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SUSTAINABLE COMPUTER ARCHITECTURES: USE OF GRID, VIRTUALIZED, AND CLOUD COMPUTING IN ADDRESSING COVID-19 PANDEMIC

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Abstract

Combating electronic waste, energy consumption, as well as carbon emissions requires an enterprise to focus on creating sustainable computer architectures. A sustainable computer architecture identifies ways for an organization to stay competitive while becoming less dependent on computing resources and energy consumption. Sustainable computer architecture is a critical part of Corporate Social Responsibility. This paper highlights the components of a sustainable computer architecture: Grid, Cloud, and Virtualized Computing, and addresses their current applications in tackling COVID-19 pandemic. The COVID-19 pandemic sent virtually all office employees as well as school and University students home worldwide. Working and studying from home has been the only option for them, with in person settings implemented during Fall 21 semester. Under these unprecedented circumstances, sustainable computer architecture providers have become the cornerstone of virtual collaboration and learning platforms on a scale never experienced before. While the Internet has been part of our lives for quite some time now, without scalable Grid, Cloud, and Virtualized Computing platforms addressing the COVID-19 pandemic would have been disastrous. Under the pandemic crisis, sustainable computer architectures have become indispensable for Universities, schools, enterprises, governments, and all virtual students and business professionals.

Keywords: *Sustainable computer architectures, grid, cloud, and virtualized computing, COVID-19 pandemic.*

1. Sustainable information systems infrastructure ecosystem

Five companies utilizing sustainable computer architectures captured over 70 billion US dollars already in the 2019: IBM, Google, Microsoft Azure, Amazon, and Alibaba and they have thrived under the COVID-19 pandemic. Other global cloud based sustainable computer architecture providers include companies like: Salesforce, Oracle Cloud, Tencent Cloud, VMware, and Rackspace. All on-line teaching activities, video meetings and conferences, as well as digital collaboration tools utilized under COVID-19 pandemic by colleges and businesses: open source Moodle and Workspace, as well as Canvas, Zoom, WebEx, Slack, Microsoft Teams, Blackboard, Google Classroom, Any Meeting, Hangouts Meet, and Monday, run on cloud computer architectures. The most often utilized digital platforms: Zoom and Blackboard run on Amazon Web Services. Netflix, a streaming video service for television shows, movies, and documentaries, as well as Twitter, a social media platform also run on Amazon Web Services. Hewlett-Packard and Adobe depend on Microsoft cloud platform, while WebEx Cisco collaborating center utilizes Tata's cloud computing architecture (Frattini, 2020).

2. On-line learning shift

For Universities and schools, the biggest challenge in the on-line transition has been to acknowledge that providing a digital platform for teaching the class that would be otherwise taught in-person, is simply not enough. Additionally, studio and laboratory teaching provided additional extraordinary obstacles. On-line learning necessitates a complete makeover of the teaching and delivery modes on one hand, and the use of sustainable computer architectures, on the other hand, to satisfy curricular activities as well as students learning objectives. One needs to acknowledge that in an in-person teaching, while the professor utilizes in many instances computer classrooms with dozens of computers in them, three different learning mechanisms are being deployed. From the students' learning perspective, there is the need to transfer to students' knowledge acquisition relevant to a particular discipline. Then comes the transformation of that knowledge into professional competence by solving case studies. Third, students need to exchange ideas and to participate in discussions to satisfy class learning outcomes. These three interwoven components differ in their rankings in primary, secondary, and tertiary educational settings. In tertiary education, the application of knowledge and exchanging ideas rank first, while in primary and secondary educational settings transferring knowledge is most important. In an on-line education, these three learning mechanisms cannot be delivered through a single digital platform. They have to be taught through different tailored delivery modes. All of them utilized either Grid, Cloud, and Virtualized Computing. Knowledge acquisition and its transfer is realized through live, on-line sessions, using digital platforms such as Zoom, Microsoft Teams, WebEx, Slack, Google Hangout, for example. Exchanging ideas and participating in discussions is accomplished through semi-synchronous social platforms tools, accurately moderated by professors. Thus, these three different learning mechanisms need to be tailored carefully by schools and Universities to deliver effective on-line educational experience (Foley, 2020).

3. Grid computing

Grid Computing leverages multiple computers, often geographically dispersed, yet interconnected by internet, that are synchronized to accomplish complex joint tasks. Some of the computers are unutilized, due to the location and time difference, thus contributing to the sustainable computer architecture. Grid computing is realized through software installed on every computer that utilizes data grid. The software manages the entire system and coordinates multiple tasks across the whole grid by assigning subtasks to each computer, so the computers could work simultaneously on their respective assignments. After the completion of subtasks, the outputs are collected and subsequently combined to address a larger-scale complex problem. The software lets each computer coordinate its output over the network with the other computers, so the information on what portion of the subtasks each computer is processing could be shared and consolidated to produce the required output. One of the tiers of Grid Computing, coined Distributed Computing, is an approach used to distribute and subsequently solve complex problems. Each interconnected computer on a grid is tasked with a particular portion of the larger science problem being solved. As the tasks are completed, the results are collected by centrally controlled computer(s).

Folding at Home (Folding@Home) is an example of a Distributed Computing architecture. It is based at Washington University School of Medicine in St. Louis, Missouri. Folding at Home is an undertaking to address scientific and medical research for finding cause and effect relationships with respect to illnesses with currently unavailable medical treatments. Proteins, which are the foundational building blocks of the human body, are large complex molecules that play a significant role in addressing this challenge. Proteins are fundamental in skeletal systems, muscular systems, in hair and skin, as well as in vascular systems. Proteins are necklaces of amino acids, which are long chain molecules. They include many essential biological compounds. As enzymes, they are the driving force behind all of the biochemical reactions that make biology work. In order to carry out their function, for example as enzymes or antibodies, they must take on a particular shape, also known as a ‘fold’ (Bowman, 2020). Thus, proteins are truly amazing machines: before they do their work, they assemble themselves. This self-assembly is called ‘folding’. The process of protein folding is of significant importance in human health. If proteins do not fold properly diseases, such as Alzheimer’s disease, can occur. Therefore, understanding how proteins fold, and how errors in the protein folding process arise is important to help find solutions to and cures for cancers and diseases. Recently, the Folding at Home project has published peer reviewed articles which showcase medical applications benefited through the work of Distributed Computing. Cryptic binding sites are not visible in protein targets crystallized without a ligand and only become visible crystallo-graphically upon binding events. These sites have been shown to be druggable and might provide a rare opportunity to target difficult proteins. However, due to their hidden nature, they are difficult to find through experimental screening. Computational methods based on atomistic molecular simulations remain one of the best approaches to identify and characterize cryptic binding sites (Kuzmanic, Bowman, Juarez-Jimenez, Michel & Gervasio, 2020). Protein folding and other biological behaviors must be studied using large quantities and massive amounts of variants and simulations in order to view anomalies and stimuli which negatively impacts human health. Larger datasets help show true outliers and problematic scenarios and then can be more accurately studied. Hanson et. al. (2019) indicated that through clustering analysis of a large kinome profiling dataset, a cluster of eight promiscuous kinases that on average bind more was unusually stable in this inactive conformation, giving a mechanistic explanation for inhibitor promiscuity. This research showed that due solely to the size of the computational dataset were the researchers able to find abnormalities in the protein synthesis. Knowing the explanation for such behavior within the protein structure allows accurate treatments to be made specific to the abnormality, thus allowing for treatments to be more effective. Folding at Home has been active for twenty years. The first software was launched in the year 2000, with an initial success. Afterwards, as an example of distributed computing, thousands of unutilized computers were donating their CPU cycles to the computational task. Within five years, significant research was made in specific areas involving Parkinson's Disease, Huntington's Disease, and Alzheimer's Disease. A benefit of shared computing is that the technical elements of the computer may vary. Operating system, power, and resources matter much less, all the while the problem being solved is being computed on many devices. In 2007, Folding at Home collaborated with Sony to develop a client for Sony's PlayStation3. This allows gamers to run a disease-solving shared computing platform in the background of their entertainment and gaming system at no cost to the user.

An alternative to distributed computing is to allocate massive resources by investing in a supercomputer. Currently, the most powerful supercomputer is Summit – an IBM computer capable of computing 200 petaFLOPS. One petaflop is 1015 Floating Point Operations Per Second (10,000,000,000,000,000 operations per second). While Summit is used for scientific research, millions of dollars is spent to build and maintain its data center. Meanwhile, Folding at Home celebrated 10 Petaflops in 2013, and today, is operating around 2.3 exaFLOPS. One exaFLOP is 1018 operations. One exaflop is 1,000 petaFLOPS. With minimal resources, a global community of researchers connected via the Internet are combining scientific computational output that no supercomputer can compete with.

Folding at Home is now applying resources to research the current pandemic of COVID-19. Just as proteins play a role in human anatomy, proteins are an important element in viral activity. Viruses also have proteins that they use to suppress our immune systems and reproduce themselves. By understanding the protein structure and behaviors of this virus, medical treatments become more focused and effective. While studying viral behaviors is an established science, observing a static virus is much different than watching a virus grow and adapt. By simulating protein structures and atomic movements, scientists and researchers are therefore given a much more complete picture of what the virus is, how it grows and interacts with stimuli. Watching how the atoms in a protein move relative to one another is important because it captures valuable information that is inaccessible by any other means (Bowman, 2020). The Folding at Home team remains optimistic in its research. Calculation power has increased steadily since inception and has contributed to many excellent peer-reviewed manuscripts in medical science. As a global pandemic has strained global resources in all industries, Distributed Computing is an accessible way for citizens with merely a laptop can provide meaningful support to the medical research community. Treatment and cure for Alzheimer's and Parkinson's is still being sought, and shared computing may help accelerate treatments for novel viral pandemics such as COVID-19.

4. Virtualized computing

Virtualization is the process of designing and implementing a software-based, or virtual, representation of applications, servers, storage, and networks. It is one of the most effective ways to utilize sustainable computer architecture, combat electronic waste and energy consumption, as well as reduce information technology expenses while enhancing efficiency and agility for enterprises and business units.

A virtual computer architecture, coined Virtual Machine (VM), is a single software piece running an operating system and containing applications. Each virtual machine is completely independent and self-contained. Placing several virtual machines on a single computer enables several operating systems and applications to run on just one physical server, or host, thus addressing sustainable computer architecture issues in a very powerful way.

Within a virtualized computing system, a piece of software, called a hypervisor disengages the virtual machines from the host and dynamically allocates computing resources to each virtual machine as required. VMWare is a website which describes virtual computer architecture (https://www.vmware.com). Virtual Machines share the following features, which offer several benefits: Partitioning, Isolation, Encapsulation, and Hardware Independence.

The COVID-19 pandemic has forced organizations to rely on virtualized computing infrastructures to enable their workforce to remain productive while maintaining profitable operations. Virtualized Computing has become part of the sustainable computer architectures, and organizations' Corporate Social Responsibility agendas. The on-line workforce has, in many enterprises, become a sustainable long-term solution rather than just a digital benefit to employees in the on-line workplace environment. As such, many virtualized computing infrastructures have been built as secondary systems, or built in addition to the existing company's legacy, localized systems. Pandemic imposed increase of demand on these systems have shown the need to allocate resources in a more sustainable way. It also allowed to organize enterprises in such a way that virtualized computing has become essential to an enterprise workflow rather than a method to circumvent a problem or serving as a secondary methodology.

Distributing desktop computers as a sustainable service enables businesses to accommodate changing workplace needs as well as to seize emerging opportunities. Virtualized desktop computers and their applications could also be rapidly and efficiently deployed to branch offices, outsourced, utilized by off-shore employees as well as on-line workers using Windows or Apple-based servers, or running programs under Unix / Linux operating systems. In research reported by Sztandera (2020), using the desktop virtualization allowed Windows-based computer to run computational chemistry calculations on a virtualized Unix operating system. This virtualization provided for an inclusive tool that could facilitate manufacturers across the industrial spectrum create more hazard-free products for consumers. This application could also serve as a much-needed tool in preventive health care. The final development phase could incorporate many additional features including data about tumor tissue DNA, enabling the system to serve as a much-needed health care disruptor tool in personalized medicine for both patients and clinicians. It is envisioned that such computer architecture could provide an indispensable tool for clinicians to identify potential cancer type in patients who have a certain genetic makeup by running corresponding compound matches.

5. Cloud computing

Although both are often used technologies during the COVID-19 pandemic, and both part of sustainable computer architecture, virtual and cloud computing are not transposable. Virtual Computing is realized through software that makes computing environments unconstrained of the physical computer platform. Cloud computing, on the other hand, is a service that delivers shared computing resources data and software on demand through the Internet. As integral solutions, enterprises could begin by virtualizing their servers and subsequently moving to cloud computing for even greater coordination and self-service.

Cloud computing tools such as Oracle's Zoom virtual meeting tool has enabled organizations to transition successfully, or at least less disruptively, to a remote workforce. At Thomas Jefferson University Jefferson Health, implementation began months prior to the pandemic to equip its facilities with teleconferencing equipment run on Zoom platform. The need for an enterprise teleconferencing infrastructure became apparent as the Philadelphia health system acquired other locations, and offices and clinical treatment areas spanned the metropolitan area, and neighboring states of New Jersey and Delaware. The implementation of the virtual meeting technology added the flexibility for faculty and staff teams to meet virtually in real time, while being able to work from their traditional office areas. The execution of the tele-meeting workflow was largely on-campus, with technical support services nearby and resourced ready to assist in the facilitation of the on-line meetings. As the pandemic swept across North America, Jefferson's workforce was able to continue schedule and hold its meetings using Zoom's cloud infrastructure with minimal or no additional adaptation required.

A formal extension of the infrastructure was the establishment of the National Center for Telehealth Education and Research (NCTER) at Thomas Jefferson University. The center has led efficient practices for telehealth implementation through breakthrough research, teaching, and training to deliver health services thorough the digital mode[1]. In terms of teaching and training, it has provided ground resources to support realization and strategies for appropriation. A suite of carefully designed educational offerings was provided to equip healthcare personnel to embrace and subsequently implement telehealth technologies to improve patient care. Examples of teaching and training avenues include certificates in Telehealth and Digital Health Innovation, as well as in Telehealth Facilitator Program; coursework in Telehealth and Connected Care, and in Conducting an Effective Physical Exam. In addition, Jefferson's flagship fellowship program in Telehealth Leadership was established.

In terms of research, National Center for Telehealth Education and Research (NCTER) at Thomas Jefferson University has utilized ethically sourced data to elevate patient care, as well as outcomes to measure telehealth efficacy, and empower patients to remain healthy at home and their communities. As the use of telehealth has increased rapidly under the unprecedented circumstances of the COVID-19 pandemic, it was acknowledged that scores of patients faced digital hurdles to utilization of the services related to access and digital literacy limitations. Research in digital readiness was initiated and supported to ensure digital health equity across vulnerable communities. In addition, as a result of the implementation of a sustainable computer architecture, a computer model of uncertainty and care seeking was developed based on the primary unmet needs after the hospital emergency department visits. The Jefferson Uncertainty Scale to measure patient uncertainty during an acute care visit, and the Uncertainty Communication Checklist to improve communication with patients who are discharged with ongoing uncertainty were developed. Subsequent research projects have focused on crafting health care interventions to guide patients in terms of handling their uncertainty, improving their experience, and most importantly decreasing healthcare costs through significantly reducing the need for non-routine care visits.

[1]https://www.jefferson.edu

Cloud computing architecture also allowed for a significant contribution to, and social impact into, nutrition aspects of patients' wellbeing through research in healthy food choices to support chronic illnesses, and following recommendations on developing methods to coalesce nutrition-related services into routine scheduled care. It has also contributed to social impact of COVID-19 vaccination efforts through data analytics techniques to understand and address obstacles to vaccine confidence among minority and underserved populations in the Philadelphia metropolitan area. Furthermore, it aided conducting and evaluating multiple sustainable computer architecture approaches of telehealth care models, and incorporating telehealth as a care delivery model during the COVID-19 pandemic.

Another research area that has been investigated was utilizing cloud computing in applying qualitative and quantitative research approaches to bring forth patient perspectives with regard to unmet needs in terms of looking for non-routine care, with an ultimate goal of informing decisions of a health care provision system more responsive to personalized patient medicine interventions.

As community engagement and participation are indeed the key factors, the Jefferson VaxConnect team utilized cloud computing architecture to simulate, model, and subsequently deliver community outreach to patients across the University health system to ensure equitable access to COVID-19 vaccines. The efforts have been focused on specific geolocations to ensuring residents in underserved zip codes and communities have been reached out to. Addressing challenges of digital divide and patient self-scheduling, low health access, literacy, access, vaccine confidence, as well as logistic challenges such as lack of transportation in addition to supply issues, were key components of simulation, and subsequent vaccination delivery efforts.

Thomas Jefferson University graduate students in Public Health programs formed Digital Outreach Taskforce (DOT) to serve patients through an initial set up and following engagement in telehealth options. It was first assembled in September 2020 to provide personalized health interventions to patients through setting up computer tablets as well as remote digital monitoring devices that had been distributed as part of government secured during the COVID-19 pandemic. To date, it has conducted outreach to thousands of patients, with ongoing outreach. Thomas Jefferson University is a website which provides various examples of the university's applications of virtual computing (https://www.jefferson.edu).

6. Conclusions

As a global pandemic has strained global resources in all industries, grid, virtualized, and cloud computing have been accessible ways where merely a computer tablet or a wearable digital device could provide meaningful support to the medical research community. Treatment and cure for Alzheimer's and Parkinson's is still being sought, and sustainable computer architectures, such as shared computing, might help accelerate treatments for novel viral pandemics such as COVID-19. At the same time combating electronic waste, energy consumption, and carbon emissions requires enterprises and entities to focus on creating sustainable computer architectures as a critical part of Corporate Social Responsibility.

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