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EDGE COMPUTING VS. CLOUD COMPUTING: AN OVERVIEW OF BIG DATA CHALLENGES AND OPPORTUNITIES FOR LARGE ENTERPRISES

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ABSTRACT

There are a variety of security concerns around cloud computing infrastructure technology. Some of these include infrastructure security against threats, data privacy, integrity, and infrastructure stability. In modern cloud computing, there are two models that cloud computing infrastructures follow: centralized cloud computing and decentralized cloud computing. Centralized cloud computing is susceptible to outages, data breaches, and other security threats. Decentralized cloud computing is more resilient to outages due to geo-redundancy technology, and data is better protected by encryption through Reid Solomon erasure coding.

Keywords: Security Practices; Cybersecurity; Data Integrity; Cloud Computing; Decentralized Cloud Computing; Blockchain; Geo-Redundancy; Reed Solomon Erasure Coding, Etc.

I. INTRODUCTION

IoT and Big Data have led to mass disorganized information, which is only bound to become worse in the coming years as the IoT-connected devices rise to 43 billion by the year 2023 [1]. Large amounts of data created as a result, known as Big Data, brings new sets of challenges for large enterprises [2]. This large data needs to be processed in a way to derive meaningful insights for decision making using sophisticated software applications that are capable of processing Big Data. Cloud Computing and Edge Computing are powerful software technologies to help large enterprises process Big Data. According to Forbes, 13% of big enterprises with over 1K employees have immigrated to the cloud [3]. More large enterprises are expected to take similar actions as Big Data management eventually moves to the cloud. However, this transition is not hassle-free. Statista reports that around 60% of the enterprises find cloud data management to be extremely challenging [4]. This paper focuses on understanding the benefits and challenges of Cloud and Edge computing, and how large enterprises can adopt these two computing models in conjunction to create dynamic applications.

Organization: Section two of the paper discusses the relationship between Cloud Computing and Edge Computing, and their impact on large enterprises in terms of data analytics and processing. Section three outlines the opportunities and Challenges in both computing technologies for large enterprises or medium-sized businesses that are scaling. Section four and five discusses their use case and implementation in large enterprises.

II. EDGE COMPUTING VS. CLOUD COMPUTING FOR LARGE ENTERPRISES

Large enterprises are big companies usually with over 250 employees, focused on solving critical problems within an industry. These enterprises are retail factories, big IT companies, manufacturing plants, and the healthcare sector, to mention a few. Large enterprises utilize Big Data to make intelligent and insightful decisions that impact profitability and success in the long run. Without proper data analytics and processing, it is impossible to draw meaningful insights from structured and unstructured data that constantly flows into the enterprises' data centers. As the data grows, the traditional software applications with limited processing powers are not enough to process information and hence can render an enterprise incapable of making smart decisions.

To resolve the Big Data management challenges, large enterprises need to rely on technologies like Cloud Computing and Edge Computing.

Cloud Computing: Cloud Computing is a centralized computing architecture that enables enterprises to utilize in-demand computer system capabilities, including computing power and large data storage on the cloud without direct interference by the user. In Cloud Computing, data can be located at more than one local location including third-party servers [5]. Some examples of Cloud Computing include services like Dropbox, Microsoft Azure, and Rackspace. Cloud solutions are used in large enterprises for increased elasticity, agility, ease of processing, and accessibility [6].

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Edge Computing: Edge Computing is a distributed computing architecture that enables enterprises to utilize data collection, analysis, and processing on the edge of the network with direct interference from the user. Edge technology processes data as close to its physical source as possible [7]. Some examples of Edge Computing include autonomous vehicles, fleet management devices, remote gas, and oil monitoring, predictive maintenance devices, and smart agriculture and surveillance. Edge Computing devices make intelligent self-decisions and real-time responses based on information acquired through IoT devices.

The following figure demonstrates the difference between Edge Computing and Cloud Computing.

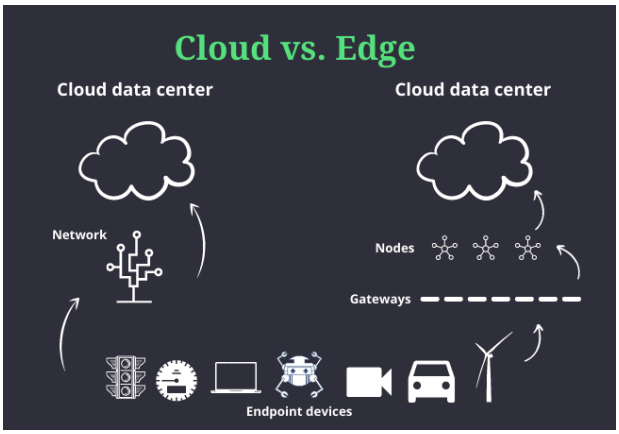

Figure 1. Cloud Computing vs. Edge Computing

Both Cloud Computing and Edge Computing help large enterprises make use of intelligent tools, including machine learning capabilities and statistical tools. The method of storing and analyzing data is the same with both technologies; however, the difference lies in the physical location, the speed by which the data is analyzed, and the amount of data analyzed at a time. And because of these differences, where one lacks, the other offers a unique opportunity. Section 3 discusses how large enterprises can use the opportunities in both Cloud Computing and Edge Computing while understanding the challenges in both technologies.

III. EDGE COMPUTING VS. CLOUD COMPUTING: CHALLENGES AND OPPORTUNITIES FOR LARGE ENTERPRISES

Data analysis and analytics

Cloud Computing offers a centralized data management architecture with organized computers which receive the data from varying sources for analytics and other purposes [8]. It offers scalable resources over several networks for data processing, creating enhanced flexibility for Big Data management [9]. Cloud Computing essentially offers access-based computing infrastructure designed to build and maintain myriad types of application services [10]. Cloud Computing utilizes internet computer resources to store and process data rather than using local computers. The work is distributed on several computers in several locations where they run a simultaneous project via a computer group. This distributed work enables a much more efficient analytics system that runs rapidly to perform the time-consuming data analysis [11].

In contrast, Edge Computing is a decentralized model that processes data locally at its place of origin. It sits between the end-user and the cloud to deliver instantaneous results without any delays [12]. By quickly accessing user analytics, large enterprises can learn more about their customer's interaction with the services and amend customer services based on user experience. Some researchers see Edge Computing as an optimized form of Cloud Computing that performs data analytics as close to its source as possible [13]. Some researchers also find Edge Computing similar to Fog Computing [14]. Fog Computing is similar to Edge Computing with minor differences. Fog Computing is more infrastructure-oriented compared to Edge Computing, but in terms of data analytics, both technologies are the same.

In terms of data analytics, large enterprises have the opportunity to use Cloud Computing for substantial data processing related to complicated web applications. Whereas Edge Computing can aid the web application by quickly processing user requests as they occur.

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The amount of data processed and real-time bug insights

Large enterprises can recognize problems with Edge Computing for instantaneous resolve. By delivering results right at the origin of data, Edge Computing helps decision-makers take quick corrective actions that would otherwise be delayed in a centralized data processing system. Quick actions lead to prompt results for improved organizational performance and ultimately better revenues. Without real-time bug identification, enterprise applications can face service delays and even lose customers. In contrast, Cloud Computing does not offer instantaneous results or real-time insights. However, Cloud Computing can process large amounts of data that can offer intricate details and meaningful insights that are simply not possible with Edge Computing as it only processes limited data and has limited memory [15]. Therefore, large enterprises need to utilize both Edge and Cloud technologies to draw comprehensive insights regarding web applications and their use.

Speed and response time

The greatest advantage of Edge Computing is reduced latency and improved network performance. In today's highly competitive environment, speed is no longer a competitive advantage but rather a necessity. In the financial sector, a slow network could reduce the performance of trading algorithms resulting in substantial losses. Similarly, in data-driven industries, lack of speed could result in frustrated customers who may never return. Edge Computing helps large enterprises take care of speed problems. Since the Edge devices collect and process data locally, the information doesn't have to travel far enough as it would in a conventional cloud architecture. However, the amount of data processed and the speed with which it is processed are directly linked with computing power. Edge technology does not have a high computing power and offers only limited capacities for data processing [16]. In contrast, Cloud Computing has higher computing power to offer more efficient computing [17]. In the future, as the data traffic increases, there are bound to be data traffic jams and Edge Computing could be the mediating force.

Network security

Both technologies face unique cyber threats that may make cloud adoption extremely challenging for large enterprises. However, there are various ways to secure data on both Edge and Cloud through proper implementation of security measures.

On one hand, Edge devices do increase certain security risks, but on the other, they mitigate other paramount security threats that could cause significant data loss. The conventional cloud architecture is based on a centralized network that is vulnerable to distributed denial of service or DDoS attacks and major power outages that can hinder progress. Edge Computing distributes data to varying locations, which ensures that a single network's disruption does not impair any other networks. Additionally, since data is processed locally, only a portion of data is actually at risk.

Edge Computing devices could be used as an entry point for cyberattacks, malware, and other forms of intrusions that can infect the network. But since the architecture of Edge Computing is inherently distributed, it is easy to apply security protocols that can efficiently seal weak points without hindering the progress of the entire network.

Edge data centers can face security risks like malicious software/hardware injections, physical tampering, and routing information attacks. Quality Edge data centers offer several tools to protect networks in real-time by offering data center metrics, including power usage, SLA uptime, Network traffic, and latency, which can reduce network security threats.

Network and data security threats in Cloud Computing include (as identified in past researches) account or service hijacking, data scavenging, data leakage, denial of service, customer data manipulation, VM escape, VM hopping, malicious VM creation, insecure VM migration, and spoofing virtual networks [18].

Currently, one of the biggest security problems with Cloud Computing is data stored in different locations and with different providers [19]. Most service providers have to rely on third-party infrastructure provided for data security. Even if an enterprise is using a virtual private cloud, the security settings can be only handled remotely, and therefore there is no way to know if the security features have been fully implemented. This can lead to unauthorized access to data centers, which can lead to several security risks [20].

Most Cloud Computing security risks can be mitigated through multi-factor authentication, permissions

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sharing, encryption, and software updates.

Scalability, versatility, and reliability

As enterprises grow, the need for a reliable cloud infrastructure grows. Edge Computing allows enterprises to use storage and data analytics capability into smaller devices located closer to the end-user. But at the same time, the limited resources and computing power do not allow Edge Computing to help large enterprises scale. Cloud Computing, on the other hand, allows increased scalability.

In terms of versatility, Edge Computing helps enterprises expand into local markets by creating partnerships with local data centers. These partnerships eliminate the need for investing in new, expensive infrastructures for expansion. Cloud Computing, on the other hand, allows data processing for large-scale applications that is not possible with Edge.

For microdata management and processing, Edge technology offers ample scalability options and network reliability. Cloud computing offers scalability and reliability for macro data management.

Data processing capacity

Compared to Cloud Computing, Edge Computing is still in its infancy. While Cloud Computing has a plethora of applications dedicated to helping enterprises manage data (For example, Microsoft Azure and Amazon web services), Edge Computing has yet to introduce comprehensive applications capable of storing substantial amounts of data. Since the data processing needs are only going to rise in the future, Edge Computing technologies need to support several types of storage options with the capacity to store data for longer.

Additionally, the computing power of Edge devices is repressed due to bulk computation conducted in the same location. As noted earlier, to avoid computational repression, Edge devices are designed to perform analysis for smaller datasets. However, while Edge Computing may have limited capacities to process large amounts of data, it still offers instantaneous, real-time results and insights as a response to user requests [21]. Cloud Computing, on the other hand, is unable to offer real-time analysis as the data processing is conducted far from the source of data [22].

Cost

Cloud computing is an expensive data management solution. While the solutions offered are worth the price for large enterprises, the price still might be a hindering factor in cloud adoption. The expense can further increase with data storage and processing needs, which may further discourage companies from taking their data to the cloud [23]. Compared to Cloud Computing, Edge technology is much more affordable with less expensive IoT devices and no additional costs [24]. However, while it offers an affordable computing model, it lacks the diverse functionalities of Cloud Computing.

Standardized IoT protocols

Lack of standardization is a noted challenge in both Cloud and Edge technologies. The lack of common IoT standards or protocols may cause data security issues during transfer or migration to Cloud [25].

Data control

Since Edge Computing processes parts of data rather than a comprehensive dataset, large enterprises may lose valuable insights that may result in loss of business. Whereas on the Cloud, big datasets can be processed deriving absolute key insights.

IV. COMPARISON OF CLOUD COMPUTING AND EDGE COMPUTING BENEFITS AND CHALLENGES

The following figure shows the comparison between the two technologies.

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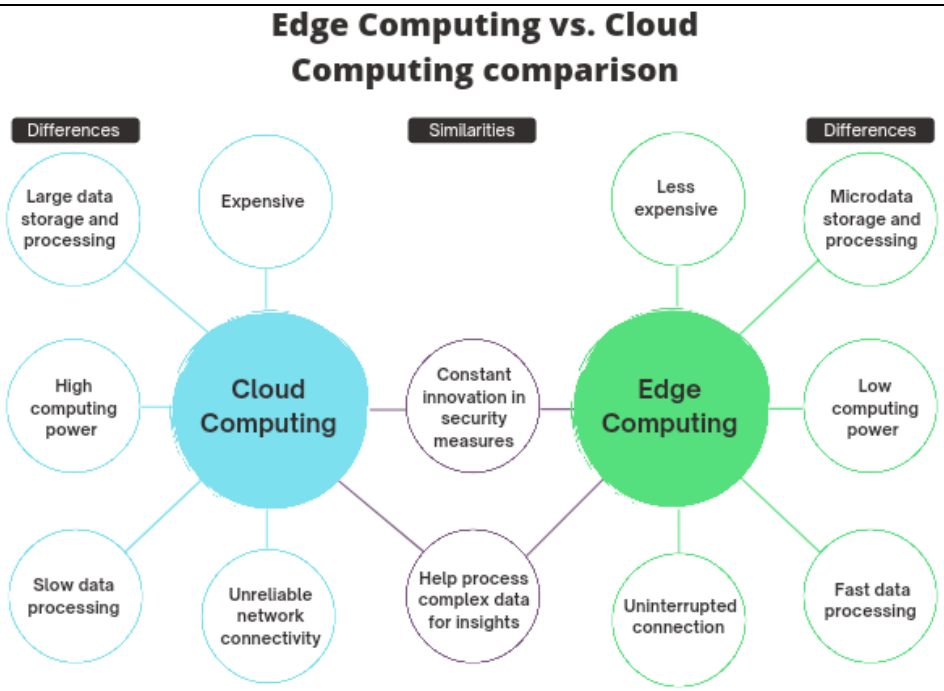

Figure 2. Edge Computing vs. Cloud Computing comparison

V. HOW CAN LARGE ENTERPRISES USE EDGE AND CLOUD COMPUTING IN CONJUNCTION?

To get past the data processing limitations, security risks, operational costs, and bandwidth issues among others, large enterprises need to encompass flexible, open architecture cloud systems for data processing. Large enterprises need data computing systems that offer easy connectivity via several communication modes, including Wi-Fi and GPS, and have the capability to run unique, multiple software stacks in a homogeneous way, including data analysis, machine learning, and a firewall. Edge and Cloud technologies will enable large enterprises to create that open cloud architecture capable of multifunctional capacities that aid in dynamic applications' development. The aforementioned challenges in Cloud and Edge Computing can be tackled through virtualization, ruggedization, enhanced container security, multi-carrier support, membership-access only, and private connectivity. Therefore, while there are challenges to overcome, there are solutions that the large enterprises can incorporate to make the transition to the Cloud easy.

VI. EDGE COMPUTING AND CLOUD COMPUTING USE CASE

Surveillance cameras for security and manufacturing purposes send large amounts of data to the cloud. With Edge Computing companies can decide what data to store and send to the Cloud for storage rather than storing all recorded data. Less data needs less bandwidth and processing times hence helping companies save computing resources, time, and reduce the amount of traffic sent through the network.

VII. CONCLUSION

Both Cloud Computing and Edge Computing offer myriad benefits to large enterprises that are bound to experience an influx of data in the coming years. Both computing technologies can readily enable large enterprises to process, organize, and store big data with their own sets of limitations. One size doesn't fit all and similarly, one technology may not serve every enterprise's needs especially as we head towards a future where data will become the lifeblood of business. In the future, when more and more businesses realize the value of big data and the power of analytics, there will be an increased demand for data processing solutions. Large enterprises can stay a step ahead of the competition by utilizing high-tech technological capabilities offered by both Cloud and Edge computing.

Based on the above research, it can be concluded that large enterprises need to utilize both Edge computing and Cloud computing as a bundle rather than independent technologies. Where one lacks, the other delivers. Edge Computing can reduce data processing time while Cloud Computing can fulfill the need for storing large

amounts of data. Enterprises need to strike a balance between using Cloud and Edge technologies for a harmonious infrastructure that readily tackles the challenges of Big Data in the coming years.

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