A Tale of Two Green Lists

Kirk W. Cameron, *Virginia Tech*

The SPECpower benchmark and the Green500 list make it possible to track energy-efficiency gains in both servers and supercomputers.

Since I've been following Green IT for nearly a decade, I'm often asked about industry trends. Identifying trends is, of course, a tricky business. In fact, when I began research in the field, one of the greatest difficulties I faced was quantitatively demonstrating a looming energy crisis for large-scale deployments of computer systems.

Now it all seems obvious, but at that time I had to draw conclusions based on somewhat subjective sources, including machines' UL (Underwriters Laboratories) ratings and ballpark power figures provided by facilities managers. Accurately isolating the power consumption of IT equipment was, to say the least, a challenge.

In 2004-2005, I began participating in two new efforts to improve our understanding of IT energy use. The first was SPECpower, a power-performance benchmark for server-class systems developed by the Standard Performance Evaluation Corp. (SPEC) Power Committee (www.spec.org/power) chaired by HP's Klaus-Dieter Lange. The second effort was the Green500 list (www.green500.org), a power-performance efficiency ranking for supercomputers I cofounded with Virginia Tech colleague Wu Feng.

In both cases, the first system measurements became public in the fourth quarter of 2007. After some initial kinks, they've become the prevailing energy-efficiency standards in their respective industries. Their success is primarily due to dozens of committed team members who have worked tirelessly to prove out the methodologies and continuously adapt to technological changes. I was lucky enough to be associated with these individuals from the beginning.

SPECPOWER AND THE GREEN500

SPECpower uses the ssj_ops/watt metric to measure server-class efficiency. The benchmark is quite sophisticated but generally indicates how efficiently a system handles server-side Java transactions (K-D. Lange, "Identifying Shades of Green: The SPECpower Benchmarks," *Computer*, Mar. 2010, pp. 95-97). The higher the ssj_ops/watt result, the more efficient the system is. The SPEC Power Committee verifies that all officially posted SPECpower measurements follow the established run rules, and it updates its lists quarterly. The committee doesn't rank systems but reports the achieved ssj_ops/watt for each system on its website.

The Green500 list uses the flops (floating-point operations per second)/watt metric to express supercomputer efficiency. Because the industry commonly relies on the High-Performance Linpack (HPL) benchmark to quantify supercomputer performance, the Green500 list uses this as the basis for a system's flops calculation and, when possible, the system's power consumption while running HPL to calculate flops/watt. The Green500 list is released twice each year—in June and November.

TRENDS

Now that these lists have been available for several years, what have we learned?

 Published by the IEEE Computer Society

SPECpower

Figure 1a shows SPECpower results for more than 170 servers from Q4 2007 through Q3 2010. The plotted values are the systems' reported ssj_ops/watt measurements for the first three years since the benchmark was released. Otherwise anonymous, Figure 1 separates results by AMD (Opteron)- and Intel (Xeon)-based systems.

Only about 25 of the reported systems, or less than 15 percent, are AMD-based, while the rest are nearly all Intel-based. Intel fares better in raw ssj_ops/watt measurements over the first three years. However, the trend line for AMD-based systems is steeper than that of Intel-based systems, indicating that they could be gaining ground in energy efficiency. Note, however, that the sample size for AMD-based systems is relatively small, and that these aren't direct processor comparisons but system-wide measurements not necessarily indicative of CPU efficiency.

Figure 1b shows the range of power values for a server versus its ssj_ops/watt value. Basically, newer systems tend to have higher ssj_ops/watt values. Higher values along the *y*-axis indicate a wider difference between active idle power and power at maximum throughput.

While most servers achieved less than 1,000 ssj_ops/watt early in the SPECpower benchmark's life, AMD- and Intel-based systems had comparable energy efficiencies. More recently, however, Intel-based systems have achieved the capability to vary their system power usage more widely than AMD-based systems by a relatively large margin.

Fully understanding the impact of dynamic power ranges requires gathering more data for AMD-based systems. However, this may be one place where such systems could improve energy efficiency as there are early indications that this could be a competitive advantage.

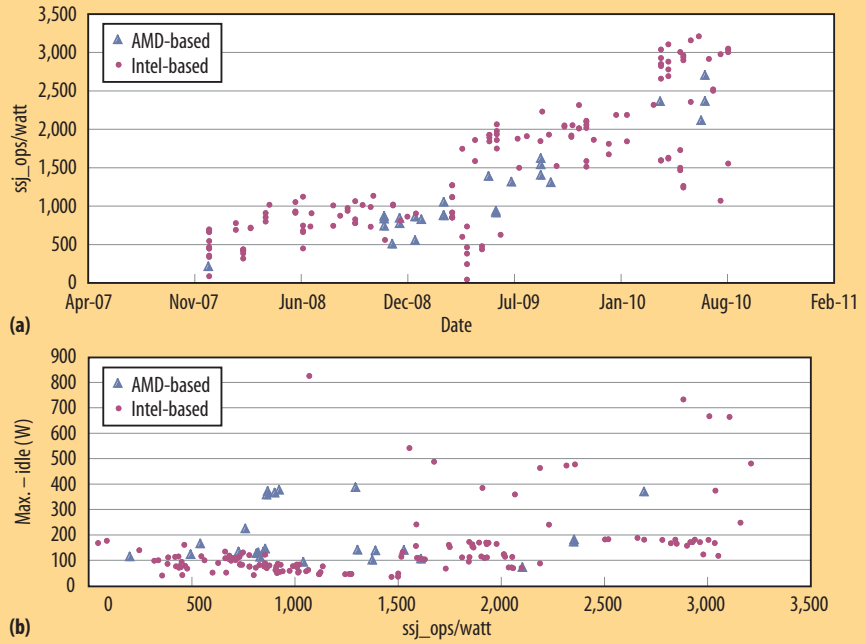

Figure 1. SPECpower benchmark trends. (a) Intel-based systems fare better in raw ssj_ops/watt measurements over the first three years, but the trend line for AMD-based systems is steeper, indicating that they could be gaining ground in energy efficiency. (b) In the benchmark's early life, AMD- and Intel-based systems had comparable energy efficiencies (in terms of maximum minus idle power), but more recently, Intel-based systems have achieved the capability to vary their system power usage more widely than AMD-based systems by a relatively large margin.

Green500

Many of the same types of servers evaluated by the SPECpower benchmark form the building blocks of supercomputers in the Green500 list. However, because the HPL benchmark's numerical linear algebra subroutines differ widely from those in SPECpower, directly comparing the two benchmarks isn't particularly useful.

Figure 2a shows megaflops/watt results for Green500 supercomputers since the inaugural list in November 2007. The top 10 systems are about three times more efficient than the average system across the list. The first systems recently passed 700 Mflops/watt, while no system exceeded 400 Mflops/watt in the inaugural list.

The top 10 systems have consistently gained efficiency, discounting a small dip in June 2009 due to some systems not reporting in successive lists. The average system overall and the bottom 10 systems have also become more efficient, but the trend for the top 10 systems is an increase of several percentage points per year better. This suggests that the top 10 system designs are more focused on energy efficiency than the average system.

Figure 2b shows the average system power for Green500 supercomputers since November 2007. Despite the focus on energy efficiency, the power needed for most systems on average is increasing, though this may be subsiding and the rate of increase has definitely slowed. The results for the bottom 10 systems are somewhat volatile due to their being pushed down the list for efficiency reasons that don't necessarily correspond to raw total power consumption.

Interestingly, the differences between AMD- and Intel-based systems aren't as striking in the Green500 list as they are in the SPECpower

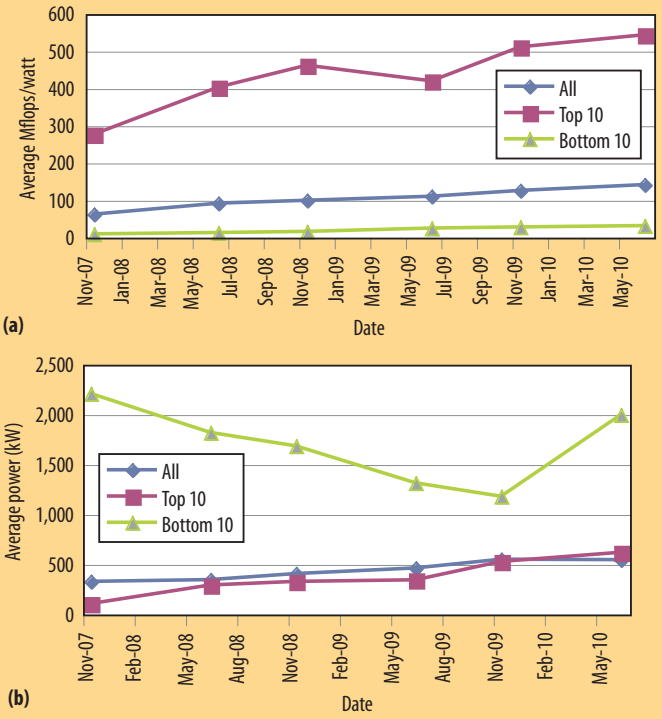

Figure 2. Green500 trends. (a) The top 10 supercomputers are about three times more efficient than the average system across the list. (b) Despite this focus on energy efficiency, the power needed for most systems on average is increasing, though this may be subsiding and the rate of increase has definitely slowed.

rankings. For example, the top 10 energy-efficient Green500 supercomputers in 2010 are evenly split between these systems. More detailed data may account for this discrepancy.

The use of graphics engines such as the NVidia Tesla and the Cell Broadband Engine, as well as FPGA-based accelerators, apparently improves efficiency dramatically for the HPL benchmark. This helps to explain the acceleration in efficiency in the top 10 systems and could also indicate a growing trend to create hybrid systems that provide additional computational power with energy efficiency.

What conclusions can we draw from the SPECpower benchmark ratings and the Green500 list? At the highest level, the industry seems to be producing more energy-efficient systems than ever before for use in both servers and specialty systems that comprise some supercomputers. These trends transcend system and workload differences.

Nevertheless, we clearly have a long way to go. Since the focus on Green IT has only recently gained momentum, most of the gains have likely come from correcting obvious inefficiencies in existing technologies. The role that emergent, competing technologies such as accelerators play in energy efficiency will likely remain an open question for some time. Thankfully, these two green lists will enable us to compare where we have been to where we are going.

***Kirk W. Cameron**, Green IT column editor, is an associate professor in the Department of Computer Science at Virginia Tech. Contact him at greenit@computer.org.*