Solution Architecture: Data Center Efficiency & Cooling

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In the infinitely expanding world of technology, data is becoming increasingly embedded into everyday lives. Many people have the misconception that their data is stored completely on their own personal computers and that data can be created endlessly. In actuality, every time you browse the internet, upload, download, or transfer a file, data is stored somewhere, somehow. And while this data is being stored, physical storage capacity plays a huge role in our ability to keep data. So if all data must be stored on some physical storage unit, where does all of our data go? In comes data centers; massive campuses or buildings that house thousands of servers to enable the storage of data, whatever that data may be. An example of data center use is Google, one of the largest computing companies in the world. Google has twelve main data centers that house almost 1 million servers in total (Wood, 1). Every time we enter a search query in Google, the information we receive back is all stored in their data centers. And while we have the unique ability to store that much data, many problems arise when we house thousands of computers in one place.

Energy efficiency is becoming more and more of a concern in our everyday lives due to global warming but we don't usually hear about how much energy it takes to store our computational data. Data centers account for at least 3% of the total electrical consumption in the United States. Just one data center can consume as much power as an entire town in America (Wood, 1). When we think about everything that is powered with electricity in this country, the numbers start to become real and energy efficiency becomes a huge concern not only in the biological world, but the computing world as well.

The main reason that data centers consume so much power is because of the amount of heat that computers produce. Computers need to be cooled; even a small home laptop has built in heat sinks and fans to keep the central processing unit from overheating. But when we combine thousands of computers in one place, the heat adds up and small fans don't necessarily do the trick. The main measure of data center efficiency is called the PUE (Power Usage Effectiveness). The measure of PUE is the total amount of energy it takes to power the entire data center divided by the amount of energy it takes to power the servers alone. The general measure of PUE is 2.0, or double the amount it takes to power the servers. This means for every watt of energy it takes for the servers to maintain power, it takes another watt just to cool them (GoogleGreen, 1). But those numbers are becoming legacy due to increased efforts to cut the amount of cooling power needed.

The two general architectures of data center cooling are hot-aisle and cold-aisle containments. The concept of both methods is that heat ascends, making cooler air descend. In hot-aisle containment, the cold air circulates around the open air freely while the hot air is pushed and contained in between server racks. From there, the heat rises to the CRAC's (Computer Room Air Conditioner) to be cooled and recirculated back to the free air. On the contrary, cold-aisle containment pumps cold air in between server racks. From there, the cold air pushes the hot air through the server racks and out into the free air. When the heat is in the free air, it will rise to the vents that will carry the heat back to the CRAC's to be cooled. There is no better way to implement these methods and neither one is right or wrong, depending on the data center design.

In both hot aisle and cold aisle containments, the general idea is that we want to separate the hot air from the cold air. When we design data centers, "hot spots" can occur almost anywhere for any reason. If a hot spot occurs near a server, this can cause the server to overheat. Many components of the server including the memory and motherboard are made of volatile metals and silicon. When the servers overheat for too long, these metals can melt or blow, leading to a loss of expensive IT equipment or large amount of data. Computational Fluid Dynamics (CFD) is used to help determine where the hotspots will be and allow data center designers to create simple architectures based on airflow to avoid unexpected overheating. CFD is not exclusive to computers and data centers and is used in a number of fields including astrology, automotive engineering, and other mapping concepts that measure hot and cold temperatures. CFD uses a thermal model of your data center with the CRAC vents to create a temperature based airflow map of every room. From there, you can analyze where potential hot spots will be using sensors and implement strategies to keep air flow consistent. This model may be slightly inaccurate due to the under or overestimation of airflow but gives designers insight of what designs could be implemented for savings.

Knowing and measuring how your air is flowing grants a huge competitive advantage in developing cooling methods. When you have different empty slots on the server rack, you might have a misconception of how the airflow is actually flowing if every server rack has empty spaces. These empty spaces can alter the flow of air and create hotspots within' a server cabinet. 'Blanking Panels' are covers that are the same size and shape of the IT servers and slip into the server racks to keep the heat and air separate and conducting to the right place. Various companies are now designing custom blanking panels that can be made to fit any server rack. Google has now implemented clear plastic curtains that bind together to keep hot and cold air separated while maintaining accessibility to the servers. Airflow leakage is also prevalent due to the cables coming out of the server racks. Implementing cable covers to ensure the wires are sealed tight in the racks offers additional support in airflow confinement. Once you have your air flowing properly in the IT sector, you can implement additional design strategies to maximize energy efficiency. Most data centers come equipped with large office buildings for database designers, installers and programmers. Instead of conducting heat out of your data center and using a separate heating system for the office, some database designers are using the heat from the IT servers to heat the rest of their on-site office buildings. This simple but smart approach just shows how many clever ways there are to be smarter about your energy efficiency.

The usual data center's power system consists of a UPS (Uninterruptable Power Supply) and PDU's (Power Distribution Units). The UPS System has three conversion stages in order to convert the necessary AC voltage to DC voltage and vice versa for the PDU's. These conversion stages are costly in energy consumption and drive the PUE in the wrong direction. Because data servers are consistently in use, data centers must have a backup supply of power to ensure no data is lost in the event of an emergency or outage. Instead of having a UPS System, attaching a power supply to every server eliminates the three conversions steps, ultimately saving energy and power. This strategy first implemented by

Google, allows every server in a data center to have their own unique source of reliable backup power and in turn saves thousands of dollars in energy per year.

On the software aspect of power savings, developers implement "stand-by" programs that utilize the minimal power needed to run every server. These software tools work in conjunction with the UPS and PDU's to ensure proper distribution of energy wherever it's needed and ensures that servers aren't getting overpowered. When the server isn't in use, it'll go into a power-saving mode similar to an iPhone's low-power mode while maintaining enough power to properly function. Stand-by programs have been used frequently over the past 20 years and are just starting to get modernized now:

> *"Oracle has introduced an innovation called Intelligent Power Monitoring. Which provides accurate, real-time power utilization for servers as a function of customer load fluctuations, fan speed variations, dynamic reconfiguration events under virtualization tiers, failover events for redundant power supplies, and during times when power management features in the CPU's are performing power-capping and/or thermal-capping roles. IPM is an entirely software-based tool that requires no Power Distribution Units"* (University of California, Berkley, 1).

Since Oracle's IPM tool can eliminate the PDU's from the database architecture and is entirely software-based, it can save companies thousands if not millions of dollars in IT equipment and energy costs.

When we talk about data center cooling and we say "cold air and hot air", we actually mean warm air and hot air. A common misconception about data center cooling is that the servers need to be cold. In reality, the servers just can't get too hot to the point where they won't function properly. ASHRAE's (American Society of Heating, Refrigeration and Air-Conditioning Engineers) data center temperature guidelines range in temperature from 59°F to 89.6°F (Smith, 1). With temperatures ranging that high, most of the time that 'cold' air is never a requirement in a data center and just leads to wasted energy. The more energy we use in the CRAC's, the more electricity is consumed and the more electricity is consumed, the more money and electricity gets wasted. Google recently upped the temperature of their data centers from 72 degrees to 80 degrees and with this temperature raise, they save thousands of dollars in energy costs every year while their servers consistently run safely (GoogleGreen, 1).

Location also plays a big role in data center cooling. A colder natural ambient temperature makes it easy to save energy because if the air outside is cool, additional energy isn't needed to run the CRAC's colder. Google currently has two data centers in Europe that have no chillers at all due to the natural temperatures. "We locate the data centers in areas where we can maximize the natural cooling and minimize the mechanical cooling" (GoogleGreen, 2). A huge part of cooling and air conditioning in general is water consumption. Just like energy, water is also on the decline in the world and there are ways to be able to save water. Data centers don't need extremely clean water "drinking water" to be able to cool its servers. An example of Google's efforts to limit water consumption is their water renewal process with the government of Douglas County, Georgia. This process allows them to intercept incoming water from a side stream plant. From there, Google cleans the water just well enough to be used in their data center. After the water is used to cool their IT servers, it is sent to an Effluent Treatment Plant to be cleaned and returned back to the local natural river. This process saves water and at the same time makes the water returned into the local river much cleaner.

These practices aren't the only way to save energy in data centers. The typical energy efficient practices of solar energy, wind energy, and geo-thermal energy can be paired with data centers to ensure maximum efficiency. The co-location company Switch is a world leader in data center efficiency. In 2016, Switch built two solar energy fields in Las Vegas, Nevada that lead to all of their data centers being powered of 100% renewable energy. Switch also partners with local governments and industries to develop water-saving methods throughout their energy-saving initiative, which saved 155 million gallons of water in the last three years alone (Switch, 2). Their newest data center campus in Reno, Nevada named "The Citadel" will run with a PUE of 1.08 (Switch, 2). The Citadel campus is the largest data center campus in the world and runs off 100% renewable energy. Being the largest data center campus in the world and achieving those standards is proof that the computing world can minimize, if not completely eliminate the overhead in every data center's PUE. The technology, research, and capabilities are here; it's up to the rest of the companies to climb on board towards a computing world without energy limitations.

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