Powerful Ideas

Virtually all the power that goes into a modern processor comes out as heat. Circuit densities have reached a point where the ability to dissipate that heat is a fundamental limit on performance. The costs of power and cooling also have become significant fractions of the total cost of ownership. We are developing open systems technologies to deliver high performance at low cost, without exceeding power and thermal limits.

HAK – Half-powered Athlon cluster in Kentucky. We have long known that the power supplies in most of our nodes are running at only about 1/3 their design output. We also have found that power supplies are the most commonly failing components. In June 2010, we built HAK to answer the age-old question of whether nodes sharing commodity power supplies is beneficial.

Pairs of Athlon XP nodes (which have no internal power management) were constructed by inverting one case and using metal duct tape to form a hinge and to block unwanted airflow paths. Each pair shared a single power supply using a simple Y-cable. Metering individual pairs showed anywhere from 8% reduction to 20% increase in power consumption as compared to separately powering the nodes. However, as a complete 96-node cluster, we found a *typical reduction in power consumption of about 20%*. Using half as many power supplies also reduces purchase cost, although physical assembly is more labor-intensive.

Per-node power monitoring. Although monitoring power consumption per node is theoretically easy, it has not been cheap. A University of Kentucky undergraduate senior project team is building a USB-interfaced "smart" power strip that can report ambient temperature and AC power use for each individual node... with a cost target of less than $15 per node. The project will be completed in Spring 2011.

Power management via priority control of an idle process. Although most modern processors incorporate sophisticated power management mechanisms like frequency and voltage scaling, it should be possible to have a completely generic power saving mechanism by modulating the priority of a power-saving idle process. This method was experimented with by an REU student at the University of Kentucky in Summer 2010. The method seems to work, but construction of a portable, truly low power, idle process has been an elusive goal.

Predictive Control. Power management is complicated by the fact that temperature of a system can continue to rise long after power consumption has been cut. Reactive control based on real-time sensor readings must allow for this hysteresis, which effectively means the control must be very conservative. To allow the system to safely operate closer to its limits, control must make use of predictions more tightly bounding future behavior.

Over the last four years, we have demonstrated new compiler technology that can annotate a program with worst-case power consumption predictions covering time intervals long enough to allow true predictive control at runtime. It uses *variable-N N*-gram analysis to empirically model instruction-level costs and a state machine analysis of the program's executable object file to look ahead millions of instructions. See Muthulakshmi Muthukumarasamy's 2010 Ph.D. dissertation, `http://hdl.handle.net/10225/1176`, for details.

A broader view of power issues. Launched in 2010 with initial funding from the *Department of Energy*, the *Power and Energy Institute of Kentucky* (PEIK) has as its goal to attract engineers to the field of power and energy and to provide them with the innovative education they will need to join the 21st century power engineering workforce. Power issues are becoming a focus of the University of Kentucky at all levels.

Next year, our group will be partly moving into the new 45,000 square-foot *Davis Marksbury building*, shown below. This building is the second of four planned buildings in the *digital village*, and will house the *Center for Visualization and Virtual Environments* (CVVE) and portions of the CS and ECE departments. It also is the University of Kentucky's first *Leadership in Energy and Environmental Design (LEED)* rated building. Our group's new machine room there is designed to efficiently support a petaflop-class research cluster.

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