Cloud Migration and GraphQL Implementation to Improve Cost Measures

Evaluating and Mitigating the Environmental Footprint of Cloud Computing Data Centers

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Science

By
Shriman Selvamani

3/31/2023

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Kathryn A. Neeley, Department of Engineering and Society

Rosanne Vrugtman, Department of Computer Science

Assessing the Environmental Impact of Cloud Computing: A Comprehensive Study on Energy Consumption, Carbon Footprint, and Sustainability

STS 4500 Prospectus

School of Engineering and Applied Sciences

B.S. Computer Science

The University of Virginia, Charlottesville

Name: Shriman Selvamani

Technical Advisor: Aaron Bloomfield

STS Advisor: Alice Fox

Projected Graduation Date: May 2024

Submission Date: 3/31/2023

Assessing the Environmental Impact of Cloud Computing: A Comprehensive Study on Energy Consumption, Carbon Footprint, and Sustainability

Overview:

Cloud computing is a rapidly growing technology that has revolutionized the way organizations operate their servers. With new features and hardware being developed at a rapid pace, it's important to consider the potential consequences of this technology, especially with regards to the environment. During my summer internship, I had the opportunity to gain a deeper understanding of the immense capabilities of cloud computing. However, in this work, I will be examining the potential negative consequences that cloud computing may have on the environment, and the impact that it may cause.

Positionality:

I was born and raised in Northern Virginia where there was an immense number of data centers being rapidly built in my area by cloud provider giants such as Amazon, Google, and Microsoft. Seeing these large buildings led me to be curious about the technology of cloud computing and how it can impact society. Ever since I was a young child, I have been very interested in building large Lego structures as well as being an avid chess player, both of which helped me grow skills that I still use as an engineering student to this day.

Over the summer, I had the opportunity to explore an internship in the field of cloud computing where I gained experience with numerous state-of-the-art technologies to complete my project. I learned that cloud technology is a field I would like to continue exploring and my interest skyrocketed during the internship seeing the rapid innovative changes cloud providers are bringing to the market. Also, I was always employing the innate behaviors that I had learned throughout my childhood from building Legos. However, when traveling to India one summer, I realized that technology could have a devastating impact on other areas including the environment. In some tech cities in India, I noticed the pollution to be unbearable and this led me to want to dig deeper and understand the impact of certain technologies on the environment.

Problematization:

Cloud computing has several negative environmental impacts that should not be ignored. First off, it is an energy-intensive technology and requires a lot of electricity to power the large-scale data centers. These data centers are the backbone to cloud computing and have a very wide geographic footprint that can lead to a severe environmental impact across the world. The high usage of energy leads to an increase in carbon emission and thus leading to a negative impact in climate change. Additionally, the production and disposal of electronic devices used in cloud computing such as servers, storage device, CPUs all contribute to electronic waste and toxic pollution. Finally, the transportation of the devices and shipping of data also contribute to carbon

emissions and this all these impacts should be thoroughly considered as this technology is growing at a rapid rate but has several impacts that should be carefully examined.

Main Argument:

Are there potential negative environmental impacts of cloud computing based on the rapidly growing technology?

Projected Outcomes:

My research aims to analyze the environmental impact of cloud computing using STS-related approaches, such as examining the power dynamics among stakeholders and exploring the socio-technical implications of cloud computing. By challenging dominant ways of thinking about cloud computing as a purely technological issue, my research can suggest policy changes that promote sustainability and empower communities. The outcomes of my research can benefit a range of stakeholders, including policymakers, cloud service providers, and users, by providing a more comprehensive understanding of the environmental impact of cloud computing and suggesting strategies for reducing it.

Technical Project Description:

During my summer internship at Costar Group, I had the opportunity to work on a database migration project for the company's flagship product, generating $800 million in revenue annually. Working on such a significant project and gaining hands-on experience with cloud technology was a valuable learning experience that stood out from my previous internships. I used state-of-the-art technologies to migrate the legacy database from the on-premises data center to the AWS Cloud DynamoDB database system, resulting in cost savings and improved performance. Additionally, we rewired a new middleware API system of GraphQL, making querying data from the frontend user interface and the backend database more efficient and faster. Throughout the internship, I gained an understanding of the importance of data privacy and security and learned about the various security measures in place to protect sensitive data, such as encryption, access control, and backup and disaster recovery. I was impressed by the company's commitment to data security and their investment in the latest technologies to keep their data safe. Overall, my experience at Costar Group has deepened my interest in exploring the rapidly innovative changes that cloud providers are bringing to the market.

Preliminary Literature Review & Findings:

Cloud computing has been a field where engineers and STS researchers have spent a large amount of time researching efficient and advanced solutions to some problems that are present. Engineers have focused on developing energy-efficient hardware and software to reduce the energy consumption and carbon footprint of data centers. They have also explored the use of renewable energy sources such as solar and wind to power data centers [2]. STS researchers, on

the other hand, have studied the socio-technical aspects of cloud computing, including the power dynamics among stakeholders, the politics of data sovereignty, the implications of cloud computing on privacy and security, and the environmental impact of cloud computing and its relation to sustainability.

One of the main challenges faced by researchers and engineers is the lack of comprehensive data on the energy consumption and carbon footprint of cloud computing [1]. The complex technology of cloud computing also poses challenges in accurately measuring and assessing its environmental impact as there are so many components involved and scattered across the world, this includes both hardware and software components.

My work can build on these approaches by providing a comprehensive study on the environmental impact of cloud computing, including energy consumption, carbon footprint, and sustainability. I can use a combination of quantitative and qualitative methods to analyze data and assess the socio-technical implications of cloud computing to build on the work of engineers and STS researchers. My work can also contribute to resolving some of the difficulties faced by researchers and engineers by providing a better understanding of the environmental impact of cloud computing.

STS Project Proposal:

"Science, Technology, & Society" is a discipline that outlines the relationship between these three fields and how they are shaped by political, economic, and social forces. This is because science, its knowledge, its methods, and its practices, are disciplinary cultures. Also, it is interdisciplinary in nature and draws from humanities and social sciences to give a deep understanding of the topics. STS creates and fosters engineers to be capable of making creative, ethical, and inspired contributions to the design of a socio-technical future. Understanding the environmental impact of the immense field of Cloud Computing can help touch on ethical dilemmas surrounding a rapidly growing technology. Ultimately, the goal of this project is to examine through a unique lens, the impacts of technological advancements in cloud computing, on society and the environment. Hopefully, this will encourage future engineers to build a society that is more sustainable and builds technology that serves humanity.

The study on the impact of cloud computing on environmental resources touches on the STS approach of the environment and sustainability. An approach that prioritizes sustainability and environmental justice would align with the values and frameworks of environmental studies which will be examined. Authors who align with the idea of addressing climate change as a social justice issue such as Kelly S. Fielding and Matthew J. Hornsey, will be referenced in my studies and can provide significant insights to the research.

The method that I will use to approach this study is Value Source Analysis in Value Sensitive Design (VSD) which analyzes the values of the users impacted by the technology, which in this case is cloud computing. I will be using Friedman's version of Value Sensitive Design and by using Value Source Analysis to investigate the environmental impact of cloud

computing, researchers can identify and prioritize the values that are most relevant to sustainability, such as energy efficiency, carbon reduction, and resource conservation. This approach can help to ensure that the design of cloud computing technologies aligns with the values of environmental sustainability and can also help to promote social and ethical values.

I plan on accomplishing the analysis of my research primarily through literature review and analysis. This will be done through several articles that I have access to through the school database and derive both quantitative and qualitative data from these studies.

Barriers & Boons

Some potential blind spots or limitations in research on the environmental impact of cloud computing may include financial and time barriers. There may also be knowledge and collaborative barriers, such as the need for interdisciplinary expertise in fields such as energy and sustainability.

To address these potential limitations, researchers can use a myriad of strategies. For example, they can utilize easy to use methods such as online surveys or data mining to collect data on the energy consumption and carbon footprint of cloud computing. Researchers can also prioritize building trust with participants and communities by engaging in participatory research and involving stakeholders in the research process.

Knowledge and collaborative barriers that exists can be addressed through researchers can seek out interdisciplinary collaborations and engage with communities of practice in energy and sustainability research. They can also undertake further reading and training to build expertise in relevant areas.

Overall, it is important for researchers to be mindful of potential limitations and challenges in their research and to take steps to address them, whether through methodological adjustments, community engagement, or collaboration.

References

[1] S. G. Monserrate, “The staggering ecological impacts of computation and the cloud,” The MIT Press Reader, https://thereader.mitpress.mit.edu/the-staggering-ecological-impacts-of-computation-and-the-cloud/ (accessed May 9, 2023).

[2] L. Marston, The environmental footprint of data centers in the United ... - iopscience, https://iopscience.iop.org/article/10.1088/1748-9326/abfba1 (accessed May 9, 2023).