Explicit Preemption Point (EPP) placement for conditional code

Marko Bertogna and Nathan Fisher

RTSOPS’11
July 5, 2011, Porto, Portugal
Deferred-preemption model

- Introduced by Burns in 1994
  - a.k.a. Cooperative scheduling or Fixed Preemption Point (FPP) model
- Tasks are divided into a sequence of statically defined non-preemptive chunks
- Preemptions can take place only at chunk’s boundaries (Preemption Points)
Selecting Preemption Points

• A task has a set of Possible Preemption Points (PPP), each with a corresponding preemption cost.

• Only a subset of them is selected to become an Effective Preemption Point (EPP).

• Which EPPs have to be selected to minimize the WCET without affecting schedulability?
Existing results

• Upper bound on the maximum non-preemptive region $Q_i$ allowed for each task $\tau_i$
  
  - Bertogna, Baruah TII’10: EDF case (tight)
  - Yao et al. RTSJ’11: FP case

• Algorithm for the optimal selection of EPPs (ECRTS’11)
  – Conditional branches and loops assumed to be entirely contained inside a non-preemptive region (basic block)
Example

- Tasks composed of a sequence of Basic Blocks (BB) separated by a PPP

WCET of the BB

Preemption cost of the PPP

Constraint on the maximum distance between two consecutive EPPs

Q=8
Example

• Which PPP to activate?

\[ Q = 8 \]
Example

• Which PPP to activate?

• If all PPPs are activated, the overall WCET is 22

$$2 + 1 + 2 + 2 + 2 + 3 + 1 + 3 + 2 + 1 + 3 = 22$$
• Which PPP to activate?

A possibility is to activate only one point (PPP₄) with a resulting WCET of 15

\[2 + 2 + 2 + 1 + 3 + 2 + 3 = 15\]
Example

- Which PPP to activate?

![Diagram showing PPPs and Q=8]

- The optimal strategy is to activate two points (PPP₁ and PPP₅) obtaining a WCET of 14

\[2 + 1 + 2 + 2 + 1 + 2 + 1 + 3 = 14\]
Considerations

• The EPP selection algorithm evaluates each PPP at most once

• **Complexity linear** in the number of PPPs
  – Memory requirement: O(N+Q)
  – Computational complexity: O(N)

• Does not work if a conditional branch spans more than one basic block
• Tasks include lots of conditional branches!
• A conditional branch might span a big share of the task code:

• In these cases the deferred preemption model shows its limits (degenerates to non-preemptive)
Open problem

• How to select which EPP to activate for a (DAG-based) task structure including conditional branches?
Naïve idea

- Treating each branch separately does not work
- Example:

![Diagram showing a network with nodes and edges labeled with numbers. The network starts at node 3, passes through nodes 4 and 1, and ends at node 2, with a total value of Q = 8.](image-url)
Naïve idea

- Applying the linear method to the upper branch activates the red EPPs
Naïve idea

• Applying the linear method to the upper branch activates the **red EPPs**

• Applying the linear method to the lower branch activates the **green EPPs**

\[ Q = 8 \]
Naïve idea

• The optimal solution uses both red and green EPPs
Open problem(s)

• Algorithm that optimally selects which EPP to activate in a task structure including conditional branches, such that
  – Distance between two consecutive EPPs is at most Q
  – Overall WCET is minimized

• How to consider loops?

• Which task structures have to be considered for strictly structured programming languages
  – i.e., those including only (see Böhm-Jacopini theorem)
    • Sequential execution
    • Conditional execution
    • Iteration
thank you!

marko@sssup.it
Example

- For the $5^{th}$ PPP, the beginning of the task cannot be the preceding EPP ($2+2+2+1+2 > Q$)

\[ Q = 8 \]

What are the possible candidates?
Example

• What are the possible candidates for the preceding EPP of the 5th PPP?

Possible candidates:
PPP₀ : 2+2+2+1+2=8 ≤ Q → NO
PPP₁ : 1+2+2+1+2=8 ≤ Q → OK
Example

- What are the possible candidates for the preceding EPP of the 5th PPP?

Possible candidates:
- PPP\(_0\) : 2+2+2+1+2=8 \leq Q \to NO
- PPP\(_1\) : 1+2+2+1+2=8 \leq Q \to OK
- PPP\(_2\) : 2+2+1+2=7 \leq Q \to OK
Example

• What are the possible candidates for the preceding EPP of the 5th PPP?

Possible candidates:

PPP₀ : 2+2+2+1+2=8 ≤ Q → NO
PPP₁ : 1+2+2+1+2=8 ≤ Q → OK
PPP₂ : 2+2+1+2=7 ≤ Q → OK
PPP₃ : 3+1+2=6 ≤ Q → OK
Example

- What are the possible candidates for the preceding EPP of the 5th PPP?

Possible candidates:

- \( \text{PPP}_0: 2+2+2+1+2 = 8 \leq Q \rightarrow \text{NO} \)
- \( \text{PPP}_1: 1+2+2+1+2 = 8 \leq Q \rightarrow \text{OK} \)
- \( \text{PPP}_2: 2+2+1+2 = 7 \leq Q \rightarrow \text{OK} \)
- \( \text{PPP}_3: 3+1+2 = 6 \leq Q \rightarrow \text{OK} \)
- \( \text{PPP}_4: 3+2 = 5 \leq Q \rightarrow \text{OK} \)
Example

- Which one minimizes the WCET up to $\text{PPP}_5$?

Potential WCET of $[0, \text{PPP}_5]$:

- $\text{PPP}_1 : 2+1+2+2+1+2=10$
- $\text{PPP}_2 : 4+2+2+1+2=11$
- $\text{PPP}_3 : 6+3+1+2=12$
- $\text{PPP}_4 : 7+3+2=12$
Example

- Which one minimizes the WCET up to \(\text{PPP}_5\)?

Potential WCET of \([0, \text{PPP}_5]\):

- \(\text{PPP}_1: 2 + 1 + 2 + 2 + 1 + 2 = 10\)
- \(\text{PPP}_2: 4 + 2 + 2 + 1 + 2 = 11\)
- \(\text{PPP}_3: 6 + 3 + 1 + 2 = 12\)
- \(\text{PPP}_4: 7 + 3 + 2 = 12\)
Example

- PPP₁ is the best preceding EPP for PPP₅

![Diagram showing Q=8 and Min WCET values for PPP₁ to PPP₅]
Example

- Reaching the end of the task

Q = 8

Only two potential candidates:
PPP₄ : 7 + 3 + 2 + 3 = 15
PPP₅ : 10 + 1 + 3 = 14
Example

• PPP₅ is the best preceding EPP of the End point, i.e., it is the last one to be activated

Q=8
Example

- PPP₁ is the best preceding EPP of PPP₅
Example

- The start of the task is the best preceding EPP of $\text{PPP}_1$

![Diagram showing task sequence and execution time]

- $Q = 8$

- Min WCET: 2
- $\text{PPP}_2$: 4
- $\text{PPP}_3$: 6
- $\text{PPP}_4$: 7
- $\text{PPP}_5$: 10
- End: 14

© 2011 Scuola Superiore Sant’Anna