Putting Bugs in Your Data Center Might Actually be a Good Idea

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Abstract

Data centers of cloud providers hold millions of processor cores, exabytes of storage, and petabytes of network bandwidth. Research shows that in 2019, data centers consumed more than 2% of global electricity production, where 50% of consumption targeted for cooling infrastructures. While the most effective solution for thermal distribution is liquid cooling, technical challenges and complexities make it expensive.

We suggest using living spiders as cooling devices for data centers. A prior work shows that spider silk has high thermal conductivity, close to that of copper: the second-best metallic conductor. Spiders not only generate spider silk but maintain it. Recruiting spiders for the job requires no more than inserting bugs to the data center for the spiders to catch. This solution is effective, self-sustaining, and environment-friendly, but requires solving a number of non-trivial technical and zoological challenges on the way to make it practical.

1. Introduction

Data centers of cloud providers hold millions of processor cores, exabytes of storage, and petabytes of network bandwidth [1]. As such, they have become one of the most power-hungry facilities humanity ever made. Research shows that the worldwide Information-Communications-Technologies ecosystem requires about 10% of the world electricity generation, and enterprise expenditure power supply and cooling has been estimated to be more than 30 billion USD [7, 8]. Approximately half of this electricity consumption goes toward powering cooling infrastructure. For example, a 30 K square feet data center with ten megawatts power consumption consumes on the order of 5 million USD for cooling in a year. [6, 8].

The conventional method to remove heat from silicon devices is using heat sinks and circulating large amounts of chilled air. However, the increased power density of modern devices already demands better cooling infrastructure. For instance, some chip designs make switching to water cooling inevitable [11, 4]. The reason is that thermodynamically liquid cooling is much more efficient than air cooling, as the heat capacity of liquids is much higher than that of air [6]. Water cooling not only eliminates the need for chillers but opens up the possibility of heat reuse [11].

Water cooling also bears downsides as well. Integrating on-board liquid cooling infrastructure such as in [11, 4] (see illustration in Figure 1) requires additional plumbing support (e.g., pumps, pipes). Not only they entail additional costs and maintenance complexities, but they might result in dangerous hazards. Any leakage can create circuit shortage and permanently damage the hardware. As a consequence, dedicated moist sensors must be employed and monitored by data center operators, which in turn induce additional costs.

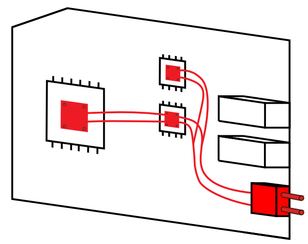

Figure 1: Illustration of on-board liquid cooling infrastructure (in red). Leakage and moisture may lead to permanent hardware damage.

Table 1: Thermal conductivity of several materials [2, 10].

Material	Thermal Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
Air	0.01 - 0.09
Water	0.52 - 0.68
Copper	390 - 401
NC Silk	349 - 416

We suggest using living spiders as cooling devices for data centers. Huang et al. [2] show that spider silk has high thermal conductivity, close to that of copper: the second-best metallic conductor. Moreover, it appears that the silk's thermal conductivity is even higher under strain, surpassing that of copper. The authors of [2] performed various tests over the silk of an orb-weaver spider named Nephila clavipes, and explain that its high thermal conductivity is a result of its extraordinary biomolecule structure (see Table 1).

Using living spiders will not only make cooling infrastructure easier to install but will reduce maintenance costs, as spiders are cheap and self-sustained. To integrate spiders as cooling devices, one needs to understand what is their natural habitat in order to make them prosper in a data center environment.

2. Spider Attributes and Habitat

The golden silk spider (Nephila/Trichonephila clavipes) is a large orange and brown spider with feathery tufts on its legs (see Figure 2). Its webs are made typically in open woods, usually attached to trees and low shrubs, and its prey consists of a wide variety of small to medium-sized flying insects, including flies, bees, wasps, and small moths and butterflies. Naturally, these spiders are located all across America, from North Carolina in the north to Argentina in the south. Their

Figure 2: The golden silk spider (Nephila clavipes) is a large orange and brown spider with feathery tufts on its legs [3, 9].

length depends on their gender, as females range from 24 mm to 40 mm and males average in 6 mm. The meshed, large web of golden silk spiders is often 1-2 meters in diameter and placed to exploit insect flying paths. The hub of the web, where the spider waits, is located near the top, making an asymmetrical orb. The spiders repair web damages periodically while leaving the remainder undisturbed, and their bites are not dangerous and produce only localized pain with slight redness. Female golden silk spiders make large egg sacs with several hundred eggs once a year [3].

3. Spider-Friendly Data Centers

Integrating golden silk spiders into data centers requires organizing server racks such that spiders will naturally prefer to connect their webs to heat-generating chips. We now describe the layout of *spider-friendly* data centers.

Branch-like heat sinks. One possible way of making spiders connect their web to designated places is to use dedicated heat sinks that shaped like branches (see Figure 3). These heat sinks should be extended outside server racks for making them visible and attractive to spiders. A second branch-like facility (left gray branch in the figure) should be connected to a centralized cooling infrastructure, making the spider web transfer heat from hot-zones to cool ones. Another possibility is to address spider webs as heat sink extenders, and use circulated chilled air for cooling.

Insect flying zones. As golden silk spiders weave their webs to catch prey, dedicated zones should be reserved for flying insects. Insect flying zones should be proximate to the server racks and the branch-like heat sinks and preferably limited in space. Mosquito nets can be used to bound such zones.

Semi-controlled ecosystem. To make spiders thrive in a data center environment, one should control their supporting ecosystem. The amount and type of prey insects should match the spiders' preferences. The number of spiders should be monitored and match prey availability. External hatching farms [5] can provide flying insects to data centers without the need to control the data center's ecosystem completely (e.g., planting nourishing plants to provide the prey's needs, aggregating those plants).

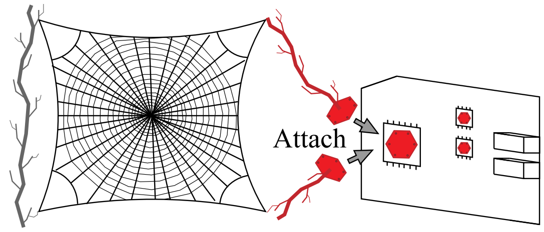

Figure 3: Connecting branch-like heat sinks to heat-generating chips may allure spiders to weave their webs in desired places.

4. Challenges

Inserting spiders to data centers might raise several challenges. First is handling dead spiders and bugs inside racks, which may cause circuit shortages. A possible solution is to cover the racks with mosquito nets. Second is avoiding damage to spiders and their webs when performing hardware maintenance. A third challenge is handling data center operators that have arachnophobia (i.e., fear of spiders).

5. Conclusions and Open Questions

We have presented a possible research direction for using spiders as living cooling devices in data centers. The advantages of spiders over on-board liquid cooling systems include but not limited to fewer risks, autonomous maintenance, and lower costs. However, several questions remain open for research:

Web control. What is the simplest way of making spiders connect their webs to designated spots? How can one force spiders to repair web damage, or extend existing webs? What are the statistics of spider weaving speed?

Spider sustainability. What is the ideal ratio between the number of spiders and the number of flying insects? How can one make sure the spiders are healthy and willing to work? Do spiders get along with each other? What is the simplest way of remotely monitoring the spiders' behavior? Do spiders tolerate the extreme temperatures that exist in data centers?

Collateral effects. Which rack design utilizes spider webs best? Can spiders' feces damage the hardware?

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