Variation Among Processors Under Turbo-Boost

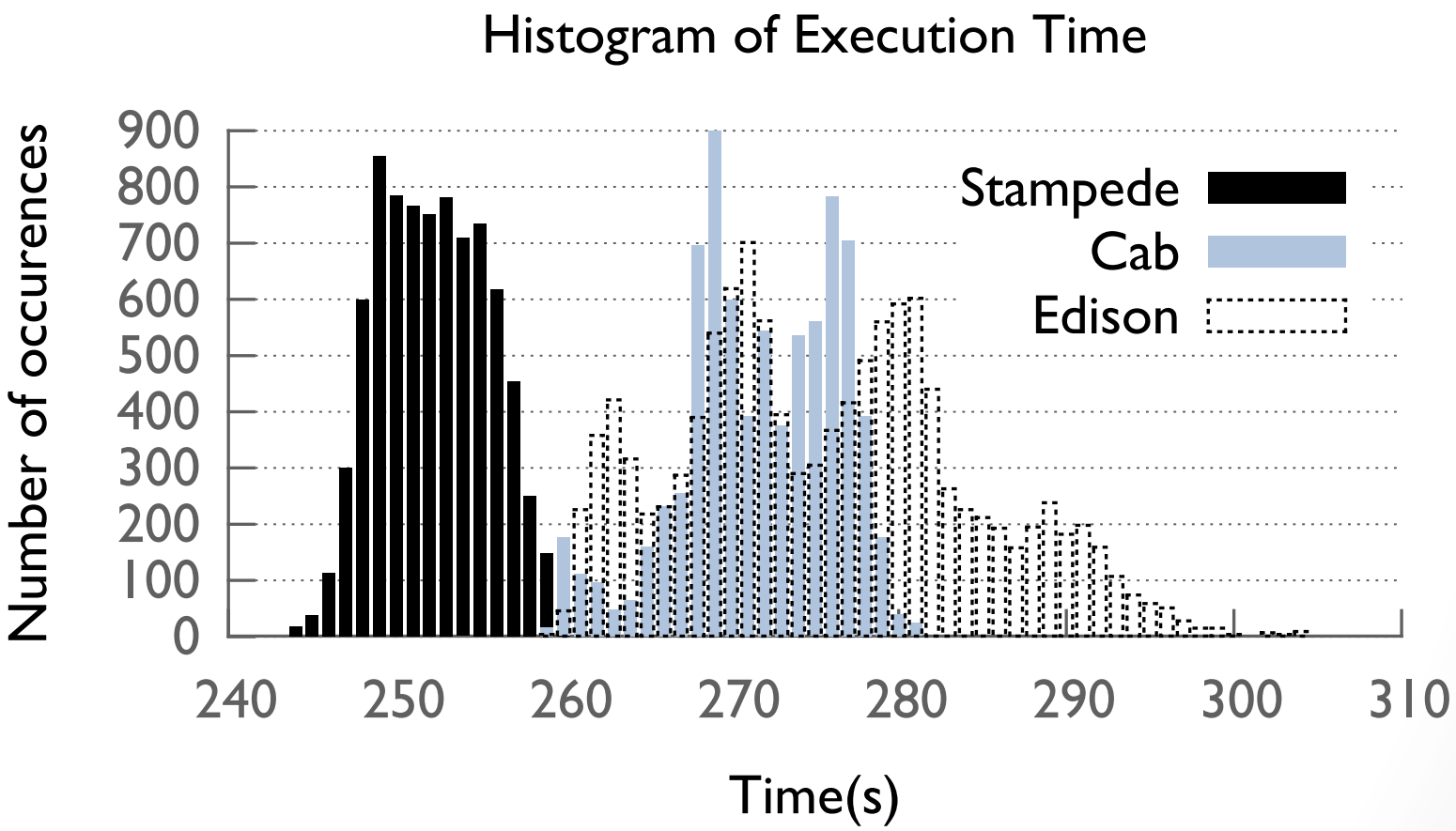
Bilge Acun, Ph.D. Candidate
Department of Computer Science
University of Illinois at Urbana-Champaign

This talk is based on the publication:
Bilge Acun, Phil Miller, Laxmikant Kale. ICS 2016.
"Variation Among Processors under Turbo Boost in HPC Systems".

Motivation: Performance Variation

16% Performance Variation on Edison, Cab, Stampede!

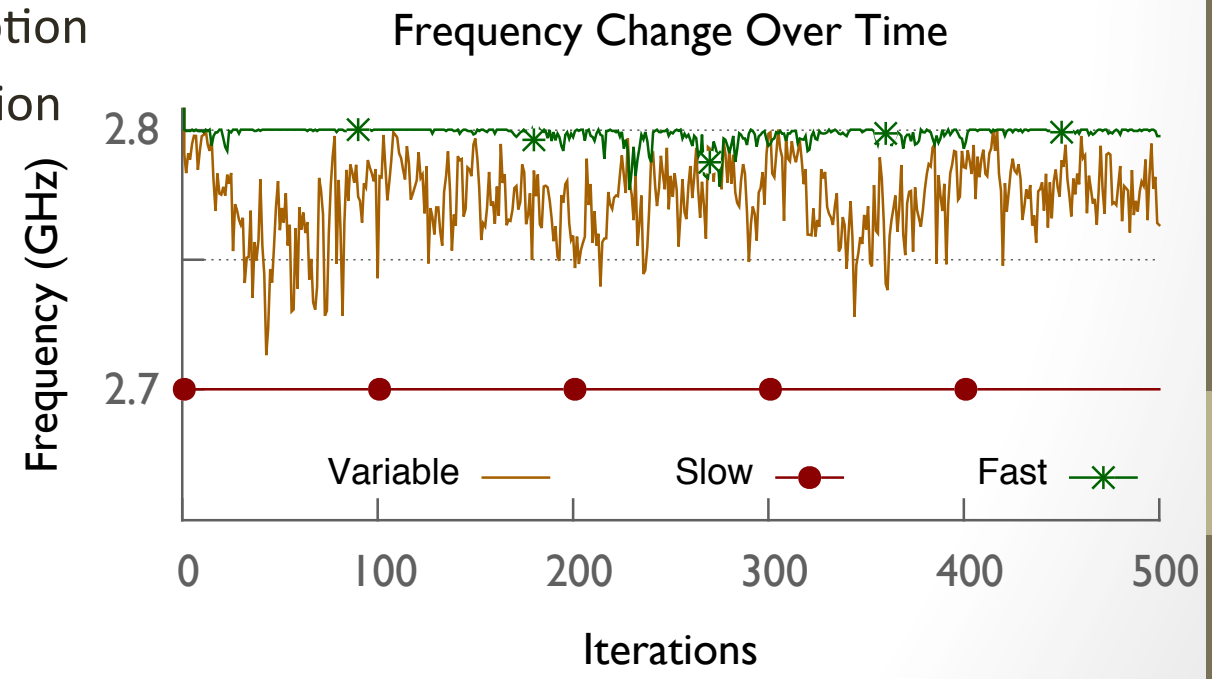
Only 1% Variation on Blue Waters!



- 16K cores running local DGEMM kernel of Intel-MKL

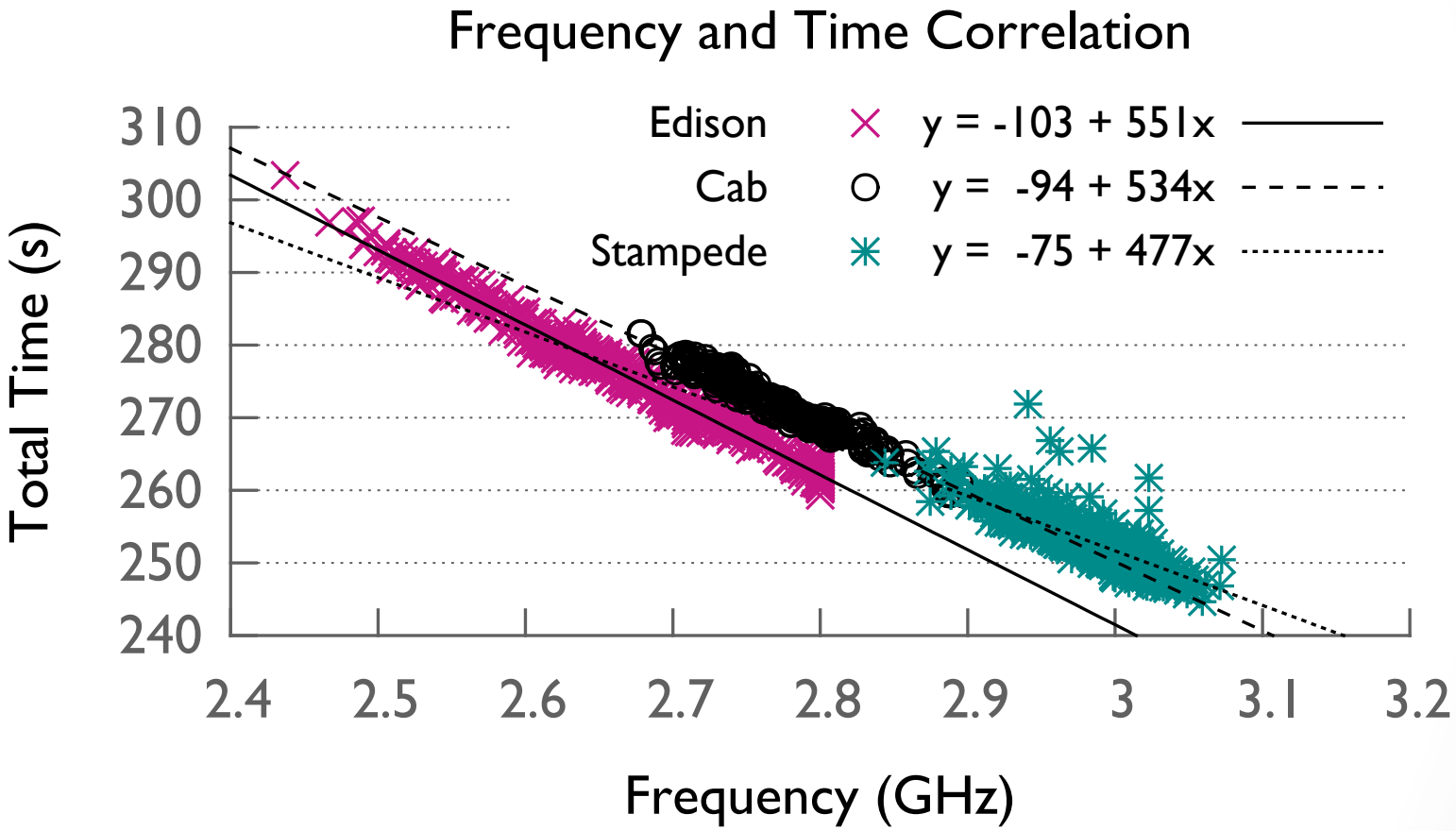
What is Dynamic Overclocking?

- Processor changes the frequency opportunistically since it cannot run at the highest limit all the time.
  - E.g. Intel Turbo Boost Technology
- Factors effecting the dynamic frequency:
  - Type of the workload
  - Number of active cores
  - Current consumption
  - Power consumption
  - Temperature



Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Motivation: Frequency Variation



Edison: Intel Ivy Bridge

Stampede, Cab: Intel Sandy Bridge

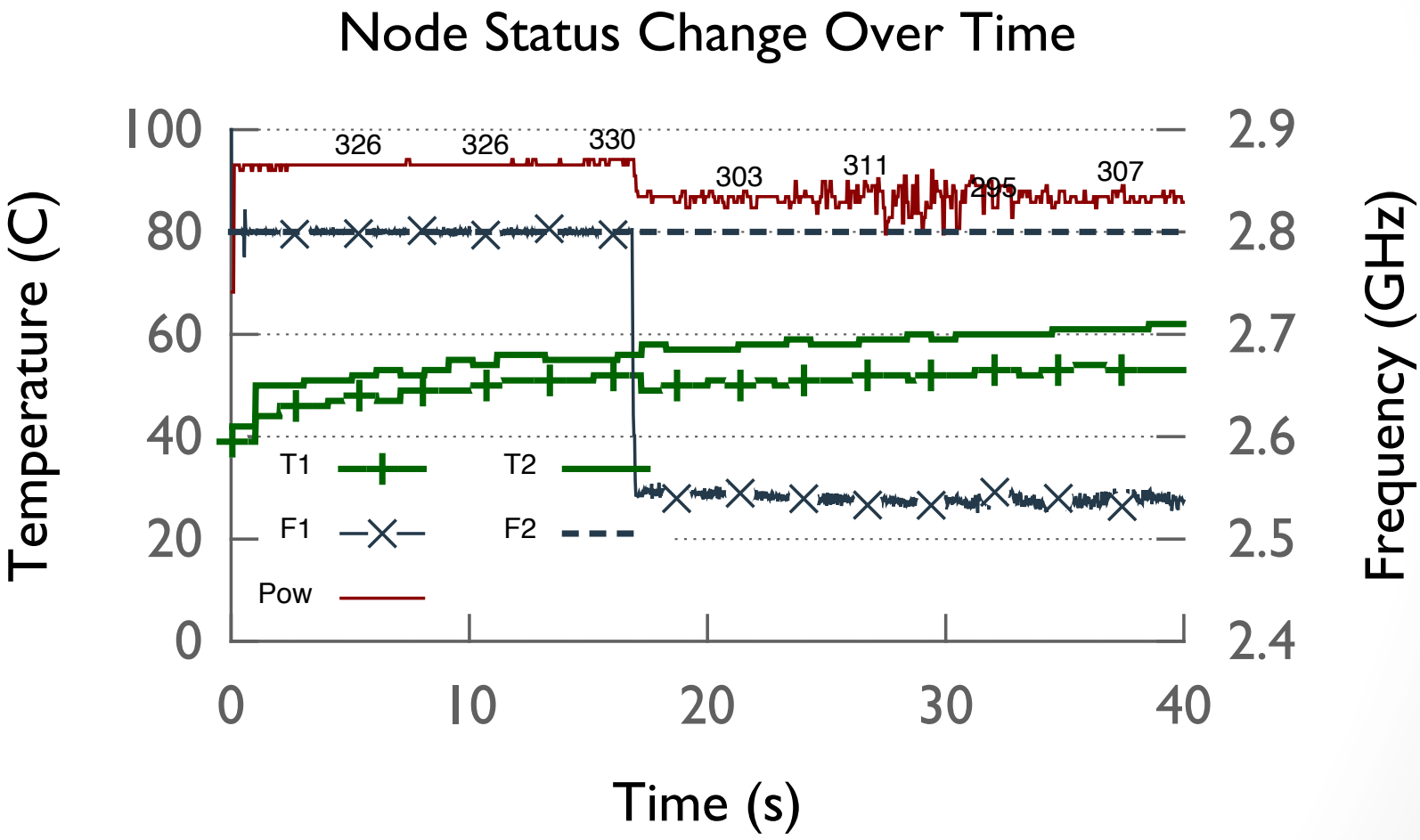
Motivation: Frequency Variation

- Distribution of steady-state frequencies on Edison

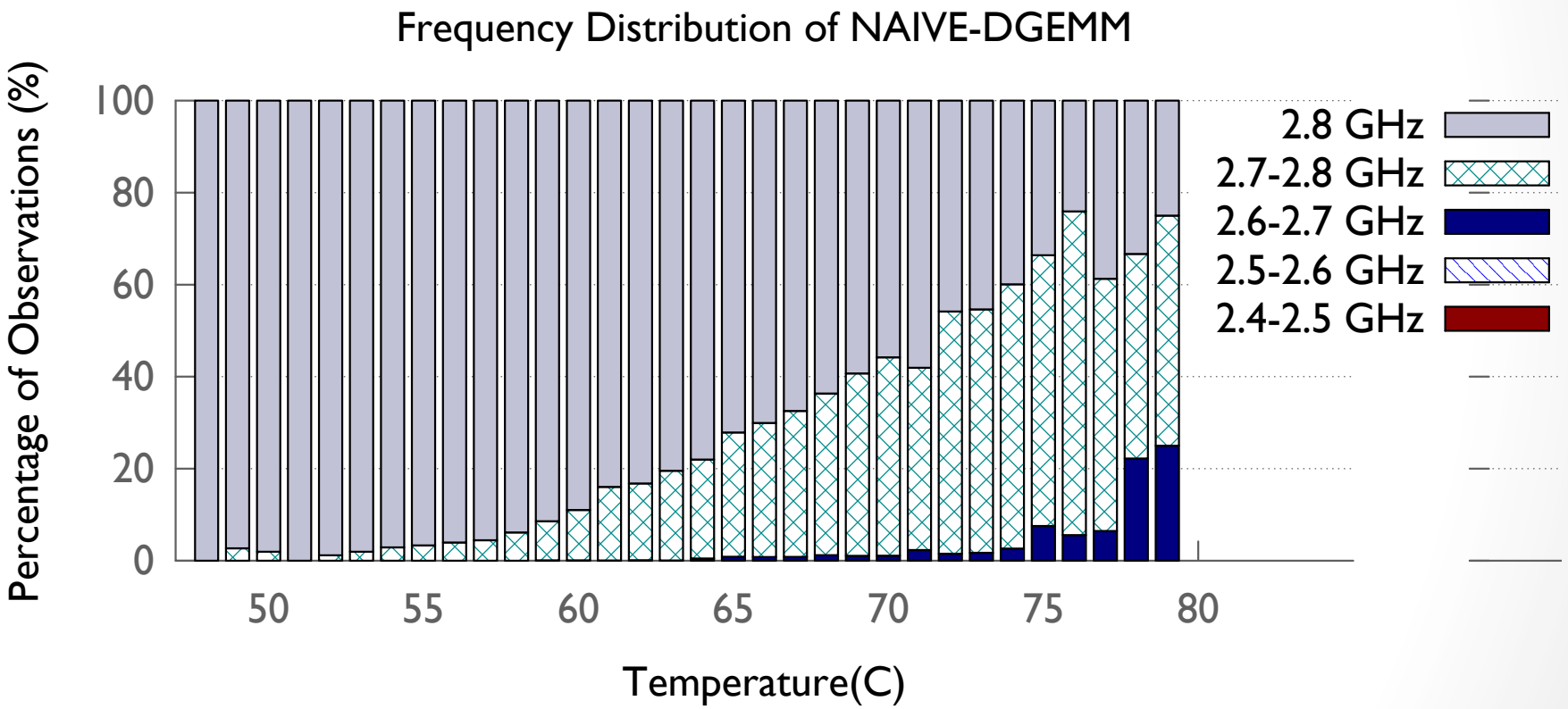
Application	Frequency (GHz)								
	Idle cores	2.4 – 2.5	2.5	2.5 – 2.6	2.6	2.6 – 2.7	2.7	2.7 – 2.8	2.8
MKL-DGEMM	0 1	5 0	31 0	116 0	125 20	254 42	154 116	211 256	128 590
NAIVE-DGEMM	0 1	0 0	0 0	0 0	0 0	2 0	49 2	23 0	950 1022
LEANMD	0 1	0 0	0 0	0 0	0 0	0 0	0 0	186 8	838 1012
JACOBI2D	0 1	0 0	0 0	0 0	0 0	0 0	200 50	100 50	720 924

Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

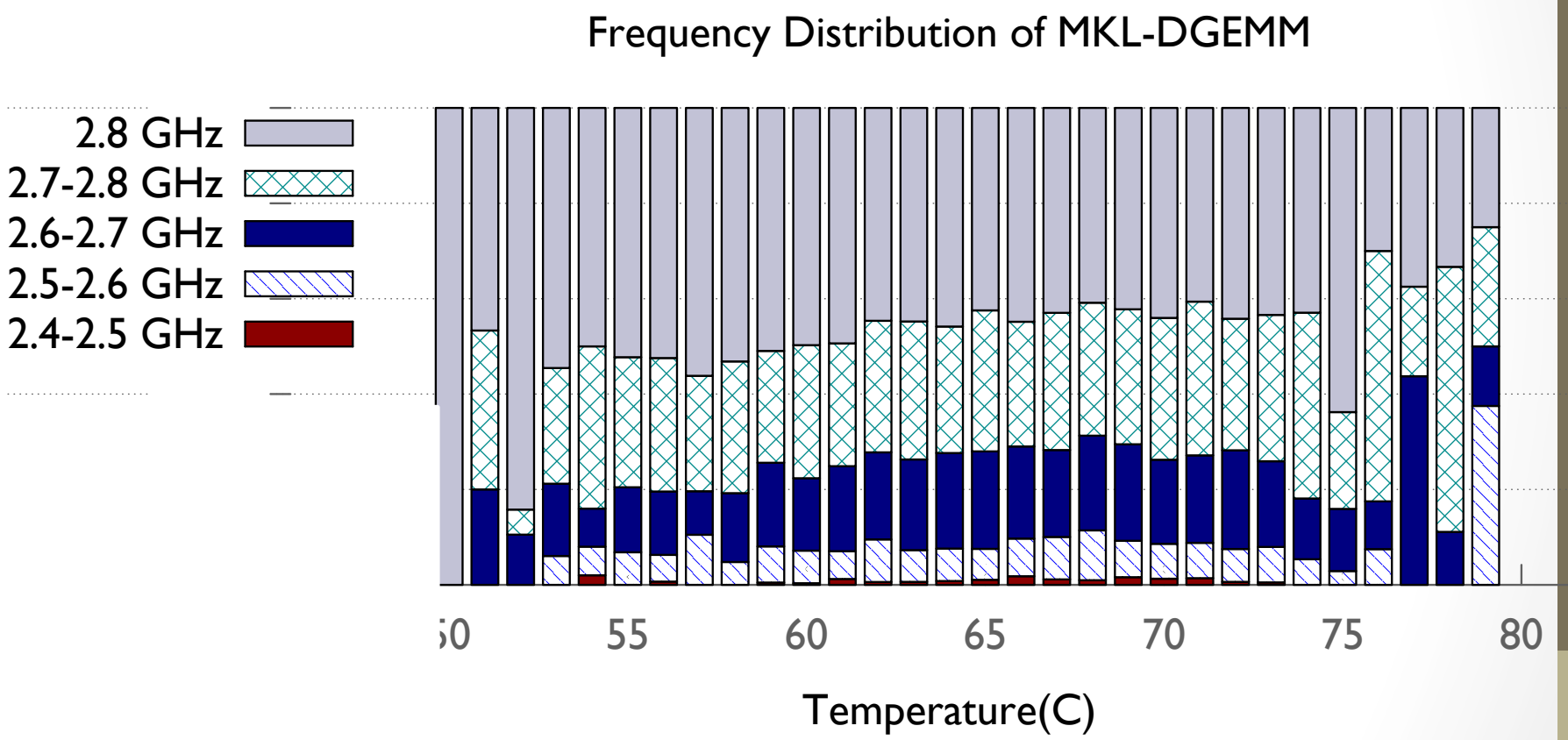
Why there is variation?



Is it caused by temperature?

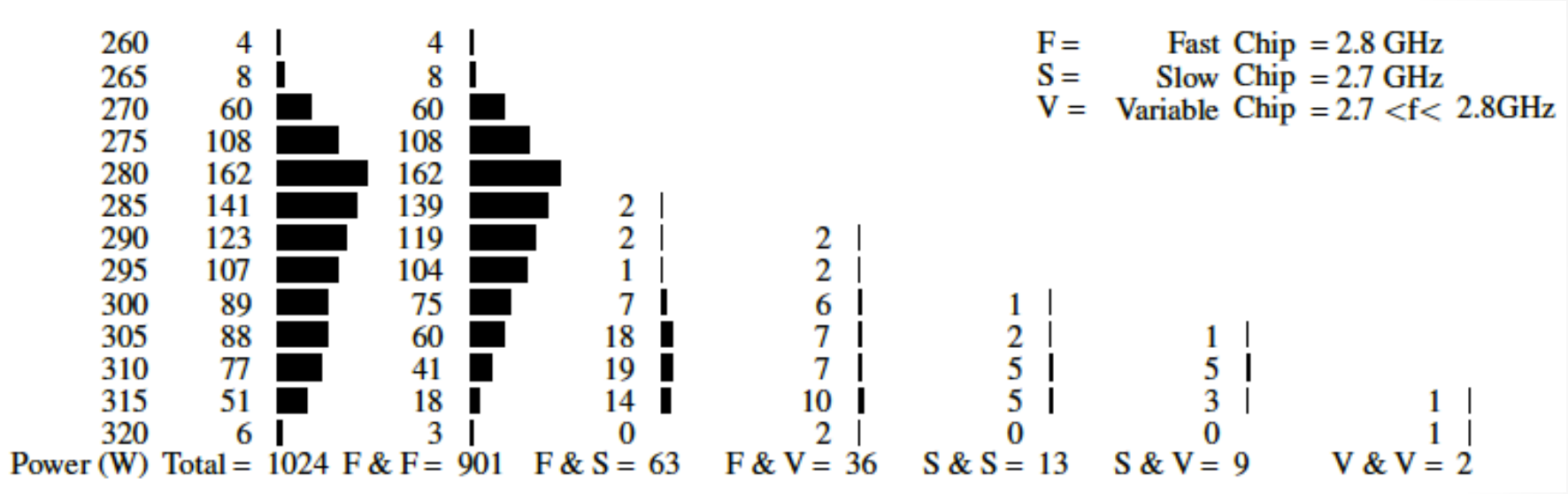


Is it caused by temperature?



Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Is it caused by power?



Fast processors' power are similar to uniform distribution

Slow and variable processors have higher power

What can we do about it?

1. Disable Turbo-Boost
2. Replacing the slow chips
3. Selectively idling the cores
4. Dynamic load balancing

Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

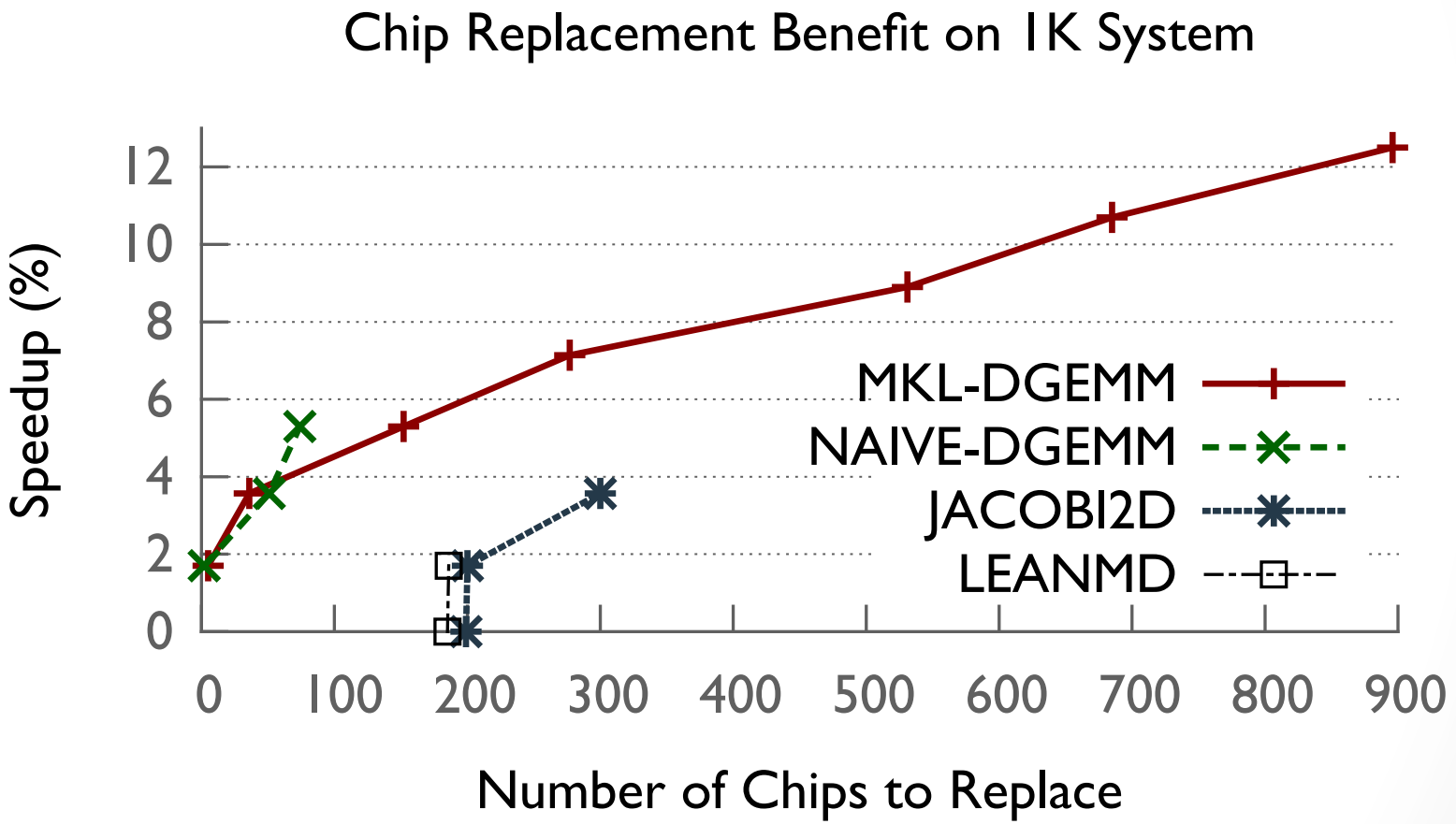
Solution 1: Disable Turbo-Boost?

Application	% Slowdown
MKL-DGEMM	9.1
NAIVE-DGEMM	18.1
LEANMD	16.8
JACOBI2D	4.2

- Naïve-DGEMM slows down more compared to MKL because it was running at higher frequency with Turbo Boost.
- Jacobi2D suffers less from disabling Turbo-Boost because it's memory intensive.

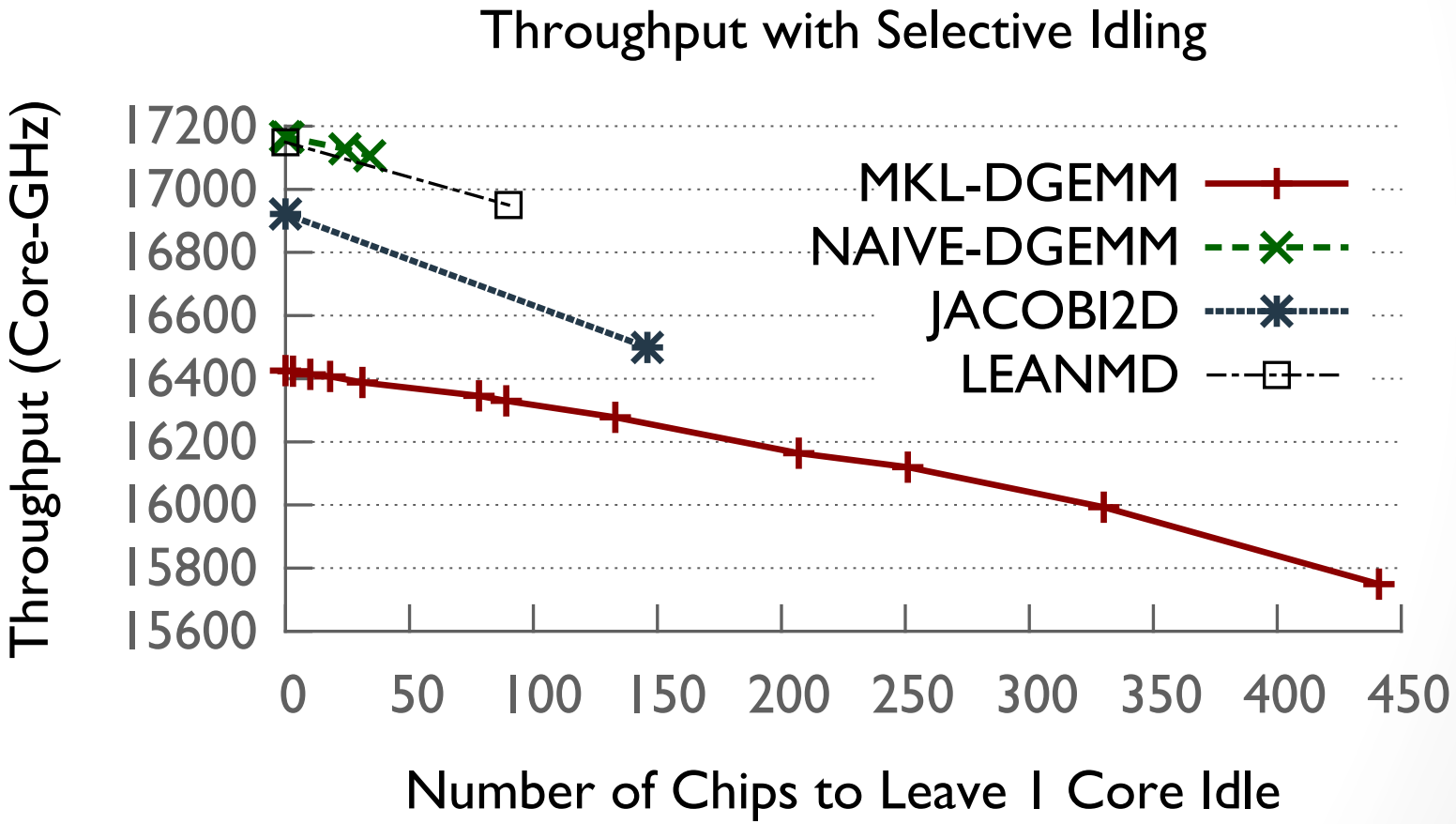
Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Solution 2: Replace the chips?



Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Solution 3: Idling the cores?

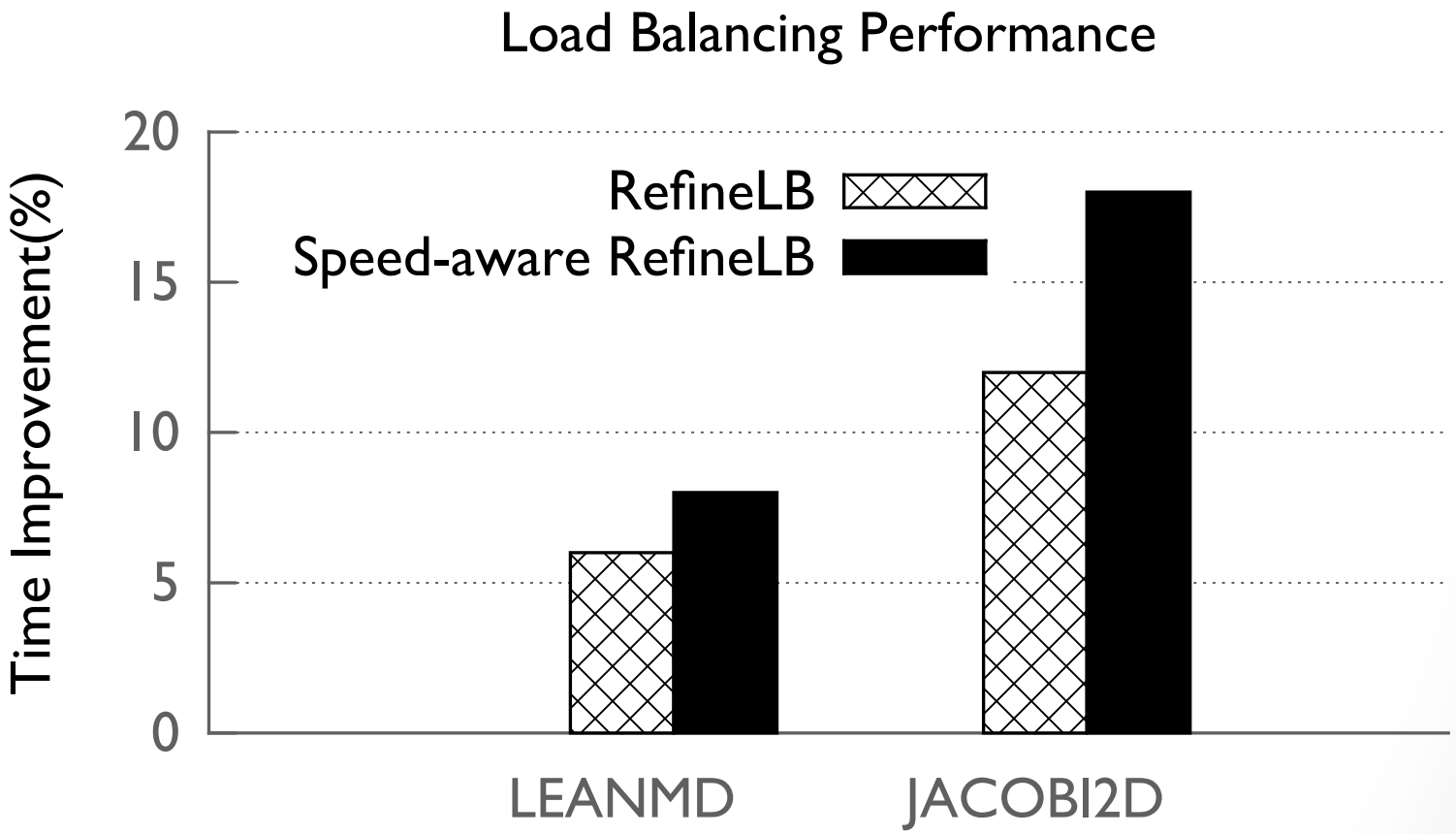


Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Solution 4: Speed-Aware Load Balancing!

- Runtime tracks processor speeds dynamically
- Balance the workload with taking into account the speed

+LBTestPESpeed



Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Summary & Conclusion

Software can do a lot more if the desired support and access is given.

✓: There is support and access. ✗: There is no support.
◐: Hardware supports, but the software does not allow.

Need \ Platform	Edison	Cab	Stampede
Frequency Data	✓	✓	✓
Temperature Data	✓	◐	◐
Node Level Power Data	✓	◐	◐
Chip Level Power Data	◐	◐	◐
Core Level Power Data	✗	✗	✗
Per-chip Power Capping	◐	◐	◐
Per-chip Frequency Scaling	◐	◐	◐
Per-core Frequency Scaling	✗	✗	✗

Acun, Miller, Kale. "Variation Among Processors under Turbo Boost in HPC Systems" [ICS 2016]

Future Work

- Variation analysis on newer generation processors
- Variation in memory operations

Thank you!