Calculating Latencies in an Engine Management System Using Response Time Analysis with MAST

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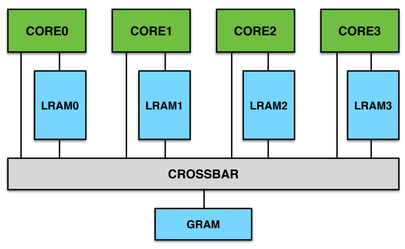
The Challenge

Challenge: To calculate latencies in an engine management system

The Platform



200 Mhz system-wide

Memory access times (cycles)

	LRAM0	LRAM1	LRAM2	LRAM3	GRAM
CORE0	1	9	9	9	9
CORE1	9	1	9	9	9
CORE2	9	9	1	9	9
CORE3	9	9	9	1	9

FIFO arbitration at memories

Real-time situation: Amalthea Model

http://www.amalthea-project.org/

Amalthea Tasks

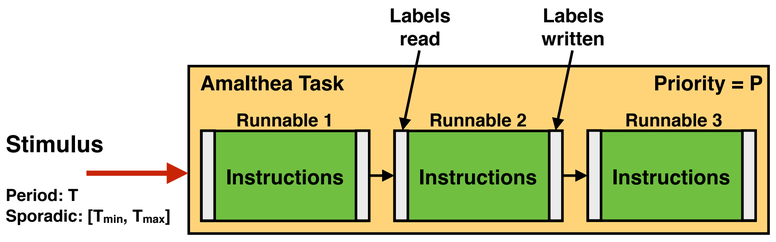
- 21 Tasks
- Statically assigned to a core
- Fixed Priority: preemptive/ cooperative
- Released by stimuli: periodic/ sporadic (arbitrary phasing)
- D=T
- Series of Runnables

Amalthea Runnables

- 1250 Runnables
- Read labels (memory)
- Instructions: constant/deviation
- Write labels (memory)

Labels

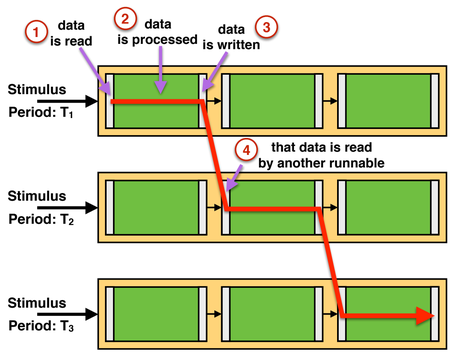
- 10000 Labels
- Mapped to GRAM/LRAM
- Local RAM = 1 cycle
- Non-Local RAM = 9 cycles



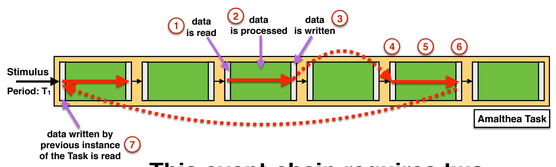
Event-chains

Latency model of data flows among non consecutive runnables

Event-chains crossing different tasks



Event-chains in the same task



This event-chain requires two activations of the task to complete

We assume stimuli are not synchronized (arbitrary phasings)

Approach: RTA with MAST

MAST Tool

Tool to model, analyze and optimize real-time systems

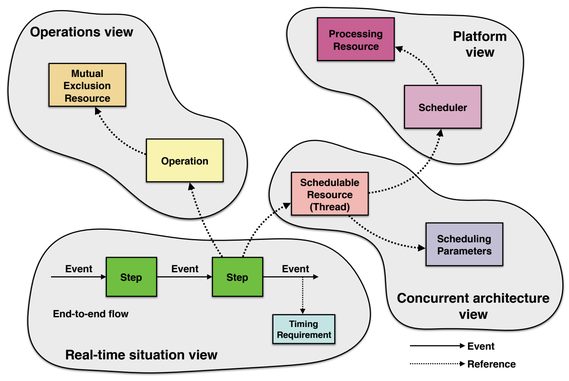
Open source, available at mast.unican.es (Windows and Linux)

Schedulabilty analysis tools	Optimization tools	Other tools	Support
• Holistic • Offset-based • Offset-based slanted • Offset-based w/ precedence • Offset-based brute force	• Simulated annealing • UD • ED • PN • NPD • EQS • EQF • HOSPA	• Simulator • Sensitivity analysis • Graphical editor • Results viewer	• Shared resources • Multipath e2 flows • Sporadic and Polling Servers • FP+EDF scheduling • Networks (AFDX) • Partitioned systems • Generator (GEN4MAST)

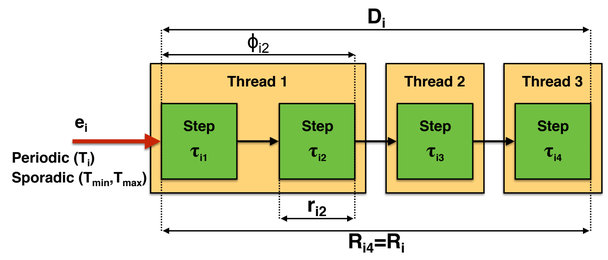
MAST Model

Aligned with OMG MARTE (SAM profile)

MAST model overview



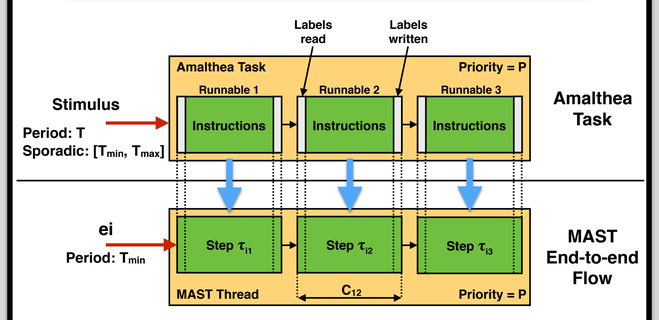
MAST model for analysis



Results from response-time analysis:

- Worst-case Local response time: r_{ij}
- Worst-case Global response time: R_{ij}
- Best-case response times: r^b_{ij}, R^b_{ij}

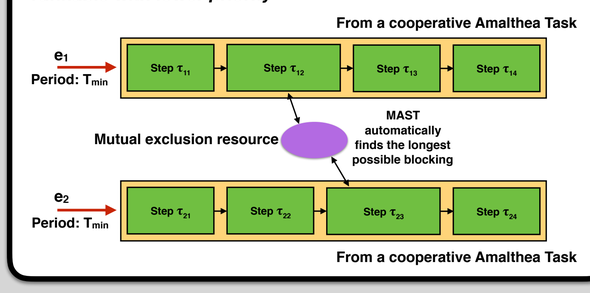
Amalthea to MAST transformation



WCET of steps = instructions + worst-case memory accesses

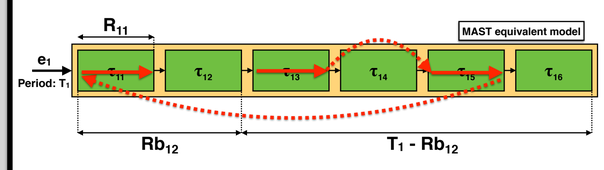
Modeling of cooperative tasks

Cooperative tasks can preempt lower priority cooperative tasks at runnable borders. As a consequence, cooperative tasks are blocked by an amount equal to the longest cooperative runnable with lower priority



Analysis of event-chains with MAST

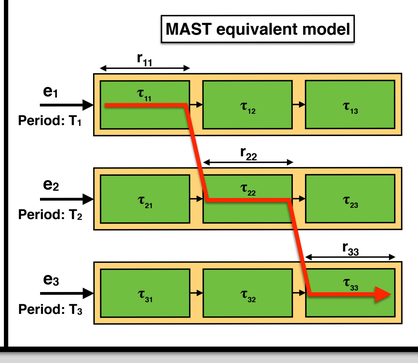
Event-chains in the same task



Worst-case latency $L=(T_1-R^b_{12})+R_{11}$

Best-case latency $L^b=(T_1-R_{12})+R^b_{11}$

Event-chains crossing different tasks



Worst-case latency assumes labels are written just after they are going to be read

$L=r_{11}+T_2+r_{22}+T_3+r_{33}$

Best-case latency assumes labels are written just before they are going to be read

$L^b=r^b_{11}+r^b_{22}+r^b_{33}$

Results

Sub-challenges

1 Ignoring memory accesses — "No_memory"

Only instructions are considered

2 All labels to GRAM — "All_GRAM"

Each memory (label) access consumes 4*9 cycles

3 Find optimized label to LRAM / GRAM assignment — "Optimized"

MAST doesn't support label optimizations, but…

83% of labels are accessed by only one core

PROPOSAL: Shared labels to GRAM, Non-Shared Labels to LRAM

LRAM is accessed without contention (1 cycle access)

Just 17% of labels have contention (4*9 cycles access)

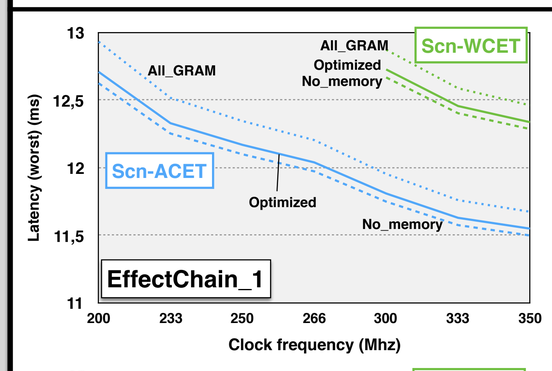
Latencies and system slack

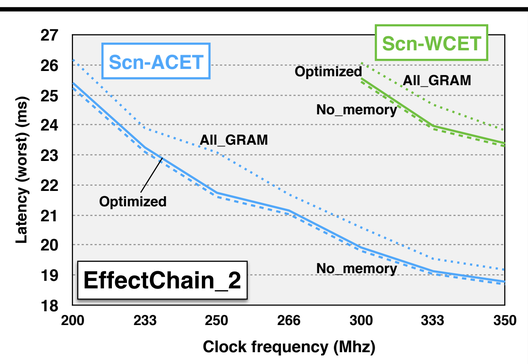
Problem: Provided model has utilization above 100%

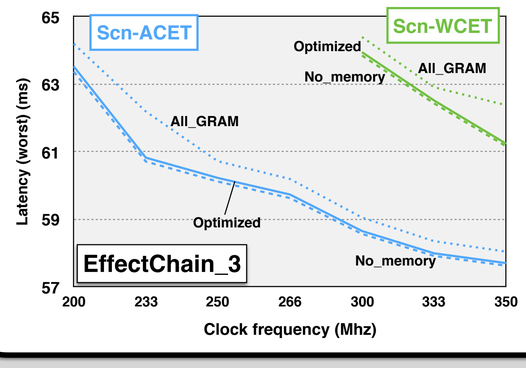
We test different clock frequencies [200-350 Mhz] +

Two scenarios:

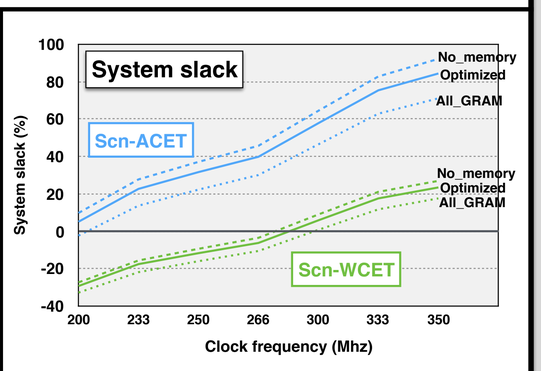
- Scn-ACET: mean number of instructions
- Scn-WCET: upper bound number of instructions







- Offset-Based w/ precedence relationships optimizations analysis is used
- Latencies with the optimized label assignment ("optimized") are closer to the case ignoring memory accesses ("no memory")
- Latencies cannot be calculated when utilization is above 100% (SCN-WCET for frequencies below 300 Mhz)



- System Slack: percentage by which execution times of the steps may be increased while still keeping the system schedulable
- Can be calculated for system with utilizations above 100% (such as SCN-WCET for frequencies below 300 Mhz)