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Strategies for Solving the Datacenter Space, Power, and Cooling Crunch: Sun Server and Storage Optimization Techniques

ORACLE

Introduction

By meeting the requirements to deploy new applications and support a larger number of internal and external customers, IT organizations are facing a space, power, and cooling crunch. Silo-architected legacy applications that do not share resources and energy-inefficient legacy servers that are sized to handle the maximum possible workload have pushed datacenters to the limits of space and energy consumption. Many datacenters built to last 10 to 15 years have reached a premature end of life because they were not meant to support the growth that has actually taken place.

Limited space, power, and cooling capacity have led many organizations to recognize that capital and operating expenses for datacenters have become an increasing part of their budgets over time. The lack of flexibility caused by outdated, inefficient datacenters has also begun to affect business agility.

In the face of rapidly escalating energy costs and datacenters contributing to global greenhouse gas emissions at a similar rate as the airlines, organizations are realizing that increased datacenter efficiency can simultaneously reduce costs and increase business agility.

Oracle has the following two-step approach to datacenter efficiency:

- **Optimize power.** Replace aging datacenter equipment with up-to-date, more-powerful, and energy-efficient servers and storage. Use virtualization to consolidate onto a smaller number of systems. Improve power and cooling efficiency in every aspect of operations, from servers to the equipment yard.

- **Reconfigure datacenter spaces.** Reconfigure datacenter spaces with a modular, flexible, more-efficient design that supports growth and can handle the constant equipment turnover that characterizes most datacenters today.

Oracle has undertaken a project to restructure its own datacenter space worldwide, resulting in reductions in datacenter space of up to 66 percent and decreases in operating expenditures of up to 30 percent, and thus avoiding the cost of building new space.

This white paper discusses how Oracle has made these strides through an innovative approach to datacenter design—one that's available to customers through a comprehensive set of service offerings.

Optimize Power

IT organizations can continue to build more and more datacenters, and consume more and more power, but that's not a responsible choice from either a financial or an ecological perspective. A better option would be to optimize existing datacenter space, which would result in lower capital and operating costs as well as a reduced carbon footprint.

IT organizations can optimize power in their datacenters in several ways:

- Decommission servers that are no longer associated with a running IT service.
- Replace aging, inefficient servers with current, more-energy-efficient technology that can perform more work and consume less space.
- Consolidate multiple workloads onto a smaller number of servers by using appropriate virtualization technologies.
- Consolidate physical datacenters into a smaller number of more-efficient facilities.
- Deploy modern storage systems and tape libraries that hold more data while using less power.
- Use various techniques for improving the efficiency of cooling systems.
- Use the appropriate tier levels by implementing only the level of redundancy that the organization really needs.

Coordinate Actions

Because server replacement results in higher density—and thus higher spot cooling requirements—the actions listed above need to be taken in a coordinated fashion. The good news is that the server power consumption reductions are amplified by savings in the datacenter power and cooling requirements. Estimates of this impact vary, but it's generally accepted that for every watt delivered to the IT equipment, at least one watt in overhead is required, including power distribution and cooling. In its 2007 report titled *Institute Opinion on EPA Report,* the Uptime Institute[1] states that 2.2 kW of power are delivered to the building for every 1 kW delivered to the IT equipment; in other words, only approximately 45 percent of datacenter power actually drives the IT load. This estimate was derived by averaging a set of statistics from a range of Tier 1 through Tier 4 datacenters. Estimates by American Power Conversion for a full Tier 4 datacenter suggest that the number is even lower—approximately 30 percent (see Figure 1). Regardless of which numbers are most accurate, it's clear that reducing IT

[1] Uptime Institute, *Opinion of the Institute: EPA Report Should Spur Industry-Wide Green Data Center Movement*; 2007.

loads and increasing the efficiency of power and cooling systems can have a dramatic impact on the overall datacenter power consumption.

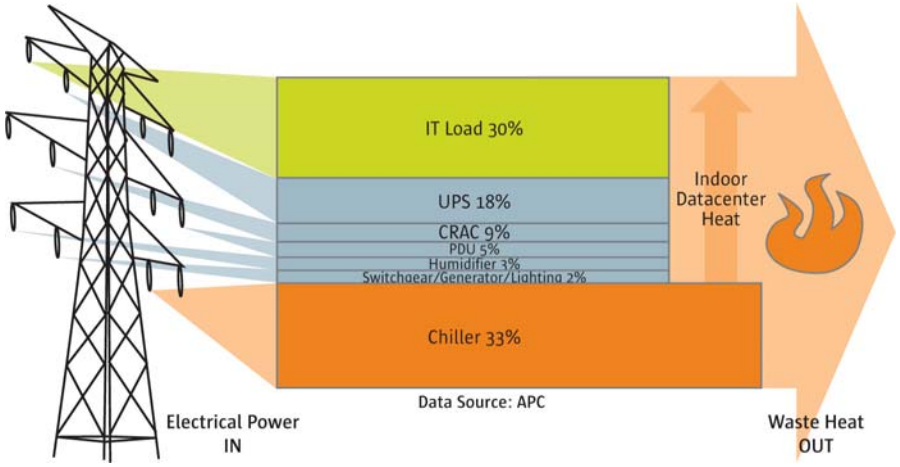

Figure 1. Only a fraction of incoming power is delivered to the IT equipment in a datacenter, underscoring the need for both server and infrastructure efficiency improvements.

Source: **American Power Conversion**

Use Energy-Efficient Servers

Replacing aging servers with energy-efficient systems reduces the overall datacenter space requirements, while cutting the amount of energy required to deliver a given unit of compute power. The entire system design—including processors, memory, power supplies, and cooling systems—contributes to efficiency.

- **Processors.** The CPU is one of the largest power consumers in today's servers, and the choice of processor has a significant impact on the server's power consumption. It's important to choose the processor that's best suited to the task it performs. Designed to excel at handling highly multithreaded workloads, the UltraSPARC T1, UltraSPARC T2, and UltraSPARC T2 Plus processors with Oracle Solaris CoolThreads technology consume less power per thread than any other processors in their class. Oracle's x64 server product line is powered by AMD Opteron and Intel Xeon processors, each of which provides different trade-offs between power consumption and performance that depend on the workload.
- **Memory.** As processor speeds have increased, manufacturers have begun using the fastest Fully Buffered Dual Inline Memory Modules (FB-DIMMs), increasing power consumption per amount of memory. Installing the fewest, most dense FB-DIMMs for the job will draw the least amount of power.
- **Power supplies.** Power supplies must be designed to handle the worst-case scenario of a server with all memory and PCI slots occupied, running at 100 percent utilization. In practice, most servers operate at 50 percent or less of their nameplate power, a range where many power supplies can be relatively inefficient. In the United States, 80 PLUS—a program supported by electric utilities and

the computer industry—is promoting the use of power supplies that are at least 80 percent efficient at 20, 50, and 100 percent of their rated load.[2] Most of the power supplies on Oracle servers exceed this specification, with some of them 93 percent efficient at an 80 percent load.

- **Cooling.** A server's internal cooling system can have a significant impact on the power consumption. Servers that are engineered to optimize airflow can cool internal elements, including processors and memory, with less power consumed by fans. Good servers use strict front-to-back cooling with straight-through airflow, and their fan speeds are modulated by measured internal temperatures.

Technology Refresh, Virtualization, and Consolidation

Technology refresh can dramatically reduce the power consumption in its own right. Simply replacing aging, inefficient servers with new, more-powerful, energy-efficient systems can help to reduce the power consumption. Adding virtualization technology can help to reduce the number of new servers required in a server replacement effort, because it simplifies the task of consolidating and running multiple workloads on the same server.

Choosing the Right Virtualization Solution

Virtualization solutions vary in how they isolate applications, limit the propagation of faults, and support multiple operating systems (OSes). As a developer of its own virtualization solutions Oracle is in an ideal position to advise customers on making the most appropriate choice of virtualization technology based on their business and technical requirements.

Oracle supports the following four categories of server virtualization technologies, each of which offers varying degrees of isolation between applications (see Figure 2):

- **Resource management.** Simplifies the running of multiple applications on the same server and OS instance. Applications are isolated only to the degree that OS-level security and resource management features keep them (and their administrators) from interfering with each other. Oracle Solaris Resource Manager is an example of technology that helps isolate applications through precise control over their resource allocation and consumption.
- **Operating system–level virtualization.** Provides more isolation than simple resource management, enabling multiple applications to share the same OS instance with separate security domains for each application. With Oracle Solaris Containers, customers can migrate existing Oracle Solaris 8 and Oracle Solaris 9 OS environments onto Oracle's current hardware, without having to redeploy existing applications.

[2] For more information on the 80 PLUS program, please refer to www.80plus.org.

- **Virtual machine monitors.** Provide still-greater isolation by supporting multiple OS instances on the same machine. Each application can run in its own OS instance, and a hypervisor gives each one the illusion that it "owns" a complete, dedicated set of hardware. Available for Oracle's x64 servers, virtual machines can support multiple types of OSes. Resource management and OS-level virtualization can also be used within each environment running Oracle Solaris. Domains technology is a virtual machine monitor that allows resources to be dedicated to virtual machines on a per-CPU thread basis on servers powered by UltraSPARC T1, UltraSPARC T2, and UltraSPARC T2 Plus processors.
- **Hard partitions.** Support multiple OS instances, without the overhead of a hypervisor. Available on high-end Oracle servers, including Oracle Sun SPARC Enterprise M-Series servers, Dynamic Domains provide the ultimate in isolation, with a separate electrically isolated environment for each OS. With Dynamic Domains, one domain can be powered off and components replaced without affecting the state of other domains on the same server.

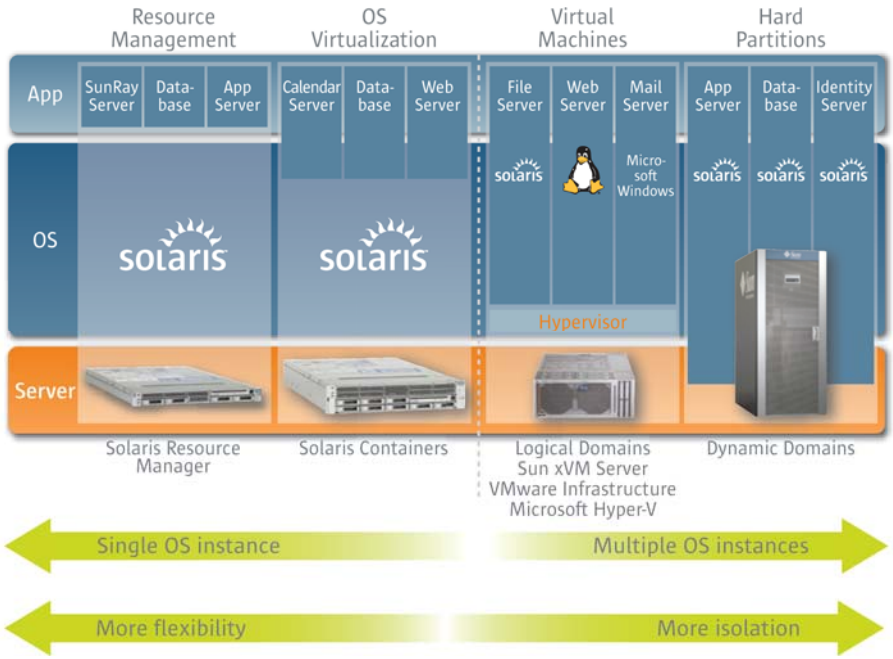

Figure 2. Oracle supports a range of virtualization approaches based on its own, as well as third-party, technology.

Increasing Storage Power Efficiency

Organizations are often unaware of the ways they can improve the power efficiency of their storage. An assessment can highlight which of several approaches best meets their goals. Here are some ways to drive storage power and cooling efficiency improvements:

- **Allocate data to different storage tiers based on information lifecycle management policies.** At the high end, high-rpm drives and storage systems with multiple processors host the most critical

data. At the low end, high-density, low-rpm serial-attached SCSI drives or serial ATA drives save cost and power. Archiving data onto tape is also extremely energy efficient, with a tape cartridge at rest using no energy at all.

- **Use hybrid storage systems with solid-state drives mixed with serial-attached SCSI or serial ATA drives.** This setup provides performance similar to previous-generation high-end systems, but using only one-third to one-half the energy.
- **Centralize storage so it can be managed as a single pool of resources.** When virtual volumes can be carved out of a global pool and allocated to the servers and applications that need them, overall use levels can be raised and less energy spent on spinning disks that are only partially used. This can be especially useful if the file system, such as Oracle Solaris ZFS, can manage the storage pool, allowing for the most appropriate use to be matched to the correct storage types in the centralized storage.
- **Replace older storage systems with systems offering higher-density drives.** Efficiency can also be increased by choosing solid-state drives that use less power because they have no moving parts.
- **Manage data replication and snapshot images with policies focused on removing copies as soon as possible.** In many datacenters, it's not at all surprising to find up to 10 copies of the same file. Data deduplication can help manage the archiving of data.
- **Leverage arrays and file systems that support thin provisioning.** With this technique, a much-smaller amount of storage is allocated to a logical volume than its size, and storage consumption increases only as the volume fills. Thin provisioning allows for much-higher disk space use because less storage is held in reserve.

Increasing Datacenter Power and Cooling Efficiency

Given that nearly two-thirds of a datacenter's power is dedicated to facility overhead, an IT organization's power optimization plans should include a strategy for increasing power and cooling efficiency.

Techniques for Improving Power Efficiency

There are several ways in which customers can improve their datacenter power distribution systems to improve overall efficiency:

- **Reduce power conversions.** A typical carrier datacenter converts power many times before it reaches its servers, each step introducing another degree of inefficiency. One way to economize is to make these power conversions more efficient. "World power" at 480 V / 277 V AC enables the use of widely available, highly efficient transformers and eliminates a layer of power distribution units

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- **Use appropriate tier levels.** Every organization would prefer to have a Tier 4 datacenter, with two complete power distribution systems that allow either system to be taken out of service (or fail) without affecting uptime.[4] In practice, few organizations need this level of redundancy or the capital and operating costs to build and run it. Complete redundancy means that each distribution system normally provides 50 percent of datacenter power, but each must be sized to deliver 100 percent of the power in the event of a failure. This causes every power distribution element—from server power supplies to UPSs—to run at a lower, less-efficient use level. Instead, organizations can use a datacenter electrical design that supports multiple tier and use levels that are appropriate for the business task at hand.
- **Remove power distribution units from the datacenter.** Most IT organizations configure their PDUs on the datacenter floor, adding to the cooling load. A datacenter could use transformers outside the datacenter to feed a modular busway inside. These transformers would not require the same level of cooling as PDUs located inside the datacenter.

Techniques for Improving Cooling System Efficiency

Improved cooling system efficiency is a requirement for high-density datacenters. Cooling system improvements need to be part of an end-to-end strategy that efficiently moves heat from servers to the outdoor cooling tower. This transport mechanism can be improved at every step, from the choice of servers to the type of chilled water systems employed. Here are some ways to improve cooling efficiency:

- **Choose servers with efficient cooling systems.** Cooling systems shouldn't be an afterthought. The most efficient servers have straight, unobstructed airflow that reduces turbulence, making the most of every watt provided to cooling fans. Server fan speeds should be modulated based on internal temperatures.
- **Block unused rack spaces.** Simply closing off unused rack spaces can increase efficiency by reducing the mixing of hot and cold air within the datacenter.
- **Contain hot/cold aisles.** Cooling efficiency can be increased significantly by fully containing either the hot or cold aisles to avoid mixing hot and cold air and feeding hotter exhaust air to the cooling

[3] American Power Conversion, *Increasing Data Center Efficiency by Using Improved High Density Power Distribution* (2008), www.apcmedia.com/salestools/NRAN-6CN8PK_R1_EN.pdf.

[4] As defined by the Uptime Institute's white paper *Tier Classifications Define Site Infrastructure Performance,* tier levels range from Tier 1 to Tier 4, with Tier 4 being the most fault tolerant.

units. This can be accomplished by various means, from simple draping systems to price listed hard containment systems. In a hot aisle contained methodology, greater efficiencies can be achieved by aligning the cooling units directly with the hot aisle. This means that the heat exchangers work more efficiently by cooling the warmest air and handling only the air in the contained area. Computer room air conditioners (CRACs) and air handling units have to work on the entire volume of air in the datacenter. Efficiency also can be improved with variable frequency drive (VFD) fans within heat exchangers to match variable heat loads with variable airflow rates. This better matches actual cooling to cooling needs as systems go through different use cycles—from fully idle up to fully used.

- **Install efficient spot cooling.** Nearly all datacenters end up with hotspots due to the inability to deliver the right amount of cooling to every rack, especially in datacenters where server density varies significantly. In datacenters without hot aisle containment, there are a number of ways to perform directed spot cooling for racks with the highest heat loads. Some products sit directly above the rack, pulling warm exhaust air through a heat exchanger and pushing cool air down in front of the rack. Others fit over the hot aisle, pulling warm air through a heat exchanger and pushing cool air out into the cold aisle. Also, other technologies sit among the racks and pull hot air from the rear and push cool air out the front. Spot cooling can use either water or a refrigerant in the heat exchanger coils.
- **Choose innovative racks.** Some new rack designs can include a passive rear door heat exchanger to provide localized cooling. They can be water or refrigerant based.
- **Increase ambient inlet temperature.** The legacy of cold air in datacenters is one that arises from the inefficiency of mixing hot and cold air in uncontrolled ways. As long as hot and cold air mix randomly on the datacenter floor, supply air temperatures need to be kept low. As much as hot aisle containment, spot cooling, and other techniques are able to control this mixing, then datacenter air temperatures can be higher, placing less of a load on the cooling system.
- **Install variable frequency drives.** Datacenters use industrial motors throughout their cooling infrastructure. Using demand-driven VFDs enables the cooling system to adjust its output to closely match the load, increasing efficiency by providing only the cooling that's needed. VFDs are available in CRAC units, chilled water pumps, chillers, and cooling tower fans.

Reconfigure Datacenter Spaces

To reap the most benefit from implementing power optimization strategies, it's often necessary to reconfigure existing datacenter spaces or build new ones. Oracle has experience with reconfiguration and new construction projects for its own facilities and for its clients and has developed a design methodology and philosophy that has produced startling results.[5]

[5] For more information about Oracle's own energy-efficient datacenters as well as many of the topics discussed in this white paper, please visit oracle.com.

Oracle's design philosophy includes the following principles:

- Availability through a design that includes appropriate use of tier levels and the ability to support multiple tiers in the same datacenter
- Agility through a design that's flexible and adaptable, ready to align IT resources with changing business objectives
- Efficiency that's implemented through the techniques described in the previous sections, with an emphasis on appropriately sizing IT equipment and its supporting cabling, power, and cooling infrastructures
- Future-proofing by designing not just for today, but also for the next few generations of equipment, which are likely to have even-higher power, cooling, and cabling requirements—allowing organizations to avoid the cost and disruption of retrofitting additional infrastructure into a running datacenter
- Environmental consciousness that recognizes that "going green" makes good business sense, especially when it involves simple techniques, such as using outside air for cooling, that can save significant amounts of money over time
- Intelligent monitoring that enables power consumption to be monitored at every level in the power distribution hierarchy, giving visibility into current operational parameters and the impact of other energy-saving steps

Addressing Inefficiency

Inefficiency can be difficult to address because facilities organizations don't always understand—or even believe in—the ever-increasing power requirements of IT organizations. Conversely, IT organizations typically don't understand the time and expense required to implement power and cooling infrastructure to support higher-density datacenters. Oracle addresses inefficiency by helping clients achieve one or more of these goals:

- Create an independent organization with the funding and authority to make decisions for the IT and facilities organizations.
- Define management processes that treat datacenter and IT management holistically.
- Consolidate datacenter space to free up valuable space.
- Improve the ability to accommodate current and future high-density servers.
- Replace aging, inefficient equipment with up-to-date, more-efficient systems.
- Reduce the overall number of servers required to support existing activities.
- Increase flexibility so that equipment can be changed to support new business and product development activities—including further increases in density—without significant changes to datacenter infrastructure.
- Build an electrical and cooling plant that can scale as needed.

Efficiency Through Density

It might seem counterintuitive to think that moving to higher-density equipment, which generates more heat in a smaller space, could actually increase efficiency. But server consolidation results in higher performance per watt, and space consolidation enables more-efficient power, cooling, and cabling systems to be deployed. The energy savings of newer equipment is so substantial that it's worth dedicating a percentage of datacenter reconfiguration costs to acquiring new equipment.

Over the past few years, Oracle has successfully consolidated 202,000 square feet of datacenter space into 72,000 square feet in Santa Clara, California, and an even more ambitious project in Broomfield, Colorado, consolidated 496,000 square feet of space into only 126,000 square feet. This averaged out to a 60 percent space compression, resulting in a 30 percent operating expense reduction. In one of Oracle's datacenters in Santa Clara, more than 78 percent of the datacenter power budget is delivered to IT equipment (see Figure 3), whereas 30 percent is the norm, as discussed in the previous section, "Optimize Power."

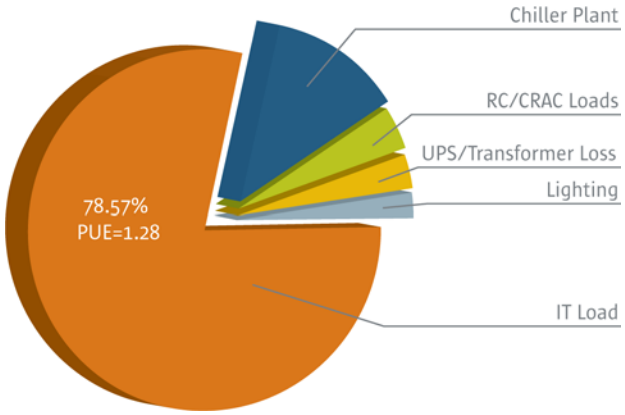

Figure 3. Oracle's Santa Clara, California, datacenter achieved a percent of its power budget is delivered to IT equipment.

Efficient, Oracle uses a set of generic design and construction standards to speed the process of building efficient, up-to-date environments. The standards can be adapted to different types of spaces, including raised floors and concrete slabs. Although generic, these standards support scalability and mobility, better supporting the normal turnover of equipment and space reconfiguration.

Using these standards, Oracle has created an innovative "pod" design—a self-contained group of racks that optimize power, cooling, and cabling efficiencies (see Figure 4). The design can be scaled up or down as needed and is easily replicated. The base power and cooling parameters can also be adjusted from 4 kW to 30 kW per rack. This allows complete flexibility in placing equipment in racks and pods, without having to be concerned about creating difficult-to-manage hotspots.

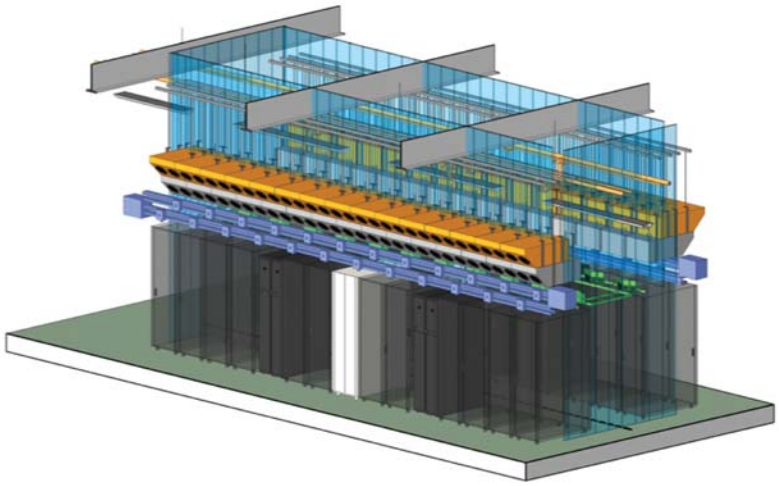

Figure 4. Oracle's pod design defines flexible, modular spaces that can be replicated in datacenters around the world. This design is for a Tier 4 datacenter with high-density equipment and a total capacity of 860 kW, or 45 kW per rack.

Power

Where appropriate, Oracle recommends building service yards containing power and cooling infrastructure that's adequate for today's needs, with conduit, plumbing, and transformer pads that allow the yard's capacity to scale over time. Ideal cooling systems—from evaporative cooling towers to chilled water circulator pumps—use VFDs throughout. Depending on the datacenter's location, outside air can be used to chill the water directly, yielding a significant amount of free cooling.

Oracle sizes UPS systems appropriately. If customers want to use traditional lead-acid battery UPSs, the systems are sized to increase in capacity by adding modules over time. Today, Oracle recommends a more-environmentally friendly approach: a rotational UPS that stores energy in a flywheel that, after a power failure, provides sufficient power until generators automatically spin up.

Oracle standardizes on a hot-pluggable overhead busway to distribute power to each rack. With the busway, it's a straightforward process to change breakers and receptacles or pull new cable when rack configurations change. The modular busway enables power drops to be installed and moved on demand, making the space much more flexible, while eliminating large amounts of copper and waste. The busway eliminates the need for on-floor PDUs, which consume costly floor space and generate heat. Instead, Oracle uses energy-efficient transformers with cooling requirements that are much less stringent than the equipment on the datacenter floor.

The updated American Society of Heating, Refrigerating, and Air-Conditioning Engineers TC9.9 standards not only broadened the recommended datacenter inlet temperature range, but also increased the dew point range. This allows organizations to set the overall environmental controls to enable the dew point to reach 59°F (15°C); so dehumidification systems, which are very energy intensive, can be used far less.

Cooling

As rack densities increase, standard CRAC units increasingly fail to provide sufficient cooling. The use of perforated floor tiles provides some degree of control over where chilled air is delivered, but the general mixing of hot and cold air that occurs in datacenters cooled this way requires lower ambient air temperatures, which causes greater inefficiency. Oracle's approach is to deliver cooling capacity exactly where it's needed through in-row or overhead cooling units. Oracle uses two different solutions, depending on the specific datacenter requirements.

In-Row Cooling and Hot Aisle Containment

One way to nearly eliminate the inefficient mixing of hot and cold air is to completely separate hot and cold areas through hot aisle containment. For environments without high ceilings, or where floor space can be devoted to cooling devices, in-row cooling units with hot aisle containment can be used. This mechanism completely contains the hot aisle, eliminating hot air recirculation. Hot air passes through the in-row units, which use chilled water to cool the air, while variable speed fans provide the right amount of cooling based on real-time temperature measurements. Oracle recommends installing double the capacity needed today, with every other unit stubbed out and baffled to block airflow. In Oracle's Santa Clara datacenter, each pod's hot aisle is contained with a door at the end (see Figure 5).

Figure 5. The use of hot aisle containment with in-row cooling makes pods self-sufficient from a cooling perspective.

Overhead Cooling for High-Density Equipment

In high-density situations and in open datacenter designs, such as those where equipment is rolled in and out frequently, Oracle uses overhead cooling systems to direct chilled air directly to the racks (see Figure 6). This design can be used with or without a draping system (illustrated in Figure 4) that contains the hot aisle. For these situations, Oracle recommends overhead heat exchanger systems that circulate refrigerant back to an in-room coolant chiller through preplumbed and tapped refrigerant pipes. This setup enables units to be installed right where they're needed. The coolant chiller moves

heat from the refrigerant into the datacenter's chilled water system, efficiently removing heat from the datacenter.

Figure 6. Overhead cooling units can effectively cool high-density racks in raised floor or slab configurations.

Water Treatment

Oracle recommends using technology, rather than chemicals, to treat cooling system water. This helps to reduce pollution, promotes employee health, and saves a significant amount of water. Payback time from water and chemical savings can be less than one year, and used water is clean enough for gray water applications such as irrigation.

Cabling

Oracle's strategy is to move network racks, cabling, and equipment to the pod itself, increasing flexibility and reducing the amount of cabling required. Each pod is considered its own room, with high-speed uplinks from each pod to the core switching equipment. Oracle's approach can cut cable costs by more than 50 percent, saving copper, improving airflow, and simplifying reconfiguration for new, high-density equipment.

Consult with the Experts

Oracle has the technology, experience, and portfolio of services that can help customers through the process of building and optimizing all aspects of the modern data center. Here are just a few of the services Oracle provides:

Server and storage optimization services. Oracle's optimization services leverage best practices and proven methodologies to evaluate your implemented Oracle Sun server and storage systems,

understand current conditions, identify problem areas, and optimize for both performance and energy usage. System consolidation and technology refresh strategies enable data centers to provide more applications and services in less space and at less cost. Learn to plan more effectively for the on-going demands of your business.

Virtualization services. Oracle can develop a strategic approach to virtualization with expert service offerings that identify and implement the best technologies to drive system efficiency. Offerings are available for server, storage, and desktop virtualization.

System application readiness: Provides project management, configuration, and testing to prepare systems for application installation.

Operations management: Highly skilled experts in technology and operations help ensure that our customers' infrastructures are running smoothly. A secure shared service supported by a common global knowledgebase, standardized ITIL-based processes, and a proven technology stack mean that our customers can focus on the quality of their own IT services.

With more than 25 years of hands-on experience in datacenter innovation, including creating some of the most efficient datacenters on its own campus, there is no better partner than Oracle to deliver the services that help customers reach their goals.

Oracle is committed to developing practices and products that help protect the environment

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