes in total [illegible]ltiple applications)
- Cope wit[illegible]ties in resource availability
  - Ch[illegible]. the amount of resources (# cores, # nodes, clock freq[illegible]ency, …)
    - To save power, minimize heat, ….
  - Changes in the quality of resources (network variability, ….)

Same as last year

Goals for Adaptivity

- Maximize the service delivered with a [illegible] level of resources
- Minimize the resources [illegible] while maintaining an acceptable se[illegible]el
- Increase [illegible]ability
  - Re[illegible]ty, safety, availability, maintainability, ….

Same as last year

Challenges for Adaptivity

- Adaptivity with formal guarantees
- Resource-efficient adaptivity
- Modeling of adaptive emb… …stems
- Modeling of the a… …mechanism
- ……

Same as last year

High-Level Objectives

- Integrate the efforts and combine the comp[illegible]es related to adaptivity in embedded syst[illegible] the thematic clusters of ArtistDesign
- Create suitable interfac[illegible] points, and research contacts between t[illegible]s and the communities.
- Define th[illegible] for adaptivity in embedded systems,
  - De[illegible]tionship between adaptivity, reconfigurability, flex[illegible]ility, sustainability, and robustness

Same as last year

State of the Integration in Europe

- Adaptivity is a very general concept
- Most research on embedded systems relates to adaptivity in some way
- However few forums that are specifically aimed at adaptivity in embedded systems
- Adaptivity is of highest concern in consumer electronics and telecommunications (multimedia & soft realtime)
- However, also in the more hard and safety-critical sectors one finds needs and efforts related to adaptivity
  - E.g. the DySCAS project

Building Excellence

- Joint and individual research projects
  - Mainly funded by other sources → Networking and contacts
- Workshop on Adaptive Resource Management (WARM 2010) organized jointly by ULUND, TUKL, UYORK, SSSA, UPorto, UCantabria
- Smaller meetings organized by the partners
- Strong involvement of the partners in FP7 Call 7 project proposals

Overall Assessment and Vision at Y0+3

- Numerous research projects and activities
- 44 publications including 9 joint publications
- Contributed to education about adaptive and feedback-based approaches.
- Several industrial contacts
  - E.g. NXP, Ericsson, Volvo, Evidence, Enea
- The common wiki has not progressed as planned
  - http://www2.control.lth.se/ArtistAdapt/
  - Maybe not such a good idea after all…..

Reviewer Recommendations From Y2

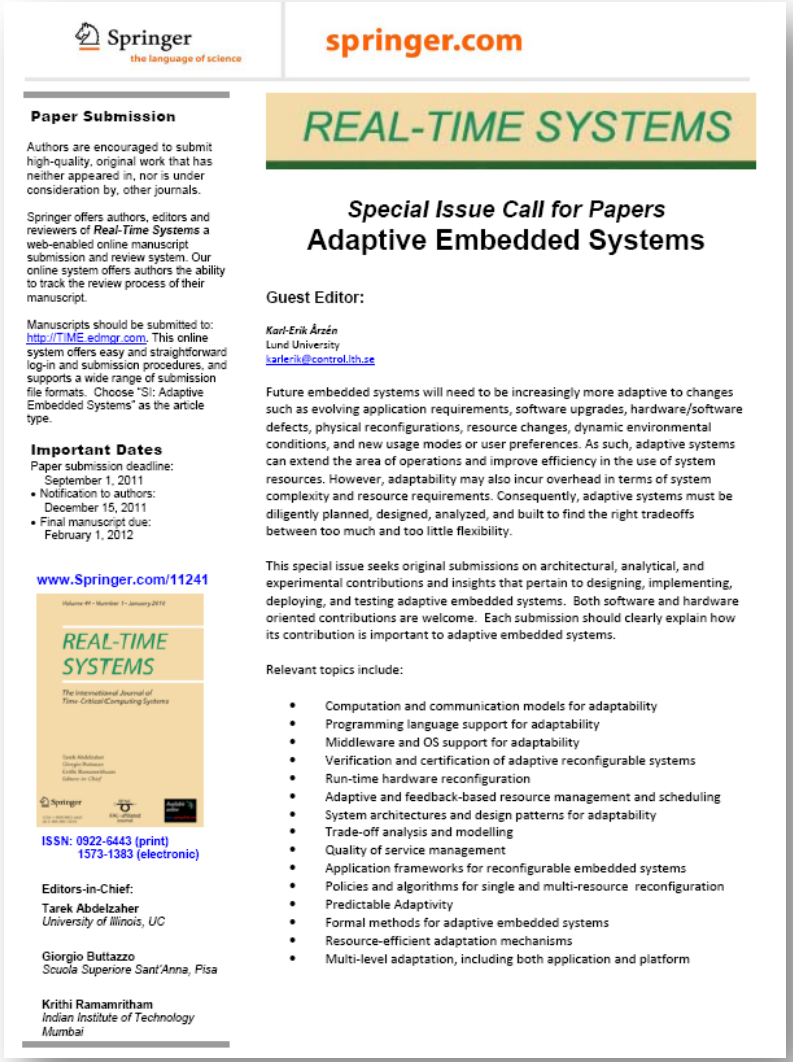
Progress of the clusters design for adaptivity and predictability would be stimulated by writing an annual position paper about the new/emerging insights. This is a very complex issue and taking stock periodically of the status of current thinking would be very helpful not only for the cluster but also for the research community.

Status:

- Annual position paper too ambitious
- Instead White Paper / Survey at the end of Year 4 summarizing the work done coordinated by ArtistDesign and the experiences gained
- Authors decided and outline of the paper available
- Main common activity for Y4

RTSJ Special Issue

- Special Issue on Adaptive Embedded Systems
- Årzén guest editor
- Deadline Sep 2011
- The partners of the activity are encouraged to submit their work



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Paper Submission

Authors are encouraged to submit high-quality, original work that has neither appeared in, nor is under consideration by, other journals.

Springer offers authors, editors and reviewers of *Real-Time Systems* a web-enabled online manuscript submission and review system. Our online system offers authors the ability to track the review process of their manuscript.

Manuscripts should be submitted to: http://TIME.edmgr.com. This online system offers easy and straightforward log-in and submission procedures, and supports a wide range of submission file formats. Choose "SI: Adaptive Embedded Systems" as the article type.

Important Dates

Paper submission deadline:
September 1, 2011
- Notification to authors:
December 15, 2011
- Final manuscript due:
February 1, 2012

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Indian Institute of Technology Mumbai

REAL-TIME SYSTEMS

Special Issue Call for Papers
Adaptive Embedded Systems

Guest Editor:

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Future embedded systems will need to be increasingly more adaptive to changes such as evolving application requirements, software upgrades, hardware/software defects, physical reconfigurations, resource changes, dynamic environmental conditions, and new usage modes or user preferences. As such, adaptive systems can extend the area of operations and improve efficiency in the use of system resources. However, adaptability may also incur overhead in terms of system complexity and resource requirements. Consequently, adaptive systems must be diligently planned, designed, analyzed, and built to find the right tradeoffs between too much and too little flexibility.

This special issue seeks original submissions on architectural, analytical, and experimental contributions and insights that pertain to designing, implementing, deploying, and testing adaptive embedded systems. Both software and hardware oriented contributions are welcome. Each submission should clearly explain how its contribution is important to adaptive embedded systems.

Relevant topics include:

- Computation and communication models for adaptability
- Programming language support for adaptability
- Middleware and OS support for adaptability
- Verification and certification of adaptive reconfigurable systems
- Run-time hardware reconfiguration
- Adaptive and feedback-based resource management and scheduling
- System architectures and design patterns for adaptability
- Trade-off analysis and modelling
- Quality of service management
- Application frameworks for reconfigurable embedded systems
- Policies and algorithms for single and multi-resource reconfiguration
- Predictable Adaptivity
- Formal methods for adaptive embedded systems
- Resource-efficient adaptation mechanisms
- Multi-level adaptation, including both application and platform

Project Classification

- Adaptive Resource Scheduling
  - Incl modeling and analysis
  - 18 projects/activities (8 joint)
- Adaptive Networking
  - Wireless networks and distributed systems
  - 6 projects/activities (4 joint)
- Hardware-Based Adaptivity
  - 2 projects/activities (1 joint)

Projects: Adaptive Resource Scheduling

Adaptive and Feedback-Based Resource Management (SSSA, ULUND, TUKL, Evidence, Ericsson)

- ACTORS project (more later)

Adaptive Resource Management for Uncertain Execution Platforms (ULUND, ERICSSON)

Feedback Control of Computing Systems (ULUND)

Theory for distributed performance analysis (TU Braunschweig)

In-system Distributed Sensitivity Analysis Against Jitter (TU Braunschweig)

Change impact analysis (UYork)

Parametric WCET Analysis (MDH)

Projects: Adaptive Resource Scheduling

Run-Time Management of Cache-Related Preemption Delays (IPPorto)

Fault Tolerance in Adaptive Cooperative Systems (IPPorto)

Dynamic Behaviour of Embedded Systems (IMEC, NTUA)

- Adaptive resource management on CPU and GPU (Graphical Processing Unit) running CUDA (IMEC, BARCO)

Adaptive Control of MPEG-4 Decoding (TUKL, ULUND)

Improving Real-time BIP (Verimag)

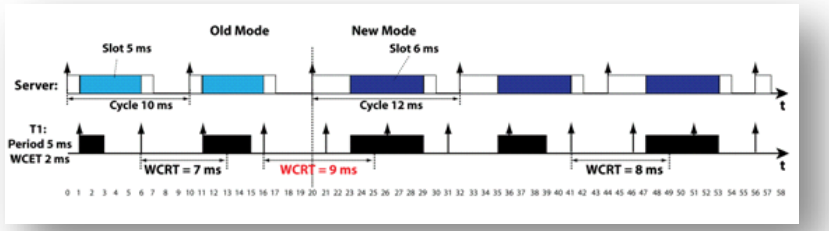
- BIP (Behaviour, Interaction, Priority) Component Framework

Adaptation in SOA (UPM)

Projects: Adaptive Resource Scheduling

Adaptive Servers with Guarantees (ETHZ, SSSA)

- Predictable reconfigurations with resource guarantees
- TDMA scheduling
- Real-Time Calculus analysis



Adaptive Power Management (ETHZ, SSSA)

Sampling Mechanisms for Event-Driven Control Systems (UPC, ULUND, SSSA)

Feedback scheduling vs Event-Driven Control (UPC)

Optimal online sampling period assignments (ULUND, UPC)

Projects: Adaptive Networking

Adaptivity in wireless networks (UPorto, UCatania)

Adaptivity in distributed systems (UPorto, MDH, UAveiro, UPC)

Adaptive management in energy harvesting systems (ETHZ, UBologna)

Adaptive energy management of wireless smart camera networks (UBologna)

Adaptive TDMA bus allocation and elastic scheduling (UBologna, SSSA)

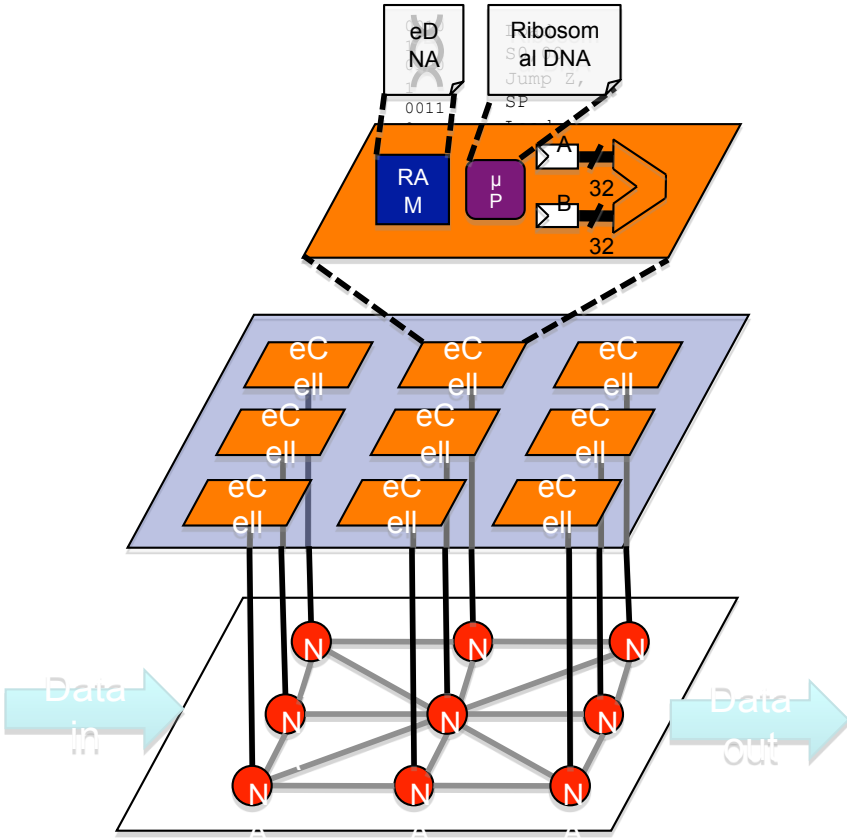
Fault-Tolerant Reliable Communication Platforms (KTH)

Projects: Hardware-Based Adaptivity

eDNA: Reconfigurable self-organizing and self-healing hardware (DTU)

JPL
Jet Propulsion Laboratory
California Institute of Technology

Adaptive allocation of applications on MPSoC platforms (ETHZ, SSSA)



Scientific Highlight: Adaptive Resource Management in the ACTORS Project

- The activity that involves the most number of partners
- Recently finished ➔ A lot of results
- Will continue during 2011 with ArtistDesign funding

Feedback-Based Resource Management

- ACTORS – Adaptivity and Control of Resources in Embedded Systems
  - Ericsson , SSSA, TUKL, ULUND, EPFL, Akatec, Evidence

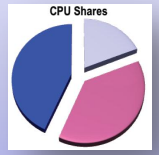
- Adapt applications to changing resource availability
  - Change the application service levels
- Adapt the resource distribution to changing application requirements
  - Change the amount of resources allocated to an application

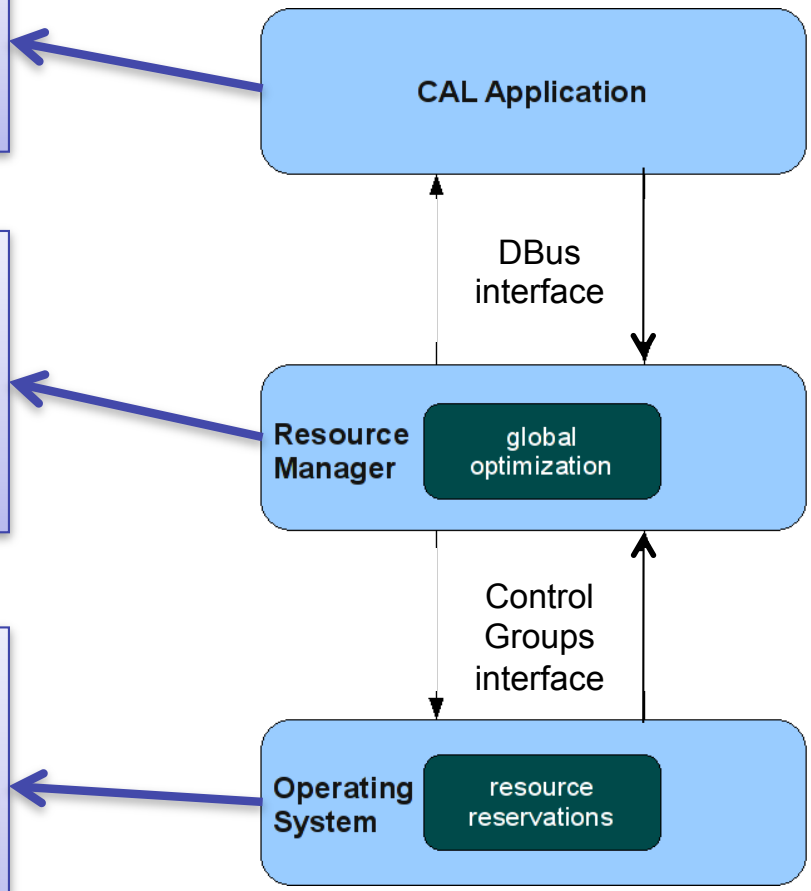
Overview

- CAL Dataflow Applications
- Legacy applications through wrapper

Resource Manager
- C++ framework
- DBus IPC to application
- Control groups API to scheduler

SCHED_EDF scheduler
- Partitioned multi-core scheduler
- Hard CBS Reservations





Static Information

From applications to RM at registration:

- Service Level Table

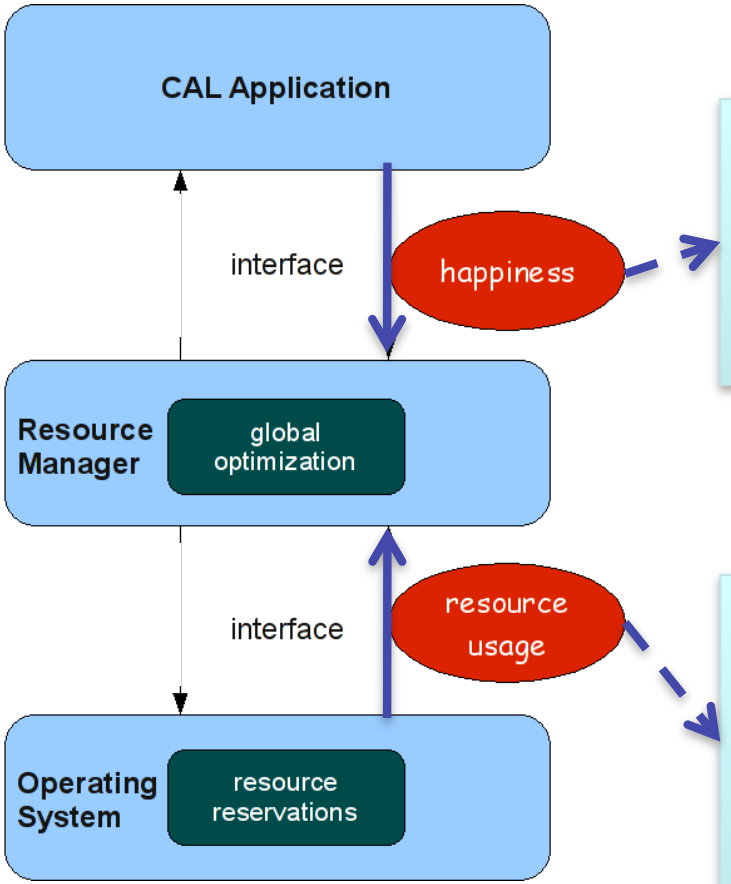
Service Level	QoS	BW Requirement	BW distribution	Timing Granularity
0	100	240	60-60-60-60	20 ms
1	75	180	45-45-45-45	20 ms
2	40	120	30-30-30-30	20 ms

- Thread IDs and how they should be grouped

From system administrator to RM at startup:

Appl.	Importance
Appl 1	10
Appl 2	20
Appl 3	100
Default	10

Dynamic Inputs



Happiness:

- boolean indicator of whether the QoS obtained correspond to what could be expected at the current service level

Used Budget (Bandwidth):

- average used budget

Exhaustion Percentage:

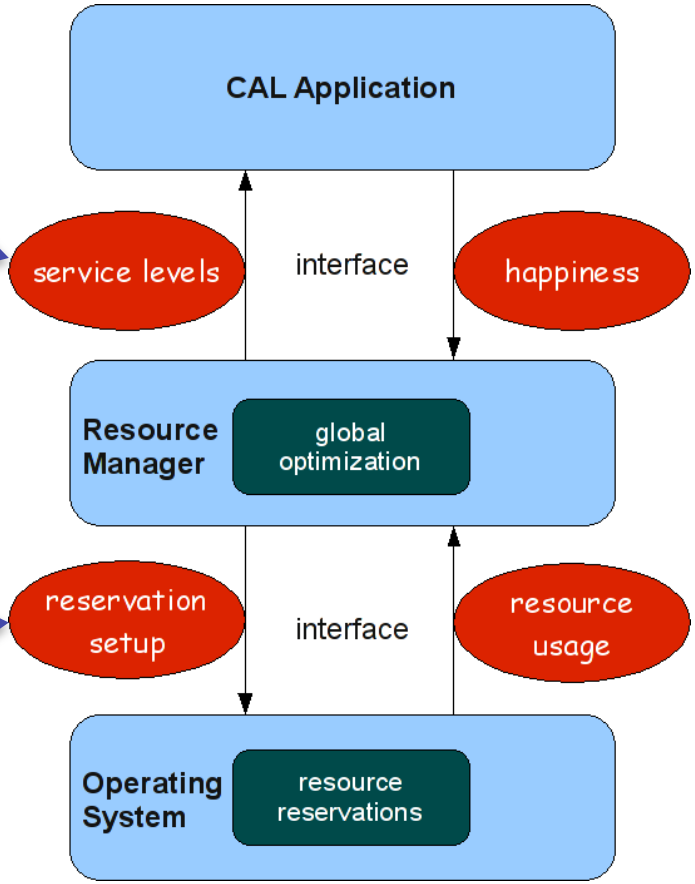
- percentage of server periods in which the budget was exhausted

Outputs

Current Service Level

Reservation Parameters:

- Budget
- Period
- Affinity



Resource Manager Tasks

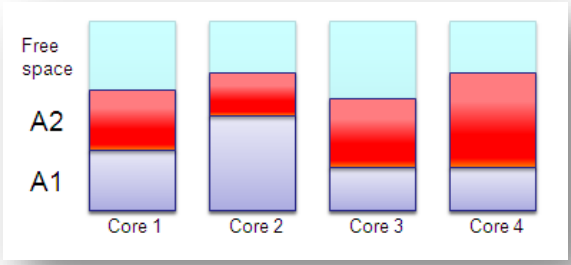
- Assign service levels
  - When applications register or unregister
- Mapping & bandwidth distribution
  - Map reservations to cores
  - Distribute the total BW to the reservations
- Bandwidth adaptation
  - Adjust the server budgets dynamically based on measured resource usage and obtained happiness

$$\max \sum_{i=1}^{n} w_i q_i x_i$$

$$\sum_{i=1}^{n} \alpha_i x_i \leq C$$

$$\forall i, \sum x_i = 1$$

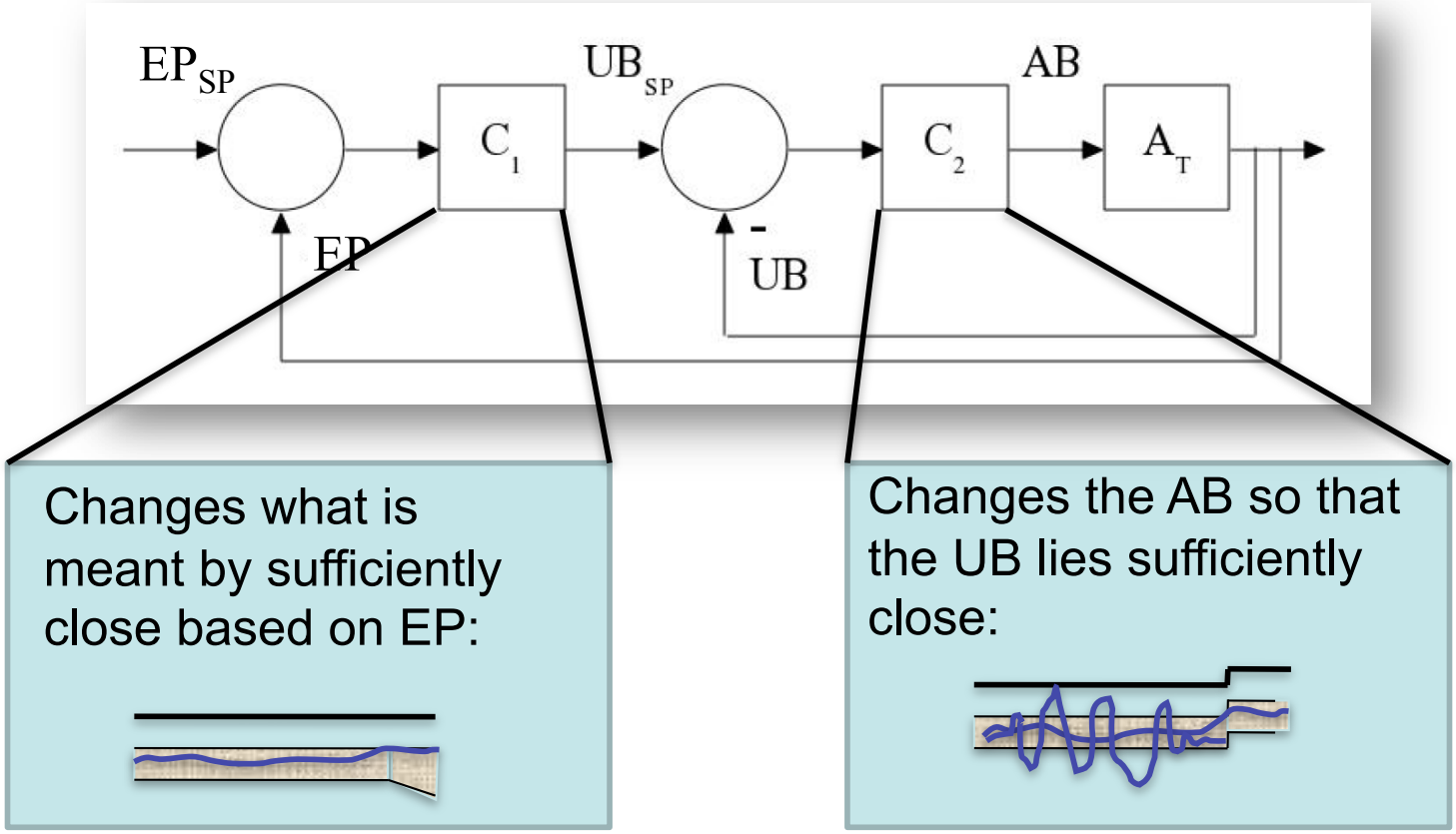
ILP Problem



Bin-Packing Problem

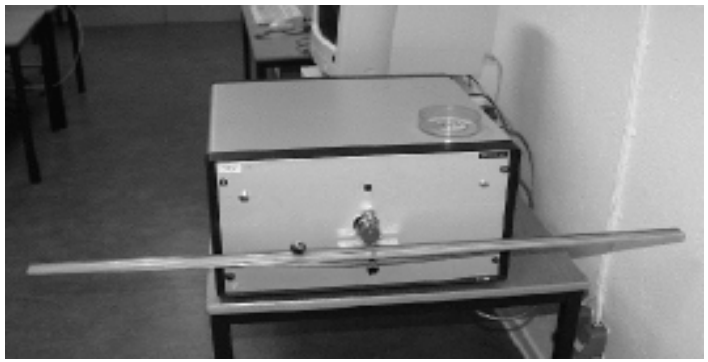
Resource Manager Tasks

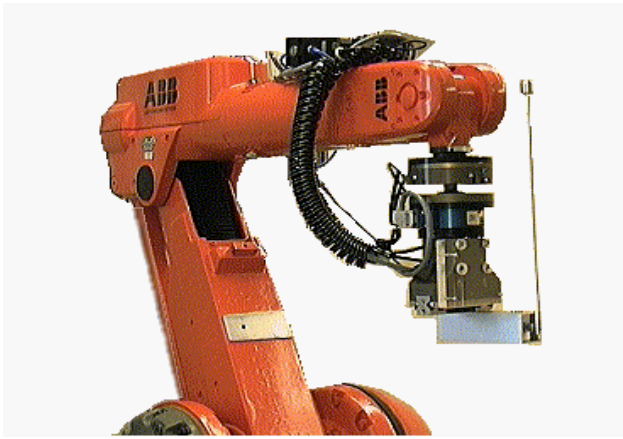
- Bandwidth adaptation
  - Adjust the server budgets dynamically based on measured resource usage and obtained happiness



Demonstrators

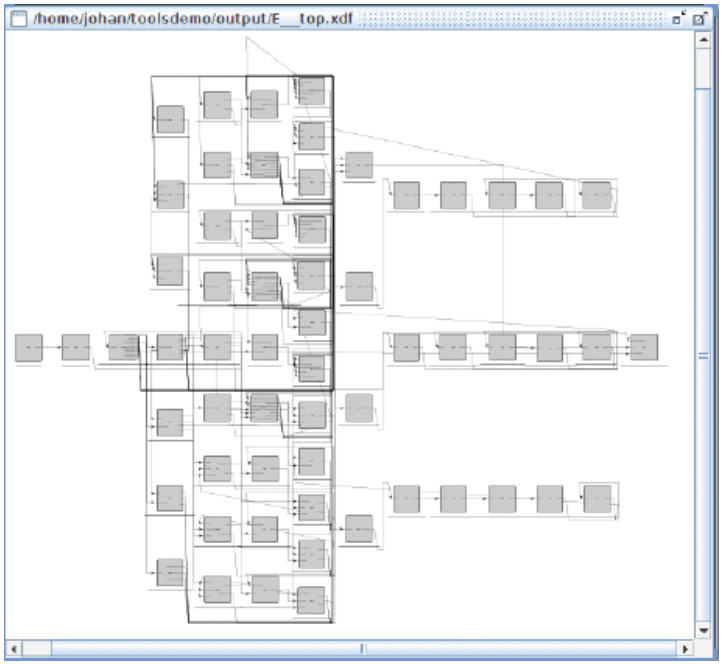
- Video Quality Adaptation
  - MPEG-2 and MPEG-4 frames
  - TUKL
- Control demonstrator
  - Industrial robot balancing inverted pendulum
  - Ball and Beam Processes
  - ULUND
- Image Processing
  - HW and/or SW mapping
  - EPFL





Demo

- Video decoding application
  - MPEG-4 SP decoder in CAL
  - MPEG-4 stream from camera
  - Reducing service level ➔ lowering the resolution and/or frame rate



Meetings, Workshops & Courses

Workshops & Special Sessions:

- **First International Workshop in Adaptive Resource Management (WARM 2010), CPSWEEK 2010, April 12, Stockholm**
  - Organizers:
    - Giorgio Buttazzo (SSSA)
    - Gerhard Fohler (TUKL)
    - Alan Burns (UYork)
    - Luis Almeida (UPorto)
    - Karl-Erik Arzen (ULUND)
    - Michael Gonzalez Harbour (UCatania)
  - http://www.artist-embedded.org/artist/Theme.html
  - One keynote (Raj Rajkumar), three mini-keynotes, and 8 submitted papers
  - Cofunded by ACTORS
- **Special Session: QoS and Resource Management in Adaptable Real-Time Systems**
  - 15th IEEE Int Conf on Emerging Technologies and Factory Automation, Bilbao
  - Alejando Alonso (UPM) and Marisol Garcia Valls (U Carlos III)

Meetings, Workshops & Courses

Courses:

- **Graduate Course on Embedded Control Systems; Theory and Practice**
  - SSSA, Pisa - June 14-18, 2010
  - Organizers:
    - Giorgio Buttazzo (SSSA)
    - Pau Martí (UPC)
    - Ettore Ricciardi (Pisa)
  - http://www.artist-embedded-org/artist/Overview.2037.html
- **Tutorial: Real-Time Calculus**
  - Pisa, March 22-23 2010
  - Lothar Thiele (ETHZ) and Giorgio Buttazzo (SSSA)
- **Tutorial: Sampling in Event-Driven Control Systems**
  - CDC 2010 satellite workshop on Co-Design of Control and R-T Computing
  - Manel Velasco, UPC

Tools and Platforms

- SHARK, Erika and ForSyDe reported in Y1 and Y2
- SWEET (SWEdish Execution Time tool)
  - Parametric WCET analysis
  - Mälardalen and USaarland
- Hardware setup
  - Demonstrate self-protection and adaptability of embedded Real-Time Systems
  - TUBraunschweig, UErlangen, Symtavision

Tools and Platforms

- TrueTime Simulator
  - Networked embedded control simulation in Simulink
  - ULUND + several Artist partners as users
  - Three new releases during Y3
    - Mac support
    - TrueTime Network for Modelica
    - Support for Network Code Machine (S Fischmeister, UWaterloo)
  - Support for partitioned multi-core scheduling, hierarchical scheduling, and hard CBS (not yet formally released)

Plans for Y4

- Continued integration
  - TUKL, ULUND and Ericsson will continue the work on the ACTORS resource manager incl transfer into open source, using ArtistDesign funding
- Complete the joint white paper / survey on adaptivity in embedded systems
- At least 10 joint publications
- More than 10 research collaborations
- More than 10 meetings or workshops organized by the partners.
  - APRES 2011, CPSWEEK, Chicago, April 2011
- Two educational events