Boosting Privacy and Security with Edge and Fog Computing Technologies

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ABSTRACT

Information security and privacy is one aspect of the information technology sector that currently attracts a lot of research interest. From Cloud computing to Edge computing and then Fog computing, all forming a unique ecosystem but with different architectures, networks, storage, and other capabilities. The heterogeneity of this ecosystem also comes with certain issues, particularly security and privacy challenges. Therefore, this thesis is research-oriented and mainly focused on Systematic Literature Review (SLR) of other research papers based on security and privacy in Cloud, Edge, Fog paradigms. The thesis aims at identifying similarities, differences, attacks, and countermeasures in the various paradigms mentioned. We performed an SLR to choose articles centered specifically on security and privacy in Cloud, Edge, and Fog paradigms, using modified PRISMA-2009 guidelines. The research articles were released between 2005 and 2021 within the recognized academic databases, some other articles were selected which were published before 2005. We selected 77 studies after carefully examining the issued works to assist in responding to the established research questions (RQs). Several databases were used as the main libraries of information for the systematic literature review. The generated criteria for inclusion/exclusion were applied in the selection process of works of literature. A modified version of the PRISMA-2009 checklist to suit the objective was used as the defined methodology. The systematic literature review outcome pointed out several security and privacy challenges. The presented results outlined some important similarities and differences in Cloud, Edge, and Fog computing paradigms. Some other threats and vulnerabilities were found relating to the individual paradigms. The SLR outcome also reveals that the heterogeneity of such an ecosystem does have issues and poses a great setback in the deployment of security and privacy mechanisms to counter security attacks and privacy leakages. Different deployment techniques were found in the review studies as ways to mitigate and enhance security and privacy shortcomings. Other discoveries relating to the strengthening of information confidentiality, integrity, and availability were seen in the systematic literature reviews envisioning the future research pathways to be performed.

Keywords: Cloud paradigm, Edge paradigm, Fog paradigm, Information Security, Privacy, vulnerabilities, attacks, countermeasures

I. INTRODUCTION

The continuous growth in technology, especially with the massive migration to Cloud, Edge, and Fog paradigm coupled with the extensive integration of Internet of Things (IoT) technologies in homes and work environments, creates great concern for security and privacy. Weak security and privacy implementation mean potential threats from attackers. These threats can be security attacks or privacy leakages. This thesis is research-oriented, and its primary objective is focused on the systematic literature review of other research papers based on security and privacy in Cloud, Edge, and Fog paradigms. An overview is taken on the challenges and countermeasures in- volved. The thesis also aims at identifying similarities, differences, attacks, and counter measures in Cloud, Edge, and Fog paradigms. This will help develop proposals for possible future improvements in the facet of security and privacy.

We will be examining the general overview of three different Paradigms: Cloud, Edge, and Fog Paradigms. This will focus on security and privacy aspects. From a layman's perspective, one may think that Cloud, Edge, and Fog are strongly or almost the same paradigms, but we will carefully present some similarities and differences for these paradigms. For clarity and consistency, each paradigm is carefully discussed separately concisely. The reason for discussing each of these paradigms is to have an overview that will guide our understanding of the research goal for this thesis, which is primarily the information security and privacy aspects for each paradigm.

The goal of having a huge capacity for storage with efficient scalability has recently been the driving force for different companies, organizations, and small firms to switch to Cloud, and Fog Paradigms. Interestingly, the aspect of security and other issues regarding privacy, in particular, becomes a matter of concern when Cloud providers holding large amounts of data and essential applications share it with customers [1]. As a result of these concerns, security and privacy issues arise to present major problems in Cloud, Edge, and Fog paradigms. Currently, the biggest attention in each computing model is about protecting the privacy of users (essential data) from unauthorized groups or individuals gaining access and hindering attacks. Moreover, the keeping of data integrity intact and also maintaining it is a very vital aspect. This research takes an approach to review the security and privacy aspect in Cloud, Edge, and Fog paradigms [2]. The rapid and ever-increasing need for Cloud, Edge, and Fog Computing is a great challenge when it comes to protecting personal information (privacy) and other important data [3]. Cloud customers possess legitimacy to their individual information and data (in other words, users should have the right as to how, when, and to the certain defined range that persons can gain access to their personal information) [4]. Importantly, five different features relating to security and privacy aspects are raised here in any order: integrity, accountability, confidentiality, availability, and the preservation of privacy [4, 5, 6]. This thesis focuses on how security in Cloud, Edge, and Fog Computing systems is provided and how users' privacy is protected from attackers. Essentially, the vision here is to render a holistic management style for personal data at the global centers hosting Edge, Fog, and Cloud. It is noteworthy that clients' data confidentiality must be preserved, which is only possible by acquiring access control and monitoring devices. Figure 3.1 shows that acting in place of customers (data proprietor), a Trusted

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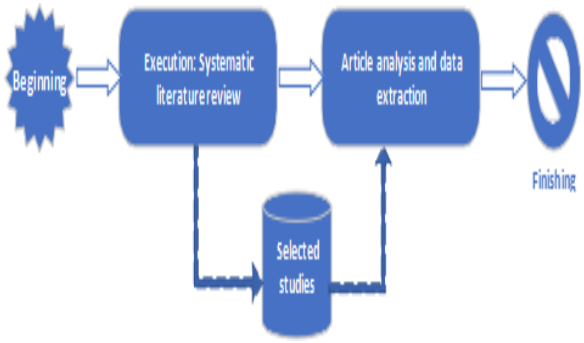
Third Party can gain access to stored data in the cloud to control information. Customers could also be provided with special tools to facilitate the monitoring and accessibility with control over their data [7]. Recently, there has been a sharp, universal shift from traditional operations in organizations to embracing innovations such as Cloud Computing and other paradigms. These different paradigms, such as Cloud, Edge, and Fog Computing, have many academic studies and reviews from students and researchers. It is greatly difficult or if not very challenging for different Information and Communication Technology (ICT) engineers, researchers, and students to generally match up with the ever-growing pace of new journals, literature, and article reviews. One important area concerning the various paradigms is the security and privacy aspect, which we shall systematically review based on PRISMA guidelines. This review is essential because it provides the opportunity to see into gaps of other journals after carefully examining them, thereby making room for improvement with proposed solutions. This is considered a more efficient way of getting a "baseline" on what was right and what wasn't right [8].Moving forward, it is of opt-most importance that we take a glimpse at the overall idea of a Systematic Literature Review (SLR). Firstly, we shall be answering the question, what is SLR by defining it. According to Denyer David and Tranfield David, "Systematic review is a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and is not known".



II. OVERVIEW

CLOUD PARADIGMS

The growth and expansion of many company's infrastructures have come from evolving technologies and innovations. Cloud computing is seen as the unique solution to provide applications for enterprises. Cloud computing uses different components such as hardware and software to render services, especially over the Internet. The possibility of accessing various files and using provided applications from technological devices with Internet access is made easy by cloud computing. Over several servers, the execution of Cloud computing applications is carried out, and developers require clarity on this vital information, particularly when offered as a service by the provider.

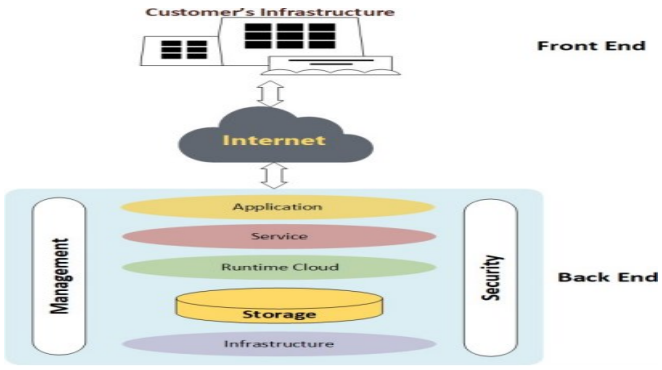


Figure1. CloudComputingArchitecture

EDGE PARADIGMS

A few years back, offices hosted servers with edge computing. No one thought of it in such a manner. The result was all that mattered and not how it worked. Later on, Cloud was introduced, and everything was different. Devices such as computers have been placed hundreds of meters and milliseconds apart. In certain offices, their applications were quite fine with the latency.

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However, with the rapid increase of 5G, IoT, and the constant quest for internet speed, an innovative form of computing has been born, known as edge computing. This type of computing is not only popping up like any normal technology by the day.

The word “cloudlets” describes small nodes of edge-located computing ends. As a new aspect or computing paradigm, edge computing helps position important compute and save resources at the Internet Edge, close to various office and home appliances such as mobile devices, IoT devices, clients, and clients sensors. There has been fast growth in industrial and research investment in Edge computing in recent years. The pivot for Edge computing is the physical availability and closeness, which end-to-end latency is influenced by this essential point of cloudlets, with bandwidth achievable economically, trust creation, and ability to survive.

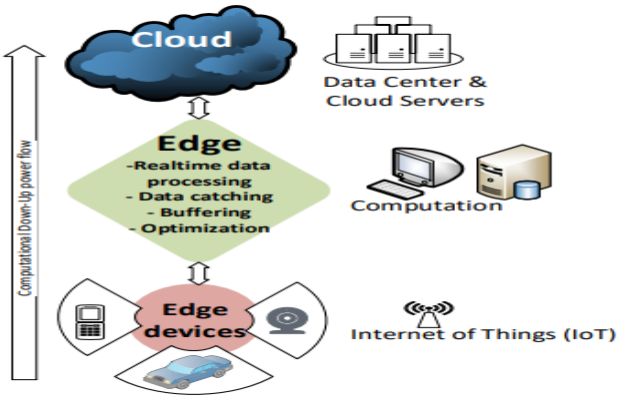

Figure2,. Edge Architecture

FOG PARADIGMS

Access gateway or set-top-boxes are end devices that can accommodate fog computing services. The new paradigm infrastructure permits applications to operate nearby to observe activities easily and huge data, resonating from individuals, processes, or items. The creation of automated feedback is driving value due to the fog computing con cept. Customers benefit from Fog and Cloud services, such as storage, computation, application services, and data provision. In general, it is possible to separate Cloud from Fog. Fog is closer to clients in terms of proximity, mobile assistance for mobility, and dense locational sharing.

At the Edge of the network regarding Cloud computing, Fog computing is considered an extension or advancement of cloud computing. Cloud computing ideally focuses mostly on a central system for computing, and it occurs on the upper section of the layer. Fog computing is responsible for reducing the load at the edge layer, particularly at the entrance points and for resource-constrained devices.

The term ‘Fog Computing’ and ‘Edge Computing’ refers to the hosting and performing duties from the network end by Fog devices instead of having a centralized cloud platform. This means putting certain processes, intelligence, and resources to the Cloud’s Edge rather than deriving utilization and storage in the Cloud. Fog computing is rated as the future huge player when it comes to the Internet of Everything (IoE) and its’ subgroup of the Internet of Wearable Things.

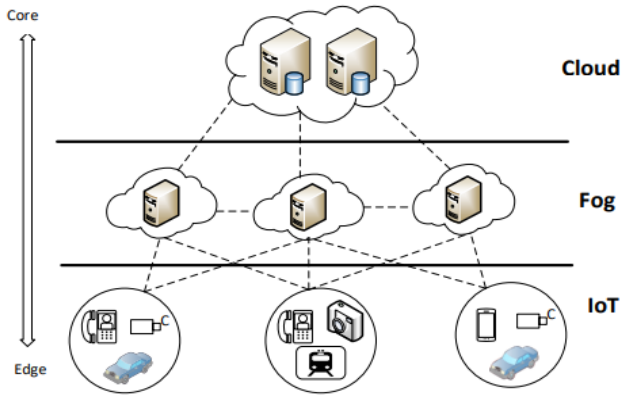

Figure3. FogComputingArchitecture

III.ANALYSIS OF SECURITY AND PRIVACY IN CLOUD, EDGE, AND FOG PARADIGMS

Cloud Computing Paradigm

Based on cloud architecture, clients can gain cloud access from any corner of the globe with their supported gadgets. Cloud computing has experienced exponential advancement over the years. The coming of cloud computing brought great advantages, especially in cost reduction in devices, enhanced cooperation, and more flexibility. Since the initial periods of cloud computing, many were reluctant to migrate to it due to issues relating to security. Many establishments dealing with very sensitive data never deemed it necessary or safe to move to the Cloud for fear of exposing their important information to an unauthorized individual or group of persons. Presently, many previous doubters have reluctantly embraced cloud computing because of its huge gains in using it. Despite the massive choices by organizations to migrate to the Cloud, the biggest concern remains that of security.

Security And Privacy in Cloud Paradigm

Cloud Data Security

Data security is an essential aspect that plays a significant role in handling Cloud devices and keeps them running. This may involve protection and restoration guides for data and centers for Cloud services. Data involved in transmissions or transfers must always be protected. There is a huge problem the Cloud sector is encountering, which is that of cloud security.

Cloud Data Privacy

The public Cloud faces more privacy threats, although these threats are very different based on their cloud model variants. Some of the concern of the danger here is a proliferation of information, malicious usage from an unauthorized person and incapability to control by clients. Clients' sensitive documents stored in the Cloud can be reached by attackers using the file's hash codes, with the help of a mechanism used in duplicating information.

Edge Computing Paradigm

This section will focus on the main aspects of Edge Computing since most of the details had been given previously in the Cloud Computing Security and Privacy section. Cloud Computing is the pioneering paradigm but later lost its status, which brought about the introduction of Edge Computing to continue the demanding activities of cloud Services. Two attempts will be approached to have a clear understanding of all these: Cloud paradigm

Security And Privacy in Edge Paradigm

Edge Data Security

Information Integrity, confidentiality, and attack detection are the common goal and rea- sons for data security. It helps in designing an edge-computing system that is secured. Issues such as information breach and information loss are resolved by outsourcing in- formation under control, non-fixed storage, and sharing responsibility. Data duties are allowed to be carried out securely by customers. We can rarely find research works on Edge Computing security and privacy since many academicians do mostly focus on cloud paradigms, or perhaps fog paradigm .

Edge Data Privacy

In Edge Computing, accessing the system does not reflect trust. Averagely accepted systems are used to store customers' important data, resulting in some critical privacy leakage. Some clients' data stored are personal information, location data, and data identity. The focus areas to be discussed herein any order includes privacy, identity, and location privacy safeguarding.

Fog Computing Paradigm

Many businesses have transformed massively, especially with the fast growth in large data usage, due to the presence of cloud computing. Meanwhile, the quest for private services also began to grow hugely. A great amount of well-centralized systems is offered by cloud computing platform, although with some shortcomings. Clouds and their endpoints show certain unwanted long and irregular delays and time-conscious services to some. There is a pertinent high risk in a situation whereby there is a breakdown in the information building and between network interconnected systems.

Security And Privacy in Fog Paradigm

Fog Data Security

Issues arising from network systems are imminent, and vital data security measures should be put in place while establishing a fog infrastructure. Some attacks usually threaten private and government entities since they function in Cloud, Edge, and Fog computing. To offer a level of protection to the structure, a TIP is important to be developed. Data security is the most prioritized aspect in the industrial sector, especially as information must be safeguarded. Intelligent equipment and sensor devices are deployed to reduce threats and security attacks extensively.

Fog Data Privacy

Protecting the privacy of individuals and enterprises is often a primary concern encoun tered by the Fog paradigm, especially with the Fog nodes positioned near the individuals and facilitates the gathering of vital information sometimes relating to geographical location, identity, social security numbers, and many. One great challenge is that it is quite hard to keep centralized monitoring due to the distributed nature of Fog nodes.

IV. SECURITY AND PRIVACY ISSUES - SUGGESTED SOLUTIONS

Cloud Paradigm Challenges

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Data loss, privacy leakage, multi-tenancy, unpermitted access to management platforms, Internet protocol, injection attacks are some of the main challenges faced in cloud computing. Such challenges turn to make room for potential attacks, letting access control to cybercriminals, granting access to unauthorized services, thereby disclosing several classified data, if not all.

Cloud computing faces enormous threats when involved with these vulnerabilities and thus affects business too, either directly or indirectly.

Edge Paradigm Challenges

The Edge paradigm is considered to offer huge benefits to edge customers such as stor age, data processing, just to name a few. However, despite these many gains, unlike the Cloud paradigm, Edge computing is still faced with big security and privacy challenges, which we are going to explore in this segment below.

Fog Paradigm Challenges

Cloud paradigm has countermeasures for its security and privacy threats. Notwithstanding, these countermeasures may not apply to the Fog paradigm due to the active presence at the network edge of Fog entities. The immediate vicinity where Fog entities operate will confront various threats which may not constitute a good functioning Cloud. The security solutions in the Fog paradigm are improving and increasing well.

V .RESULTS

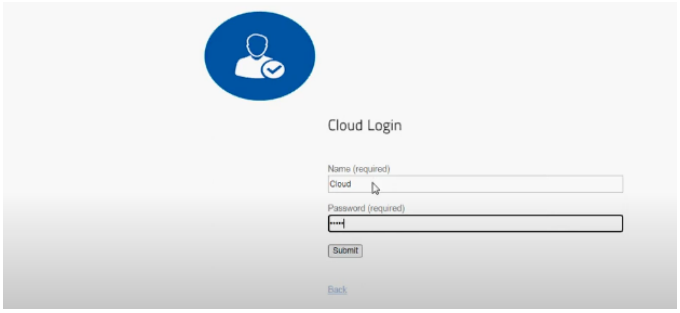

Fig:1.Cloud Login

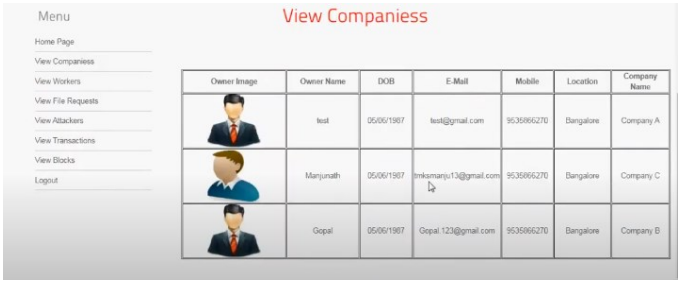

Fig:2.View Companies

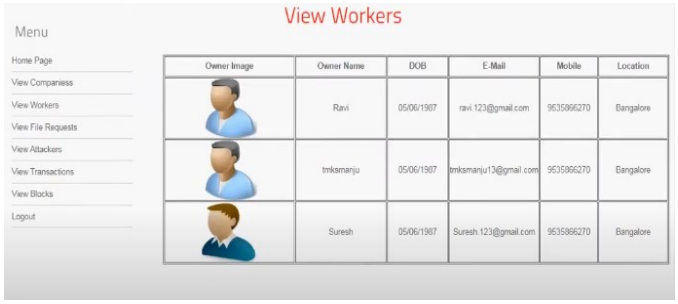

Fig:3.View Workers

Fig:4.File Blocks

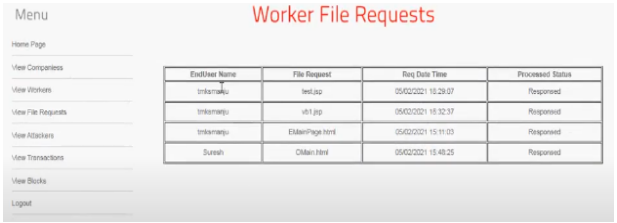

Fig:5.File Requests

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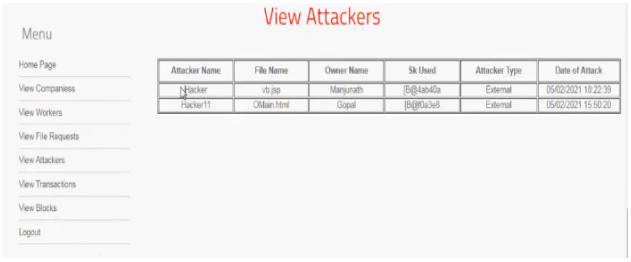

Fig:6.View Attackers

Fig:7.Throughput

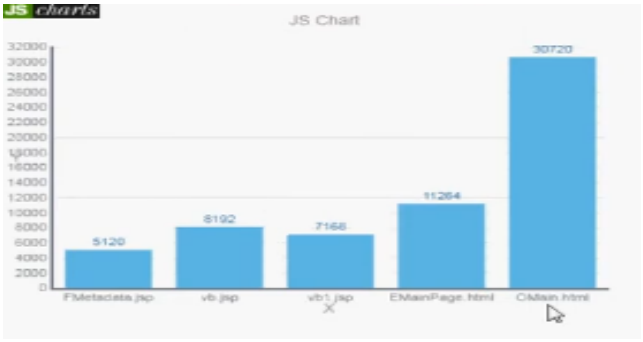

Fig:8.Time Delay

VI.CONCLUSION

The essential aim of this thesis was to execute a comprehensive article review on Cloud, Edge, and Fog paradigms, respectively, with a special focus identifying similarities, differences, attacks, and counter measures based on security and privacy aspects.

One big challenge in most SLR is gathering every single paper relating to the field of work, but desirably representing these papers is far more vital than showcasing a huge amount of documents. We developed search queries in a methodological pattern to obtain a good review, and several databases were queried for studies. A possible 447 important papers were gotten from the start search queries and were slashed down to 77 selected papers employing a Systematic scheme consisting of various stages. For the sole goal of this work, different papers were read extensively and critically analyzed. We moved further to deliberate the existing security and privacy challenges, vulnerabilities, threats, attacks, and some specifics of the main suggested countermeasures.

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