Using real-time data to improve efficiency and reduce total cost of ownership

The main purpose of data center cooling infrastructure is to provide a good thermal environment for the protection and reliability of IT equipment, especially the servers.

Some data centers use supply or return air temperature to control CRACs. Others base their control policy on distributed physical sensors on the ceiling of hot and cold aisles. However, these approaches can’t reflect the nonuniform temperature distribution at server inlets—caused by any recirculation or bypass of air between hot and cold aisles—with sufficient granularity.

Nonuniformity of inlet temperatures often produces “false-positives” that will increase overall supply airflow (higher fan energy). Nonuniformity could also result in cooler supply temperatures (lower chiller efficiency). And if you use nonuniform control mechanisms, you will not be able to target cooling where it is needed, which means you will probably overcool servers that don’t need the cooling.

Ideally, the IT equipment itself should be able to communicate its discrete cooling needs to the facility’s control system. In most real world situations, however, the connection between server thermal status and cooling system is indirect and inaccurate.

Raising the ambient temperature of your data center would improve energy efficiency and reduce unnecessary overcooling, but it would also shrink the thermal “safe” margin for the electronic components in a server, which may adversely affect the lifetime reliability of critical components such as processors and memory.

The obvious challenge is to devise a control strategy that balances wasted cooling energy and a reasonable thermal margin for safe operation. If you could somehow use real-time thermal information from your servers (demand) as the direct feedback information to control the cooling system (supply), you could reduce operational costs while guaranteeing the safe operation of your critical IT equipment. But is this possible?

Challenges

- Reduce power consumption/costs. How to raise the IT and power density of data center racks to meet business growth and better service delivery is a top concern for many cloud service providers and a barrier to some companies’ growth. For efficient and intelligent operation and for improved service, data centers must maximize available resources while reducing operating costs.

- Cool equipment intelligently and efficiently. Tailoring data center cooling needs on a case-by-case, server/rack/row basis has not been possible until now.

Solution

- Real-time monitoring and targeted cooling. By deploying Intel® PTAS to enable real-time thermal management controller for thermal control and improved energy efficiency, and using Intel® DCM to monitor server-level thermals, data center administrators can target cooling and raise ambient temperatures, without the risk of overheating critical server components.

Benefits

- Up to 24% energy savings on cooling. Decrease energy consumption by reducing overcooling, yet still achieve PUE 1.21.

- Efficient real-time thermal management controls. Intel platform telemetry data, metrics, and analytics solution provides data center administrators with heat distribution alarms and real-time information on cooling issues.

“Intel® PTAS and Intel® DCM provided capabilities that allowed us to improve our current thermal and cooling calculation needs. So we could target cooling where it was needed and not overcool the entire data center. “

“Being able to monitor and manage our facility’s cooling infrastructure dynamically will allow us to grow our compute capacity—while reducing operational costs. That is huge for us.”

— Chao Liu, Director of System, Baidu
How real-time temperature monitoring works

The traditional method of cooling data centers does not take into account the actual needs of the servers. Consequently, cooling devices will operate inefficiently because they do not accurately anticipate cooling requirements. However, by retrieving server inlet air temperature and providing this information to the building management system to control the cooling system in the data center, we figured we could reduce energy consumption by precisely controlling the amount of cooling required.

Figure 1 shows the four-phase process.

Intel® PTAS represents the silicon component and hardware layer. Intel® PTAS exposes silicon- and chassis-level power, thermal sensors, and fan speeds to the platform firmware, which runs a baseboard management controller (BMC) to monitor inlet temperatures, platform power consumption, and fan speed from platform sensors. The firmware also calculates real-time outlet temperatures and server airflow.

One server acts as the Intel® DCM Server and gathers information from other servers. Intel® DCM aggregates the server level information (at rack, row, and room levels), calculates efficiency metrics, develops three-dimensional thermal maps of your data center, and determines air conditioning control.

The three-dimensional thermal and power maps generated from the real-time power and temperature data are continuously updated. They display regions that are within the ASHRAE-recommended range (green), regions that are overcooled (blue, cyan), regions with some level of air mixing (yellow), and regions with temperatures higher than the recommended range (orange, red). These real-time 3D thermal maps identify thermal problems. The data is also used to generate 2D inlet temperature distribution maps of each rack.

The derived metrics and indexes, along with server sensor information, help identify and address data center energy efficiency issues like hotspots, coldspots, recirculation, and bypass issues.

You can save this real-time data from servers for several months and analyze it to determine whether the results meet your original design goals. This information is also valuable to data center architects when they need to design a new data center or upgrade existing data centers.

The monitoring capabilities of Intel® PTAS/Intel® DCM allow data center operators to continuously confirm that their servers are operating within thermal spec limits when the data center’s ambient temperature is raised. Alarms or alerts issue when temperatures exceed thresholds.
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The Intel/Baidu case study

Data centers across the globe consume around 100 GWh, a figure industry analysts expect to grow by 30% by 2016. In 2012, the increase alone in data center energy consumption in the United States and China was 800 MWh and 500 MWh respectively. This growth in power consumption presents a challenge, especially to data center administrators who are trying to introduce efficient thermal management controls.

With a customized server and data center design, Baidu used real-time thermal information of servers—including power, inlet/outlet temperature, and air mover speed (airflow demand)—as input information of your thermal management system control policy. Baidu used the inlet temperature and mass flow rate demand of servers to control the cooling system directly. With the server inlet as a control point, Baidu could raise the supply airflow temperature safely as long as the server’s inlet temperatures were within the ASHRAE recommended ranges. This reduced the power consumed by chillers and pumps.

With a smart thermal operation like this, Baidu was able to implement an aggressive thermal management control policy with thermal safety.

Target temperature was set to 80°F (27°C). Using the physical sensor on the cold aisle ceiling as the control input, the AHU supply temperature was about 70°F (21°C), and most server inlet temperatures were below 75°F (24°C).

Based on testing and simulation, we found that the physical sensor cannot represent either the supply air temperature or server inlet temperature, due to the airflow mismatch between supply and demand, and the leakage between the hot and cold aisles. But if we used the server Tinlet directly as the control input, we could raise the AHU supply temperature to 75°F (24°C). By using the server sensors as our control point, with a target value of 80°F (27°C), we could raise the AHU supply temperature from 70°F (21°C) to 75°F (24°C).

Furthermore, we found that we could safely raise the target value to 85°F (30°C) and expect server inlet temperatures to remain in acceptable ranges. We concluded from this observation that we could raise the supply air temperature of the AHU to 80°F (27°C).

1. Based on Forest & Sullivan market survey.
Summary

Based on our test results, we determined that Intel® PTAS, with its centralized monitoring capability and real-time thermal control, could reduce Baidu’s annual PUE from 1.31 to 1.21.

The proposed real-time thermal information can produce 3D thermal maps and power maps for monitoring real-time status of the data center. Therefore, the facility manager becomes empowered to identify possible problem areas in specific locations of the data center as they occur. The temperature maps identify hot spots, measure the level of overcooling, detect thermal anomalies, and quantify the level of hot and cold air mixing. We could also initiate maintenance processes based on this diagnostic data, without disturbing the service.

A mismatch between the server’s thermal demand and a data center cooling supply results in inefficiencies like undercooling or overcooling of servers in data centers. This mismatch needs to be addressed to improve efficiency and reduce overall costs. To overcome the problem, we used data directly from the servers to control cooling.

Server inlet air temperature replaces the physical temperature sensor to control the supply air temperature (cooling valve of CRAC coil) and use the airflow demand of servers to control the supply airflow mass (speed of an EC fan).

The ability of the new management control to use more granular and precise information through time and space makes accurate cooling control possible, which then results in potential energy savings while not compromising on thermal safety margins.

Next steps

Our analytical test proved that Intel® DCM with Intel® Node Manager and Intel® PTAS could reduce power consumption of data center cooling equipment by up to 30% and improve overall operating efficiency at Baidu’s data center. Key platform telemetry data, metrics, and analytics (monitoring events in server/rack, early hotspot identification, advanced CRAC control strategies) enable real-time power and thermal monitoring, reporting, analytics, and cooling control in a data center.

The next step is to show the feasibility of integrating real-time server data with a building energy management system (BEMS) to manage cooling infrastructure dynamically, and to compare the performance of different cooling algorithms developed for CRAC/ACU units. We also hope to add thermal capabilities, using other sensors and metrics, and demonstrate the integration of compute (CUPS) data with the data center, using the data, along with thermal metrics, to balance compute workloads to correct thermal events in real-time.

Spotlight on Baidu

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