Cache Persistence Aware Response Time Analysis for Fixed Priority Preemptive Systems

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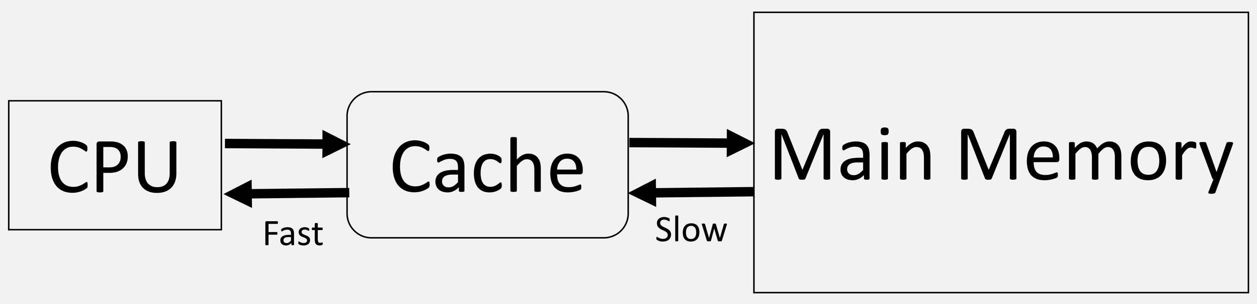
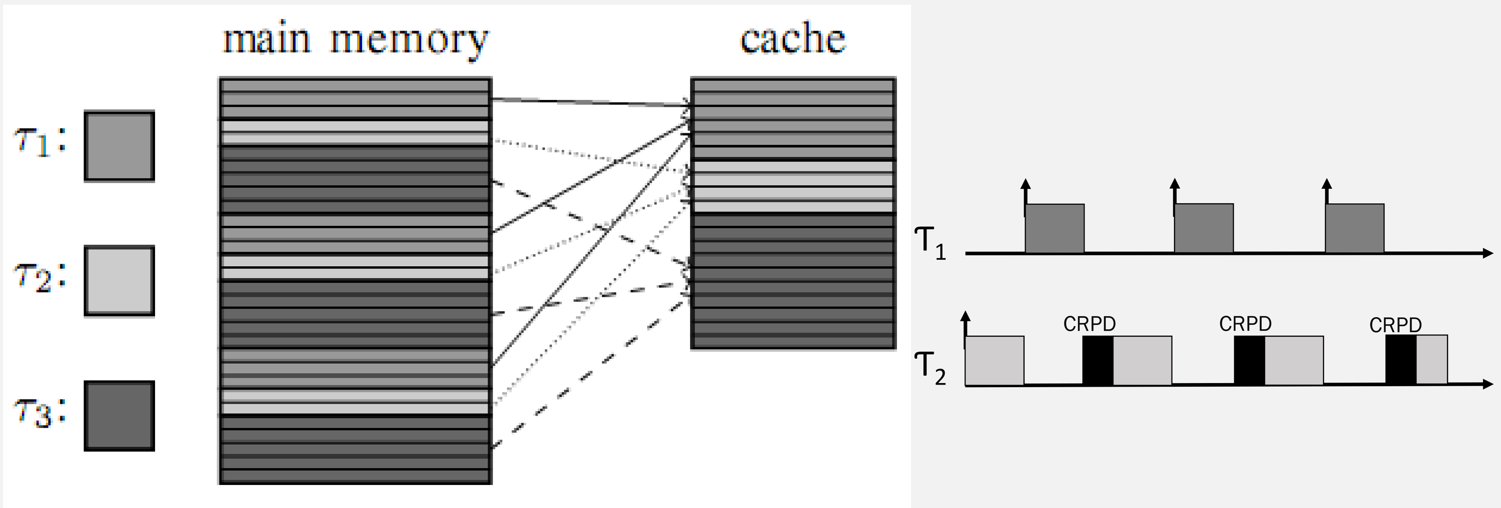
1. Motivation

- **Variations** in WCET/WCRT due to cache hit/miss.
- Low priority tasks may need to account for **cache evictions** due to execution of high priority tasks **(CRPD).**
- State-of-the-art approaches for CRPD calculation **only** consider the **impact of high priority taks** on memory demand of low priority ones.
- However, state-of-the-art **does not consider** the effect of low priority tasks on the memory demand of high priority tasks.

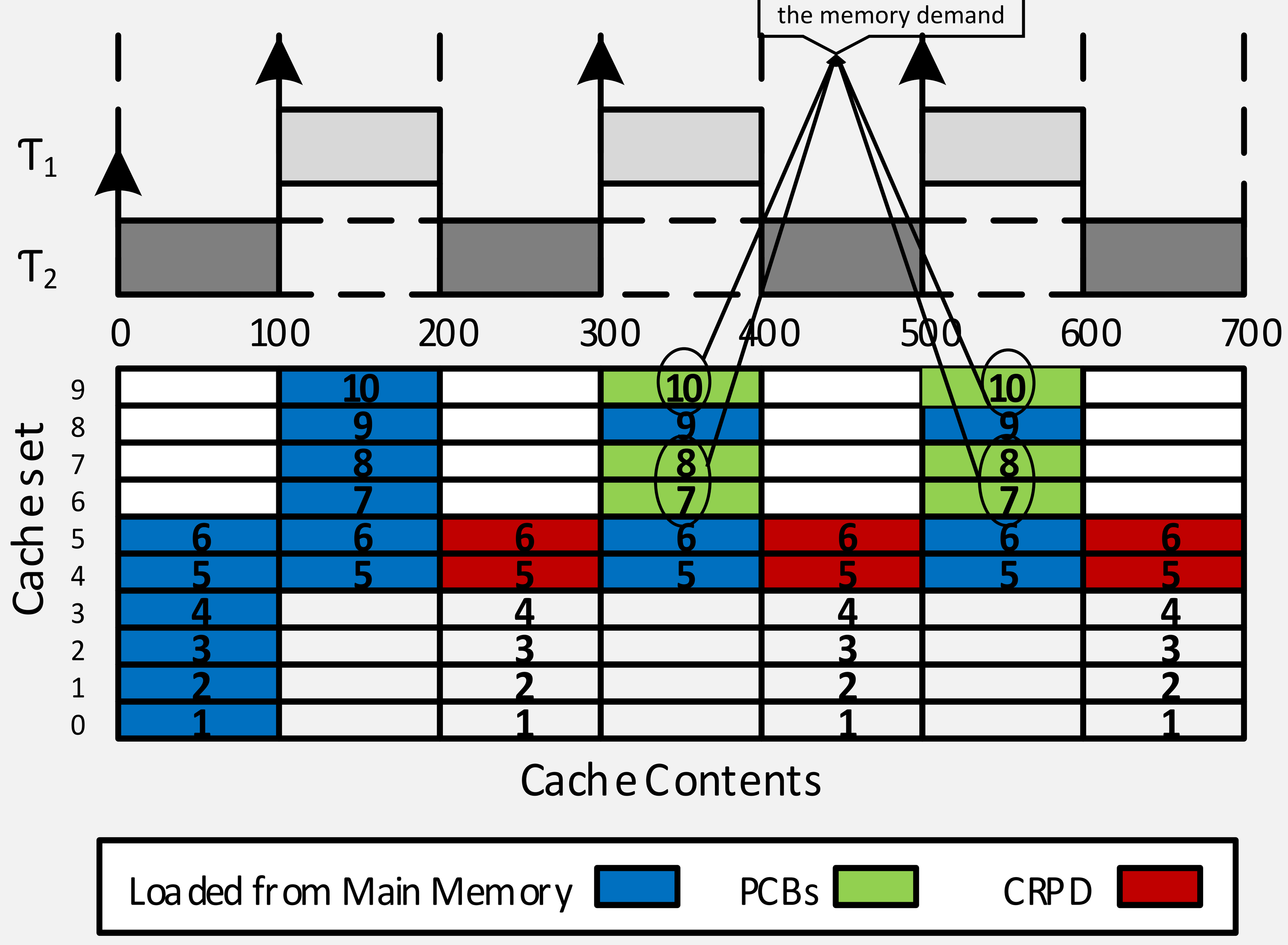




2. Contributions

- Preempting task can have content persisting in the cache between successive job executions.
- We introduce the concept of **cache persistence** in the context of **WCRT analysis.**
- We model the effect **of Persistent Cache Blocks (PCBs)** on the memory demand of preempting tasks.
- We account for the number of PCBs that can be evicted, i.e., **Cache Persistence Reload Overhead (CPRO)**

3. Example



4. Calculating CPRD and CPRO

4.1 ECB-Union and UCB-union Multi-set Approaches

- CRPD is usually calculated using **Evicting Cache blocks (ECBs)** of the preempting task and **Useful Cache Blocks (UCBs)** of the preempted task.
- **ECB-union** approach considers **ECBs** of the preempting task T_j as well as all tasks in **hep(j).**
- **UCBs** of all tasks in **aff(i,j)**, i.e., **hep(i) and lp(j)** can be evicted by T_j.

$$CRPD_{i,j} = \max_{\forall k \in aff(i,j)} \left(|UCB_k| \cap \left(\bigcup_{\forall j \in hep(j)} ECB_j \right) \right)$$

- **UCB-union multi-set** approach **improve** upon the ECB-union approach by additionally taking into account the **actual number of jobs** released by T_j and all tasks in **aff(i,j).**

4.2 A Union approach for CPRO calculation

- **Persistent Cache blocks (PCBs)** of a preempting task T_j executing during the response time of T_i can be evicted due to executions of tasks in **hep(i).**
- **Similar** formulation to ECB-union approach but considering **PCBs** of the **preempting task T_j** Instead of UCBs.
- **ECBs** of all tasks in **hep(i)** can evict PCBs of T_j.

$$CPRO_{j,i} = PCB_j \cap \left(\bigcup_{\forall k \in hp(i) \setminus j} ECB_k \right)$$

5. Improved WCRT Analysis

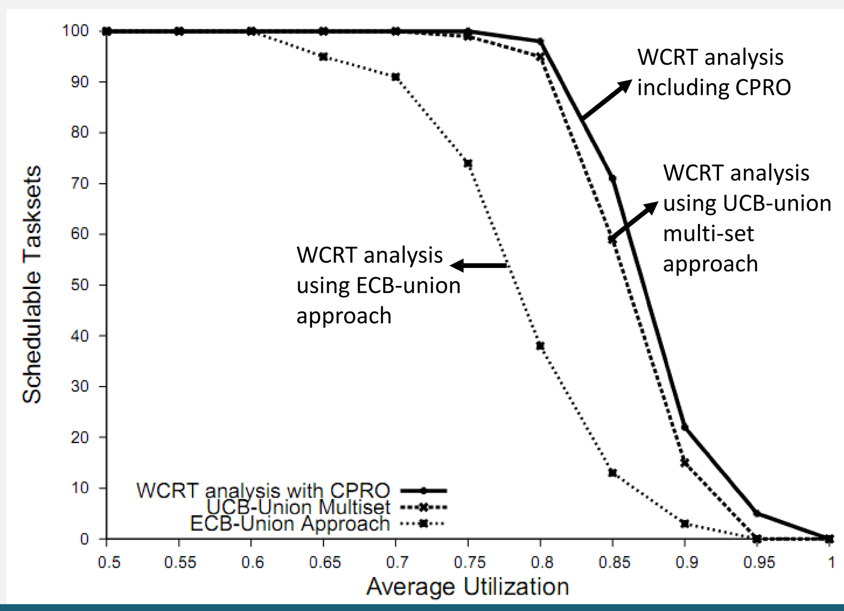
- **Existing WCRT analysis** for FPPS in the state-of-the-art **only** account for **CRPDs.**
- Our **Proposed WCRT analysis** incorporates for **both CRPDs and CPRO**, resulting in less pessimistic WCRT bounds.

$$R_i(t) = P_i + MD_i + \sum_{\forall j \in hp(i)} P_j + MD_j + \sum_{\forall j \in hp(i)} CRPD_{i,j} + \sum_{\forall j \in hp(i)} \left[\frac{R_i}{T_j} - 1\right] * (P_j + MD^r{}_j + CPRO_{j,i})$$

- $P_i + MD_i$: Separately considering worst-case processing and memory demand instead of C_i, in order to account for variable memory demand
- MD_j: One job of T_j will load all its ECBs (max memory demand)
- $CRPD_{i,j}$: Accounting for evictions of UCBs of T_i
- $MD^r{}_j$: Memory Demand of T_j when all its PCBs are in the cache
- $CPRO_{j,i}$: Accounting for evictions of PCBs of T_j

5.1 Preliminary Results

- Initial results shows **that WCRT analysis with CPRO dominates** the **ECB-union** and **UCB-union multi-set** approaches.



6. Future Work

- In future, we plan to extend the analysis to set associative and data caches.
- Provide a less pessimistic multi-set approach to calculate CPRO.
- A combined approach to calculate both CRPD and CPRO.
- Extensive experimental evaluation using available benchmarks by varying different system parameters.

References

[1] S. Altmeyer, R. Davis, C. Maiza et al., "Cache related pre-emption delay aware response time analysis for fixed priority pre-emptive systems," in RTSS'11. IEEE, 2011, pp. 261–271

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