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Archipelago Rack Configuration for Optimizing Floor Packing Density in Data Centers

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ABSTRACT

An important factor that drives cloud computing costs is the cost of constructing and maintaining data centers. This disclosure describes techniques to arrange the data center floor layout to achieve high compute power per square foot. Server racks are arranged in the form of islands of an archipelago. An island of the archipelago has at its center a hot aisle surrounded by eight compute racks, to achieve a rack:hot-aisle ratio of 8:1 (approximately four times more efficient than the 2:1 ratio of current layouts). Aisles between the islands are cold aisles. The archipelago configuration can provide higher compute power per square foot, power usage effectiveness closer to unity, reduction in capital and operating expenses, and improved employee efficiency.

KEYWORDS

- Data center
- Rack configuration
- Hot aisle
- Cold aisle
- Power usage effectiveness (PUE)
- Heating, ventilation, air conditioning (HVAC)
- ASHRAE 90.4
- Data center floor configuration

BACKGROUND

An important factor that drives cloud computing costs is the cost of constructing and maintaining data centers. The cost of a data center is dependent on its area. For cost reasons, cloud providers aim to optimize computing power (or server racks) per square foot. While a low server density is energy inefficient, too high a server density can lead to overheating and air-conditioning problems.

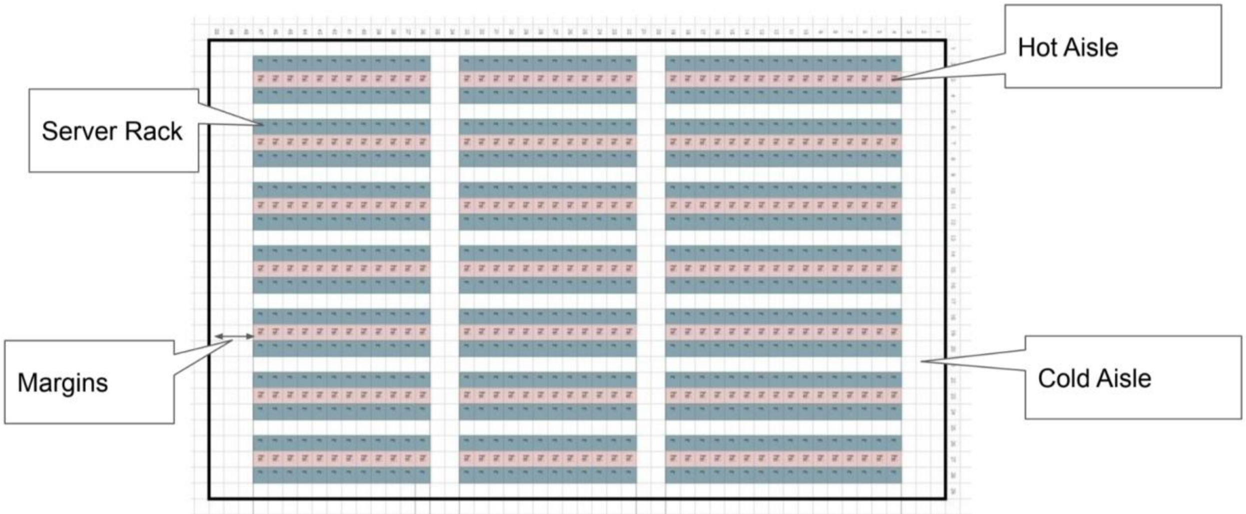

Fig. 1: An arrangement of alternating hot and cold aisles prevents the mixing of hot and cold airflows and achieves energy efficiency

Illustrated in Fig. 1, a data center floor comprises rows of racks of machines, arranged to form cold aisles and hot aisles. Rows of server racks are oriented such that the fronts of servers face each other, and the backs of servers face each other. An aisle of server-fronts constitutes a cold aisle. An aisle of server-backs constitutes a hot aisle. An arrangement of alternating hot and cold aisles reduces energy losses and prolongs server life. Cold air is circulated to the front of the server racks, it absorbs heat and exits from the rear of the racks as hot air. Airflow is managed to save energy and to reduce cooling costs. Commonly, floor layout plans for data centers allocate about 20% of the floor area to the hot aisle footprint, with racks to hot aisles being in a 2:1 ratio. Server rows include breaks to enable the passage of maintenance personnel across rows.

Mixing of hot and cold flows (which reduces energy efficiency) is prevented by containing hot and cold aisles. A cold-aisle containment system (CACS) encloses the cold aisle, effectively making the rest of the data center floor a large cold-air return path. A hot-aisle containment system (HACS) encloses the hot aisle to collect and remove hot exhaust from equipment, effectively making the rest of the data center a large cold-air return plenum. Cold air is contained using doors, plastic curtains, and ceiling/floor panels to direct it to servers without obstruction or mixing with hot exhaust. Hot air is similarly contained so that it is removed before it mixes with incoming cold air.

Air handling and conditioning, including the monitoring and control of minimum and maximum temperatures, is essential to energy efficiency and optimal performance/reliability of information technology (IT) equipment. An air conditioner (AC) uses mechanical refrigeration to cool air, while a computer room air handler (CRAH), generally used in smaller data centers, uses fans, cooling coils, and water chillers to remove heat. Liquid cooling (as opposed to air cooling) entails the flow of liquid refrigerants (e.g., cold water) with a large heat-absorbing capacity close to heat sources such as CPUs and GPUs. Liquid cooling can remove heat thousands of times faster than air cooling, and is especially useful for racks with high CPU/GPU densities. Green (or free) cooling is a sustainable cooling technology wherein data center windows covered with filters or louvers are opened to enable natural air circulation and cooling. Changing data center temperature and humidity standards alter the selection of cooling technologies, budget considerations, and the physical footprints of data centers. Some considerations in data center design include:

- Operational efficiency, which refers to the ease with which the floor layout enables personnel to perform maintenance and administrative tasks.
- Cooling efficiency, enabled by a layout and rack-and-cabinet arrangement that facilitates airflow to minimize cooling costs.
- Availability, e.g., rapid troubleshooting and minimized downtime, enabled by optimized management of power, cooling, components, and cables.

DESCRIPTION

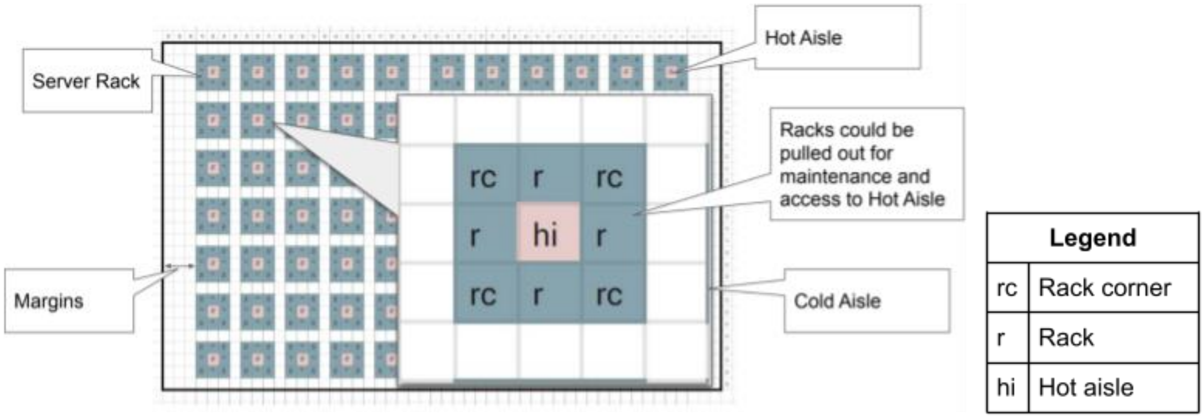

Fig. 2: Archipelago rack configuration for optimizing floor-packing density in data centers

This disclosure describes techniques to arrange the data center floor layout to achieve high compute power per square foot. Illustrated in Fig. 2, the data center floor is arranged in the form of an archipelago. An island of the archipelago has at its center a hot aisle (hi) surrounded by eight compute racks, to achieve a rack:hot-aisle ratio of 8:1 (approximately four times more efficient than the 2:1 ratio of current layouts). The island sits in a bath of cold air, such that aisles between the square islands are effectively cold aisles. Racks can easily be pulled out of an island for maintenance and for access to the hot aisle.

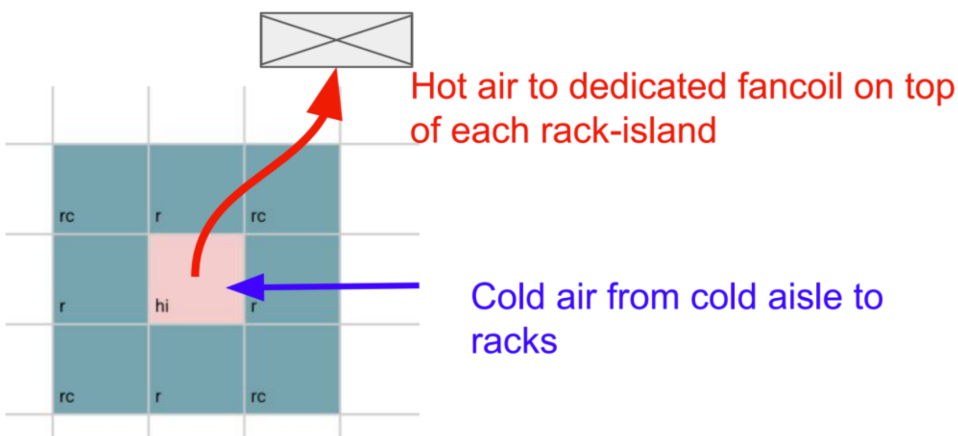

Fig. 3: Cooling technique

Fig. 3 illustrates an example technique for cooling the described archipelago layout. Cold air from the cold aisle is pushed laterally through the racks of an island, and hot air exits the central hot aisle of the island to a fan coil situated on top of and dedicated to the island. The illustrated per-island cooling enables temperature control to be optimized locally over each island and reduces its failure domain.

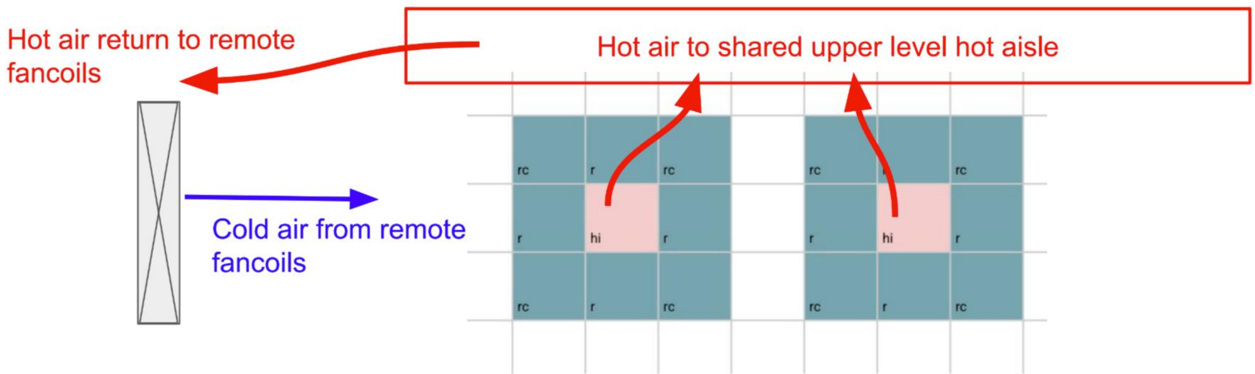

Fig. 4: An alternative cooling technique

Fig. 4 illustrates an alternative cooling technique. Cold air from remote fan coils is blown into one or more islands. Hot air exits each island to a shared upper-level hot aisle before returning to the remote fan coils. The illustrated cooling technique increases the air-sharing zone, resulting in increased cooling redundancy. It also enables optimization of fan power.

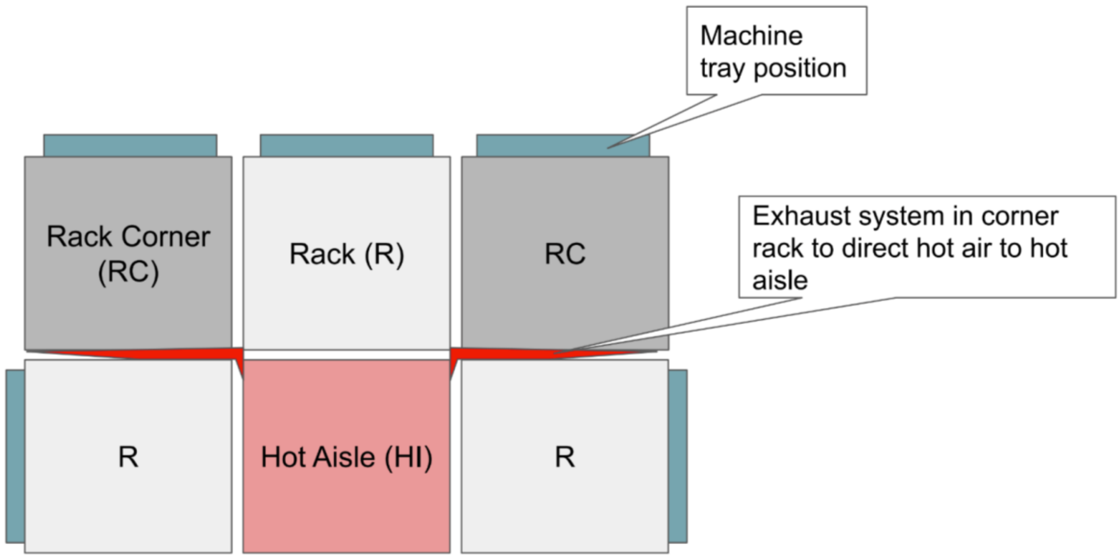

Fig. 5: Corner-rack exhaust

The described archipelago floor layout enables corner-rack exhaust, illustrated in Fig. 5. In corner-rack exhaust, an exhaust mechanism is fitted in corner racks to direct hot air to the hot aisle, further improving cooling efficiency.

	Standard	Archipelago	Delta	Delta %
Number of racks	560	616	+56	+10%
Hot aisle footprint	280	77	−203	−72.5%
Cold aisle footprint	610	757	+147	+24%

Table 1: Comparing the number of compute racks between standard and archipelago configurations

Table 1 shows a comparison of the number of compute racks of the archipelago configuration with that of a standard configuration. As can be seen, in the same floor space (a data center of 29×50=1,450 squares, with equal margins from the walls), the described archipelago configuration fits 10% more compute racks. The hot aisle footprint reduces by more than 70%, enabling more efficient removal of heat. The cold aisle footprint increases by nearly 25%, providing greater airflow and cooler air.

Aside from higher compute density per square foot, the described archipelago floor layout configuration reduces capital expenditures on electrical and mechanical cooling equipment by decreasing the footprint of the hot aisles. It enables easier maintenance of hot aisles, as the walkable area increases by 25%. The number of breaks between server rows is higher, streamlining navigation between servers. The number of server racks shut down during maintenance is substantially decreased.

Applicable to all geographies, the archipelago layout is especially valuable in markets with limited land, for data centers in dense urban areas, and results in better power usage effectiveness (PUE). It provides an economic alternative to investing in newer and larger facilities, e.g., retaining existing facilities at the same size and power consumption while expanding capacity.

In this manner, rearranging the data center floor layout per the described techniques can provide higher compute power per square foot, PUE closer to unity, reduction in capital expenses (avoiding or postponing the building of new facilities), reduction in operating expenses (lower cooling costs and energy consumption due to economies of scale), and improved employee efficiency due to optimized walk time on the floor for maintenance.

CONCLUSION

This disclosure describes techniques to arrange the data center floor layout to achieve high compute power per square foot. Server racks are arranged in the form of islands of an archipelago. An island of the archipelago has at its center a hot aisle surrounded by eight compute racks, to achieve a rack:hot-aisle ratio of 8:1 (approximately four times more efficient than the 2:1 ratio of current layouts). Aisles between the islands are cold aisles. The archipelago configuration can provide higher compute power per square foot, power usage effectiveness closer to unity, reduction in capital and operating expenses, and improved employee efficiency.

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