Year 1 Review
Brussels, January 23rd, 2008

Transversal Activity

Achievements and Perspectives

Design for Adaptivity

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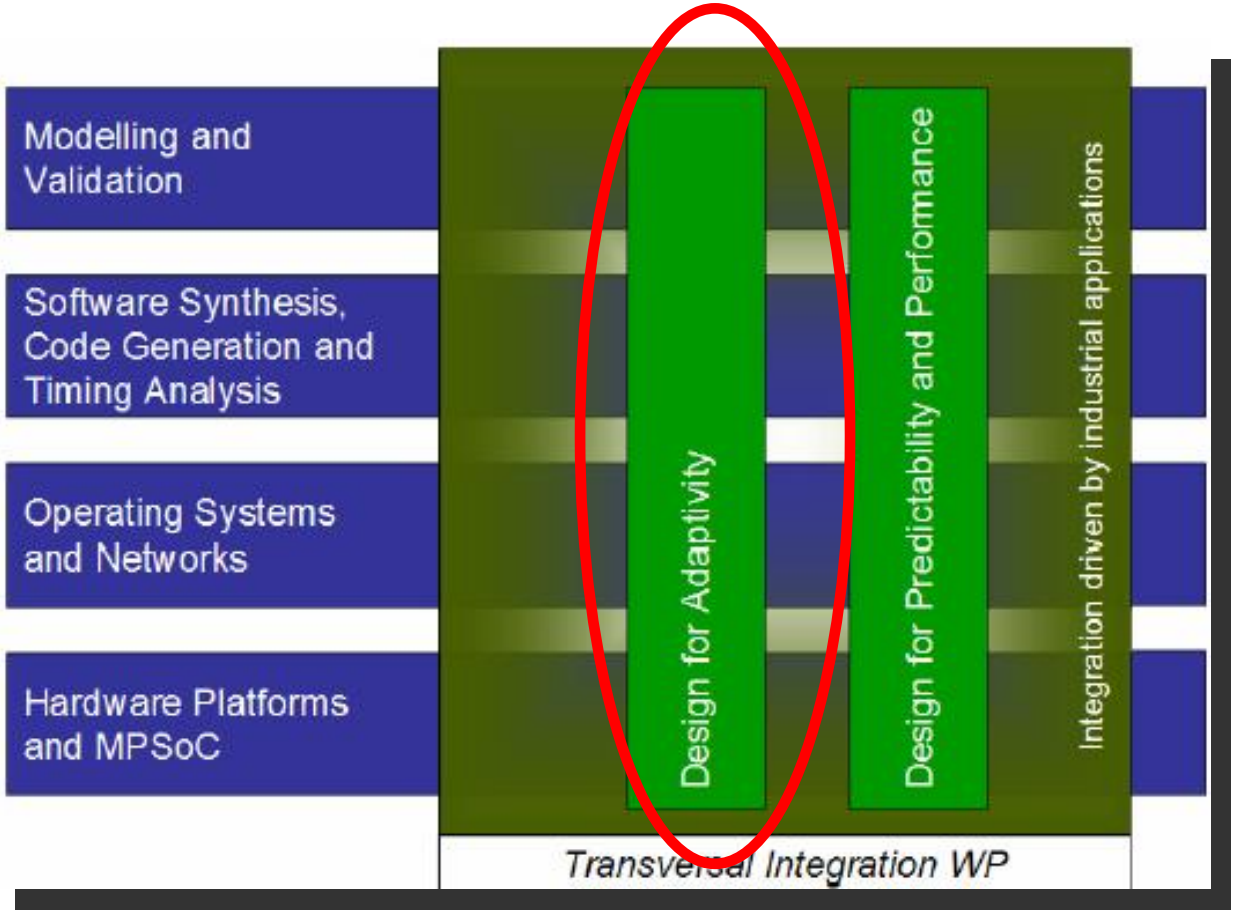
Outline

- Structure
- Why adaptivity?
- Objectives and Vision
- Assessment of Year 1
- Scientific Highlights
  - Project Examples
  - ACTORS – Adaptivity and Control of Resources in Embedded Systems
- Plans for Year 2

Structure



- Around half the size of a thematic cluster

Involved Partners

Core Partners:

- Karl-Erik Årzén (ULUND)
- Gerhard Fohler (TUKL)
- Giorgio Buttazzo (SSSA)
- Luis Almeida (Aveiro)
- Luca Benini (Bologna)
- Eduardo Tovar (Porto)
- Björn Lisper (MdH)
- Alan Burns (York)
- Lothar Thiele (ETH-Z)
- Hamid Brahim (CEA)
- Axel Jantsch & Martin Törngren (KTH)
- Jan Madsen (TU Denmark)
- Rolf Ernst (TUBraunschweig)
- Joseph Sifakis (VERIMAG)

Affiliated Partners:

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

- All four thematic clusters represented
- Dominated by partners from the OS and Networks cluster
- Influences the nature of the work done

Definitions

- "An embedded system is **adaptive** if it is able to adjust its internal strategies to meet its objectives"
- *Comment:*
  - *The adjustment is made in response to a change in, or increased knowledge about, the environment or platform*
  - *The objective for the change is to maintain the system performance or service at a desired level*
  - *That fact that the adjustment is performed at run-time is implicit in the definition*

Definitions

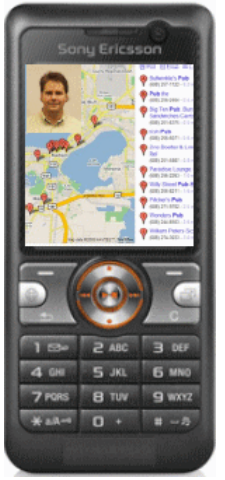
- “An embedded system is **robust** if it meet its objectives under changing conditions without modifying its internal strategies”

- “A **reconfiguration** is a change in the structure of the system “
  - *Comment: A mechanism, among others, that could be used for achieving adaptivity*

- **”Flexibility** is a broader concept than adaptivity that, e.g., also covers off-line, design-time activities”

Why Adaptivity?

- Increasing complexity of embedded systems
  - From small microcontrollers to embedded laptops
  - Higher requirements on autonomous behaviour
- Increasing uncertainty in use cases and resource requirements
  - Designs based on worst-case prior information unfeasible
- Rapid hardware development
  - Multicore, reconfigurable computing
- Increasing demands on short time to market
  - Flexibility, ease of change



Need for Adaptivity

- **Changes in:**
  - Load / traffic
  - Operational environment
    - energy availability
    - operating temperature
    - noise levels
  - System configuration
  - Number of users
  - Use cases
- **Demands on:**
  - Timeliness
  - Quality of Service / Performance
  - Safety
  - Fault-tolerance
  - .....

- **Need for adaptivity:**
  - QoS Optimization
  - Graceful degradation
  - Dependability/Survivability
  - ....
- **Higher Uncertainty:**
  - → Feedback

Adaptivity versus Predictability and Dependability

- The relation between adaptivity and dependability and predictability is interesting
- Ideally, all changes of a system due to adaptation should be predictable and shouldn't jeopardize dependability.
- However, in many cases adaptivity increases the risk of non-predictable behavior.
- On the other hand adaptivity can also be a prerequisite for dependability.
- Tradeoffs between:
  - Dependability
  - Predictability
  - Adaptivity
  - Performance

  Cost, Value, Risk

Problems of Adaptivity

Adaptivity can introduce new problems:

- The adaptation mechanism itself consumes resources
- Harder to provide formal guarantees about the system
- Adds to the complexity
- May complicate the design process
- Requires tuning
- Bad tuning might lead to oscillations (stability problems)
- Sensors and actuators are necessary

Adaptivity Issues

- Adaptivity in system modelling – how is adaptivity modelled
- Efficient adaptation – how can adaptation mechanisms be made resource efficient
- Frameworks for adaptivity – unified frameworks for adaptivity (negotiation, contracts, QoS)
- Predictable and dependable adaptivity – what types of formal guarantees concerning predictability and dependability can be stated for an adaptive system
- Robustness and adaptivity – the relationships between robust design techniques and adaptive design techniques

Adaptivity Issues

- Verification and testing of adaptive system
- Adaptivity from an application's point of view – how should the adaptation mechanisms be exposed to the application developers (APIs etc)
- Interface between software and hardware
- Hardware based systems – How do model adaptivity?
- Run-Time reconfigurable hardware – How to use it to improve adaptivity
- Embedded multicore – Will the problems related to e.g. WCET estimation force the use of more adaptive and feedback-based approaches?

High-Level Objectives

- Integrate the efforts and combine the competences related to adaptivity in embedded systems within the thematic clusters of ArtistDesign.
- Create suitable interfaces, meeting points, and research contacts between the partners and the communities.
- Define the ontology for adaptivity in embedded systems,
  - Define relationship between adaptivity, reconfigurability, flexibility, sustainability, and robustness
  - Define relationship between adaptivity and predictability.

Long Term Vision

To generate a substantial advance in theory, methods and tools of relevance to adaptivity in embedded systems and to disseminate this into industry and to the scientific community at large.

State of the Integration in Europe

- Adaptivity is a very general concept
- Most research on embedded systems relates to adaptivity in some way
- However very 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
  - Funded by other sources → Networking and contacts
- Annual general meeting for the activity
  - Kick-off meeting in Lund 13-14 May 08
  - 20 participants representing 15 partners
  - http://www.artist-embedded.org/artist/Design-for-Adaptivity.html
- Smaller meetings and workshops organized by the partners
- A common wiki is under development
  - http://www2.control.lth.se/ArtistAdapt/
  - Public, but only partners may edit the content

Overall Assessment and Vision at Y0+1

- Good start and well attended kick-off meeting
- Numerous research activities
- Contributed to education about adaptive and feedback-based approaches.
  - Summer schools or special courses, often co-organized with Artist2.
- Several industrial contacts and
  - E.g. NXP, Ericsson, Volvo, STMicroelectronics, Evidence, Enea
- Major challenges
  - Integration between hardware and software communities
  - Align all views on what adaptivity in embedded systems really means

Quantitative Assessment of Y1

- More than 8 joint publications
- More than 12 research collaborations involving more than one partner, including several European projects
- More than 9 meetings or workshops organized or co-organized by the partners.
- Three educational events (summer schools, courses etc) organized or co-organized by the partners (sometimes jointly with Artist2)
- The creation of a wiki (http://www2.control.lth.se/ArtistAdapt/) in order to communicate and disseminate the results of the activity.

Meetings, Workshops & Courses

General Meeting:

- Kickoff Meeting, Lund 13-14 May 2008

Smaller Meetings:

- Bologna March 6-7, 2008
  - dynamic adaptation to changes in system behavior and requirements. Resource abstractions and interfaces.
  - University Bologna, SSSA, ETHZ, University Dortmund, University Saarland.
- Grenoble, 15th-16th Sept. 2008
  - BIP and DOL
  - Verimag, ETHZ
- Bologna June 5, 2008
  - Application model that serves as a basis for the joint work on adaptive changes.
  - UBologna, SSSA, ETHZ

Meetings, Workshops & Courses

- CASTNESS 2008 Workshop, Rome, Italy; date: 15- 18 Jan 2008
- First International Workshop on Adaptive and Reconfigurable Embedded Systems APRES 2008, St Louis, April, 08
- ArtistDesign meeting, location: Düsseldorf, Germany; date: 27th and 28th of November 2008:
- Workshop : Multicores: From Theory to Practice, Kaiserslautern, Oct 28, 08
- Course on Real-Time Control Systems: Theory and Practice, *Pisa, Italy – April 2-18, 2008*
- Course on Real-Time Kernels for Microcontrollers: Theory and Practice, Pisa 23-25 June

Tools and Platforms

- SWEET (SWEdish Execution Time tool)
  - Parametric WCET analysis
  - Målardalen and Usaarland
- MPA (Modular Performance Analysis) Toolbox
  - Real-Time Calculus of distributed embedded systems
  - Integration with DOL and BIP
  - Link to Symta/S tool and MPARM simulator
  - VERIMAG, ETH-Z, TU Braunschweig, Bologna, Uppsala
- TrueTime Simulator
  - Networked embedded control simulation in Simulink
  - ULUND + several Artist partners as users

Tools and Platforms

- SHARK RTOS
  - Soft and HArd Real-time Kernel
  - SSSA + others as users
- ForSyDe – Formal System Design
  - Framework for studying models of computation and various modelling and analysis techniques
  - KTH, Offis
- Hardware setup
  - Demonstrate self-protection and adaptability of embedded Real-Time Systems
  - TUBraunschweig

Scientific Highlights: Some project examples

- Modeling of Adaptive Systems
  - ANDRES Project
    - Modeling of adaptive systems using ForSyDe and SystemC
    - KTH, Offis, TU Vienna, ….
  - Integration of the design frameworks BIP and DOL
    - Combination of state-based and stream-based semantics
    - Verimag and ETH-Z

Scientific Highlights: Some project examples

- Adaptivity in Media Processing
  - Symbolic Quality Control for Multimedia
    - Fine grain quality control method for multimedia
    - Controller consisting of QoS manager and action scheduler
    - Verimag, ST Microelectronics
  - Adaptive Control of MPEG-2 decoding
    - TUKL, ULUND

Scientific Highlights: Some project examples

- Networks
  - Adaptive energy management in sensor networks
    - Energy harvesting and management through multiparametric programming
    - University Bologna, ETHZ
  - Networking support for flexible traffic scheduling
    - Switched Ethernet techniques
    - Aveiro, Mälardalen, UPVLC
  - Adaptive techniques to enhance Real-Time support of IEEE 802.11e
    - University of Catania

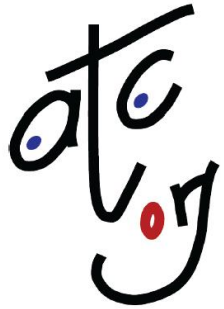
Scientific Highlights: Some project examples

- Adaptive & Flexible Resource Management
  - Task allocation
    - Optimization using search methods to support flexibility in design
    - Not only timing constraints (energy efficiency)
    - York
  - Adaptive Resource Management
    - Reservations, contracts, QoS management, media streams, feedback control
    - FRESCOR and ACTORS
    - York, SSSA, ULUND, TUKL, Evidence, Ericsson, Cantabria

Scientific Highlights: Some project examples

- Reference architectures for self-configuring automotive embedded systems
  - DySCAS project (KTH, Volvo, Offis)
- Flexible scheduling of control systems
  - Feedback scheduling, event-based control, …
  - UPC, ULUND, SSSA
- Run-time resource management
  - Simulation framework to study the dynamic behavior of run-time reconfigurable systems
  - DTU

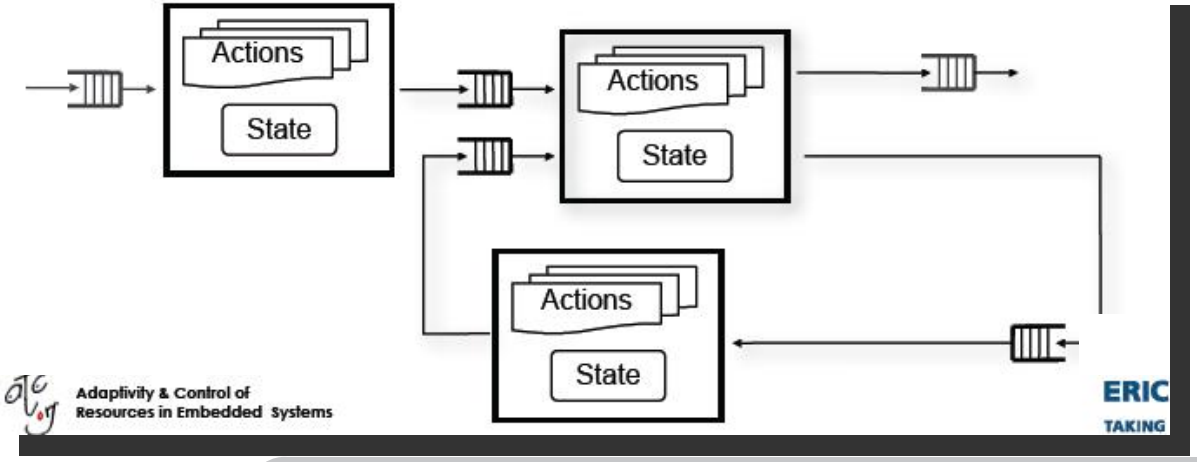
Feedback-Based Resource Management



- ACTORS – Adaptivity and Control of Resources in Embedded Systems
  - Ericsson (coord), SSSA, TUKL, Lund, EPFL, Akatech, Evidence
- Three main parts:
  - Dataflow Modeling for multimedia, control and signal processing
  - Reservation-based resource management (virtualization)
  - Feedback for providing adaptivity
- Demonstrators
  - Media streaming on cellular phones, control, high-performance video
- Platform: ARM 11 multicore with Linux 2.6.26

ACTORS: Dataflow Modeling

- Data flow programming with actors (Hewitt, Kahn, etc)
  - Associate resources with streams
  - Clean cut between execution specifics and algorithm design
  - Strict semantics with explicit parallelism provides foundation for analysis and model transformation
- CAL Actor Language (UC Berkeley, Xilinx) http://opendf.org
  - Part of MPEG/RVC

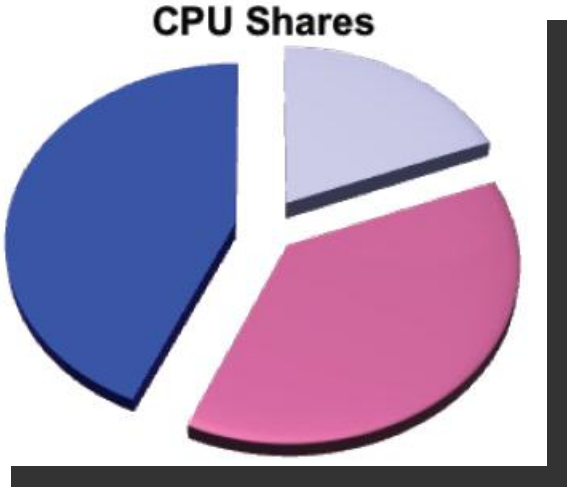


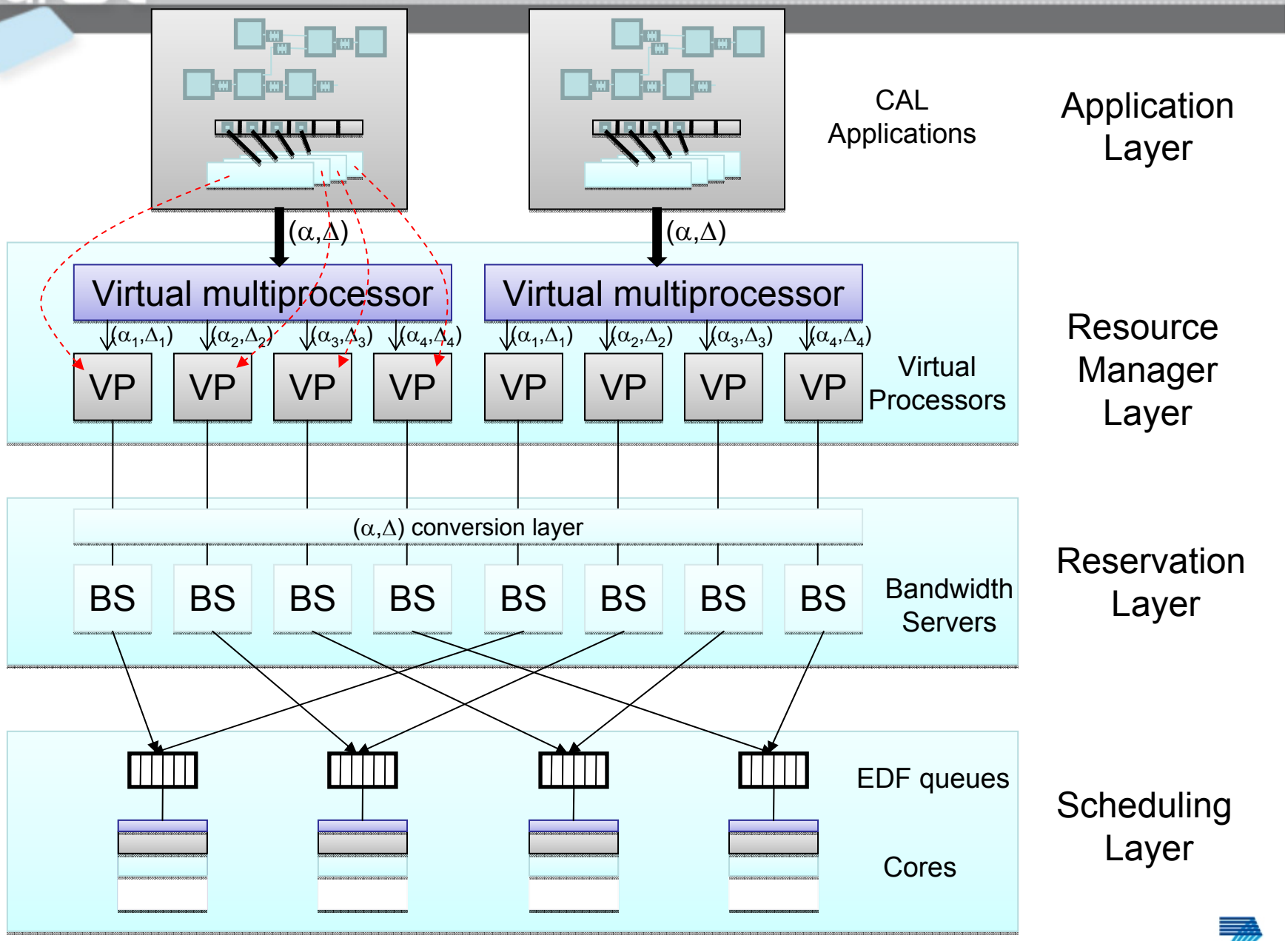
ACTORS: Model Transformations

- Merging of actors within statically schedulable regions
  - Singe-core or multi-core based platforms
- Splitting of actors
  - Express fine-grained parallelism
  - FPGA platforms
- Off-line schedulability analysis for CAL applications that can be translated into static precedence graphs (DAGs)
- Best-effort scheduling with dynamic processor allocation for dynamic CAL applications on multi-core platforms

ACTORS: Resource Reservations

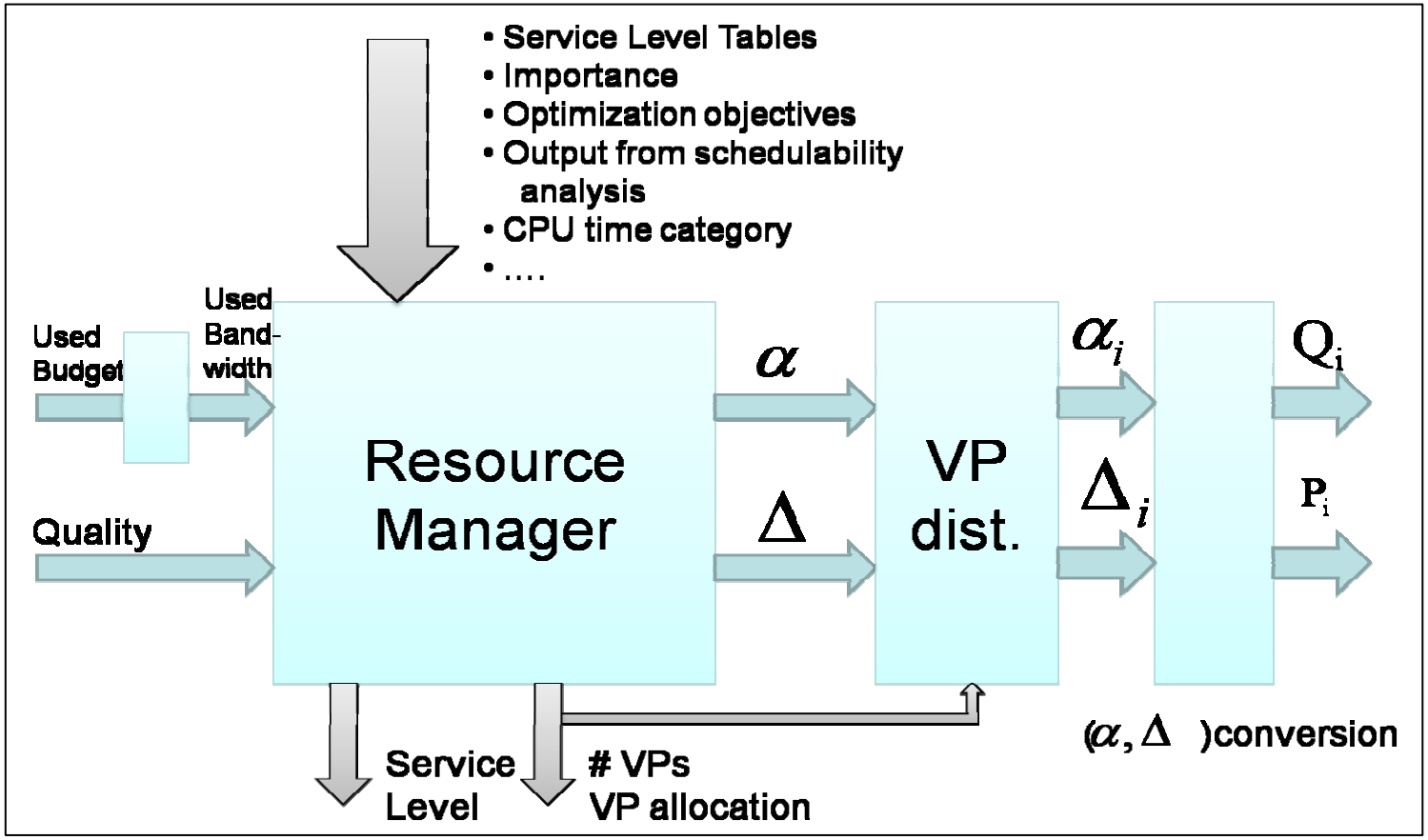
- Bandwidth servers for resource reservations
- Virtual processors
- Decouples the behavior of parallel activities (temporal isolation)




CAL Applications
Application Layer
(α,Δ)
(α,Δ)
Virtual multiprocessor
Virtual multiprocessor
(α1,Δ1)
(α2,Δ2)
(α3,Δ3)
(α4,Δ4)
VP
Virtual Processors
Resource Manager Layer
(α,Δ) conversion layer
BS
Bandwidth Servers
Reservation Layer
EDF queues
Cores
Scheduling Layer

ACTORS: Feedback

- Feedback at multiple levels:



Plans for Y2

- Continued integration of the work related to adaptivity in ArtistDesign
- At least 10 joint publications
- More than 15 research collaborations
- More than 10 meetings or workshops organized by the partners.
  - General activity meeting, Pisa 2-3 April, 09
  - FeBID ‘09, St Louis, 16 Apr, 09
  - APRES ‘09, Dublin, July 09
  - DySCAS Open Workshop, Feb 18, 09
- Three educational events (incl. the Artist Graduate School on Embedded Control)
- The content of the wiki will be substantially expanded.

Questions?