

Comparative Study of Cloud Computing and Edge Computing: Three Level Architecture Models and Security Challenges

Abhay Verma^{1*} and Vinay Verma²

¹Student, Department of Computer Science & Engineering, Vivekananda Institute of Technology, Jaipur, Rajasthan, India. Email: verma.abhay2420@gmail.com

²Independent Researcher, Jaipur, Rajasthan, India. Email: vnverma03@gmail.com

*Corresponding Author

Abstract: The procreation of IoT (Internet of Things), mobile internet and the attainment of cloud computing services have innovated a new computing archetype, known as edge computing. According to the International Data Corporation (IDC) forecast, worldwide data will reach about 180 zettabytes (ZB) and out of which 70% of data generated by IoT devices will be processed on the edge of the network by 2025. IDC also forecasts the IoT devices connected to reach 150 billion by 2025. Edge computing has the ability to deal with the huge volume of data and to handle the requirement of response time, data handling, bandwidth cost saving, along with privacy and data security. Edge computing enables low latency, mobility, and real-time data processing at a very faster pace. This paper is meant to introduce with the notion of edge computing, the three-level architecture of the edge model with the detailed difference between the edge computing model and the traditional cloud model. The various edge models that enable processing at the edge includes mobile edge computing, fog computing and cloudlet computing. Possessing the various advantages and models, edge computing still suffers from various security challenges. The paper concludes stating the security challenges that edge computing still need to focus upon.

Keywords: Cloud architecture, Cloud computing, Edge computing, IoT.

I. INTRODUCTION

Edge Computing is the networking philosophy which mainly focuses on bringing the computing power as closest as possible to the source of data which will enable fast processing with low latency and bandwidth utilization. It is the “Distributed Computing” epitome that conveys the computation power and data storage nearer to the user location [1]. It has been gathered and required, thus preventing the time delay taken in to communicate with the server or cloud, and hence it improves response time and saves bandwidth. *Edge* can be defined as any

network or computational resources in-between the source of data and the cloud data center. The edge is generally located one hop (network segment) away from the associated end devices, which are the source of data generated [2]. Due to the nearby availability of the computing power, it is idyllic for low-latency offload infrastructure which supports evolving applications in augmented reality, public safety, connected vehicles, autonomous driving, smart manufacturing, and healthcare.

Edge Computing is combination of numerous technologies, including Cloud Computing, IoT and Grid Computing. Edge Computing reduces the latency time and enhances the quality of service for the real-time processing tasks, including data processing, video processing, artificial intelligence, and time-sensitive. The edge undergoes two-way computing stream- one is upstream “from devices to the cloud” and other is downstream “from the cloud to devices” [2]. Edge has ability to execute the computation offloading, data storing, caching, processing, and also distributes the requests and delivers the services from cloud to the user, which enables edge to act in the real-time data processing. The devices do not restrict request services and content only, but also can perform computing task from the cloud which is possible in edge computing.

A vital part of edge computing is the network edge. Network edge is where the devices, or the local network containing the device, communicate with the internet. The important takeaway is that the network’s edge is geographically close to the device, unlike cloud servers, which might be far away from the source.

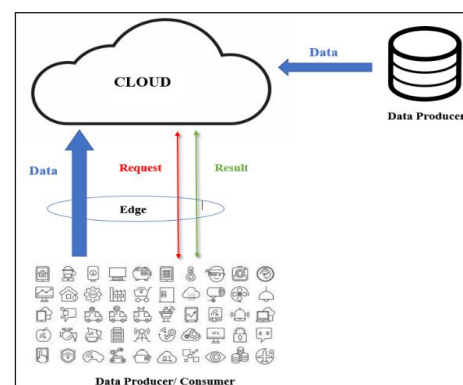


Fig. 1: Edge Computing

Edge computing has been emerging out as a new approach towards the network architecture with aim to reduce the drawbacks of the traditional cloud computing architecture. The growth of the edge, the volume of the usage has been gradually increased since 2010 and has a major impact in the technology since 2016.

II. LITERATURE REVIEW

This section of paper includes various comparisons of the different technologies, like IoT, edge, cloud computing. In the research paper [3], the trends of edge computing, cloud computing, fog computing and Internet of Things is analyzed on basis of scientific study. It concluded that it might be difficult to fully understand the main differences and similarities among the technology paradigms.

Another research paper [4], compared the edge and cloud computing keeping in mind the performance, data filtering, etc. and concluded that the both paradigms are likely to follow the hybrid approach and complement to each other, and suggested the real-time future study needed in the industries like manufacturing, mining, transportation to detect anomalies and send alerts.

Also, the research paper [5] made a comparison among the fog computing, cloudlet, and mobile-edge computing on theoretical model consists of node devices, context awareness, access mechanisms, etc., concluding that these have a different set of characteristics which set them apart from each other, but lacks standardization.

III. THREE-LEVEL EDGE COMPUTING MODEL

The three level edge computing model entails the cloud, edge and the IoT. The first level is IoT (Internet of Things) [6], which includes the end devices, like sensors, drones, mobile phones, smart watches connected in health area, smart homes, industrial internet, etc. The second level is the edge [7], which is connected to the first level using various protocols. For example, drones can be connected with 4G/LTE, and sensors can communicate with home Wi-Fi, whereas the smart watch and health devices can communicate via mobile internet. The edge here processes the data and then accordingly save it in the cloud or sends the processed data back to the user. It is capable of storing and computing the data at its end without sending and receiving from the cloud. The edge actually acts as an interface to connect the devices with the cloud with power to process data [8]. For the complex task, it utilizes large computing and data storage capabilities of the cloud. The third level is the cloud which is accountable for offering services to store, process, and analyze data.

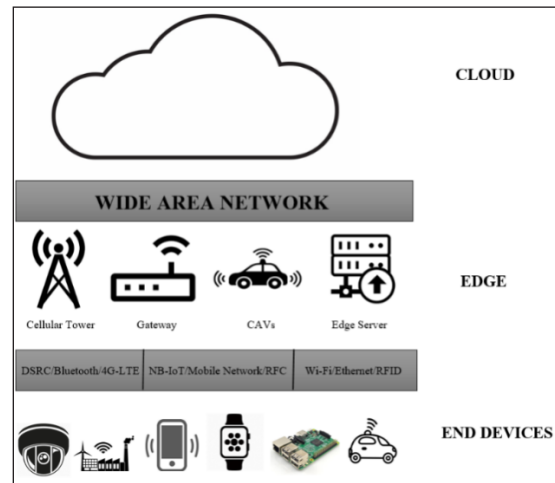


Fig. 2: Three-Level Architecture Model of Edge Computing

IV. EDGE VS. CLOUD

When the two terms are compared, the main difference arises over the data processing techniques. In cloud computing architecture, all the data captured and generated by the existing IoTs are processed in the cloud by the series centralized servers. While edge computing differs in way as it follows the phenomena of moving processes away from the cloud and bring them near to the end devices, which are closer to the source of origin. By now in 2020 about 45% of the worldwide data which is stored and managed in the network's edge [9]. The major drawback that the cloud faces over the edge is the amount of data processed per second is not passably supported by the cloud. Other than the issue of latency, the cloud faces the issues of wastage of resources as well. Also, when data is piled up and transferred to the cloud, it overloads the network and results in latency and high bandwidth usage. It rises challenges for the cloud-based data processing system. In the case of edge computing, the device nodes process out the data and utilize the underlying hardware of the device only, which does make use of all available resources without need of extra ones [10]. Edge Computing not only helps in minimizing the data dependency over the app or any service, but also helps in speeding up of the processing. The various different features amid edge computing and traditional cloud computing are given in Table I.

Since, edge computing is still in the growing period, whereas the cloud environment is a developed one. The theoretical comparative study provides the blurry differences among both the environments, due to which it becomes a bit difficult to get a concrete picture of both paradigms. Both the technologies are complementary to each other, instead of the substitution. One is supporting other and similarly getting the benefits out of it.

TABLE I: COMPARISON BETWEEN EDGE COMPUTING AND CLOUD COMPUTING

Features	Edge Computing	Cloud Computing
Latency	Highly decrease latency as the processing power is near to the source of data.	Highly increased latency as the cloud is situated at far from the source of data.
Computational capacity	Medium to low	High
Overloading	Prevents overloading of network and data center.	The resources might overload due to transfer of vast amount of data at a time.
Size and operation mode	It is smaller in size and placed over many locations.	Servers are very large in size and centralized.
Real-time data processing	Capable in processing real-time data more efficiently than cloud.	It can a longer time to process data in real-time.
Security	It demands a robust security plan that includes advanced authentication methods, and proactive tackling attacks.	It demands a less robust security plan.
Programming	Different multiple platforms can be used for programming, having different runtime.	It is made of one target platform and uses single programming language, which is best suited in cloud.
Suitable application	Suitable for operations with intense latency concerns.	Suitable for projects which deals with massive data storage.
Data handling	It has limited capacity, and cannot handle huge set of data.	It is efficient enough to store and process enormous amount of data.
Fronthaul/backhaul communication overhead	Low, since devices can get cached content directly from edge gateway.	High, since devices need to be connected to internet throughout entire duration.
Deployment	Leeway of ad-hoc deployment with no or minimal planning.	Require complicated deployment planning.

V. TYPES OF EDGE COMPUTING ENVIRONMENT

Edge offers a lithe, decentralized architecture which ensures that everything is processed in the end device itself. There are mainly two types of edge computing model:

- *Cloud Edge*: In case of cloud edge, the public cloud is protracted to a series of point-of-presence (PoP) location.
- *Device Edge*: In device edge, the applications run on the local existing hardware.

The major difference that exists between them is that the cloud edge is stretched form of the traditional cloud, where the cloud provider is responsible for operation and maintenance of the whole model, while device edge exists primarily within the hardware, which enables real-time processing of data at the end devices which is very fast and accurate.

Edge computing employs three technologies:

- *Fog Computing*: Cisco has introduced the term of fog computing in 2012 and described it as a highly simulated computing environment for the migration of cloud computing data center's task to network

edge devices [11]. The fog computing and edge computing techniques has many similarities, while it mainly focuses more on augmenting communication at the infrastructure level. The action involves machine-to-machine (M2M) communication or human-computer interaction (HCI). Edge computing pays attention to the computing requirements and network demand for both the end devices and infrastructure [12], which includes the association-between the end devices, edge and the cloud.

- *Mobile Edge Computing (MEG)*: It is network architecture that supports the potentials of cloud computing and an IT provision environment at the users' cellular network. It mainly focuses on running services and executing processing tasks on the customers' cellular device, which reduces congestion and application performs better [13]. MEC underlines the foundation between the edge servers, cloud servers and among various edge devices to perform computing tasks, which are similar to the architecture, and regarded as an important role of edge computing.

- *Cloudlet Computing*: Cloudlet computing majorly focus on supporting resource-intensive and interactive mobile-device application by offering powerful computing resources to mobile devices [14]. It is a structural element that extends current cloud computing infrastructure by enabling mobility-enhanced minimal cloud datacenter for offloading of data that is located at the edge of network.

The three models are contributing in the development of edge computing on the various domains of the society [14], with a single motive to bring the computational power at the every smallest IoT devices which are in daily and regular use by the people.

VI. EDGE SECURITY CHALLENGES

Due to diverse benefits and features of edge computing, like heterogeneous distributed architecture, support of massive data processing, aided parallel computing, associated low latency, location-awareness, mobile support, but the traditional data security methods [15], and privacy-safeguarding mechanism are no longer suitable for protecting massive data in edge computing. 76% of risk specialists think IoT leaves them at risk of cyber-attacks [16]. IoT, being most vulnerable possess risk to the edge as well. The data security and privacy-safeguarding mechanisms in edge computing technique mainly challenged by the following new challenges:

- *Lightweight and Fine-Grained*: The new necessities for lightweight data encryption and decryption methods and the fine-grained data sharing based on multiple authorized parties in edge computing.
- *Distributed Identity and Access Control*: Multi-sourced assorted data distribution control and secure the data management issues in distributed computing.
- *Resource-Constrained Devices*: Security challenges that exists between the large-scale edge-based services and resource-constrained edge devices.
- *Efficient Privacy-Preserving*: There are continually growing demand of effective and efficient privacy-preserving mechanisms for number of edge services and edge computing model associated with IoT.

The various security challenges associated with the edge are the only key factors that are restricting the companies and the users from using IoT resources. Once these challenges are addressed properly, then it may be possible that IoTs are mostly used and enhancing the processing power of the traditional cloud and lead to the edge's development with a faster pace.

VII. FUTURE WORK

In this new era of computing, every electrical equipment is integrated with IoTs and sensors with more advanced features of artificial intelligence [17]. Edge computing clearly proposes a number of benefits that cannot be easily achieved in traditional cloud computing, but also outsides a lot of technical and non-technical challenges as mentioned previously. The current study lacks the standardization in terms of the actual implementation of edge computing. The algorithm and software contrivance of the edge and IoT requires collective control of cloudlets. The features mentioned in comparison could be taken towards the analytical observation by implementing both in required scenario. On the technical side, the quantitative data can be collected and compared by analyzing the various factors, like performance, latency, data accuracy & loss, amount of data storage & processing capability, level of data security offered, deployment complications, expense occurrence of both the edge and traditional cloud computing environment. The analytical comparative study could help identify the technology being more useful and effective, providing maximum benefit out of it.

For the collection of such data, edge computing and cloud computing services can be implemented in different scenarios. For example, the application of both the technologies can be implemented on the healthcare department, where data and readings are very critical. Also, the use of edge devices is growing immensely in the sector. In such case, it will become easier to calculate the efficiency and better productivity out of both technologies. The one with less latency, less data loss, more accuracy, better productivity and other factors can determine the best implementation among the both and would be more clear on the feature and implementation of edge nodes.

Another imperative area of study will be the improvement of contrivances which can compensate for the weaker perimeter security of the IoT and cloudlets, as compared to the traditional cloud computing environment.

VIII. CONCLUSION

Edge computing with its advanced features associated with IoT, smart & mobile connected devices, etc. are bringing processing power as close as possible to the end devices, which is enabling low latency, real-time processing, enhancing mobility, quality of service, and acting as a thin line between the cloud and the devices tier [18]. The various models enabling edge computing on the three level architecture simplifies the edge implementation and processing. Edge differs from the traditional cloud in terms of mobility, and distributed architecture. Although edge provides the advantages, but the flaws that confines the cloud computing model currently remain as the lead of the generated data that continues to increase. The technology of edge computing still need development and further studies which could help in making a clear line to differentiate among

the effectiveness of the cloud and edge computing paradigm, as the current study lacks the calibration of one technology over the other on the specific implementation field. The orchestration of edge services become more challenging as edge node can be mobile and rapid changes can cause connectivity failure and bandwidth fluctuation.

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