High Performance Computing Systems

- Power Consumption

Doug Shook

Background

- HPC systems used to use specially designed chips
- Personal computing changed a lot of things
- Now, changes in PC directly affect HPC

Background

- Personal computing has shifted focus

- Other important factors as well

Considerations

- Average U.S household uses ~1-2 kW per day

- PC left running all day (active, high end PC)
  - ? kW per day

Reducing Power Consumption

- Frequency Scaling
- Parallel Scaling
- GPUs
- Power Gating
- Clock Gating

- Power per transistor is dropping

- Mobile CPUs for HPC?

Heat Dissipation

- Common:
  - Air Cooling
  - Liquid Cooling (water)
  - Heat Sinks
- Not so common:
  - Liquid Submersion
  - Thermoelectric
  - Phase Change
  - Nitrogen / Helium / Freon

Thermoelectric

- Heat flux between the junction of two materials

- Pros
- Cons

- Common Usage:
  - Satellites

Liquid Submersion

- Submerge the components in thermally conductive liquid
  - Must not be electrically conductive!
- Variety of dielectrics shown to work:
  - Mostly specialized, but don't have to be
- Not used much in practice
  - But picking up steam...

Tsubame KFC

- 2992 CPU Cores
  - All submerged in mineral oil
- > 4.5 GFLOPs / Watt
- Why Japan?

Tsubame KFC



Hot Water Cooling

- Idea: The temperature of the components is much greater than room temperature
- Don't cool the water first!
- Advantages
- IBM SuperMUC, eBay data centers

HPC Cooling

- Fans, water, heat sinks
  - Scale is much bigger, though

- Why?

Measurement

- It is easy to reduce power consumption in a computer
- Performance is still a huge factor
- FLOPS / Watt
- SWaP
  - Performance / (Space * Power)

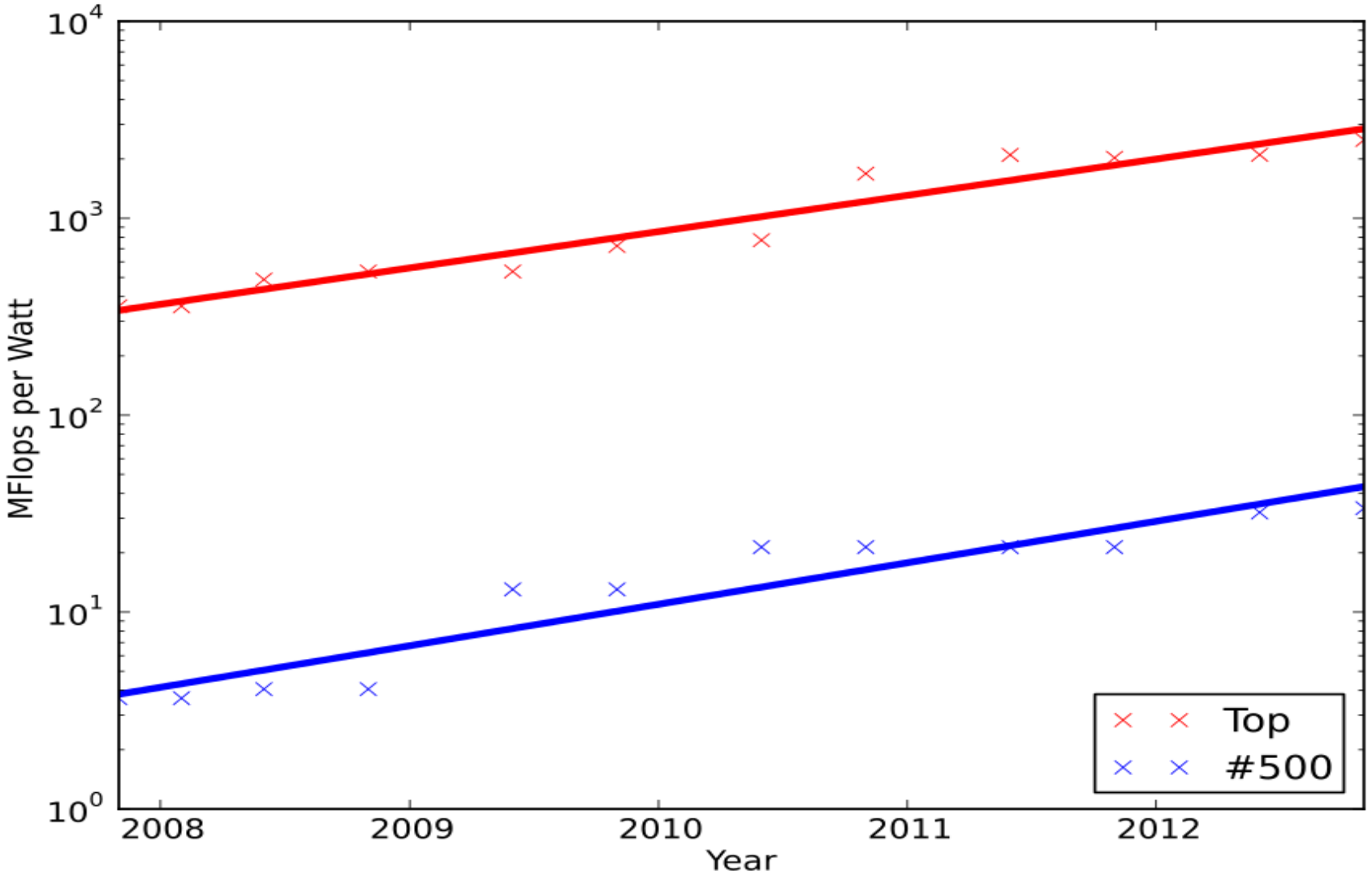
Green 500

- Similar to TOP500 – based on FLOPS / Watt
- FLOPS achieved using Linpack
- Watts
  - Average power consumption over LINPACK run

Green 500

Green500 Rank	MFLOPS/W	Site	System	Total Power(kW)
1	9462.1	NVIDIA Corporation	NVIDIA DGX-1, Xeon E5-2698v4 20C 2.2GHz, Infiniband EDR, NVIDIA Tesla P100	349.5
2	7453.5	Swiss National Supercomputing Centre (CSCS)	Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect , NVIDIA Tesla P100	1312
3	6673.8	Advanced Center for Computing and Communication, RIKEN	ZettaScaler-1.6, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband FDR, PEZY-SCnp	150.0
4	6051.3	National Supercomputing Center in Wuxi	Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway	15371
5	5806.3	Fujitsu Technology Solutions GmbH	PRIMERGY CX1640 M1, Intel Xeon Phi 7210 64C 1.3GHz, Intel Omni-Path	77
6	4985.7	Joint Center for Advanced High Performance Computing	PRIMERGY CX1640 M1, Intel Xeon Phi 7250 68C 1.4GHz, Intel Omni-Path	2718.7
7	4688.0	DOE/SC/Argonne National Laboratory	Cray XC40, Intel Xeon Phi 7230 64C 1.3GHz, Aries interconnect	1087
8	4112.1	Stanford Research Computing Center	Cray CS-Storm, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband FDR, Nvidia K80	190
9	4086.8	Academic Center for Computing and Media Studies (ACCMS), Kyoto University	Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect	748.1
10	3836.6	Thomas Jefferson National Accelerator Facility	KOI Cluster, Intel Xeon Phi 7230 64C 1.3GHz, Intel Omni-Path	111

Green 500


10^4
10^3
10^2
10^1
10^0
MFlops per Watt
2008
2009
2010
2011
2012
Year
Top
#500

Conclusion

- Power consumption is becoming increasingly important
- Variety of cooling systems available