Dynamic Fine-Grained Scheduling for Energy-Efficient Main-Memory Queries

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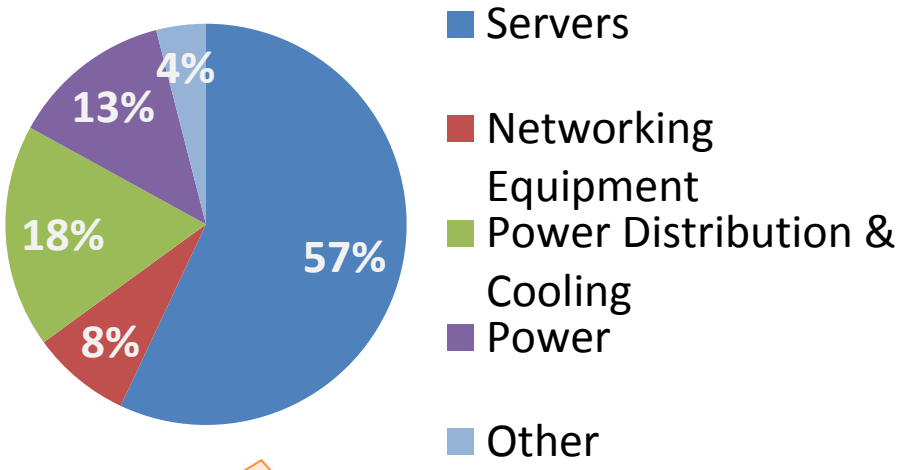






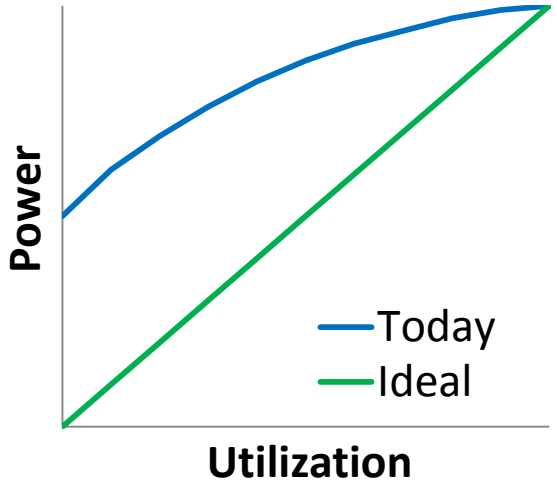
Why care about power?

Monthly datacenter costs [J. R. Hamilton]



30% power-related
Dynamic fraction increasing

Energy proportionality



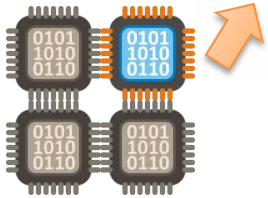
Getting there:

- Power management features
- Power-aware software

We need to make DBMS power-aware

Power management features

- Dynamic voltage and frequency scaling (DVFS)
- Turbo boost



> 2.9GHz



1.2GHz 2.9GHz

- Idle states (C-states)



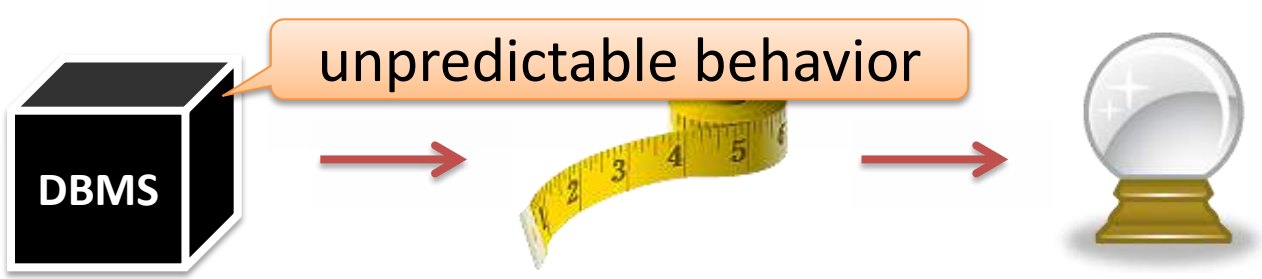
- Power-related H/W counters



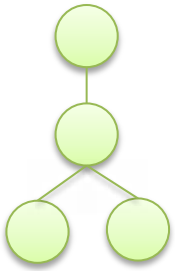
We can exploit these to improve energy efficiency

Current approaches

- Black box
  - e.g. dynamic concurrency throttling [TPDS13]



- Query optimizer [ICDE10]



+ power costs

coarse-grained, without low-level tuning

We need fine-grained energy-awareness in the database

Fine-grained energy-aware scheduling



How do you schedule this query plan?

- parameters:
  - parallelism
  - thread placement
  - data placement
  - dynamic voltage and frequency scaling (DVFS)

Calibration of operators under different parameters

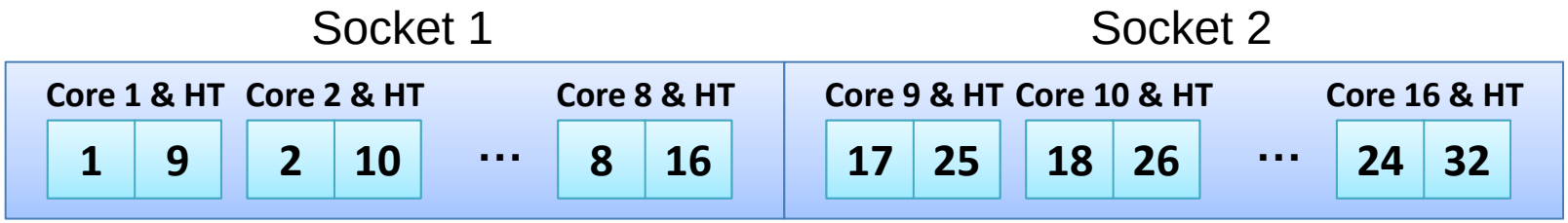
Concurrent partitioned scans

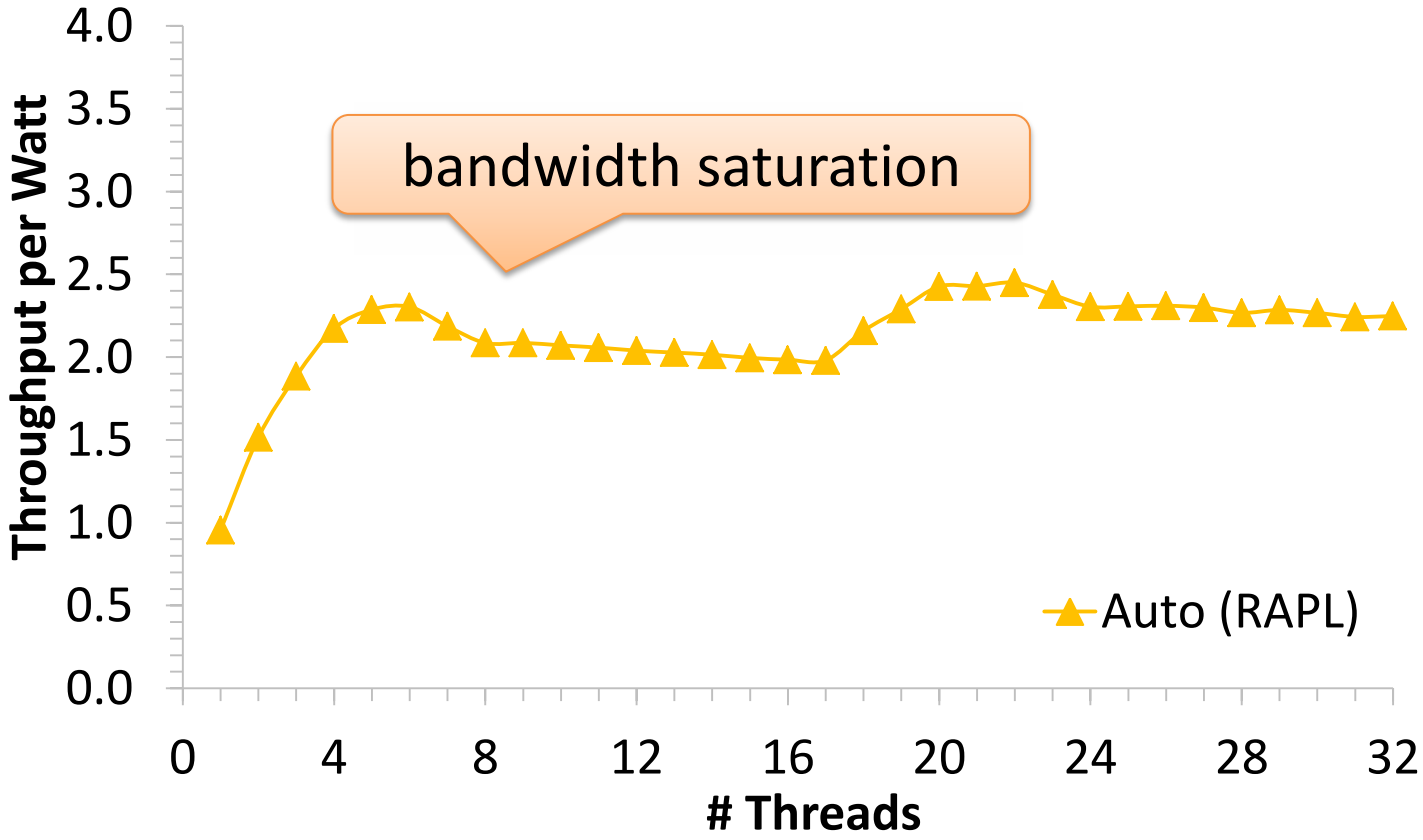
- Each thread scans 128MB of integers for 5 secs
- Maximize

$$performance\ per\ power = \frac{throughput}{power}$$

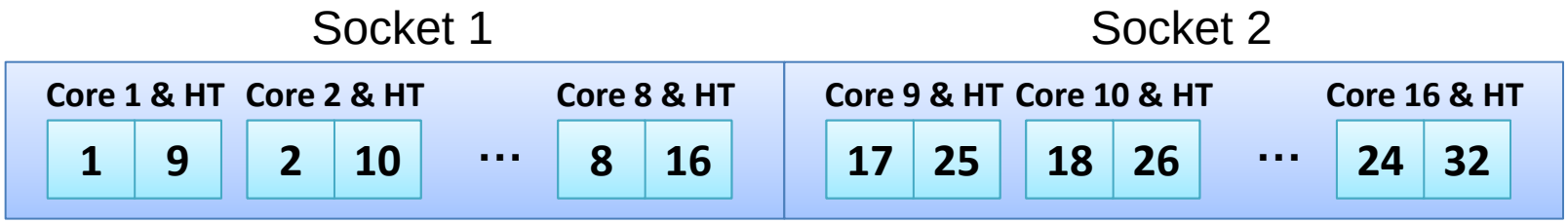
  - under different parallelism, scheduling, and frequency settings
- Machine
  - Two 8-core Intel Xeon E5-2690, HT enabled, 64GB RAM, frequencies from 1.2GHz to 2.9GHz
- Power measurements
  - Hardware performance counters RAPL (CPU & DRAM)
  - External equipment

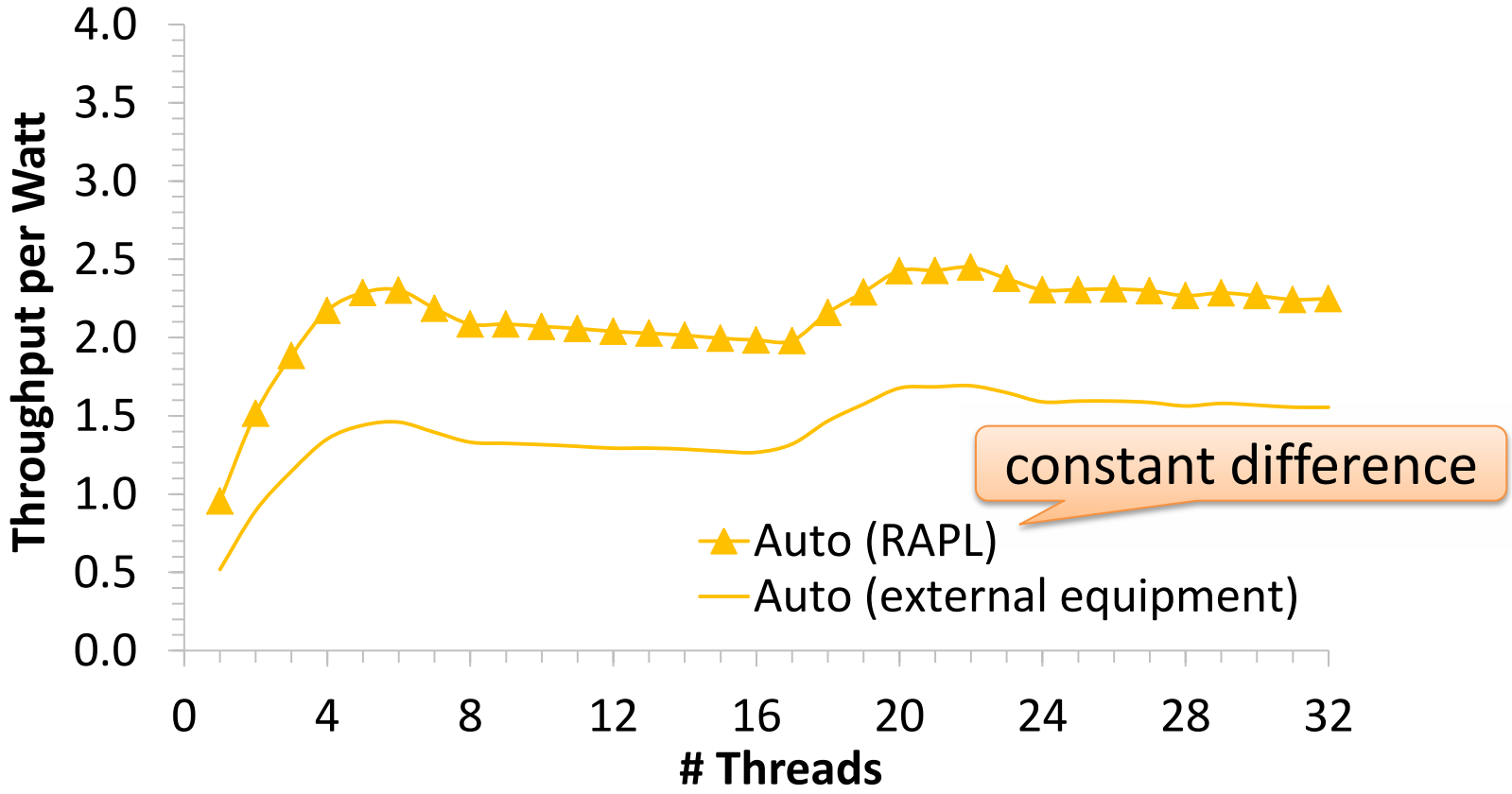
Socket-fill scheduling



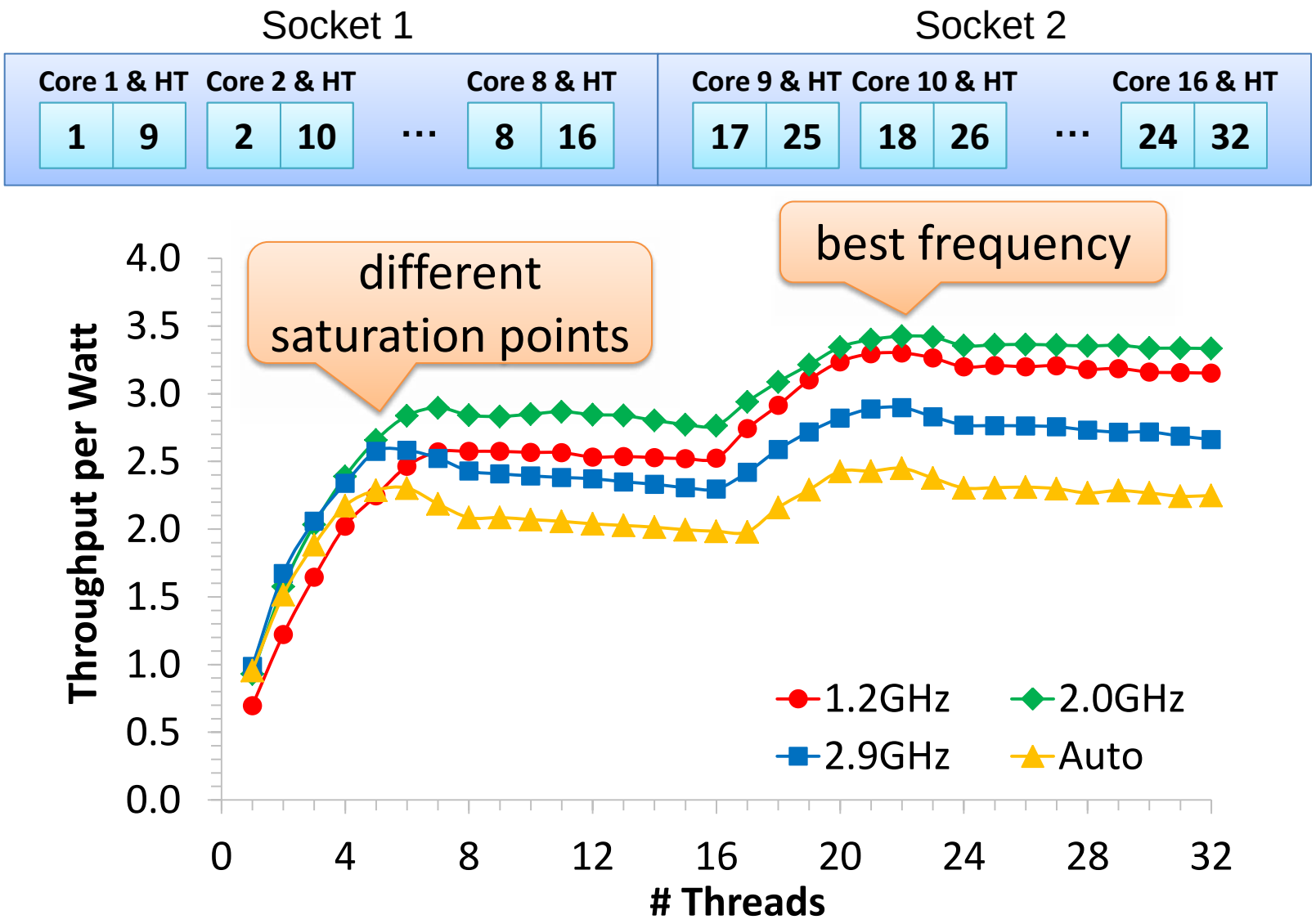


Socket-fill scheduling

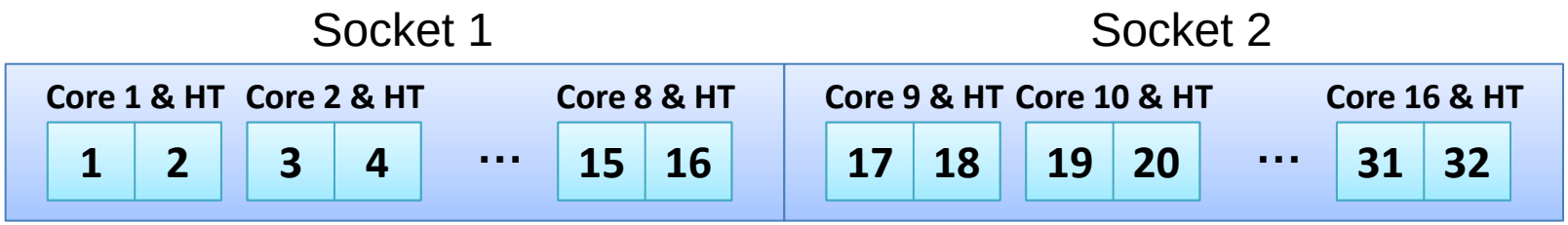


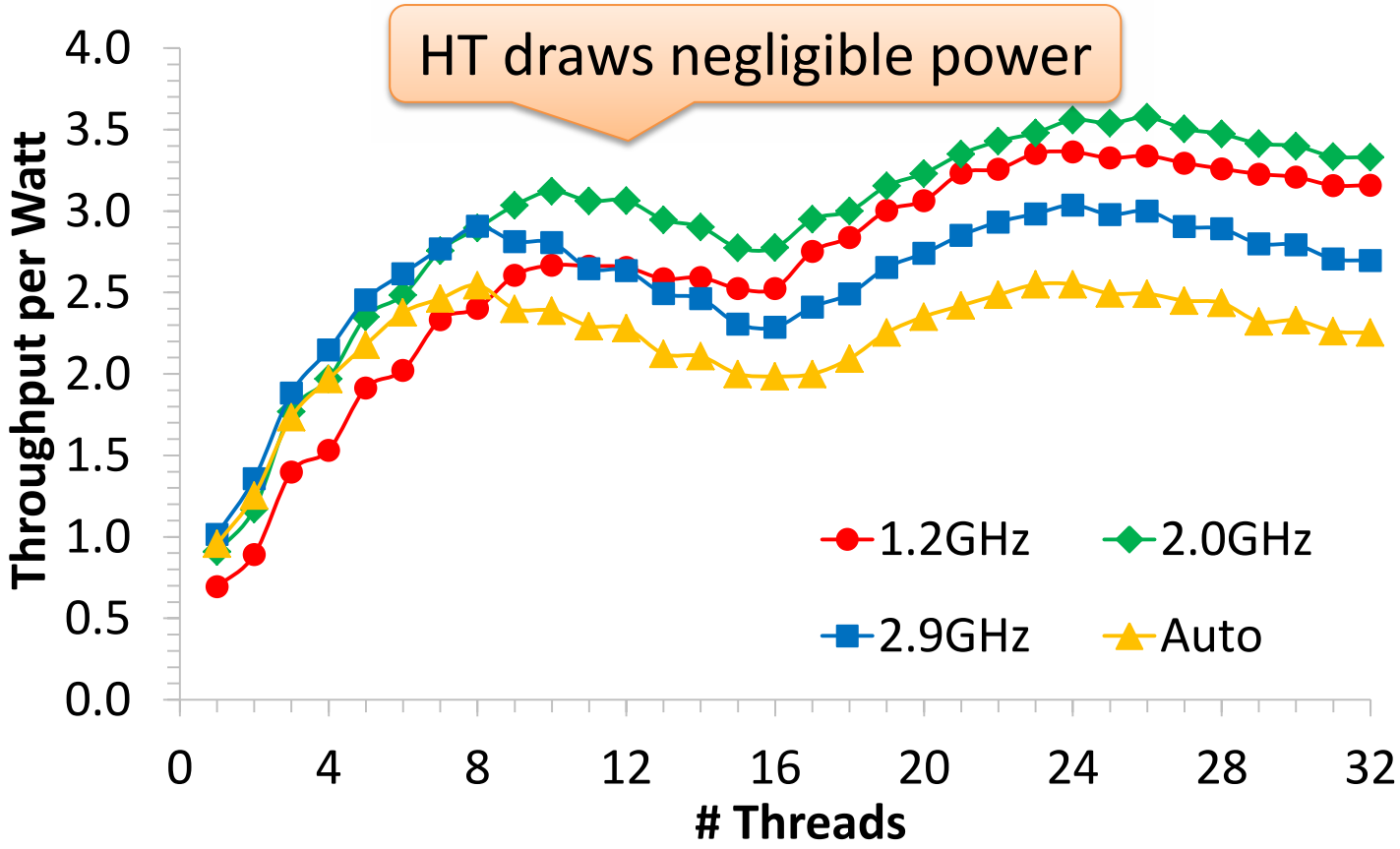


Socket-fill scheduling

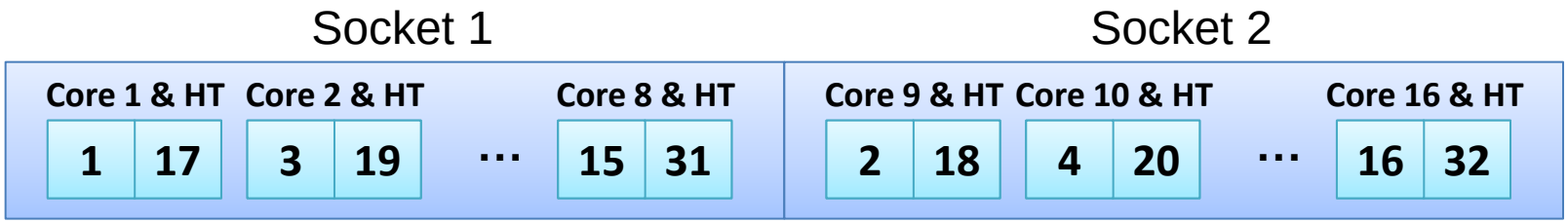


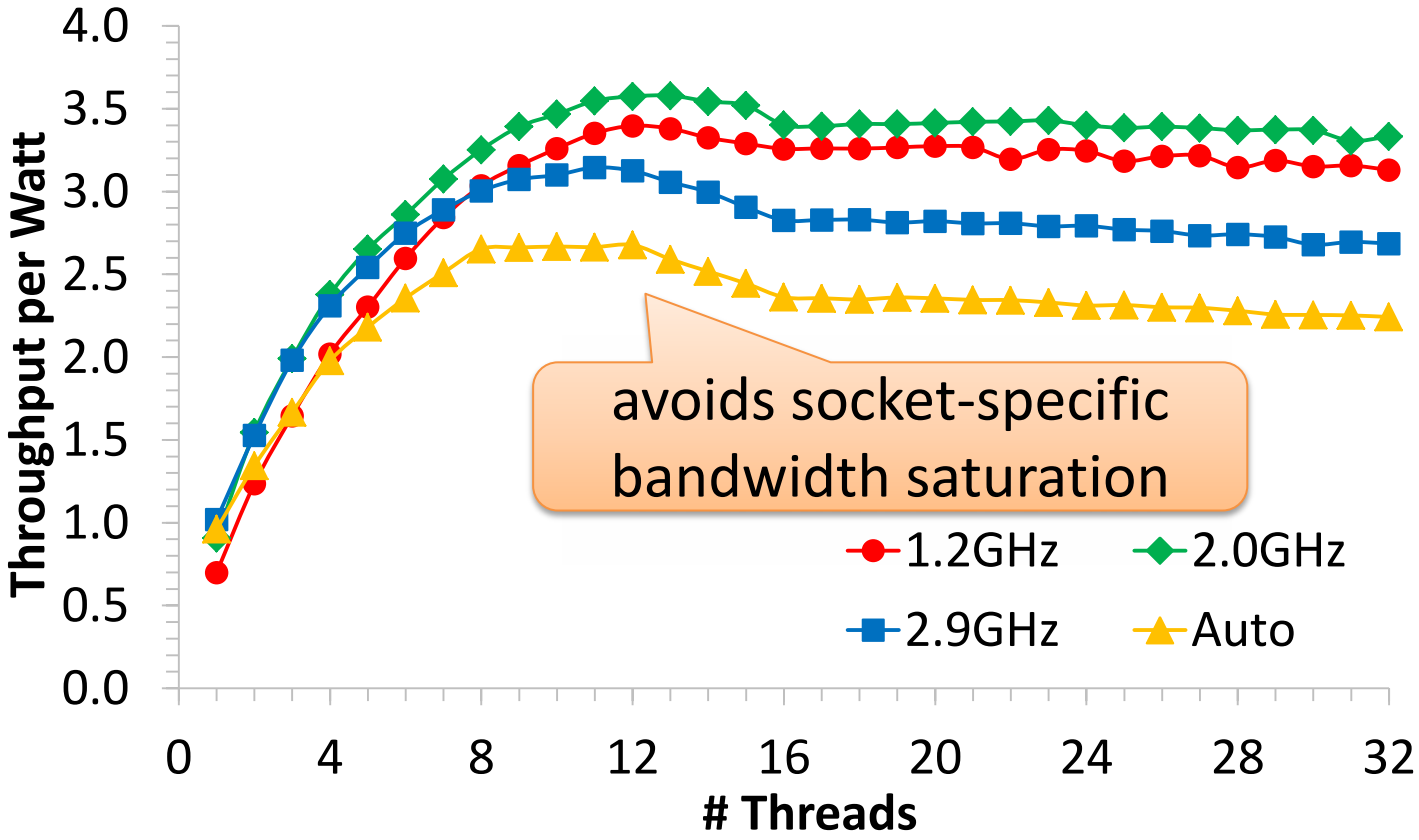
Socket-fill HT scheduling



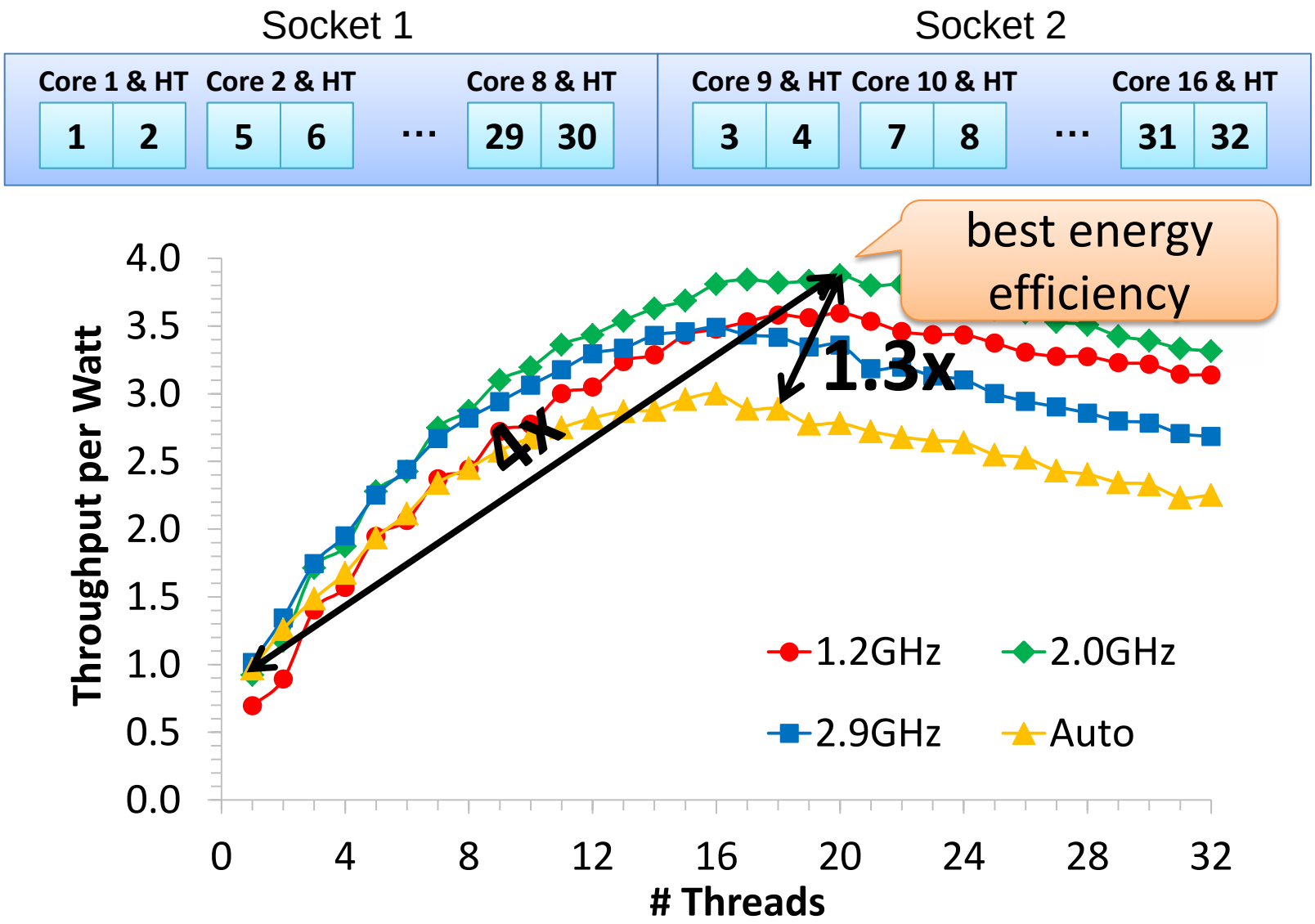


Socket-wise scheduling





Socket-wise HT scheduling



Parallel aggregation

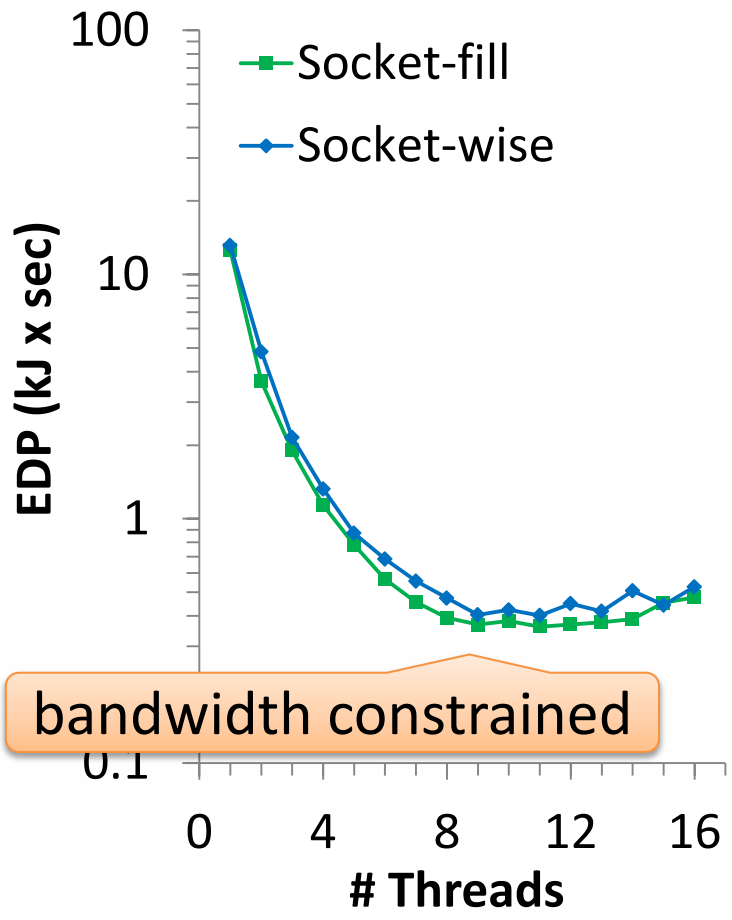
- $a = \sum\big(b(i) + c(i)\big)$, 4GB arrays
- Minimize

  $energy\ delay\ product\ (EDP) = response\ time\ (sec) * energy(\ J)$

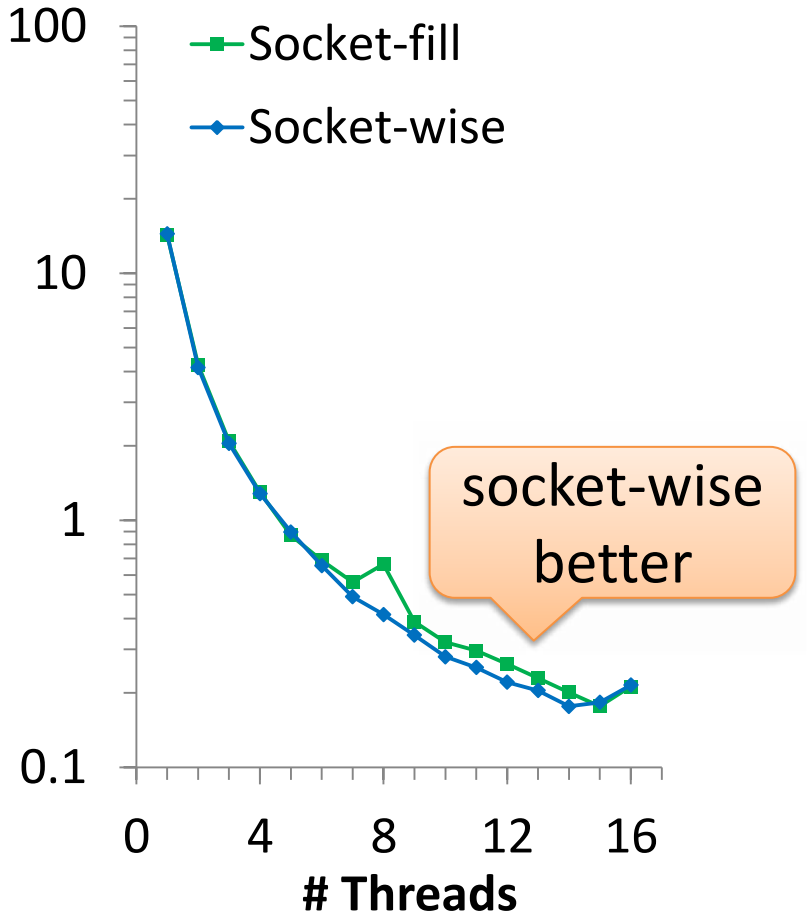
  – under different parallelism, scheduling, and memory placement
- Machine
  – Two 8-core Intel Xeon E5-2640, HT disabled, 256GB of RAM
- Memory placement
  – On first socket
  – Interleaved

Parallel aggregation

Memory on first socket



Memory interleaved



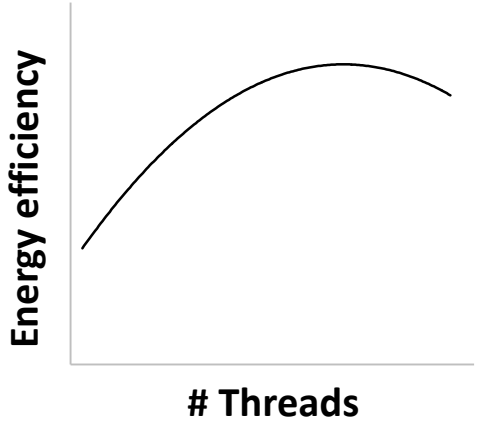
Main-memory memory-bound operations

- Intermediate frequency has best efficiency
  - Different saturation points
- Avoid memory bandwidth saturation
  - by data and thread placement
- Up to 4x energy efficiency

Fine-grained energy awareness

Calibration analysis

of operators and parameters

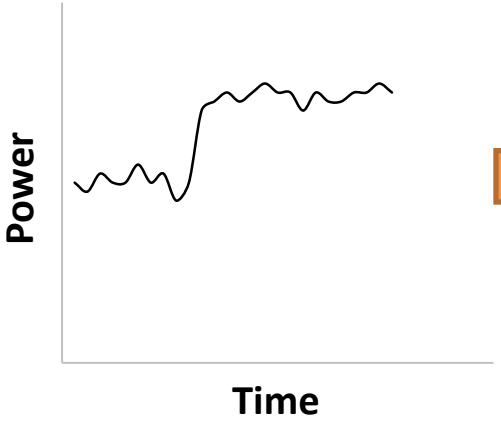


parallelism
data & thread placement
DVFS

THIS PAPER

Measurements

hardware counters and/or external equipment

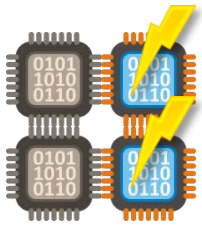


power
CPU utilization
memory utilization

Runtime decisions

scheduling, resource allocation, power management







Thank you!

References

- [J. R. Hamilton] Internet-Scale Datacenter Economics: Where the Costs And Opportunities Lie. HPTS, 2011.
- [TPDS13] D. Li, B. R. de Supinski, M. Schulz, D. S. Nikolopoulos, and K. W. Cameron. Strategies for energy-ecient resource management of hybrid programming models. IEEE TPDS, 24(1):144-157, 2013.
- [ICDE10] Z. Xu, Y.-C. Tu, and X. Wang. Exploring power-performance tradeos in database systems. In ICDE, pages 485-496, 2010.