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**| RESEARCH ARTICLE**

## **Challenges and Concerns Related to the Environmental Impact of Cloud Computing and the Carbon Footprint of Data Transmission**

**Sunil Sukumaran Nair**

*Programmer Analyst Specialist, Dominion Energy, Cayce, SC, USA*

**Corresponding Author:** Sunil Sukumaran Nair, **E-mail:** [sunil\\_nair\\_01@yahoo.com](mailto:sunil_nair_01@yahoo.com)

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**| ABSTRACT**

The paper sheds light on the rising scope of cloud computing and its impacts on businesses. Furthermore, the purpose of this article is to describe the harm caused by cloud computing despite its promised sustainable nature. The energy consumption during the operation of cloud systems is quite high. This article analyzes the factors that lead to huge energy consumption. E-waste is also a serious problem in the IT field because a large number of hardware resources are used, and once obsolete, they cause environmental pollution. There are various challenges, but taking some productive steps in the right direction can help solve the problem.

**| KEYWORDS**

Cloud Computing, Data Transmission, E-waste, Carbon Footprint, Environmental Pollution.

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### **1. Introduction**

The transformation of information technology has been raised further to the next level due to the inclusion of cloud computing. Because it offers a myriad of advantages to both commercial and non-commercial sectors (Lucivero, 2019), this technology has erupted as the cornerstone of modern enterprise expansion, allowing organizations and individuals to harness a wide array of computing resources via the Internet (quantumlifecycle.com, 2023). However, this technology has some drawbacks, as this is not without its challenges and environmental concerns. Some of the major concerns include the e-waste generated by outdated hardware components, the environmental impact of data centers, and the carbon footprint associated with data transmission. There is a need to do research in this domain, as cloud computing is expanding and requires addressing critical issues (Ghulam and Abushammala, 2023).

### **2. Cloud Computing and its significance**

Technologies related to computers are assisting in the expansion of enterprises, and this is true not only for commercial but also in non-commercial contexts. Through the internet, people and businesses can access and use computing resources such as databases, networking, storage, software, and other services thanks to a technology called cloud computing. This new computing paradigm allows customers to rent or lease physical hardware and software resources from cloud service providers instead of purchasing and maintaining these items themselves (Wang, Yang and Yue, 2023). Cloud computing provides answers to certain issues that traditional hardware solutions are unable to address. The most common justifications for using cloud computing are its scalability, cost-effectiveness, accessibility, data reliability, security, and flexible usage options. To increase agility and innovation, many businesses are embracing digital transformation and migrating their apps and IT infrastructure to the cloud. Similar reasons exist for the adoption of cloud computing, including that the COVID-19 pandemic has accelerated the transition to remote working

and the need for cloud services to support anytime, anywhere access to applications and data (Sittig, Sherman, Eckelman, Draper and Singh, 2022).

### **3. Environmental concerns associated with cloud computing, e-waste, and data transmission**

Every technology revolution is accompanied by environmental concerns, and cloud computing is no exception. It has potentially harmful effects on the environment. Amongst the main issues that the academics are researching are:

- Older hardware and infrastructure become outdated and frequently replaced as a result of technological advancements.
- The production and disposal of the physical infrastructure components of cloud computing, such as servers and networking equipment, can have an environmental impact.
- Data centers that power cloud computing services require a significant amount of energy to operate and cool the servers.
- Large-scale data transmission over long distances can increase energy consumption and carbon emissions. Data centers also need a lot of water for cooling. In some areas, data centers are powered by fossil fuels (A. Rejeb, Suhaiza, K. Rejeb, Seuring and Treiblmaier, 2022).

### **4. Growth and Significance of cloud computing in the Modern IT landscape**

Although it is now more popular, cloud computing is the way of the future for computing and will eventually replace traditional computing due to its higher degree of scalability, which enables businesses to adjust their IT resources following demand. This adaptability is essential for managing varying workloads, including seasonal needs or unexpected traffic surges, without requiring significant infrastructure expenditures. The pay-as-you-go approach offered by cloud computing, which lowers capital expenditures on hardware and ongoing maintenance costs, makes cost efficiency another top goal for customers. Businesses of all sizes find this cost-effectiveness especially appealing because it allows them to match their IT spending to their actual usage (quantumlifecycle.com, 2023).

Remote access to apps and data from any location with an internet connection is another benefit of cloud computing. Employees can now work from home or other locations through such a transformation, which has proved essential for remote work and cooperation. Prominent cloud service providers make significant investments in infrastructure, redundancy, and data centers to guarantee high service availability and dependability to lower the possibility of service interruptions brought on by malfunctioning hardware or other problems. Advanced security features like identity and access management, encryption, and compliance certifications are provided by a lot of cloud providers. Although users and providers share responsibility for security, cloud services have made it simpler for businesses to strengthen their security posture (Abalansa, Mahrad, Icelly, and Newton, 2021).

The fact that computer technology is now susceptible to unforeseeable events, such as intrusions or natural disasters, is another worry in the modern period. Planning for business continuity and catastrophe recovery is made possible by cloud computing. In the event of an outage or natural disaster, organizations may ensure that data is safe and accessible by replicating data and applications across various geographic locations (Abalansa, Mahrad, Icelly, and Newton, 2021).

### **5. Energy consumption and resource utilization in data centers**

In data centers supporting cloud computing, energy usage and resource utilization are crucial factors to take into account. Cloud data centers, which offer services to a broad spectrum of consumers and businesses, need to be extremely efficient at managing energy costs and reducing their negative environmental effects to fulfill the growing demand for computing resources. Many cloud data centers use a multi-tenant architecture in which different clients use the same infrastructure. Because cloud computing systems are elastic, they can dynamically allocate or deallocate resources in response to demand. One important aspect of cloud computing is its scalability, which guarantees the economical and efficient use of resources (A. Rejeb, Suhaiza, K. Rejeb, Seuring and Treiblmaier, 2022).

Virtualization technologies are one of the main energy-consuming components of cloud computing systems in cloud data centers. Although they allow the creation of containers and virtual machines (VMs), which share the physical hardware, it increases energy consumption, which raises concerns about the system's effectiveness (James, 2012).

### **6. Statistics and research**

The world is affected negatively by the risks associated with cloud computing and the hardware used for the same purposes, according to research from MIT. Data centers, which are a component of cloud infrastructure, use a lot of electricity; in many cases, cooling accounts for over 40% of this consumption. To add even more detail, the electricity used by data centers accounts for 0.3% of global carbon emissions, and when networked devices such as laptops, smartphones, and tablets are considered, the total carbon emissions associated with digital technology rise to 2% globally.

The installation of cloud computing systems and maintaining the temperature for continuous operation have increased water demand. Data centers can use water for cooling, and in certain situations, they use a lot of water resources (Lucivero, 2019). For instance, the studies specifically mentioned that the Utah Data Center, run by the National Security Agency of the United States, uses seven million gallons of water every day (A. Rejeb, Suhaiza, K. Rejeb, Seuring and Treiblmaier, 2022).

In addition, there is the worry of noise pollution associated with cloud computing hardware. One type of noise pollution that data centers produce is noise, which can be harmful to the health and well-being of neighboring residents. Affected individuals may have elevated stress hormones, hypertension, and sleeplessness as a result of this pollution. Because ICT devices, such as smartphones, have shorter average lifespans than two years, there is a comparable worry with electronic waste. Water, chemicals, and fossil fuels are only a few of the abundant resources needed in the production of these devices. Every obsolete electronic gadget ends up as e-waste, which degrades over millennia and contains hazardous materials (Hoosain, Paul, Kass and Ramakrishna, 2023).

### **7. Concept of e-waste and its relevance to cloud computing**

Electronic garbage, or e-waste, is the term for used electrical and electronic equipment and devices. A wide variety of products fall under this category, including outdated computers, cellphones, tablets, televisions, refrigerators, washing machines, and more. Batteries, cables, circuit boards, and other parts and accessories can also be considered parts of e-waste. The IT and cloud computing industries are seeing tremendous technical improvements and innovation, which is leading to a faster rate of replacement of electronic devices and infrastructure. Older gadgets eventually grow outdated and are thrown away, which adds to the e-waste issue (Radu, 2017).

Data centers, which need a lot of computers, electronic equipment, and cooling systems, are crucial to cloud computing. Older equipment must be disposed of when these data centers expand and undergo frequent modifications due to the increasing demand for cloud services. The data centers are the source of cloud computing and waste generation, in addition to other aspects. These are the backbone of cloud computing and produce a large amount of e-waste during infrastructure upkeep and upgrades. Servers, network switches, power distribution units, and cooling systems are examples of components that can quickly become outdated (Wang, Yang and Yue, 2023).

Large volumes of electricity are needed in data centers for cooling and computing. The loss of natural resources, pollution, and the creation of e-waste when equipment is retired or replaced are all issues related to this energy usage. Electronic equipment must be disposed of and recycled properly to reduce the negative environmental effects of e-waste. Unfortunately, not all electronic trash is recycled to a sufficient extent, and incorrect disposal can result in pollution and the release of hazardous materials into the environment (Radu, 2017).

### **8. Lifecycle of hardware components in data centers and the disposal challenges**

Hardware components in data centers go through several stages in their lives, from acquisition to disposal. An outline of these phases and the difficulties in disposing of data center gear is provided here. The process of procuring servers, storage devices, networking equipment, and other infrastructure components is the first step in acquiring hardware components. Following a purchase, the hardware is set up and placed in the data center to satisfy the company's unique needs (Salama, 2020). The data center's hardware components are operational, and routine maintenance is carried out to guarantee their peak performance. This covers routine inspections, hardware replacements, and software updates. It could be necessary to expand or upgrade the data center hardware to accommodate expanding business requirements or emerging technologies. This may entail changing out old components or introducing new ones. Hardware parts eventually reach the end of their useful lives or become outdated. They must be safely removed from the data center infrastructure for them to be retired (Salama, 2020).

### **9. Disposal challenges**

Hardware disposal at a data center can provide several difficulties, most relating to regulatory, data security, and environmental concerns.

#### **9.1 Effects on the Environment**

Lead, mercury, and cadmium are among the dangerous elements frequently found in data center technology. Proper disposal is essential to stop contamination in the environment. Reducing these effects requires recycling and appropriate disposal techniques.

#### **9.2 Data Safety**

Private and sensitive data might be stored on the device. To avoid data breaches or leaks, make sure that data is safely erased or destroyed before disposal. Common techniques include physical destruction or data erasure (quantumlifecycle.com, 2023).

### **9.3 E-Waste Guidelines**

The proper disposal of electronic garbage, or "e-waste," is governed by stringent legislation in many nations. Operators of data centers are required to abide by these standards, which frequently call for appropriate documentation and ecologically responsible disposal techniques.

### **9.4 Durability**

In data center operations, sustainability is becoming more and more important. Disposal techniques, such as recycling, reusing, or repurposing hardware components whenever possible, should be in line with sustainability goals.

### **9.5 Outdatedness**

Technological improvements may cause data center hardware components to become outdated quickly. Over time, disposing of obsolete equipment can become problematic due to budget and resource allocation.

## **10. Carbon emissions associated with data transmission and networking infrastructure**

The increased reliance on digital technology has raised concerns about the carbon emissions linked to data transmission and networking infrastructure, sometimes known as the "carbon footprint of the digital sector."

Carbon emissions primarily originate from data centers, which are locations where digital information is stored and sent. A great deal of electricity is needed in these facilities to run the cooling systems and servers. The carbon footprint can be greatly impacted by the energy source used. Fossil fuel-powered data centers emit higher emissions than data centers that run on renewable energy.

The carbon footprint increases along with the demand for data transfer and internet services. Data centers use more energy as a result of data transfer from streaming media, online games, and cloud services (Radu, 2017).

The emissions from data centers can vary depending on where they are located. Comparing data centers in countries primarily dependent on coal or natural gas, those in places with a high percentage of renewable energy sources, like hydroelectric electricity, have a lower carbon footprint.

Energy is also used by the network infrastructure, which includes fiber optic cables and network hardware, to enable data transfer. Emissions can be decreased by switching to more energy-efficient hardware and streamlining network traffic (Covels, Tsamados, Taddeo and Floridi, 2021).

## **11. Mitigation strategies**

The mitigation strategies that the corporate sector should adopt are as follows.

- High-efficiency hardware should be adopted for the reduction of power consumption.
- Renewable energy, such as wind, solar, and hydroelectric power, should be arranged for such facilities.
- The virtualization of the servers can result in a decline in the number of physical servers.
- Recycling should be the basic requirement for the firms; additionally, they should be required to implement environmentally friendly practices.
- Use the material for hardware development that is sustainable and can be used for a longer period (James, 2012).

## **12. Approaches and strategies to reduce the environmental impact of cloud computing**

- Invest in energy-efficient data centers.
- Use renewable energy sources.
- Innovative cooling methods like free cooling and liquid cooling.
- Consolidating multiple virtual servers on a single physical server.
- Selection of the low-power processors, solid-state drives, and energy-efficient components.
- Allocate resources based on actual demand to avoid over-provisioning.
- Reduction of the amount of data stored on the cloud.
- Comply with industry-specific standards and regulations.
- Efforts should be made to create more energy-efficient hardware and software solutions for cloud computing (Lucivero, 2019)

## **13. Energy-efficient technologies, renewable energy adoption, and green data center practices**

The creation of technologically based solutions that can support sustainability can be seen as a means of addressing the risks associated with the hardware of cloud computing and current technologies. For example, the fundamental need for energy efficiency is the virtualization of servers. The energy efficiency of the cloud's parts should be taken into consideration while

choosing them. For example, networking hardware, processors, memory, and storage devices can all use less power. For example, instead of using conventional hard disc drives, solid-state drives (SSDs) that use less energy can be used.

One novel approach to conserving energy in cloud computing may be power management. Features like this would help save energy when things aren't being used as often. Technologies such as dynamic voltage and frequency scaling (DVFS) are included in this. To buy clean energy, big businesses should enter into agreements with suppliers of renewable energy. As a result, data centers can use renewable energy sources without having to make on-site infrastructure purchases. Earn renewable energy credits to offset the carbon impact of using electricity. RECs provide funding for renewable energy initiatives.

Since energy efficiency is a consideration in the design of data centers, transforming them is also a useful step toward sustainability. Take into account elements like insulation, airflow control, and the application of natural cooling techniques. A temperature-controlled facility with features like elevated flooring, hot/cold aisle containment, and efficient cooling systems may maximize temperature control while using the least amount of energy.

#### 14. Conclusion

Cloud computing has a greater role in the modern era, as it helps businesses develop their network of information without being dependent upon hardware. This technology has brought about a revolution in the IT landscape, offering numerous benefits, including scalability, cost-effectiveness, remote accessibility, and enhanced security. However, the environmental impact of cloud computing, e-waste generation, and the carbon footprint of data transmission are significant challenges and concerns that need to be addressed. The expansion of cloud technology has caused an increased demand for computing resources, and data centers supporting cloud services must efficiently manage energy consumption and resource utilization. Scalability and virtualization are the need of the cloud to transform itself into an environment-friendly technology. E-waste has attracted the attention of many social workers and environmentalists, but there is still a need for an alternative solution. Cloud computing continues to develop the IT sector with the help of modern means of communication and data transmission. There are some interventions that should be done to reduce the hazards of cloud technology.

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