WCET Analysis of Real-Time Systems with Shared TDMA Buses

Existing Techniques to Estimate the Worst-Case Execution Time (WCET)

Analysed Program

Worst-case Path Without Feasible Path Analysis

Worst-Case Path With Semantic Analysis

Contribution: Combine semantic analysis and shared TDMA bus analysis to enhance the WCET estimation

1. Time Division Multiple Access (TDMA)

Core A viewpoint:

Period π

Offset-based Approach: Worst-Case(T) = π - (σ - acc)

2. Satisfiability Modulo Theory for WCET

Satisfiability Modulo Theories (SMT) encoding:

b_1 "true" if the basic block i is executed

b_2 "true" if the transition block i → block j is taken

T (execution time at the transition block i → block j)

Offset = absolute

Pessimistic approach: Worst-Case(T) = π - (σ - acc)

3. Satisfiability Modulo Theory for TDMA

define-fun tdma_access (T, offset) {
  if (0 ≤ offset ≤ (π - acc))
    return T + acc
  else
    return T + (π - offset) + acc
}

define-fun tdma_offset (offset) {
  if (0 ≤ offset ≤ (σ - acc))
    return offset + acc
  else
    return acc
}

4. Proof of Concept on an Example

Each load and store requests an access to the shared bus.

load and store are put in separate basic blocks.

Control Flow Graph obtained with the LLVM framework.

SMT Formula:

\( (cmp = (y < 0)) \land (t_1.5 = b.1 \land cmp) \land (t_{1.2} = b.1 \land cmp) \land \ldots \)

\( \land (b.5 = t_{1.5} \lor t_{4.5}) \land \ldots \)

\( \land (c_{6.7} = \text{tdma access}(c_{5.6}, off_{5.6})) \land (off_{6.7} = \text{tdma offset}(off_{5.6})) \land \ldots \)

\( \land (c_{7.8} = c_{6.7} + T_{c}) \land (off_{7.8} = (off_{6.7} + T_{c}) \mod \pi) \land \ldots \)

\( \land (ET = t_{8.8} \land c_{8.9} \land c_{8.9}) \)

Using an SMT-solver, Find the smallest X: ET > X is unsatisfiable.

Hamza Rihan, Matthieu Moy, Claire Maiza

{first.last}@imag.fr

This work has been funded by grant CAPACITE (PIA-FSN2 n°P3425-146798) from the French Ministère de l’économie, des finances et de l’industrie.

Fully Timing Composable Architectures

"How to compute worst-case execution time by optimization modulo theory and a clever encoding of program semantics" Henry et al. LCTES2014