DALHOUSIE UNIVERSITY

Faculty of Computer Science

**Summary Report on**
**"Post-Cloud Computing Paradigms: A Survey Report and Comparison"**

**CSCI 6704 – Advanced Topics in Networks**

Name: Arka Ghosh
Banner ID: B00911033

## Introduction

Cloud computing has gained a compact momentum [1] and is transforming the internet structure rapidly through allowing users to access storage, data, applications, and servers via their internet-connected devices [2]. With the rapid development of the wireless communication, the world has seen a rapid expansion of cloud computing over the last decade for which organizations are sprinting to host their data on cloud instead of traditional private servers [3]. Many companies, researchers, and academician, including Amazon, Google, IBM, Microsoft have developed and improved many cloud computing technologies over the years. Though cloud computing is still an emerging concept [4], it's approval rating as an emerging technology has significantly enhanced around the globe [5]. Despite the numerous advantages of cloud computing settings, several challenges confront cloud computing and have drawn the attention of many researchers and service providers. Some challenging issues that reduce the efficiency and dependability on the cloud computing include resource allocation, scalability, compatibility, load balancing, and interoperability. In recent years, personnel from industry and academia have suggested several network computing paradigms, i.e., fog computing, mobile edge computing and dew computing. Although this networking paradigms use different terminology, the fundamental idea is to expand cloud computing and shift computing infrastructure from faraway data centres to edge routers, base stations, and local servers positioned closer to customers. As a result, it may overcome the constraints observed by cloud computing while also improving speed and user experience. In this regard, Yuezhi et al. [6] presented a survey paper to highlight the key obstacles that cloud computing experiences followed by summarizing several post-cloud paradigms developed over the years and the potential of the post-clouding paradigm in meeting the ever-increasing demands and challenges of cloud environment. A detailed summary of the problem statement, and research challenges, proposed solutions of the paper has been provided in this rest of the paper with some open challenges and critique at the end of the paper that can be considered for future development in the cloud computing setting.

## Problem Statement and Research Challenges

Firstly, with the fast growth of ubiquitous electronics, a plethora of heterogeneous intelligent or nonintelligent networked devices have evolved. However, the capabilities of certain devices are not completely exploited and are frequently inactive due to the changing requirements of users and their immediate responsibilities. Other devices' computing, storage, or networking capabilities, on the other hand, continue to be insufficient for satisfying application needs. End terminals are only utilised to facilitate the input and output of human computer interactions in the centralised cloud computing paradigm. As a result, the processing, storage, and communication capacities of devices cannot be completely utilised in cloud computing, resulting in wasted resources in end devices. With the emergence new devices with big data applications, they leverage cloud computing infrastructure for large-scale and complicated processing, eliminating the need for specific hardware and software resources [7]. The processing and analyzing of big data have always been a challenging issue in cloud computing as the data size rises rapidly not only in size but also with diversity [8] that makes the processing challenging and time-consuming. Intelligent mobile devices and broadband wireless connectivity have grown in popularity as the mobile Internet has expanded rapidly. As the initial concept of cloud computing was built on stationary computing units and wired networks, it is not ideally suited for mobile internet applications. Additionally, interface is frequently located far away from the cloud servers [9]. Data transfer over longer distances causes transmission delays which does not fulfil the requirements of real time, low latency, and high quality of service (QoS) [10, 11] in a network of thousands of mobile devices and has an adverse impact on the system's overall efficiency. Additionally, with the advancement of wireless and heterogenous devices, new network applications such as IoT devices and 5G network have become more intricated and diverse than prior technologies in terms of device, processing and application demands which creates substantial hurdles to the cloud computing’s centralized approach. Though cloud storage provides the space to store and exchange files, content sharing results in numerous downloads of the same content when individuals synchronize their devices which lead to bandwidth waste and increase server workload [12].

**Proposed Solution(s)**

The authors in [6] have discussed about three network paradigm which they have referred as post-cloud computing paradigms. The three computing paradigms are Mobile Edge Computing (MEC), fog computing and dew computing which entail extending cloud computing from the data centre to network edges closer to end users, so eliminating network constraints associated with cloud computing and enhancing user service processing speeds and efficiency. The use of devices with lesser processing capacity to share part of the cloud's load is referred to as fog computing [13]. The architecture (Appendix A) of fog computing restricts the usage of the cloud to long-term and resource-intensive analysis. By offering a dispersed platform for data processing, storage, and networking, fog computing can assist solve cloud computing issues related to latency, bandwidth, and security. It allows for on-demand scalability, enabling for the supply of extra capacity as demand for cloud services grows. In addition, fog computing minimizes latency by enabling local access to data and resources, eliminating the need to send data across large distances. This is very useful in real-time data processing applications like autonomous vehicle navigation. On the other hand, another post computing paradigm Mobile Edge Computing (Appendix B), also known as Multi-Access Edge Computing, offers execution resources for applications with networking close to end users, often within or near the boundaries of operator networks. Edge computing is closely related to the notions of cloud and fog computing [14]. Although these notions have some overlap, they are not the same thing. MEC is a distributed computing paradigm that allows mobile and wireless devices to offload workloads to the network's edge, reducing latency, enhancing performance, and decreasing network congestion. MEC has the potential to transform how cloud services are provided since it allows apps and services to be installed closer to the end user, decreasing the need to transport data across large distances. MEC can aid in solving variety of cloud computing issue, including latency, scalability, and data privacy. As data does not have to be routed through the cloud from a remote server, MEC can minimize the amount of delay associated with cloud services. Furthermore, MEC can increase scalability since the edge nodes can be ramped up or down as needed to satisfy user demands. The authors have focused on another post-cloud paradigm, dew computing, which an expansion of the traditional client-server architecture, with two servers at opposite ends of the communication channel. A user has better access and freedom to access his or her personal data in the absence of an Internet connection with the aid of a dew server. It attempts to provide cloud, fog, or edge resources and services to the user's peripheral without or with little use of internetwork. Moreover, the authors in [6] have shown a comparative analysis on the architecture between the traditional cloud and post-cloud computing paradigms (Appendix C). The traditional two-tier architecture of cloud computing consists of end device and the cloud data on center whereas post-cloud computing paradigms add one or more layers of proximate facilities positioned between the end device and a faraway data center. As a result, computation and storage can be handled parallelly at multiple places in post-cloud computing paradigms due to the availability of different degrees of processing capability spread across multi-tier infrastructures.

## Open Research Challenges and Critique

The authors in [6] focused mostly on the latency and bandwidth wastage issues of the cloud computing paradigms and provided a comparative analysis of three post-cloud computing paradigms that can help in reducing these issues with cloud, but no importance has been given on the big data related problems in the cloud computing. Big data is a crucial topic that cannot be disregarded in the IT industry in today's world [17]. With the significant rise in data and data-related services, it is critical to investigate this subject and seek for methods to improve data service delivery, particularly in the cloud. Data streaming can be considered as a way of processing big data in real time which can help data processing faster and more effective. The adoption of Machine Learning algorithms and predictive analytics in the cloud infrastructure can be another solution to process and analyze massive amount of data more efficiently as this helps to acquire insights into the data patterns, trends ands and correlations between the data. Although both fog computing and mobile edge computing can help reduce latency and improve bandwidth by lowering quantity of the data that must be transferred from the cloud to the end user's device, both architectures are subject to security issues such as malicious attacks, data leakage and other cyber threats as the data is stored and processed at the network edge. This can lead to leaking many sensitive and confidential information and data of the customers. To aid the problem of security issues with fog computing and MEC, one of the most crucial security measures that should be considered is the data encryption. Before transferring the data between consumers and server provides, all data should be encrypted using a secret key which is only known to the customer that will prevent unauthorized access to the data. In order to identify any unwanted or malicious activity on such cloud infrastructure, intrusion detection systems should be established which can aid in the detection and response to security threats on the cloud in timely manner.

## Conclusion

Cloud computing have added a new edge to the world by making it easier for individuals and businesses to grow their operations without being worried about obtaining additional resources. Although cloud computing brings about many benefits, its inherent centralised processing features cannot fulfil the demands of continuously changing pervasive devices, omnipresent networks, and newly developing network applications and services. To overcome this weakness of cloud computing, personnel from industry and academic community have conducted several research and come up with some post-cloud paradigms such as fog computing, mobile edge computing, dew computing. Although these post-cloud paradigms have been proposed with different perspectives, the primary idea behind all these concepts is to bring cloud closer to the user so that it can eliminate network constraints associated with cloud computing and boost user service processing speeds and efficiency. These post-cloud paradigms have an enriching future prospect; however, before post-cloud computing paradigms can be widely adopted, a number of issues must be addressed, including the development of architecture, heterogeneous network access to tackle security issues, resource management and scheduling.

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## Appendix

## Appendix A

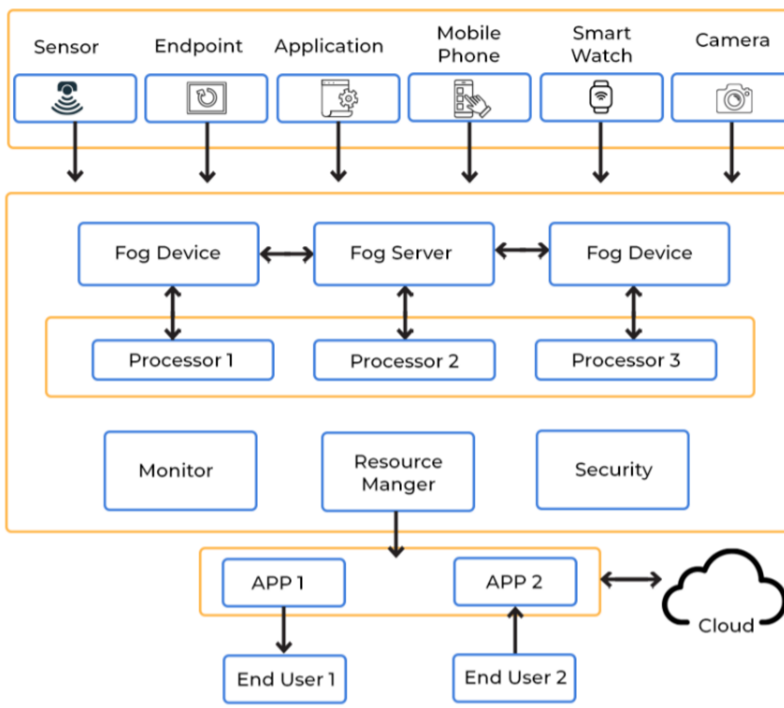


**Figure:** Fog Computing Architecture [13]

## Appendix B

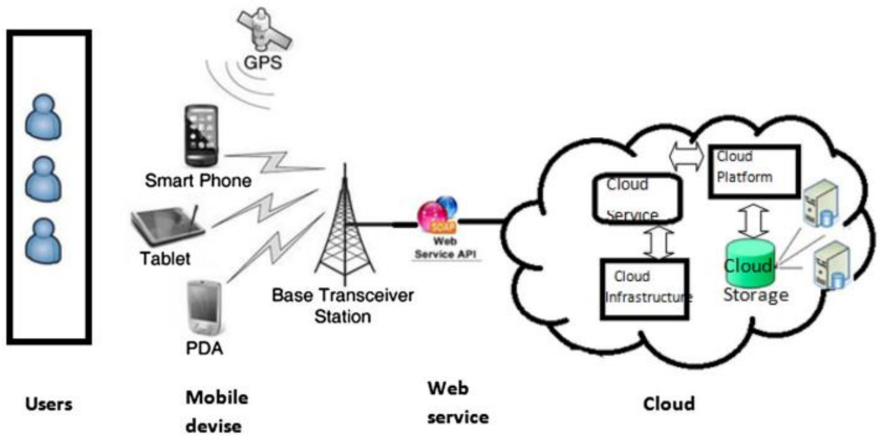


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**Figure:** Architecture of Multi Edge Computing (MEC) [16]

## Appendix C

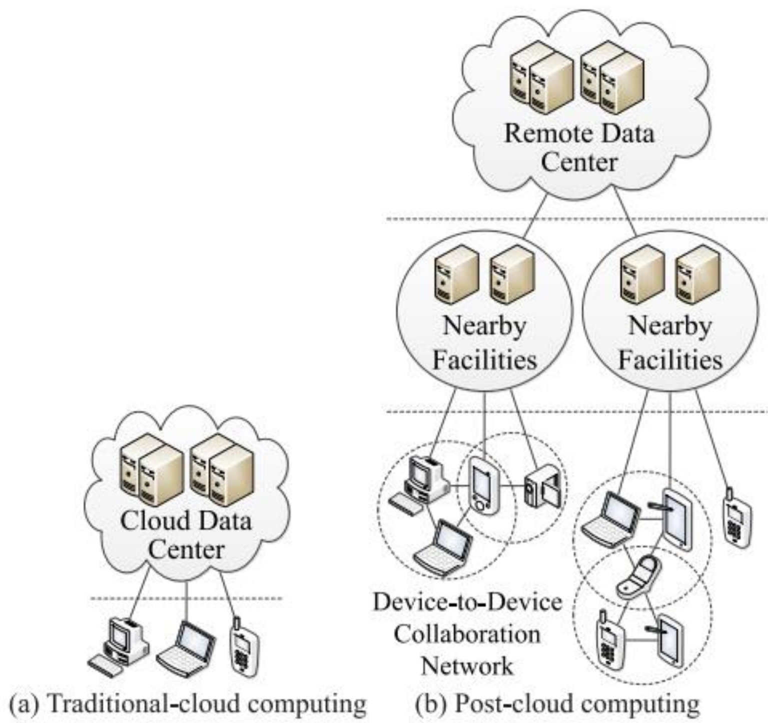


**Figure:** Architecture of (a) traditional-cloud computing paradigm; (b) post-cloud computing paradigm [6]