Using Linked List in Exact Schedulability Tests for Fixed Priority Scheduling

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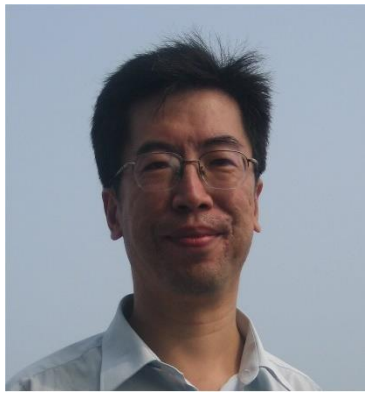

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Outline

- The classic model (LL) and the response time analysis (RTA)
- Current best exact test
- Our linked list-based methods
- Conclusion

The classic model (LL)

- **The classic preemptive model**
  - **C. L. Liu and L. Layland. Scheduling algorithms for multiprogramming in a hard-real-time environment. *Journal of ACM*, 1973, 20(1): 46–61.**
- **For *fixed priority scheduling*, synchronous release defines critical instant of tasks.**
- **The *Rate-Monotonic* (RM) fixed priority scheduling is optimal for periodic/sporadic tasks that comply with a restrictive system model and that have implicit deadlines.**

The RTA-based exact test

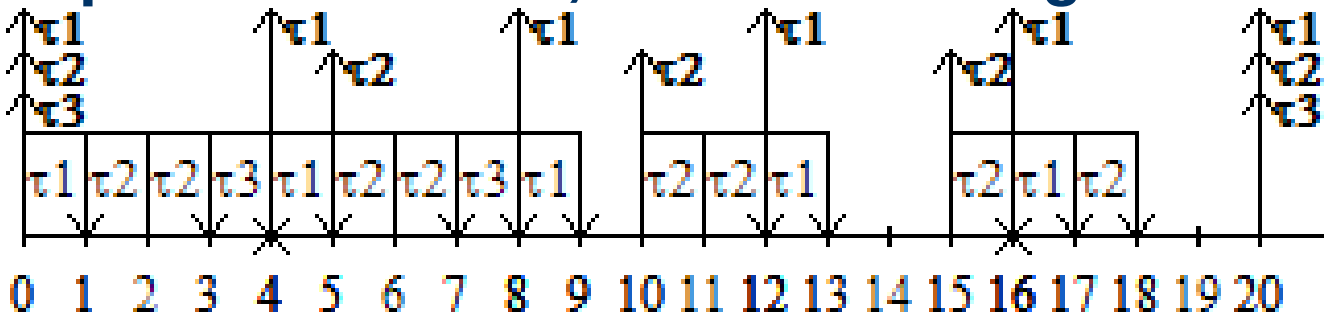
- Audsley, Burns, Richardson, Tindell, and Wellings presented the famous response time analysis (RTA) algorithm, calculating in an iterative way.
  - Applying new scheduling theory to static priority preemptive scheduling. *Software Engineering Journal*, 1993, 8(5): 284–292.
  - $R_i = C_i + sum_{0<j<i}(ceiling(R_i/T_j)*C_j)$
- The RTA-based test is a kind of exact (necessary and sufficient) schedulability test.

Current best exact test

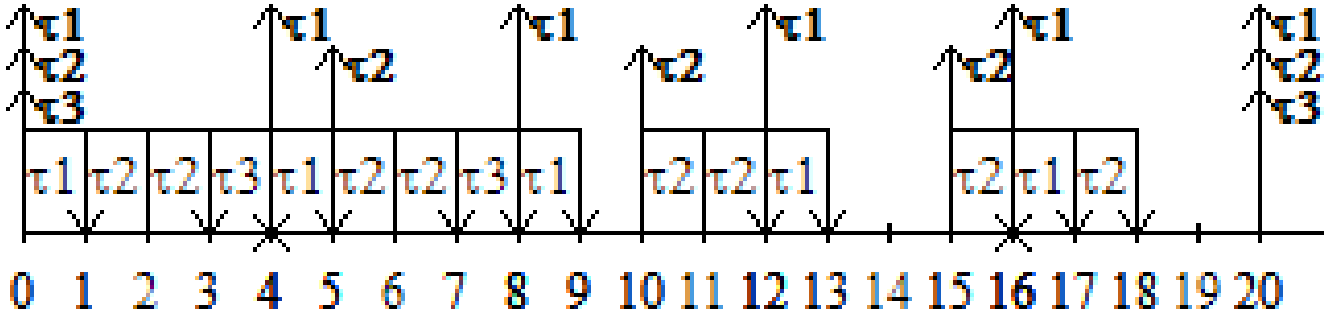
- Davis, Zabos, and Burns presented the current best RTA-based test with better initial values (In general sense, i.e., no paticular restrictions such as harmonic on task periods).
  - Efficient exact schedulability tests for fixed priority real-time systems. *IEEE Trans. on Computers*, 57(9): 1261–1276, 2008.
- Eisenbrand and Rothvoss regarded that response time computation is NP-hard.
  - Static-priority real-time scheduling: Response time computation is NP-hard. *IEEE RTSS 2008*, pages 397–406, 2008.

Our Method

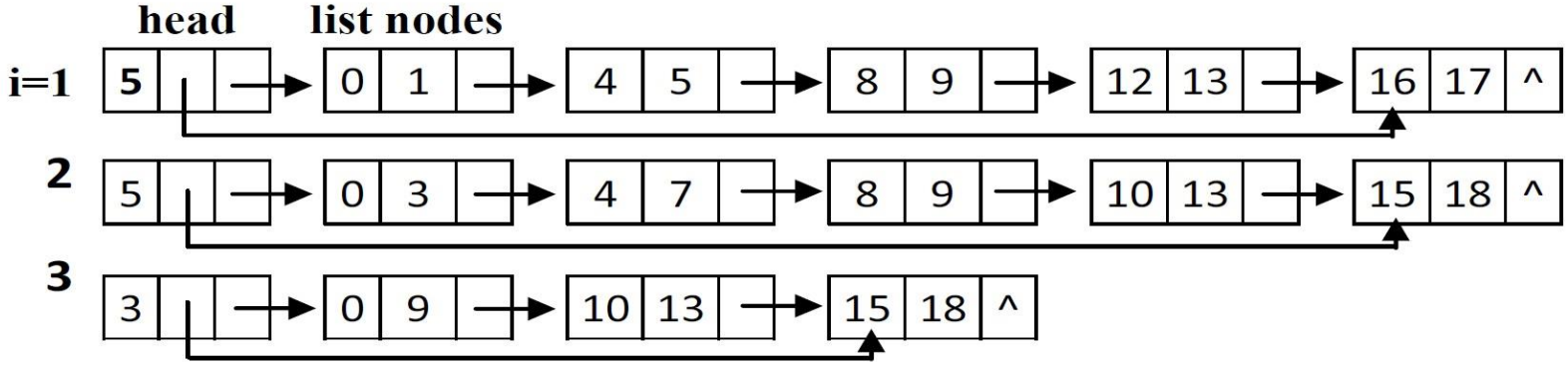
- We employ the linked list structure in the schedulability test and RTA, and
- use a linked list node to represent a *busy period* of a time interval.
- We use also a memory management in user space.
- An example
  - 3-task set: C_1=1,T_1=4; C_2=2,T_2=5; C_3=2,T_3=20; implicit deadlines; RM scheduling



An Example



C_1=1, T_1=4; C_2=2, T_2=5; C_3=2, T_3=20; implicit deadlines



The number of total jobs: 10 (=5+4+1). Response Time: RT_1=1， RT=3， RT_3=8

Performance - 1

TABLE I
HET, RTA, AND LLIST-BASED ALGORITHMS, EXECUTION TIME IN COUNTER CLOCK CYCLES × 1,000

Algorithm	Orders of magnitude spanning tasks periods						
	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4
HET	6.9	9.4	26.6	30.8	112.8	127.4	464.9
RTA	29.56	29.82	32.47	32.48	34.63	34.49	36.67
LList	1.01	1.17	4.12	4.35	25.19	25.94	208.9
RTA/LList	29.3	25.5	7.9	7.5	1.4	1.3	0.2

The range of periods starts from 10 and 10^4 for (*a*) and (*b*), respectively.

Performance - 2

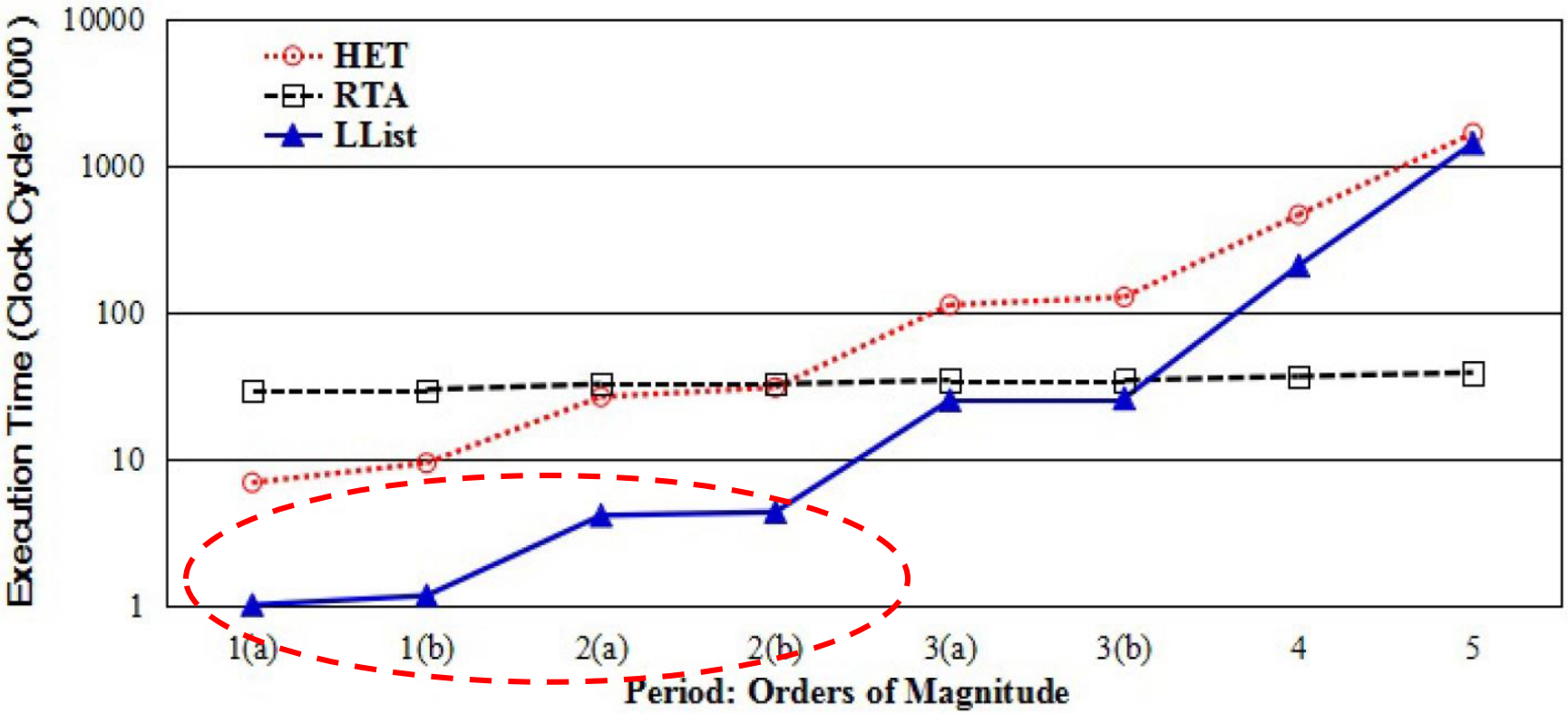


Fig. 1. Average execution time required by the HET, RTA, and LList-based exact schedulability tests versus number of orders of magnitude range of task periods. The range of periods starts from 10 and 10^4 for (a) and (b), respectively. Note both x and y-axes are logarithmic scales.

Performance - 3

- **For an *n*-task set under fixed priority RM scheduling, the total number of jobs, *N*, in the test time interval $[0, T_n)$ is at most $N = \Sigma^{n}_{i=1} ceiling(T_n / T_i)$ needed to be simulated in the LList-based exact test.**
  - **When $T_n / T_1 \leq 10$ (one order of magnitude), there will be at most 9*n*+8 jobs needed to be simulated, and our method needs only *O*(*n*) time for simulating an *n*-task set, regardless of the length of the maximum period of the task set as well as the total utilization factor.**

Performance - 4

- **Within three orders of magnitude spanning task periods, the memory space needed by the linked list is completely affordable.**

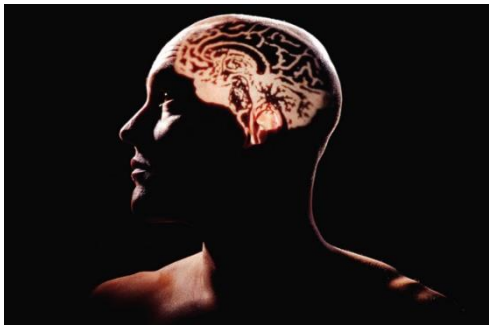
TABLE II

THE MAXIMUM NUMBER OF NODES AND CORRESPONDING MEMORY SPACE

	Orders of magnitude spanning tasks periods						
	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4
max # nodes	28	58	236	441	2302	3246	20996
KB(int32)	0.3	0.7	2.8	5.2	27.0	38.0	246.0

Conclusion

- We provide an LList-based method for the response time analysis and exact scheduability test for fixed priority preemptive systems.
- Our preliminary results have shown that the LList-based exact test is a better candidate in exact RTA-based tests when task periods span no more than three orders of magnitude.



Thanks for your interest!

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