Winter Research Recap and New Exploration: Mixed-Criticality & Probabilistic Timing Guarantee

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0. Goal of This Meeting

- Paper I read on winter
- Proposal recap
- New exploration on MC & Probabilistic timing guarantee
- Direction & plan

Part I

1. Paper I read on winter

Papers Reviewed During Winter

- Schedulability analysis of global scheduling algorithms on multiprocessor platforms (09)
- ML for RT: Priority Assignment Using Machine Learning (RTAS'21)
- RT-Swap: Addressing GPU Memory Bottlenecks for Real-Time Multi-DNN Inference (RTAS'24)
- MC-SDN: Supporting Mixed-Criticality Real-Time Communication Using Software-Defined Networking (RTSS'18)
- Cros-Rt: Cross-Layer Priority Scheduling for Predictable Inter-Process Communication in Ros 2 (RTAS'25)
- Priority-Aware Attention Meets Generative Flow Networks for Global Fixed-Priority Assignment (RTSS'25)

  $\Rightarrow$ **OPA** / **PAL** / **PANDA** / **RLRD** / **PAGFN**

Part II

2. PROPOSAL

Research Proposal Recap

Goal: Make improvement on global fixed priority assignment problem using neural network

Existing approach

- Heuristic / OPA / OPA-BK
- Supervised Learning (PAL)
- RL (PANDA / RLRD)
- GFlowNet (PAGFN)

Problem

- Not enough meaningful margin to make from the topic I chosed.

Suggestion

- broaden the topic instead of the frame inside global fixed priority assignment problem

Part III

3. Extra remark (OPA-BK)

OPA-BK: Optimality

Q. Is OPA-BK optimal on RTA-LC?

- **A**: Optimal if backtracking is performed for the worst-case $(n!/m!)$, but in practice, constraints like max iterations or time-outs are imposed due to computational complexity.

Comparison with OPA

- OPA-BK is superior as D-RTA-LC dominates the results of the DA test used in traditional OPA.
- Performance with backtracking limited to 1,000 iterations:
  - 2 CPUs: 3% difference.
  - 16 CPUs: 0.75% difference.

Table 1: Number of tasksets found to be schedulable

	#Processors			
Algorithm	**2**	**4**	**8**	**16**
DA-LC (OPA)	24,278	23,085	22,989	23,270
RTA-LC(OPA-Bk)	25,096	23,748	23,393	23,444

COMPARISON WITH OPA & OPA-BK

TABLE VI: Runtime Comparison

Model	Implicit deadline (m, n, u)			Constrained deadline (m, n, u)		
	(4, 32, 3.2)	(6,48, 5.0)	(8, 64, 6.0)	(4, 32, 2.2)	(6, 48, 3.2)	(8, 64, 4.8)
DMPO	0.0079	0.0118	0.0221	0.0033	0.0050	0.0068
D-CMPO	0.0085	0.0125	0.0243	0.0046	0.0079	0.0115
DkC	0.0087	0.0134	0.0270	0.0058	0.0121	0.0206
OPA	0.3528	0.4198	0.6440	0.2671	0.3756	0.5392
PANDA	0.0618	0.1106	0.1590	0.0575	0.1043	0.1480
RLRD	0.0142	0.0293	0.0367	0.0117	0.0266	0.0328
PAGFN	0.1013	0.1801	0.3129	0.1078	0.2115	0.2817
OPA-bk	5.6969	20.4322	36.5127	1.3223	5.4198	12.0788

Part IV

4. Recommended topics

Mixed Criticality (MC): Theory & Systems

Theoretically using MC

- Preemptive scheduling of multi-criticality systems with varying degrees of execution time assurance (RTSS'07)
- Response-Time Analysis for Mixed Criticality Systems (RTSS'2011)
- Preemptive uniprocessor scheduling of mixed-criticality sporadic task systems (JACM'2015)

Applying MC on system

- MC-SDN: Supporting Mixed-Criticality Scheduling on Switched-Ethernet Using Software-Defined Networking (RTSS'18)
- Physics-Informed Mixed-Criticality Scheduling for F1Tenth Cars with Preemptable ROS 2 Executors (RTAS'25)

Applying MC on specific domain

- Mixed-Criticality Scheduling of Energy-Harvesting Systems (RTSS'22)
- Mixed-Criticality Federated Scheduling for Relaxed-Deadline DAG Tasks (RTSS'24)

Probabilistic Timing Guarantee: Theory

RTSS 2025 Session 1: Probabilistic Real-Time Systems

Theoretically using Probabilistic timing guarantee

- Single processor Stochastic analysis of periodic real-time systems (RTSS'02)
- Efficiently Approximating the Probability of Deadline Misses in Real-Time Systems (ECRTS'18)
- Efficiently Approximating the Worst-Case Deadline Failure Probability Under EDF (RTSS'21)
- Analytical Approximations in Probabilistic Analysis of Real-Time Systems (RTSS'22)
- Reducing Worst-Case Deadline Failure Probability for EDF Scheduling (RTSS'25)
- Response Time Analysis for Probabilistic DAG Tasks in Multicore Real-Time Systems (RTSS'25)

Obtaining probabilistic worst case execution time (pWCET)

- Drawing Lines for Measurement-Based Probabilistic Timing Analysis (RTSS'24)

Probabilistic approach on specific domain

- Probabilistic Response-Time-Aware Search for Transient Astrophysical Phenomena (RTSS'25)

Part V

5. Direction & plan

4 pages excluded