Performance Estimation for Embedded Systems with Data and Control Dependencies

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Motivation and Characteristics

Performance estimation.

- Worst case delay on the system execution time.

Characteristics:

- Distributed hard real-time applications.
- Heterogeneous system architectures.
- Fixed priority preemptive scheduling.
- Systems with data and control dependencies.

Schedulability Analysis

Schedulability test:

- The *worst case response time* of each process is compared to its *deadline*.

Process models:

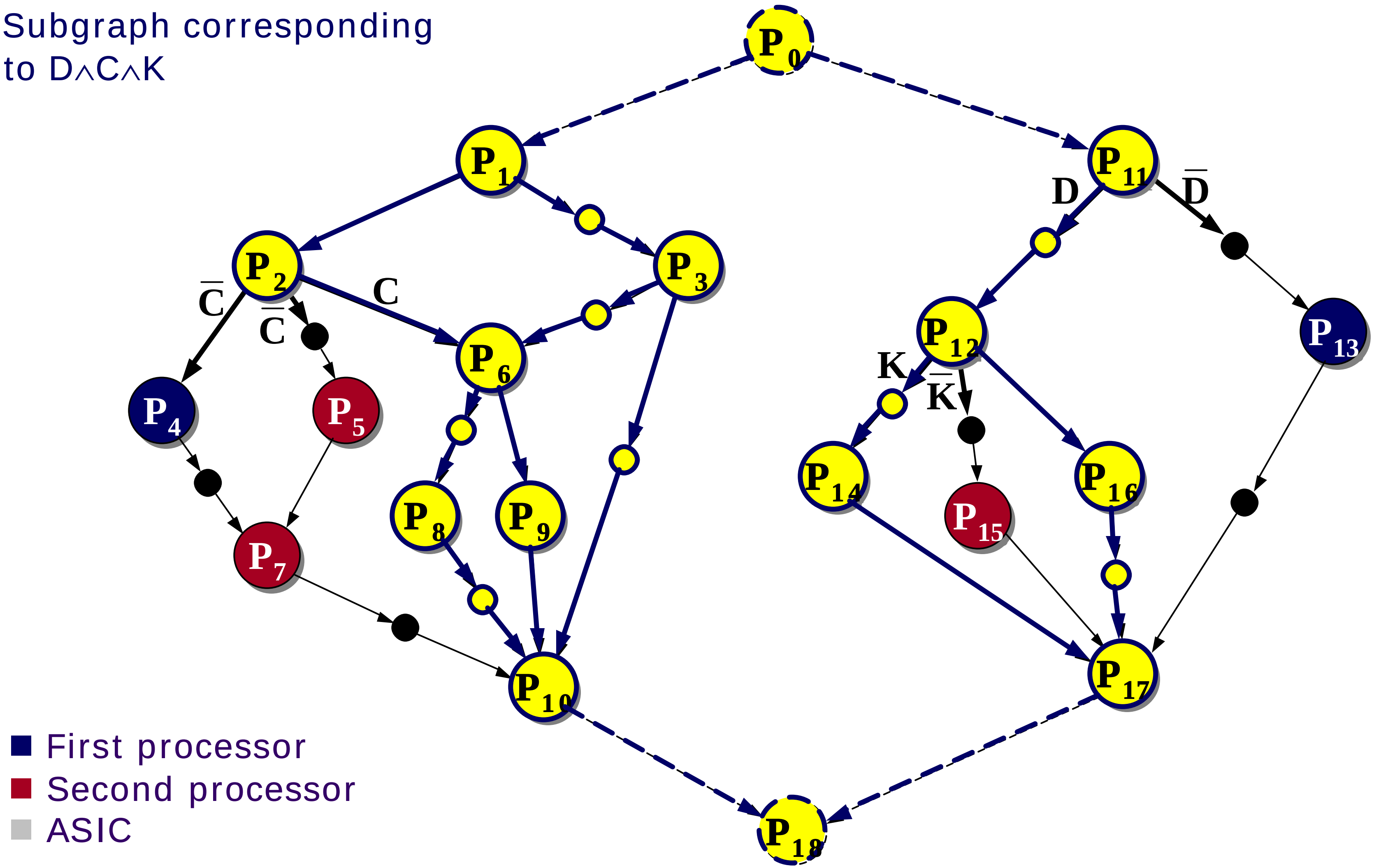
- Independent processes;
- Data dependencies: *release jitter*, *offsets*, *phases*;
- **Control dependencies**: *modes*, *periods*, *recurring tasks*.

Message:

- The pessimism of the analysis can be significantly reduced by considering the conditions during the analysis.

Conditional Process Graph

Subgraph corresponding to D∧C∧K



Problem Formulation

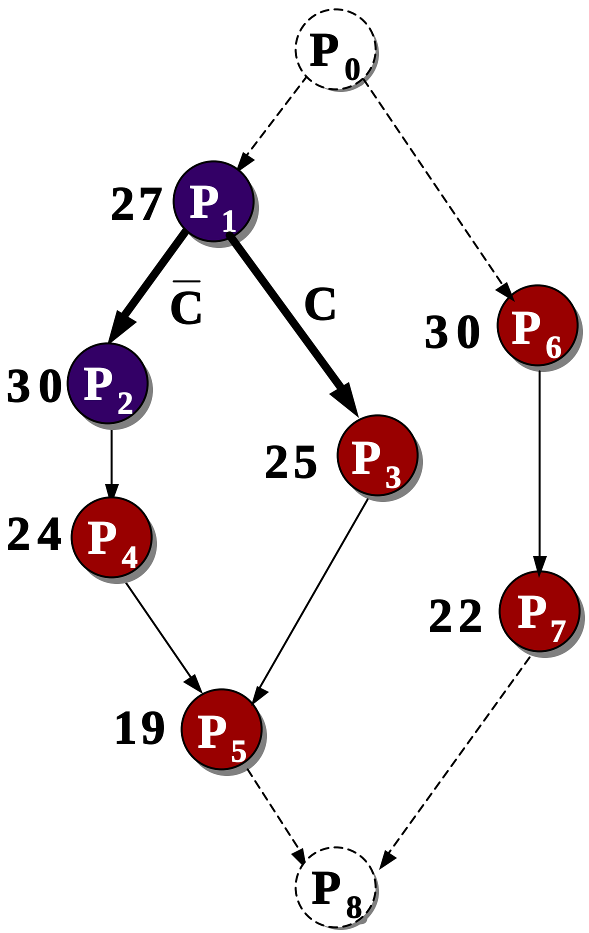
Input

- An application modelled using **conditional process graphs** (CPG).
- Each CPG in the application has its own independent *period*.
- Each process has a *worst case execution time*, a *deadline*, and a *priority*.
- The system architecture and mapping of processes are given.

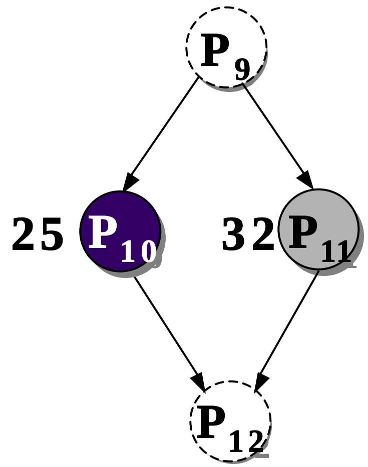
Output

- Worst case response times for each process.

Performance estimation for systems modelled using conditional process graphs.



G_1: **200**



G_2: **150**

CPG	Worst Case Delays	
	No conditions	Conditions
G_1	120	100
G_2	82	82

Deadline: 110

Task Graphs with Data Dependencies

- K. Tindell: Adding Time-Offsets to Schedulabilty Analysis, Research Report

  Offset: fixed interval in time between the arrival of sets of tasks.

  Can reduce the pessimism of the schedulability analysis.

  Drawback: how to derive the offsets?

- T. Yen, W. Wolf: Performance Estimation for Real-Time Distributed Embedded Systems, IEEE Transactions On Parallel and Distributed Systems

  Phase (similar concept to offsets).

  Advantage: gives a framework to derive the phases.

Schedulability Analysis for Task Graphs

```
DelayEstimate(task graph G, system S)
      for each pair (P_i, P_j) in G
            maxsep[P_i, P_j]=∞
      end for
      step = 0
      repeat
            LatestTimes(G)
            EarliestTimes(G)
            for each P_i ∈ G
                  MaxSeparations(P_i)
            end for
      until maxsep is not changed or step < limit
      return the worst case delay d_G of the graph G
end DelayEstimate
```

LatestTimes(G): worst case response times and upper bounds for the offsets

EarliestTimes(G): lower bounds for the offsets

MaxSeparations(P_i): maximum separation: maxsep[P_i, P_j]=0 if the execution of the two processes never overlaps

Schedulability Analysis for CPGs, 1

Two extreme solutions:

- Ignoring Conditions (IC)

  Ignore control dependencies and apply the schedulability analysis for the (unconditional) task graphs.

- Brute Force Algorithm (BF)

  Apply the schedulability analysis after each of the CPGs in the application have been decomposed in their constituent unconditional subgraphs.

Schedulability Analysis for CPGs, 2

In between solutions:

- Conditions Separation (CS)

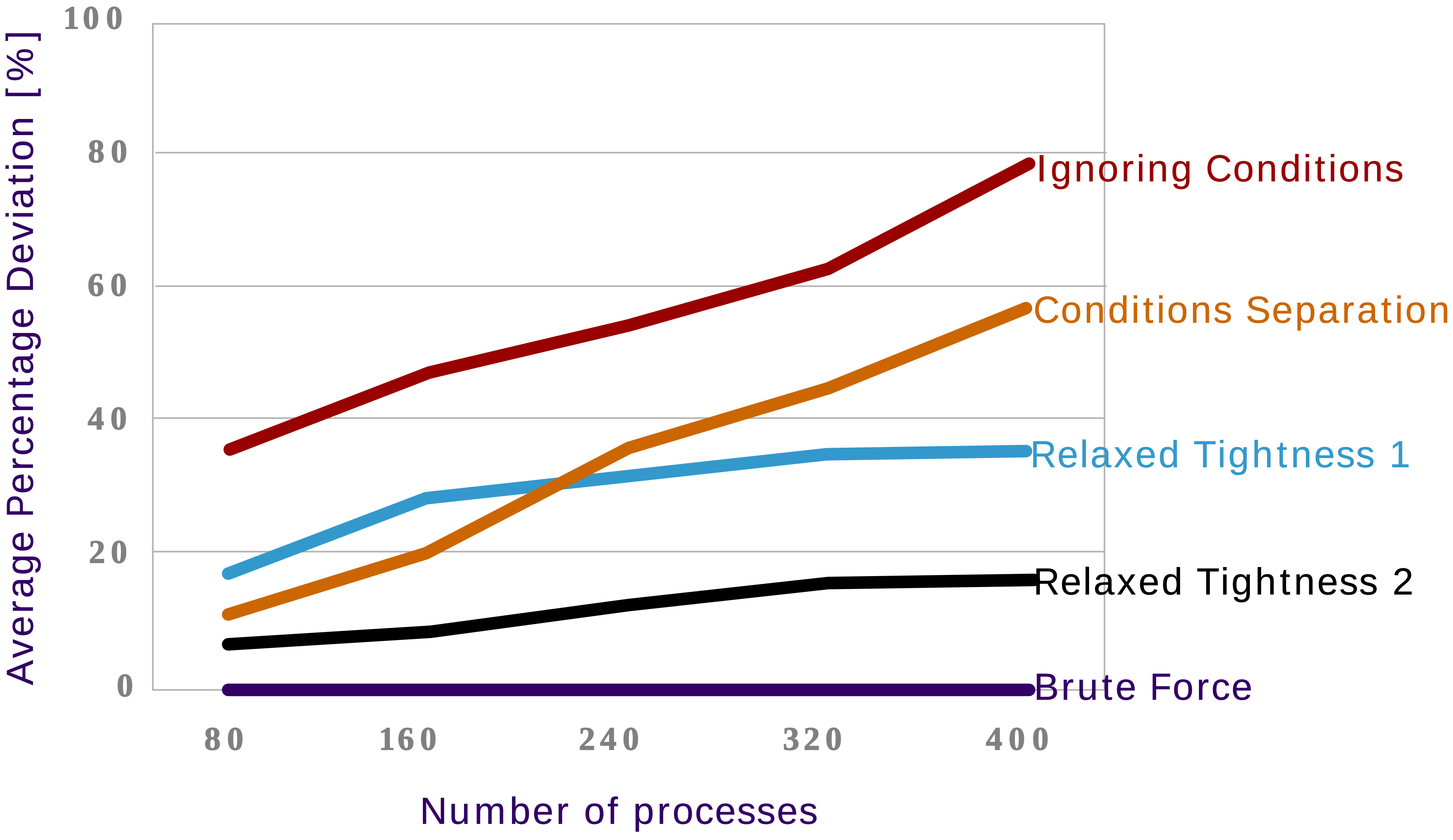
  Similar to *Ignoring Conditions* but uses the knowledge about the conditions in order to update the **maxsep** table:

  maxsep[P_i, P_j] = 0 if P_i and P_j are on different conditional paths.

- Relaxed Tightness Analysis (two variants: RT1, RT2)

  Similar to the *Brute Force Algorithm*, but tries to reduce the execution time by removing the iterative tightening loop (relaxed tightness) in the **DelayEstimation** function.

Experimental Results



Conclusions

- **Performance estimation** for hard real-time systems with control and data dependencies.
- Modelling using **conditional process graphs** that capture both the flow of data and that of control.
- Heterogeneous architectures, **fixed priority scheduling**.
- Five approaches to the schedulability analysis of such systems.
- Extensive experiments and a real-life example show that: The pessimism of the analysis can be significantly reduced by considering the conditions during the analysis.