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Adaptive SMT Control for More Responsive Web Applications

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Response time matters!

- Peak throughput has been the common metric for the Web server performance
- Even sub-second improvements in response times are essential for better user experiences†
  - Amazon: +100 msec → 1% drop in sales
  - Yahoo: +400 msec → 5-9% drop in traffic
  - Google: +500 msec → 20% drop in searches

→We focus on improving the response time of Web application servers

† Nicole Sullivan. *Design Fast Websites*. Oct 14, 2008

Key Question: How SMT affects response time?

- SMT (Simultaneous Multi Threading, a.k.a. Hyper Threading) allows multiple hardware threads to run on one core

- SMT typically
  - ☺ improves aggregated throughput
  - ☹ degrades single-thread performance

→Question: How SMT affects response times of Web application server?

Outline

1. How SMT affects response time
2. Adaptive SMT control with queuing model

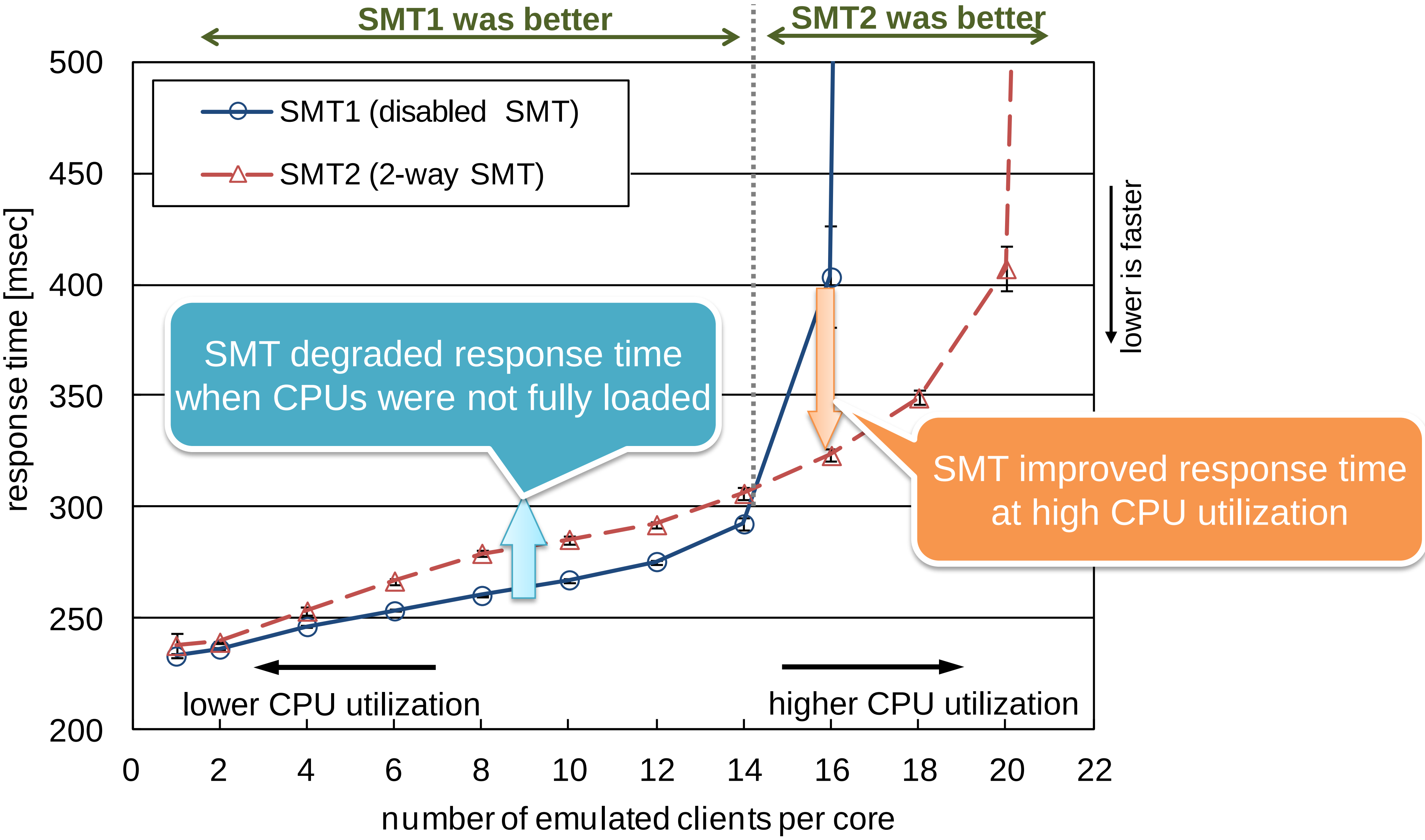
Evaluations

- Processors:
  - Xeon (SandyBridge-EP): 2-way SMT, 2.9 GHz, 16 cores
  - POWER7: 4-way SMT, 3.55 GHz, 16 cores

- Workloads:
  - PHP (MediaWiki)
  - Ruby (Ruby-on-rails)
  - Java (Cognos BI)

- OS: Redhat Enterprise Linux 6.4 (Kernel-2.6.32)

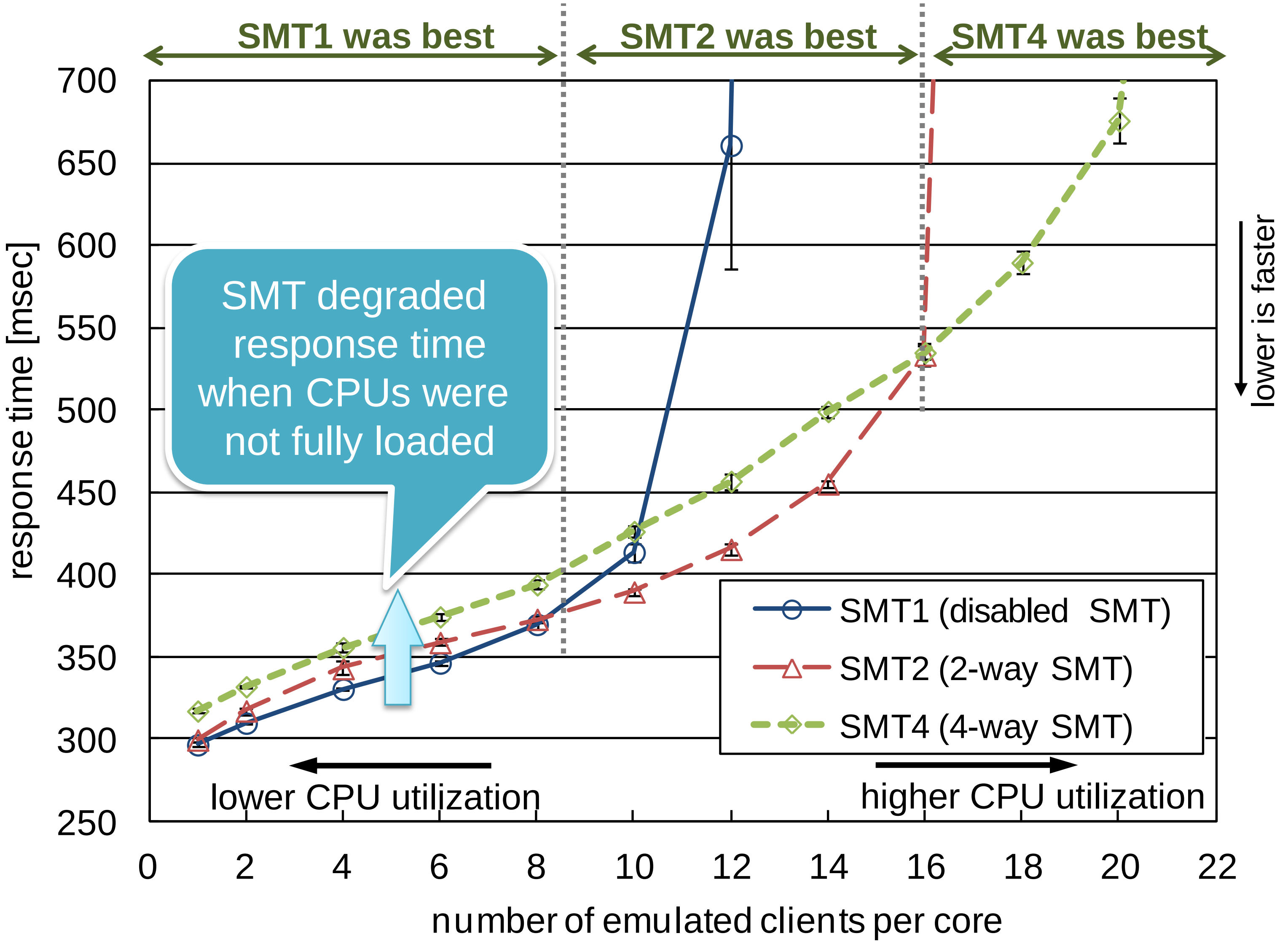
Response time of the PHP application on 16 cores of Xeon



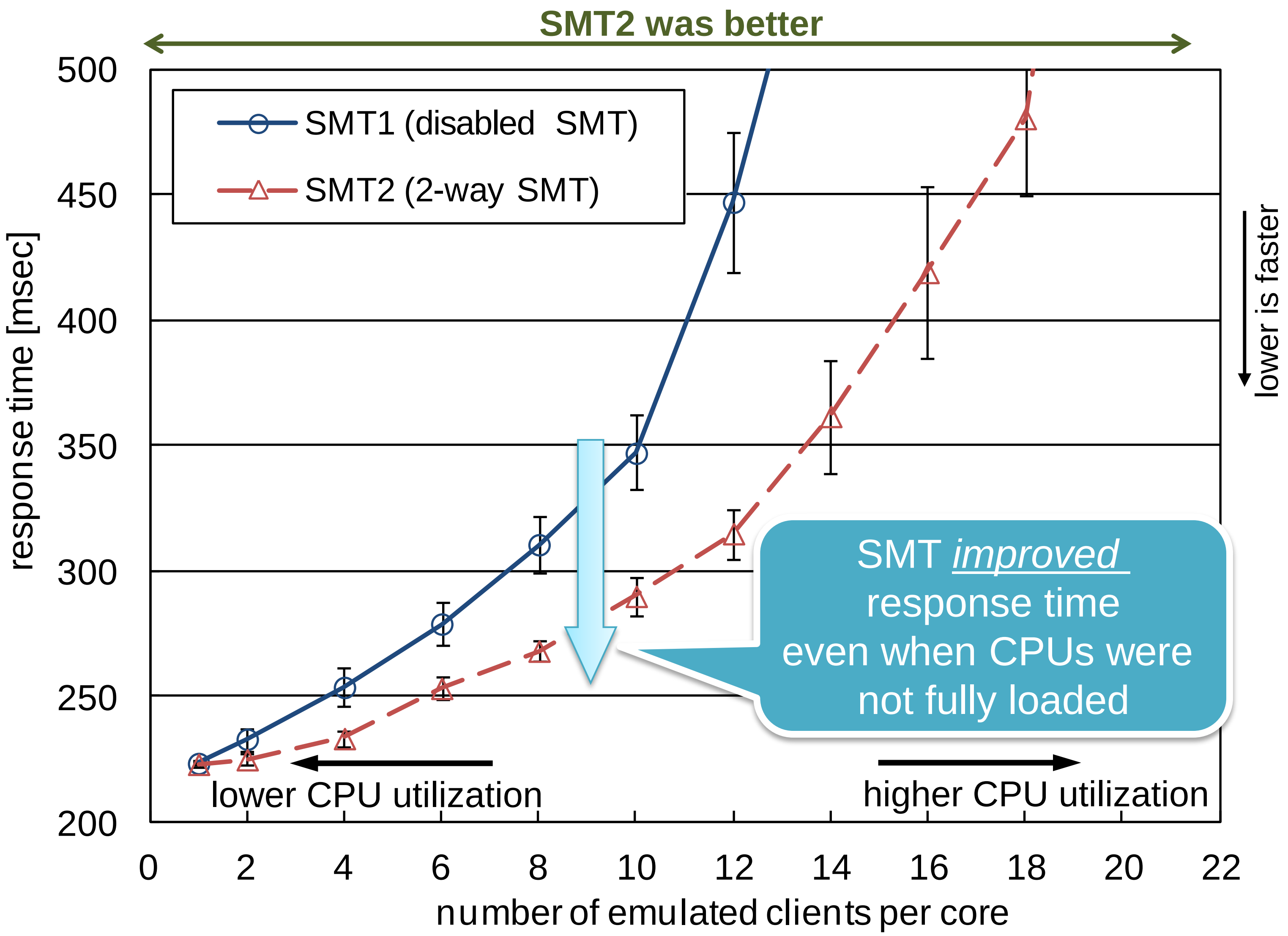
SMT degraded response time when CPUs were not fully loaded

SMT improved response time at high CPU utilization

Response time of the PHP application on 16 cores of POWER7



Response time of the PHP application on **1 core** of Xeon



SMT2 was better

lower is faster

SMT *improved* response time even when CPUs were not fully loaded

lower CPU utilization

higher CPU utilization

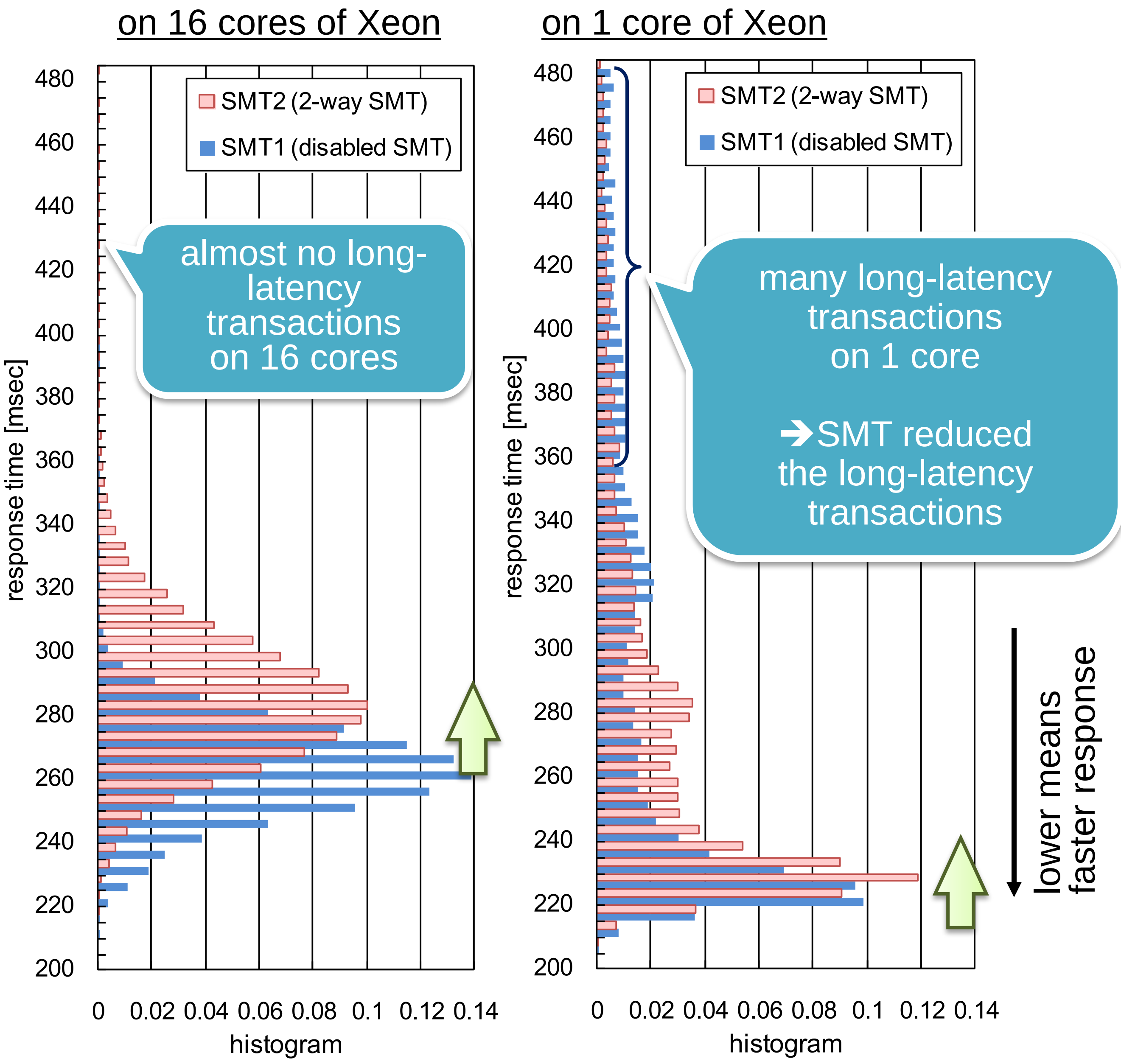
How SMT affects response time?

	Low CPU utilization	High CPU utilization
on 1 core	improve	improve
on multiple cores	***degrade***	improve

- SMT hurts the response time on multicore systems with low CPU utilization level, which is the common case in today’s server
- The crossover point depends on the number of cores

Histogram of response time at low (~25%) CPU utilization

- SMT degraded single-thread performance and shifted the peak of the histogram towards slower response times
- SMT reduced long-latency transactions on 1 core



on 16 cores of Xeon

on 1 core of Xeon

almost no long-latency transactions on 16 cores

many long-latency transactions on 1 core

➔SMT reduced the long-latency transactions

Breaking down response time

response time T_r = service time T_s ↑ ☹ + waiting time T_w ↓ ☺

- SMT typically
  - ☹ increases service time (CPU time) by lowering single-thread performance
  - ☺ reduces waiting time (in task scheduling queue) by providing more hardware threads

→SMT degrades the response time on multicore systems with low CPU utilization level because waiting time is not significant in such case

→For other cases (single core or high utilization) waiting time affect the total response time

Outline

1. How SMT affects response time
2. Adaptive SMT control with queuing model

Adaptive SMT Control

- We periodically (once per 5 sec)
  - obtain the CPU utilization from /proc/stat,
  - calculate the response time for each SMT level using *a new queuing model*, and
  - select the best SMT level
- Implemented as a user-space daemon without modification in OS kernel

Challenges in queuing model for SMT processors

- How to model single-thread performance on SMT processor
  - affected by resource contention among the SMT threads

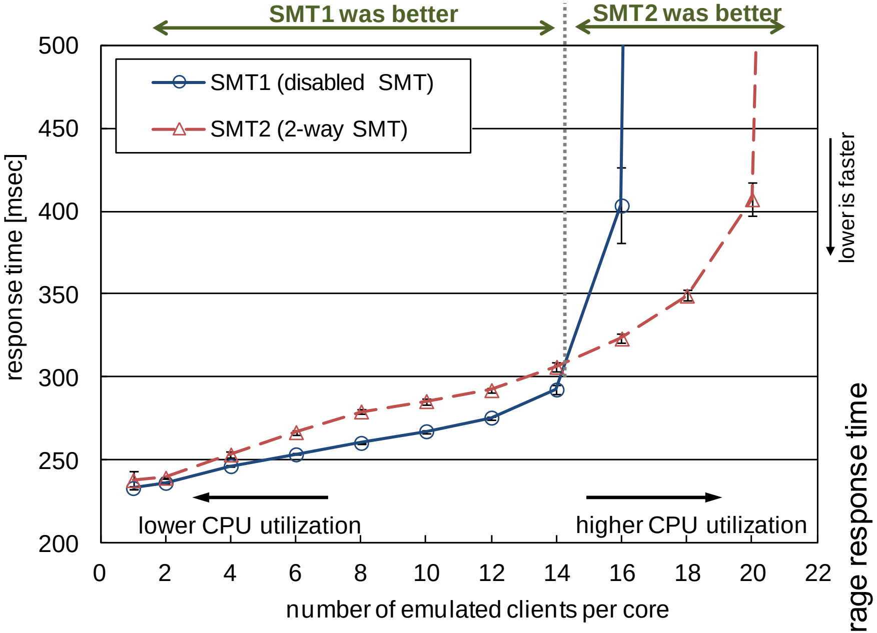
- How to model task migration behavior of the OS task scheduler
  - aggressively balances the load among the SMT threads within one core while minimizing migrations among different cores

Hierarchical queuing model

1. In-core modeling: model the single SMT core
   - To calculate service time (i.e. single-thread performance) and waiting time without considering task migration
2. Out-of-core modeling: model the task migration among cores
   - To modify the waiting time considering the task migration

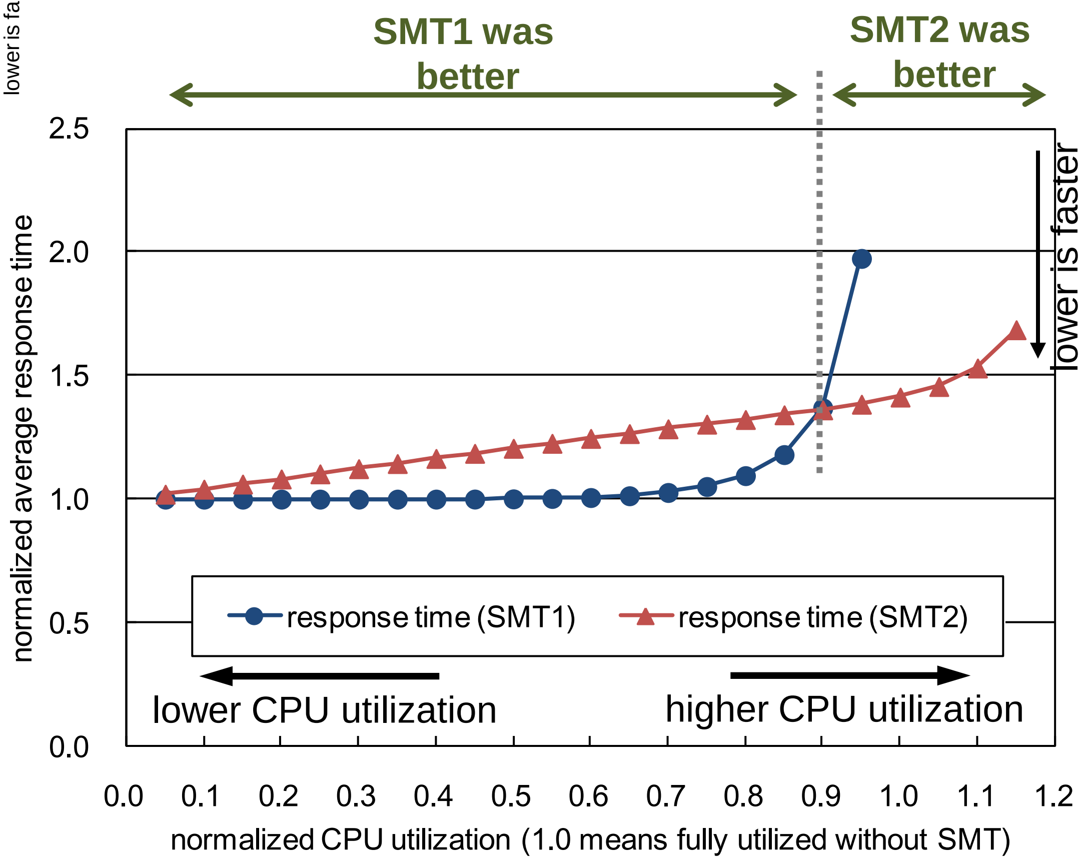
- Both phases are based on the standard M/M/s model
- Model takes CPU utilization as input w/o task characteristics
- See the paper for the model details

Response time predicted by our model on **16-cores of Xeon**

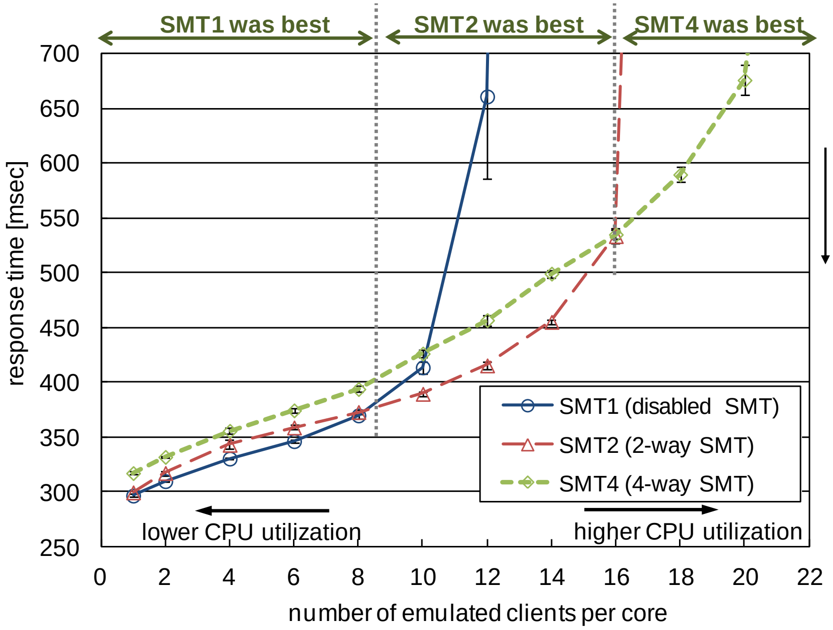


measured response time of MediaWiki (PHP)

predicted response time of MediaWiki (PHP)

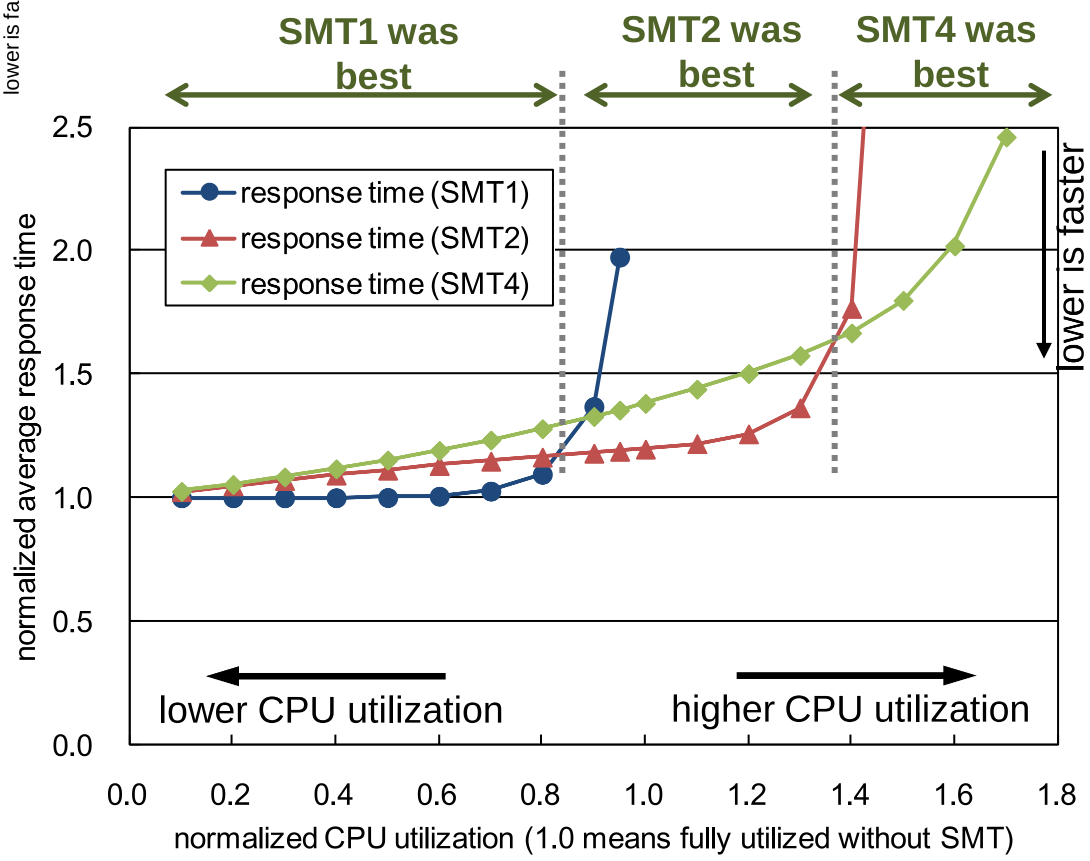


Response time predicted by our model on **16-cores of POWER7**

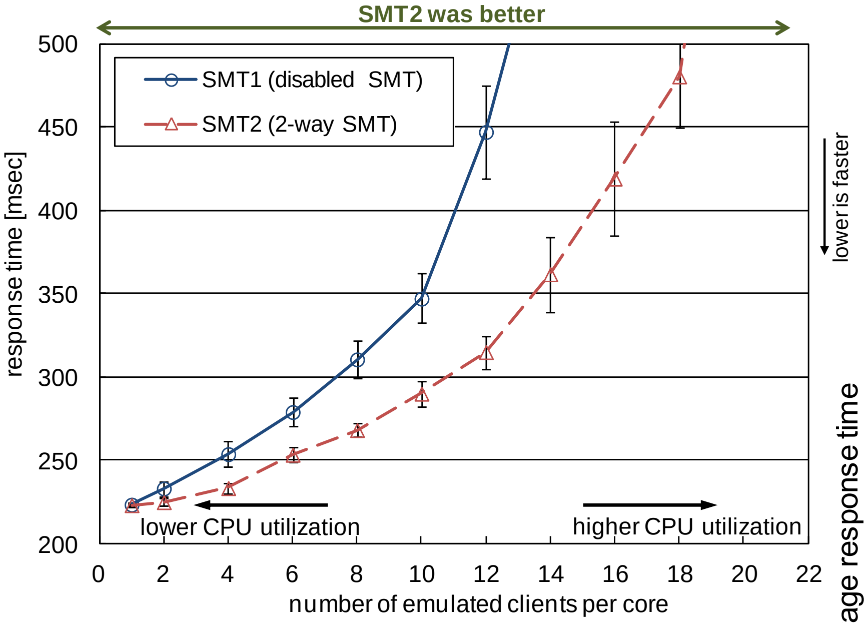


measured response time of MediaWiki (PHP)

predicted response time of MediaWiki (PHP)

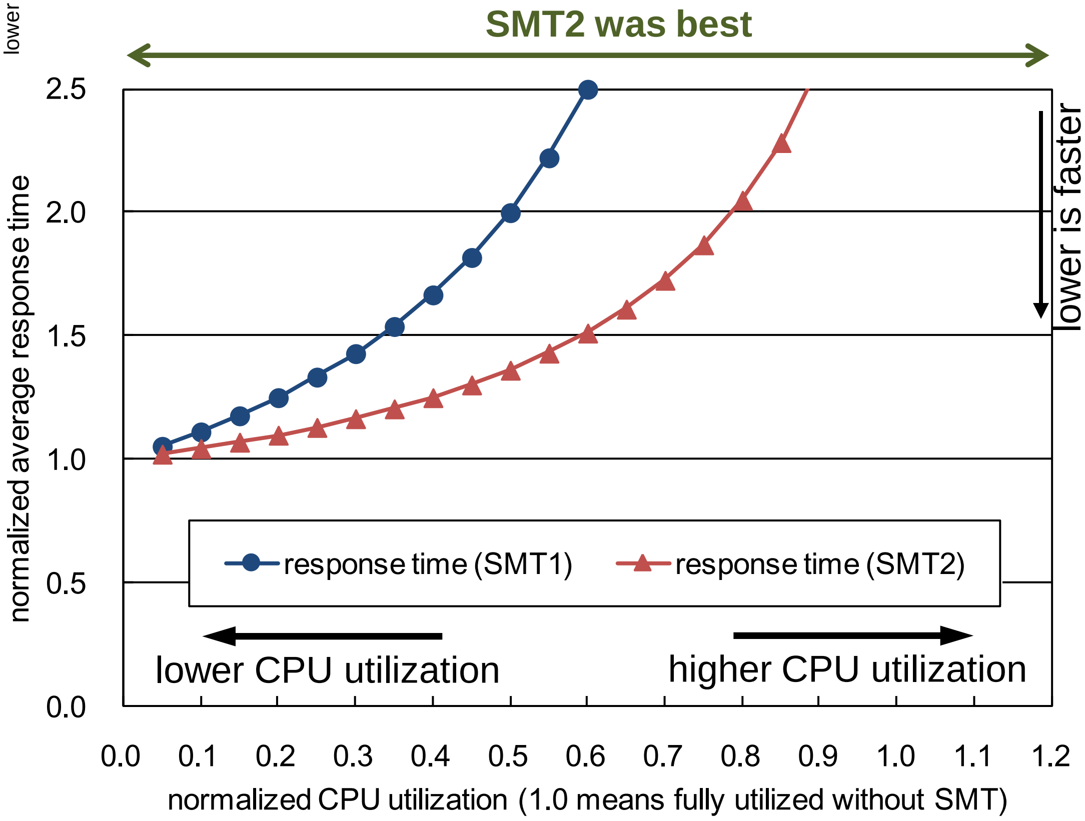


Response time predicted by our model on **1-core of Xeon**

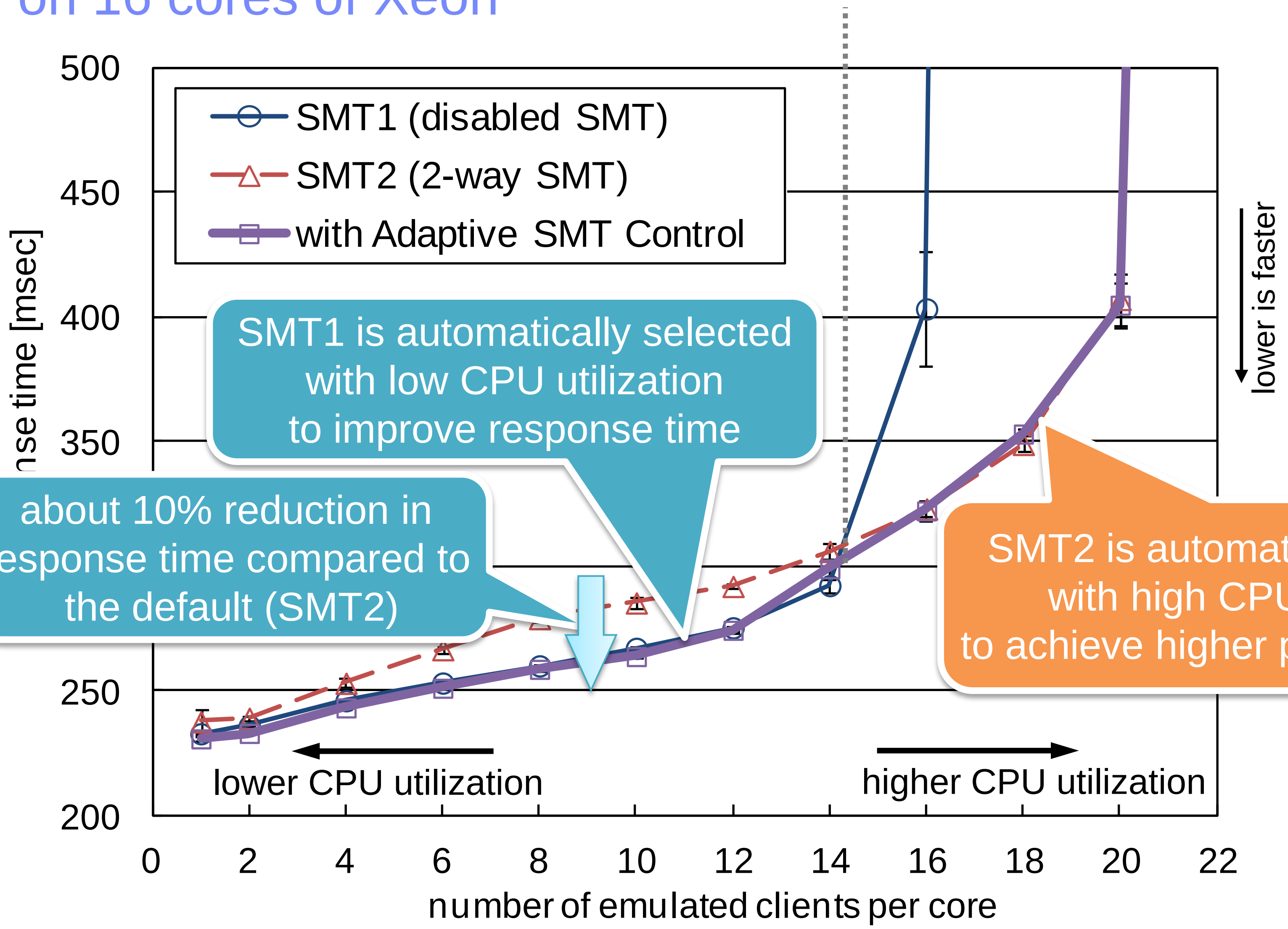


measured response time of MediaWiki (PHP)

predicted response time of MediaWiki (PHP)



Response time with adaptive SMT control on 16 cores of Xeon

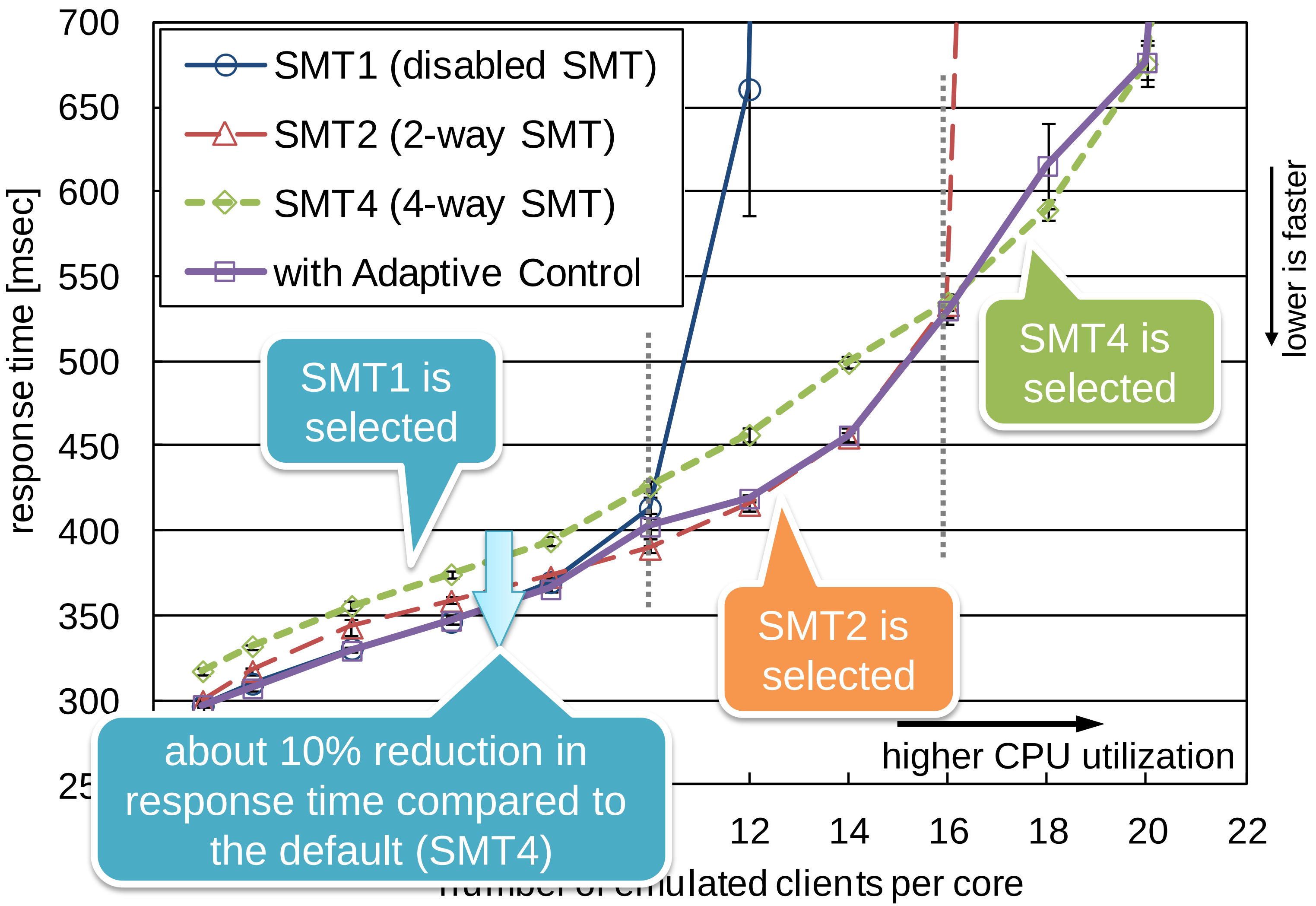


SMT1 is automatically selected with low CPU utilization to improve response time

about 10% reduction in response time compared to the default (SMT2)

SMT2 is automatically selected with high CPU utilization to achieve higher peak throughput

Response time with adaptive SMT control on 16 cores of POWER7



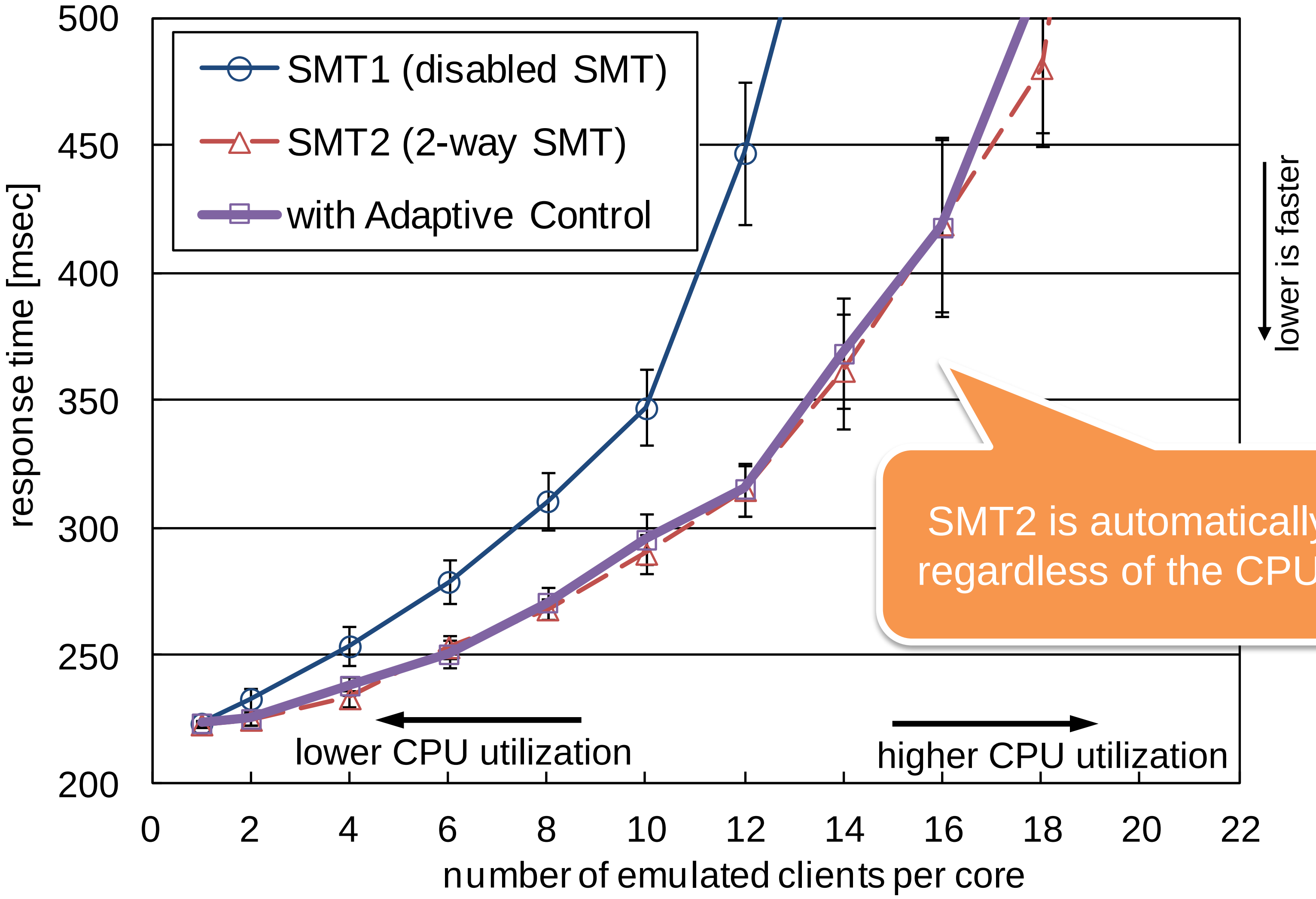
SMT1 is selected

SMT2 is selected

SMT4 is selected

about 10% reduction in response time compared to the default (SMT4)

Response time with adaptive SMT control on 1 core of Xeon



SMT2 is automatically selected regardless of the CPU utilization

Summary

- We showed that SMT may degrade the response time on *multicore* processors with *low CPU utilization*
- We developed a new queuing model to predict the response time on multicore SMT processors
- Our adaptive SMT control based on the new model automatically selected the best SMT level at runtime

See the paper for more detail
✓evaluation with Ruby and Java workloads
✓results on moderate number of cores
✓detail of the queuing model