Influence of different system abstractions on the performance analysis of distributed real-time systems

EMSOFT, Salzburg, Austria
02. October 2007

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Outline

- Motivation
- Abstractions
- Benchmarks
- Conclusions
System level performance analysis

Max. end-to-end delay?

Max. Bufferspace?

Max. CPU load?
Formal analysis methods

Distributed system

Performance values

Abstraction 3

\[ r_i = C_i + \sum_{j \in hp(i)} \frac{r_i}{T_{ij}} C_j \]

Analysis method 3
Motivating questions

- What is the influence of the different models on the analysis accuracy?
- Does abstraction matter?
- Which abstraction is best suited for a given system?

Evaluation and comparison of abstractions is needed!
How can we compare different abstractions?

- modeling effort
- scalability
- accuracy
- modular
- correctness
- exact
- compositional
- holistic
- learning curve
- performance metrics
- usability
- efficient implementation
- stepwise refinement
- tool support
- simple
- scope
- analysis time
- easy to use
- method 1
- method 2
- method 3
- method 4
- method 5
- CPU1
- CPU2
- CPU3
- I1
- I2
- O1
- O2
- AND
- OR
- system components
- connections
What makes a direct comparison difficult?

• Many aspects can not be quantified

• Models cover different scenarios:
Approach

• Leiden Workshop on Distributed Embedded Systems: http://www.tik.ee.ethz.ch/~leiden05/

• Define a set of benchmark examples that cover common area

• Define benchmark examples that show the power of each method
Contributions

• We define a set of benchmarks aimed at the evaluation of performance analysis techniques

• We apply different analysis methods to the benchmarks and compare the results obtained in terms of accuracy and analysis times

• We point out several analysis difficulties and investigate the causes for deviating results
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Abstraction 1 - Holistic scheduling

Basic concept: extend concepts of classical scheduling theory to distributed systems

- FP CPUs + TDMA bus [Tindell et al.] 1994
- CAN [Tindell et al.] 1995
- Mixed TT/ET systems [Pop et al.] 2002
- FP + data dependencies [Yen et al.] 1995
- FP + control dependencies [Pop et al.] 2000
- EDF offset based [González et al.] 2003
- ...
Holistic scheduling – MAST tool

[Reference: González Harbour et al.]

MAST - The Modeling and Analysis Suite for Real-Time Applications

System TXT

Results TXT
Abstraction 2 – The SymTA/S approach

[Richter, Ernst et al.]

Basic concept: Application of classical scheduling techniques at resource level and propagation of results to next component

Problem: The local analysis techniques require the input event streams to fit given standard event models

Solution: Use appropriate interfaces: EMIFs & EAFs
Abstraction 3 – MPA-RTC

[Thiele et al.]

Load model

Template curves

Service model

Arrival curves

Service curves

events

availability

service

$t$

$\Delta$

$t$

$\Delta$

$\alpha^u$

$\alpha^l$

$\beta^u$

$\beta^l$
Abstraction 3 – MPA-RTC

\[ [\alpha_l, \alpha_u] \rightarrow \text{GPC} \rightarrow [\beta^l, \beta^u] \]

\[ [\beta^l, \beta^u] \rightarrow [\alpha'_l, \alpha'_u] \]

\[ [\alpha'_l, \alpha'_u] \rightarrow \text{GPC} \rightarrow [\beta'^l, \beta'^u] \]

\[ [\beta'^l, \beta'^u] \rightarrow [\alpha^l, \alpha^u] \]
Abstraction 4 - TA based performance analysis

Verification of performance properties by model checking (UPPAAL)

Exact performance values

periodic stream

fixed priority scheduling

[Yi et al.]  [Hendriks et al.]
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Benchmarks

- Pay burst only once
- Complex activation pattern
- Variable feedback
- Cyclic dependencies
- AND/OR task activation
- Intra-context information
- Workload correlation
- Data dependencies
Benchmark 1 – Complex activation pattern

WCRT T3 ?

periodic
P = 60

I1

periodic
P = 5

I2

periodic

I3

CPU1
(FP)

C = 35

T1

H

T2

C = 2

L

M

CPU2
(FP)

C = 4

T3

L

C = 12

T4

H

O1

O2

O3
Benchmark 1 – Analysis results
Benchmark 1 – Result interpretation

$P_{I3} = 65$ ms
Benchmark 1 – Complex activation pattern

periodic
P = 60

I1 → T1 (H)
C = 35
CPU1 (FP)

periodic
P = 5

I2 → T2 (L)
C = 2
M

I3 → T4 (H)
C = 12
CPU2 (FP)

O1

periodic

T3 (L)
C = 4

O2

O3
Benchmark 2 – Variable feedback

periodic
P = 100

periodic
P = 5

Max delay?

CPU1 (FP)

T1
C = 2

T2
C = 2

CPU2 (FP)

T3

T4
C = 1

O1

I1

I2

O2

Exec. time C

C = 2

C = 2

C = 1

P = 100

P = 5
Benchmark 2 – Analysis results
Benchmark 3 – Cyclic dependencies

jitter

periodic with burst
P = 10

Max. delay?
Benchmark 3 – Analysis results

Scenario 1: priority T1 = high
priority T3 = low
Benchmark 3 – Analysis results

Scenario 2: priority T1 = low
priority T3 = high
## Analysis times [s]

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Discussion

- Approximation of complex event streams with standard event models can lead to poor performance predictions at local level

- Holistic approaches better in the presence of correlations among task activations (e.g. data dependencies)

- Cyclic dependencies represent a serious pitfall for the accuracy of compositional analysis methods

- Holistic methods less appropriate for timing properties referred to the actual release time of an event within a large jitter interval
Conclusions

• The analysis accuracy and the analysis time depend highly on the specific system characteristics

• None of the analysis methods performed best in all benchmarks

• The analysis results of the different approaches are remarkable different even for apparently basic systems

• The choice of an appropriate analysis abstraction matters

• The problem to provide accurate performance predictions for general systems is still far from solved
Thank you!

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Models:  http://www.tik.ee.ethz.ch/~leiden05/index2.html#publications