From E-mails to Energy:

Embracing the future of green computing

By Ryan Neff

credit: http://upload.wikimedia.org/wikipedia/commons/c/c9/Computer_sound_card01.JPEG

We are at the crisis point for digital computing. As the world we live in continues to shrink through sites like Facebook and Google, our digital world is filling up at an alarming rate. Some estimate that in less than nine months, we will exhaust the remaining address space currently available on the Internet, bringing it, and most of what we do online, to a temporary halt.

The demand for bandwidth-intensive applications on the Internet like cloud computing and digital HD video isn't only putting the pressure on Internet service providers to provide faster Internet connections, but also on utility companies, policy makers, and the entire computing industry to come up with solutions to the problem – fast.

Data centers work around the clock to manage everything from bank accounts to movie downloads to scientific research. One continual obstacle to upgrading our servers to cope with our massive digital demand has been an issue of power.

What computer manufacturers such as IBM, Dell, HP, AMD, Sun Microsystems, and others realize is that, as processors get faster, the amount of power that they use increases exponentially. For example, at the turn of the millennium, a typical single-core Pentium 4 processor dissipated about 55 watts of power. Today, even a modest quad-core laptop CPU can draw up to 130 watts - more than double the power use (1).

Because of this, energy use at data centers in the US has skyrocketed from a modest 30 billion kWh in 2000 to over a projected 100 billion kWh by 2011 in an EPA report published in 2007 (2). It is estimated that this mammoth demand for electricity is responsible for more than 2.5% of electricity consumption in the US and over 2% of global CO_2 emissions yearly (2). As servers continue to expand in size, they consume more and more energy, at a growing expense to data centers, energy providers, and our environment.

An Issue of Cooling

Up to half of the power consumed at a typical data center is used not on processing power but on keeping servers from overheating. Large, multi-megawatt cooling systems depend on specialized air conditioning units, called "chillers," which force cold air quickly through the servers to keep the processors from melting down or malfunctioning due to overheating (3).

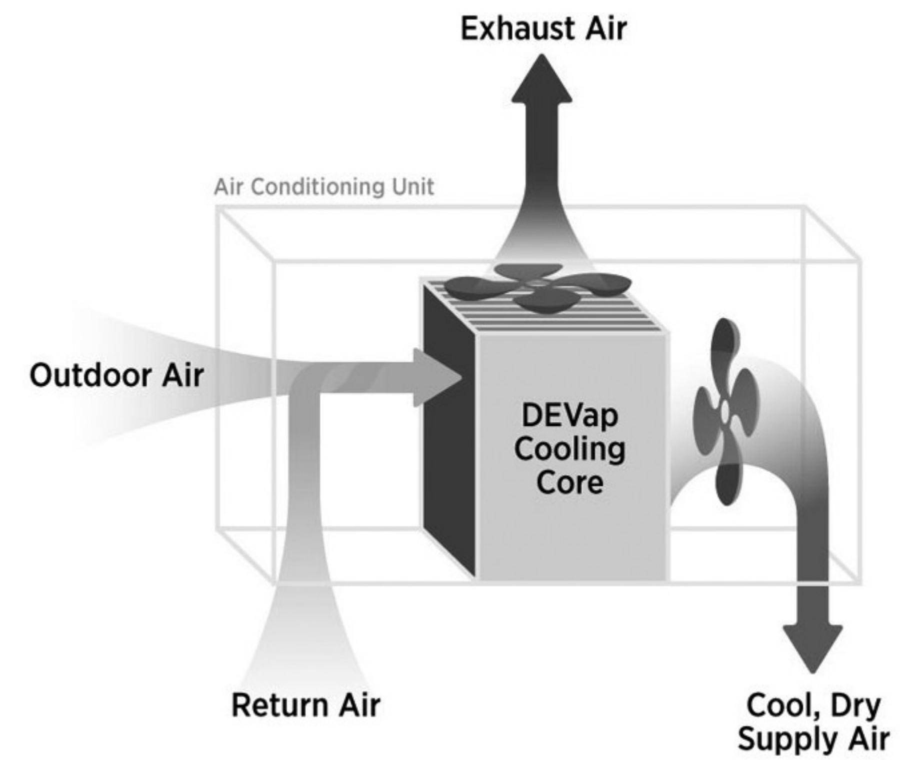
To cut down on cooling costs, IBM has developed a high-efficiency water cooled server – departing from the norm – which it expects will help cut down energy use by up to 50% at the IBM Zurich Research Laboratory (4).

In principle, water cooling is inherently more efficient than air cooling because of water's high specific heat, giving it the ability to trap large amounts of thermal energy (3). Each milliliter of water can carry away more heat from a processor than three liters of air – making water-cooled systems seem like the obvious choice. However, issues of both reliability and cost hinder our dependence on water-cooled technology today.

During the early days of the 1970s-80s microprocessors, water cooling had been the cooling method of choice for the majority of computer manufacturers. Water-filled cold plates sat atop CPUs for most of the 1980s, and, for some time, seemed like the only option available. However, that all changed in the 1990s, when microprocessor manufacturers began making the switch to complementary metal-oxide-semiconductor technology, known more commonly as CMOS (4). High-scale cooling systems were made obsolete by CMOS chips that were over 10 times more energy-efficient than their predecessors. To reduce cost and save space, air cooling through fans and heat sinks instead of pumps and cold plates moved to the forefront of chip design, and water cooling in the server room took a twenty year hiatus (5).

Today, due to the increased power demands of computing and heat-production by servers, water-cooling is making a comeback because of its energy efficiency and performance benefits. IBM's water-cooled system – dubbed Aquasar – replaces the typical cold plate with a micro-channel cooling system which delivers cooled water to the processor's surface itself rather than indirectly (5). Borrowing from biology, the micro-channels are modeled after vascular systems that can increase the surface area of the water exposed to the chip without increasing the total pressure of the system. Typically, high pressure cooling systems are more prone to costly leaks which can jeopardize the operation of the server. Furthermore, because of its heat capacity, water that is used to cool the chips only needs to be a few degrees cooler than the water exiting the system, saving thousands of kilowatts of power per cycle (5).

credit: http://www.epa.gov/region5fields/htm/methods/gps/index.html



▲ **Figure 1.** The DEVap cooling core uses water and liquid desiccant to draw in outside air, exhaust some of that air and return cool, dry air to the area being cooled

Recycling Heat

Another way that water cooling is revolutionizing computing is by allowing data centers to reuse thermal energy normally considered to be waste from the server room. For instance, the system in Zurich pumps heated water from its server room into the heating system of a nearby office building. The net effect of this heat recycling is not only seen in energy savings but also by reducing the system's carbon footprint by 85% (4). The industry's goal is to eliminate 100% of a data center's carbon footprint, greatly reducing the amount of carbon dioxide worldwide (4).

While in hot, arid environments this option is impractical, waste heat is still seen as an energy source and valuable commodity. At a data center in Sunnyvale, CA run by Network Appliance Inc., the return air pumped from its servers powers an evaporative cooling device, which can generate chilled water at a fraction of the cost of refrigeration (7). Evaporative cooling is nothing new, as it has been used in the western US for decades as an alternative to traditional A/C systems. However, in the data center, it is a notable step since previous systems could not provide adequate, reliable cooling. The system – called DEVap or the Desiccant-Enhanced eVaporative air conditioner – is being developed by the US Department of Energy's National Renewable Energy Laboratory to cool server rooms by up to 30 degrees (8). By using the heated return air to evaporate water, followed by drying the air using a series of water-absorbing materials, DEVap can achieve energy savings of up to 90% while still returning cool, dry air. These systems are being marketed as replacement options to traditional air conditioning in commercial and industrial settings.

Ice is the New Green

At a 538,000 sq. ft. computing facility in Phoenix, Ariz., i/O Data Centers, LLC is testing out a radically different cooling system that seems inspired by the early refrigerated train cars of the late 19th century (9). During the night, air conditioning units called "chillers" freeze ice balls of roughly four inches in diameter. Each ice ball is filled with water and is encapsulated in a plastic shell for easy reuse and storage in insulated vats. Using propylene glycol, a common antifreeze agent, to transfer energy from the ice balls to the server room directly, the air conditioners are reserved for only the hottest days during the summer months. The system is being developed by the San Diego, Calif., startup Cryogel, one of the first companies in the US to pioneer this technology. This company's system has already been installed at ten airports to cool planes upon landing and is now being tested at data centers. Cryogel stresses that its systems are not merely cooling systems, but that they are also suitable for use as thermal energy storage and can be turned on and off on demand like batteries (10).

> *"[These ice balls] are also suitable for use as thermal energy storage and can be turned on and off on demand"*

Certain logistical and reliability concerns for the Cryogel system still linger, however, and the thermal energy system isn't practical for most facilities yet. Large vats and coolant pipes would take up a hefty amount of space in already crowded data centers; moreover, the ice balls do not yet reduce the kilowatts of power used by the data center. The company claims that by using more electricity at night during hours of lower demand on the grid, the ice ball system has a lower carbon footprint ("dirty," auxiliary power stations are used during the day). Regardless, in areas like Phoenix where the price per kilowatt of electricity can skyrocket by 500% during peak hours (11), thermal energy storage is seen as an attractive, if not obvious, option.

Swarms to Servers

One of the most profitable areas of green computing exists not in hardware but in the software that manages networks of servers to be more energetically and computationally efficient. Since even single companies like Google can own and maintain hundreds of thousands of servers nationwide, each with different capabilities and workloads, intensive research is often multi-dimensional, pulling from mathematical, statistical, modeling, and historical analyses. Recently, the quantification of biological models towards solving network optimization problems has provided computer scientists with new tools to manage the growing data crisis.

At an international conference in 2009, German researchers reported achieving 25% power savings on a network of servers at an average load of 60%, by using a swarm algorithm that helps move workloads efficiently to where they would consume the least power and resources (12). The algorithm worked much like a group of honey bees in search for nectar. First, a series of "scouts" (small programs that collect and analyze data on the host computer) would travel in all directions along a server network and stop at each server it encountered, storing data at each stop in memory. Once a scout has found a server that could provide more computing power or power savings, the scout would return back to the original server. As data from each scout was collected, blocks of work (called "VMs") are moved from server to server in the best possible configuration.

The scouts achieve greater efficiency through random selection and live updating, in some cases achieving up to an 88% savings in power consumption. Despite adding work to the system by running the algorithm, the net benefits in efficiency far outweighed the added computational costs.

In an era of tremendous energy consumerism, environmental consciousness, and simultaneous economic restrictions, scientists are innovating creative approaches towards critical optimization problems. From encapsulated ice ball coolants to biomimetic honeybee-like network traversal, all corners of the scientific community are contributing their clever insights and specialized perspectives to the multidisciplinary field of energy science. **H**

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