**Objective**

For real-time multimedia systems with software and hardware modes, we develop:
- HW/SW Multi-Modal Model.
- Pseudo-polynomial EDF-Schedulability analysis of a real-time system with software/hardware modes.

**Models & Definitions**

A hardware mode $\Omega(i) = (\Pi(i), \Theta(i), \Delta(i))$ is a periodic resource (PR) where capacity $\Theta(i)$ is provided within $\Delta(i)$ time unit from the beginning of period $\Pi(i)$.

A software mode is characterized by a sporadic task system $\tau(i) = \{T_{i1}, \ldots, T_{in}\}$ where $T_{ij} = (e_{ij}, d_{ij}, p_{ij})$.

**Mode Change Model**

- Hardware: PR
- Software: Sporadic Task
- Job
- $d_{i}^{(j)}$ = $p_{i}^{(j)}$
- $\geq P_{i}^{(j)}$

**EDF Schedulability Requirements**

- A deadline miss is preceded by a busy interval where demand (dbf) > supply (sbf).
- $SBF(\Omega, j)$: Minimum execution supply a mode may receive over $t$ executed upon $\Omega$.
- $DBF(\tau(i), j)$: Maximum execution of jobs of $T_{ij}$ have arrival and deadline within the interval of $t$.

To avoid a deadline miss, check: $\text{dbf}(t) \leq \text{sbf}(t)$, $t > 0$.

- However, dbf and sbf derivation is non-trivial due to mode change requests.

**Mode Change Supply/Demand**

- Supply
  - $M_i$ $\beta_{\text{post}}(M_i, x, \phi)$ $M_j$
  - $t_{k}$ $\delta_{k}$ $M_i$
  - $M_j$
  - $x$
  - $\phi$
  - $\Delta$
  - $\Pi$

- Demand
  - $x$
  - $\phi$
  - $\Delta$
  - $\Pi$

**Schedulability Conditions**

Check five types of intervals to ensure that demand is always less than supply.

- Condition “C”
- Condition “B”
- Condition “A”

**Simulations**

**Environment**

- MATLAB
- Three modes with 4 random tasks.
- $\Pi_{1} = 10$, $\Delta_{1} = \Pi_{1}$.
- 200 simulation run.

Compared against state-of-the-art algorithm by Phan et al. (2010) denoted as SURG (Schedulability using a reachability graph). Our approach is SUBI (Schedulability using Bounded iteration).

To check the schedulability, the number of modes by one with randomly generated tasks from the tasks table.

**Future Work**

- Extend for multi-modal systems with mixed tasks (soft/hard deadlines).
- Apply the model to a vehicular control systems.
- Parallelize to accelerate design space exploration of multi-mode systems.

**Comparison of SUBI vs SURG**

**Execution Time**

- Schedulability
- Total capacity $\Theta(1)$, $\Theta(2)$, $\Theta(3)$

**Scalability**

**Number of Modes**

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