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
- Scientific Highlights
  - Adaptive Resource Management in ACTORS
  - Demo
- Plans for Year 4

8 minutes
8 minutes
10 minutes
2 minutes
Around half the size of a thematic cluster
Involved Partners

Core Partners:
- Karl-Erik Årzén (ULUND)
- Gerhard Fohler (TUKL)
- Giorgio Buttazzo (SSSA)
- Luis Almeida (UPorto)
- Luca Benini (UBologna)
- Maja D’hondt (IMEC)
- Eduardo Tovar (IP Porto)
- Björn Lisper (MdH)
- Alan Burns (York)
- Lothar Thiele (ETH-Z)
- Hamid Brahim (CEA)
- Axel Jantsch & Martin Törngren (KTH)
- Hamid Brahim (CEA)
- Luis Almeida (UPorto)
- Luca Benini (UBologna)
- Maja D’hondt (IMEC)
- Eduardo Tovar (IP Porto)
- Björn Lisper (MdH)
- Alan Burns (York)
- Lothar Thiele (ETH-Z)
- Hamid Brahim (CEA)
- 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 resource requirements
  - Designs based on worst-case prior information unfeasible
- Hardware development makes adaptivity a possibility
  - Reconfigurable hardware
  - Power saving technologies
- Hardware development 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
Objectives for Adaptivity

- Cope with uncertainties resource requirements (CPUs, network)
  - Unknown resource requirements
  - Varying resource requirements
  - Changes in total workloads (multiple applications)
- Cope with changes in resource availability
  - Changes in the amount of resources (# cores, # nodes, clock frequency, …)
    - To save power, minimize heat, ….
  - Changes in the quality of resources (network variability, ….)
Goals for Adaptivity

- Maximize the service delivered with a fixed level of resources
- Minimize the resources used while maintaining an acceptable service level
- Increase dependability
  - Reliability, safety, availability, maintainability, ….
Challenges for Adaptivity

- Adaptivity with formal guarantees
- Resource-efficient adaptivity
- Modeling of adaptive embedded systems
- Modeling of the adaptation mechanism
- ......
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 clusters and the communities.
- Define the ontology for adaptivity in embedded systems,
  - Define the relationship between adaptivity, reconfigurability, flexibility, sustainability, and robustness
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/](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
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)

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**

<table>
<thead>
<tr>
<th>Service Level</th>
<th>QoS</th>
<th>BW Requirement</th>
<th>BW distribution</th>
<th>Timing Granularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>240</td>
<td>60-60-60-60</td>
<td>20 ms</td>
</tr>
<tr>
<td>1</td>
<td>75</td>
<td>180</td>
<td>45-45-45-45</td>
<td>20 ms</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>120</td>
<td>30-30-30-30</td>
<td>20 ms</td>
</tr>
</tbody>
</table>

- **Thread IDs and how they should be grouped**

From system administrator to RM at startup:

<table>
<thead>
<tr>
<th>Appl.</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appl 1</td>
<td>10</td>
</tr>
<tr>
<td>Appl 2</td>
<td>20</td>
</tr>
<tr>
<td>Appl 3</td>
<td>100</td>
</tr>
<tr>
<td>Default</td>
<td>10</td>
</tr>
</tbody>
</table>
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

CAL Application
- Service levels
- Interface
- Happiness

Resource Manager
- Global optimization
- Reservation setup
- Interface
- Resource usage

Operating System
- Resource reservations
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

ILP Problem

\[
\begin{align*}
\max \sum_{i=1}^{n} w_i q_i x_i \\
\sum_{i=1}^{n} \alpha_i x_i & \leq C \\
\forall i, \sum_{i} x_i &= 1
\end{align*}
\]

Bin-Packing Problem
Resource Manager Tasks

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

Changes what is meant by sufficiently close based on EP:

Changes the AB so that the UB lies sufficiently close:
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](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
  - Alejandro 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)

- **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