Unification of IT Systems and Facilities for Next-Generation Environmentally Friendly Data Centers

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Fujitsu Laboratories is engaged in unified research and development on a global basis from low power consumption chips and system boards to server systems, networks and power-supply, cooling, and software technologies. We are taking a holistic approach to technology development and are building a value chain of energy-saving technologies. Leveraging this extensive expertise in technology development, we are now developing elemental technologies for achieving compact, next-generation environmentally friendly data centers that unify facility functions including power-feeding and cooling with information technology (IT) equipment such as servers, storage drives, and network devices. This article introduces Fujitsu's pursuit of high energy-saving performance in data centers through diverse technologies such as micro-channels for efficiently transferring heat from central processing unit (CPU) chips to cooling water, a high-efficiency green uninterruptible power supply (UPS) integrated with each server's power supply unit, multipoint temperature measurement using optical fiber for real-time visualization of the spatial temperature distribution within the data center, and simulation techniques for achieving efficient operation of a data center's IT systems and facilities.

1. Introduction

The ongoing expansion of cloud services over the Internet is expected to generate a dramatic increase in the amount of power consumed by data centers, which constitute an important infrastructure for providing services.[1] As information technology (IT) equipment becomes increasingly consolidated in data centers, the total power consumed by such equipment will, of course, increase but so will the power consumed by the computer room air conditioning (CRAC) and other building facilities. The ratio of power consumed by data center facilities has actually reached about 40%.[1] It therefore stands to reason that improving the energy efficiency of data centers will require techniques for saving energy not only in individual items of IT equipment but also in facility equipment. Achieving energy-saving data centers is an environmental issue from the perspective of combating global warming and preserving energy resources.

As part of its ongoing efforts to reduce energy consumption in its data centers, Fujitsu opened an environmentally friendly data center in a new annex of its Tatebayashi System Center in November 2009.[2] Current energy-saving measures include reducing power consumption of individual items of IT equipment through the use of low power consumption chips, making power-feeding more efficient, utilizing aisle capping to raise cooling efficiency by preventing the mixing of intake and exhaust air, and introducing heat-dissipation methods using natural energy as in the free-cooling approach. These measures, however, have so far been implemented on an individual basis. To achieve an even higher level of energy savings, a unified approach that integrates the optimization of facility equipment and IT equipment like servers will be necessary. Fujitsu is undertaking research and development in a globally coordinated manner, from the development of low power consumption chips and system boards to the construction of subsystems and networks and the development of power-supply technologies, cooling techniques, and software. It is pursing energy efficiency by holistic technology development and building a value chain of energy-saving technologies.

This article introduces Fujitsu's approach to raising the energy efficiency of facilities in next-generation environmentally friendly data centers.

2. Unification of IT systems and facilities

As cloud data centers become increasingly dominant, we can expect energy-saving IT system migration using virtual machines to become the norm, as shown in **Figure 1**. The idea here is to unify IT systems and facilities and divide them into unit blocks for which energy efficiency can be maximized and to concentrate server load by using virtualization technology to divide the data center into used and unused blocks. Here, a block in which server load is concentrated has facilities operating at high efficiency while an unused block has its power supply (including that for facilities) turned off, thereby improving energy efficiency. The key to implementing this energy-saving concept is technology development for a compact data center in which facility functions including power-feeding and cooling are unified with the operations of IT equipment such as servers, storage drives, and networks.

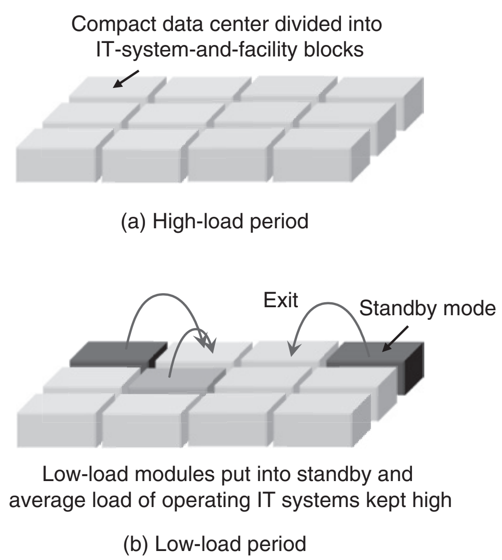

Figure 1
Concept of IT system migration using virtual machines.

To be more specific, the contact points (interfaces) between IT equipment and power-feeding and cooling facilities have to be modified to reduce the amount of energy consumed by the facility section of the data center. For example, the cooling interface could be modified by improving the heat-transfer efficiency between heat-emitting IT equipment and the heat carrier for transporting the heat in addition to making changes to operating temperature at the level of IT equipment components. The power-feeding interface, meanwhile, could be modified by reducing the number of alternating current/direct current (AC/DC) conversion steps and the number of voltage conversion steps.

The heat generated by IT equipment within a data center is discharged as a warm airflow under 100°C that is difficult to reuse. Fujitsu Laboratories has undertaken the development of a system for using waste heat that can produce cooling water under 20°C by operating an adsorption heat pump that uses the temperature difference between heated water obtained from IT equipment waste heat and water at room temperature.[3] This is a non-chlorofluorocarbon, environmentally friendly cooling system based only on an adsorption reaction. It requires no electric power other than for a circulating pump and can run on waste heat only. In short, Fujitsu is working on the development of an advanced, waste-heat-based data center that, in addition to circulating some of the exhaust air from server groups back to the air-intake side as warm air to prevent condensation during winter, makes effective use of waste heat by application of an adsorption heat pump.

3. High-efficiency cooling technology

The heat generated inside a data center originates in chips, like central processing unit (CPU) chips mounted inside server enclosures, as well as in hard disk drives and power supply units. This heat must be efficiently transported and discharged to prevent thermal runaway caused by a rise in temperature inside the enclosure in question. Cooling in a server is typically performed by using fans to route cold air into the enclosure, but the adoption of multi-core CPUs, the increase in the number of mounted CPUs, and the rise in server density have all helped to increase the amount of heat generated per rack. In the near future, there is a high possibility that the cooling performance of fan-based systems will no longer be sufficient and that water-based cooling systems will be needed owing to the fact that the volumetric heat capacity of water is approximately 3500 times greater than that of air. Cooling systems that circulate water to cool high-heat-generating chips like CPU chips have already been applied to supercomputers and even to personal computers that need to be used in quiet environments. Fujitsu Laboratories has been researching and developing a micro-channel device for efficiently transferring the heat generated by chips to cooling water.[4] A micro-channel is a narrow flow path just under 1 mm wide fabricated by microelectromechanical processing techniques. When used to circulate water, it can efficiently transfer the heat generated by chips to the water. Since the transfer efficiency of heat to cooling water is high, the amount of flowing water can be minimized, which means less energy is needed for circulating cooling water. A micro-channel water-cooling device attached to a gallium-nitride power-amplifier device is shown in **Figure 2**. In this device, a micro-channel structure 12 mm in length, 0.42 mm in width, and 2 mm in height consisting of two flow paths each 80 µm wide and 1 mm high is mounted on top of a chip. Here, water is made to flow in opposite directions through these two flow paths. This is an original design that we have adopted to achieve a uniform temperature distribution in the chip. Raising heat-transfer efficiency by using a micro-channel device in this way reduces thermal resistance by 23.8% compared to existing water-cooling

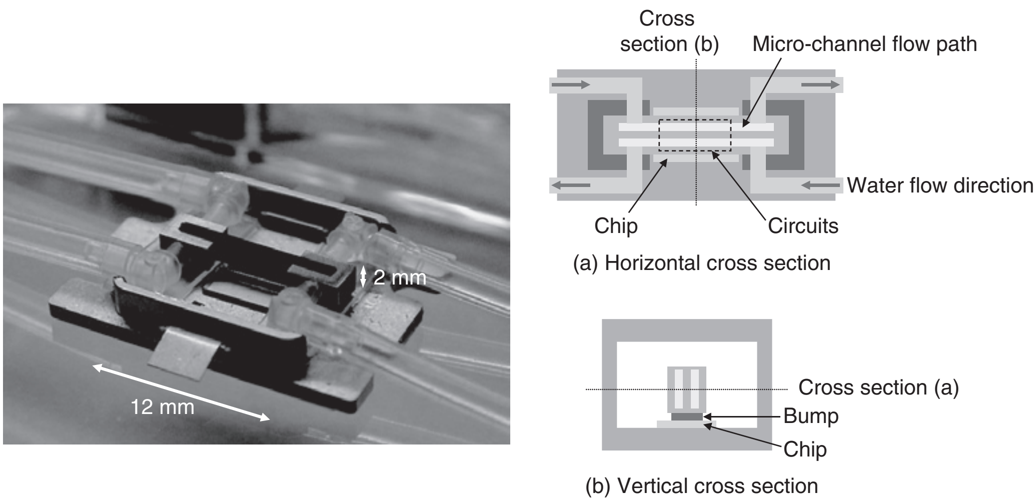

Figure 2
Micro-channel device for highly efficient water cooling.

systems, indicating that heat-transfer efficiency can indeed be improved.

4. High-efficiency power-feeding technology

To achieve a compact data center in which power supplies, including those for facilities, can be safely turned off, there is a need for a compact uninterruptible power supply (UPS) that can provide backup for an individual server power supply. A conventional data center UPS is a large piece of equipment that can provide power for the entire data center. Having a maximum efficiency of 90%, there is still room for improvement. At Fujitsu Laboratories, we have developed a system that integrates a UPS with each server's power supply unit. This system reduces the number of AC/DC conversions in the power-feed path, thereby raising efficiency (**Figure 3**). In the conventional UPS configuration, four conversions of this type are required, as shown in Figure 3 (b): A/D and D/A in the UPS and A/D and D/D (voltage conversion) in the power supply unit. A power loss occurs at each of these conversions, but with the new system that directly connects a UPS with each power supply unit, the number of conversions is reduced to two, as shown in Figure 3 (a), resulting in an efficiency of 99% in standby mode. Additionally, as the connection with the UPS is made inside the power supply unit at the point of voltage step-up to DC 380V, this configuration will be able to support a high-voltage DC power-feeding system slated for deployment in the near future.

Furthermore, to reduce the size and weight of the UPS and extend its life, we have adopted a lithium-ion battery that has a unit-cell size and weight 1/4 and 1/3 those of existing lead-acid batteries and a lifetime that is four times longer. This battery is equipped with a power leveling

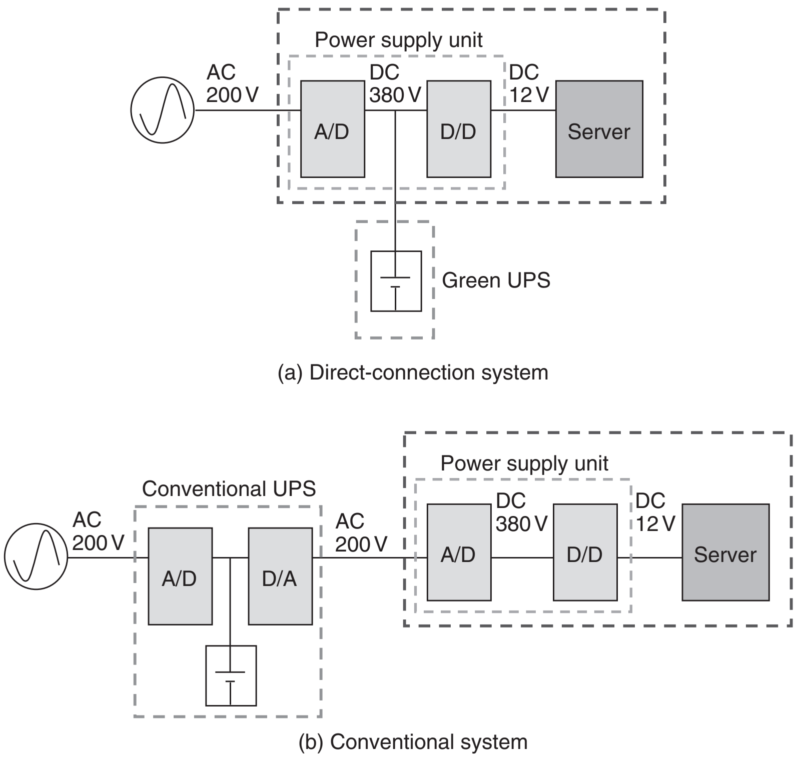

Figure 3
Reduced number of AC/DC conversions due to using direct connection with electric power supply unit.

function for reducing fluctuation on the power-feeding side by compensating for load fluctuation through battery charging and discharging.

5. Temperature sensing technology

Temperature distribution within the data center must be understood to determine the state of heat generation, which can differ from rack to rack, and to then operate the cooling system in an optimal manner. Known methods for measuring temperature include installing temperature sensors to obtain temperature data and measuring infrared emissivity at the rack surface using an infrared camera. With these methods, however, the spatial resolution of the obtained temperature distribution is low, and obtaining an accurate temperature distribution in real time is difficult. Against this background, Fujitsu Laboratories is focusing on the use of optical fiber to obtain an accurate distribution of temperature within the data center room in real time.[5] In this method, optical fiber is installed on the room's ceiling and along the air-intake panels and the air-exhaust panels of server racks. Laser pulses are propagated in the fiber, and Raman scattered light, which is sensitive to temperature, is reflected back and measured. The elapsed time after laser-pulse emission can be converted into distance to obtain the spatial coordinates, and the temperature can be calculated from the optical intensity. This method can therefore obtain a spatial temperature distribution inside the data center room and along rack islands in real time.

An example of the measured temperature distribution on rack surfaces is shown in **Figure 4**. At present, this method achieves a spatial resolution of 0.1 m and an accuracy of ±1.0°C or better for calculations performed every 30 seconds. It can deal with even complicated temperature distributions and can detect local hot spots inside the data center room. The results shown in the figure are based on actual temperature measurements—they provide a temperature distribution that is more reliable than predicted values obtained from thermal-fluid simulations. This suggests that an air conditioning system can be controlled in accordance with the actual temperature conditions of rack islands. We are currently researching and developing a linked-sensing system that connects the optical-fiber temperature measurement system with the air conditioning system so that the results of temperature measurements can be fed back to the CRAC equipment to eliminate any heat pools and achieve efficient air conditioning.

6. Simulation technology

Thermal-fluid simulations can be used to visualize the cooling air circulating through the data center room from the air conditioning system and the flow of exhaust air from each rack. It is common in such simulations to assume that servers are uniform heat sources. Operations in an actual IT system, however, are more complicated as the server load and

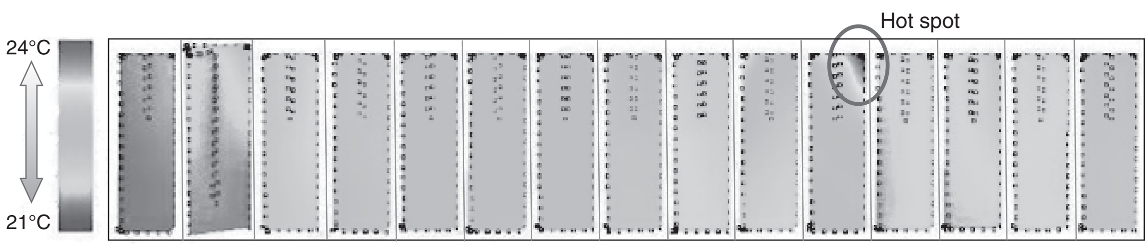

Figure 4
Example of measured temperature distribution on rack surfaces.

storage utilization rate vary with the service being provided; that is, power consumption and the amount of generated heat differ from service to service. The efficiency of the air conditioning system is also constrained by local climate conditions given that some the CRAC equipment is installed outside, as well as by temperature and humidity effects and power capacity. Fujitsu Laboratories of Europe is developing simulation technology that models the configuration of each system module including those for servers, storage drives, network devices, and cooling and power-feeding equipment and that predicts at high speed the approximate power consumption for actual services provided by the data center (**Figure 5**).[6] This simulation technology can model the generated and received heat for each module and the power consumption of an IT system on the basis of its load level. It has begun to be used at Fujitsu data centers in Japan and abroad and is proving to be effective in identifying ways to improve energy efficiency.

7. Conclusion

This paper described how Fujitsu Laboratories is leveraging its extensive expertise in energy-saving technologies to develop elemental technologies for a compact data center that unify facility functions including power-feeding and cooling with the operation of IT equipment such as servers, storage drives, and networks. These elemental technologies include micro-channel cooling that efficiently transfers the heat generated by CPU chips to cooling water, a high-efficiency green UPS integrated with each server power supply, multipoint temperature measurement using optical fiber that provides temperature data for controlling facilities in accordance with the operating state of the IT equipment in the data center, and simulation techniques for predicting the state of the data center. Looking to the future, Fujitsu Laboratories will apply these elemental technologies to further improve energy-saving performance and will explore new technology

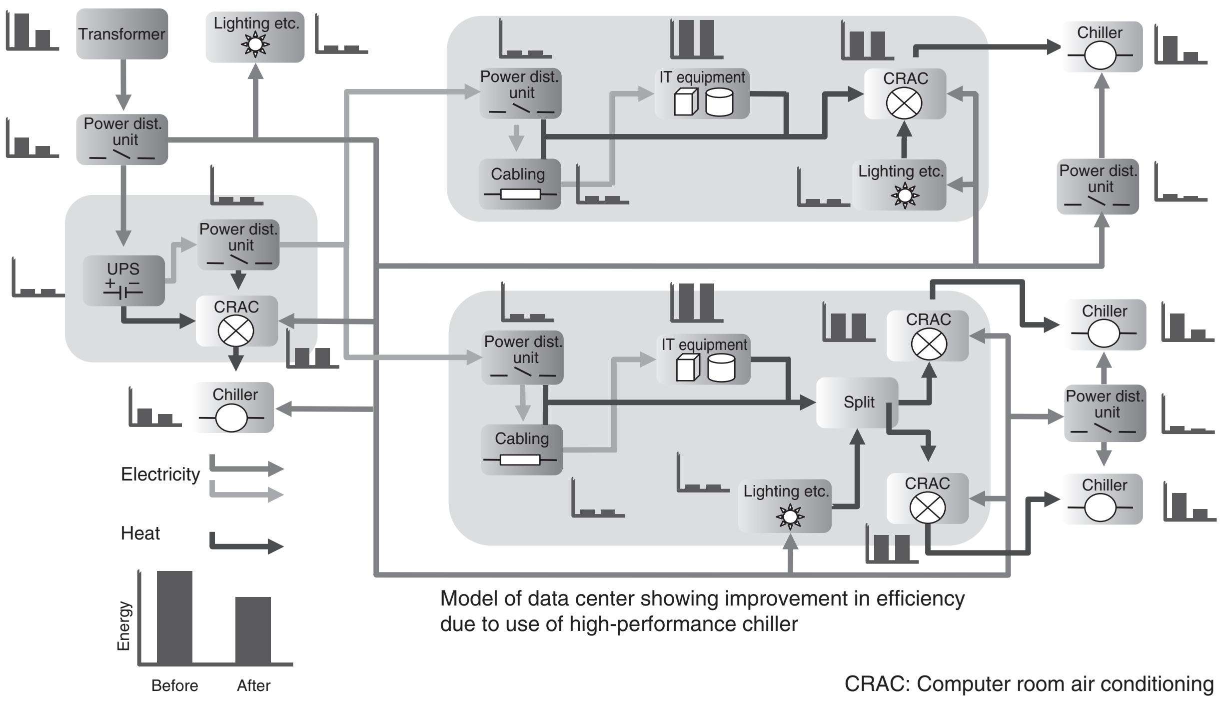

Figure 5
Simulation model for data center.

for using waste heat through the use of an adsorption heat pump toward a next-generation environmentally friendly data center.

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