Edge Computing in Cloud Computing Environment: Opportunities and Challenges

Taruna Saini[1], Sudhakar Kumar[2], Tarun Vats[3] and Manraj Singh[4]

[1]*Chandigarh College of Engineering and Technology, Sector-26, Chandigarh, 160019, India*
[2]*Chandigarh College of Engineering and Technology, Sector-26, Chandigarh, 160019, India*
[3]*Chandigarh College of Engineering and Technology, Sector-26, Chandigarh, 160019, India*
[4]*Chandigarh College of Engineering and Technology, Sector-26, Chandigarh, 160019, India*

Abstract

This paper tries to introduce the notion of edge computing and cloud computing technologies. To tackle huge amounts of information, also called Big Data, Cloud computing technologies along with Edge Computing technologies were introduced. Edge computing technology helps in storing data. The information can further be analyzed and processed in proximity to the source itself due to its location on the edges. Edge computing technology and cloud computing are dissimilar in terms of speed of processing, the quantity of analyzed data, and the location where analysis and processing take place, etc. Challenges such as the restricted availability of data in edge computing can be solved by Cloud Computing since it was designed for Big Data and provides a large coverage. This paper also discusses the future trends and developing technologies such as software-defined networking (SDN) and network functions virtualization (NFV). Due to edge computing technology, the efficiency of cloud computing can be increased and the response time can be reduced significantly. Cloud offloading, smart cities, and video analytics are some of the applications of edge computing.

Keywords: Cloud Computing, Edge Computing, Big Data, Cloud Offloading, Smart City, IoT, Smart Home, 5G

1. Introduction

Revolutions in the industry have accelerated the constant increase in the amount of data and information which is acquired. The main contributor to this is the Internet of Technology or IoT. Manufacturing challenges started to erupt due to Big Data, which is this huge amount of raw data that is generated. Powerful software applications need to be built for the storage, analysis, and processing of these complex and large datasets. These software applications perform data analysis and thus help in providing information to manufacturing companies enhancing their production [5] [7] [9].

Not enough processing power makes Big Data incapable of processing and analyzing data stored in personal computers. Hence, manufacturing companies must use Edge Computing or Cloud Computing technologies. Big Data, which is produced due to IoT, can be stored, processed, and analyzed using cloud computing. The data can be located at more than one location. Edge Computing Technology accepts the information produced by the IoT sensors. This technology can gain access to the data for storing, processing, and analyzing by gaining advantage if its location as it is located as near to the source as it could be possible[30]. Edge computing technology makes it possible for devices to make decisions on their own, and it provides a real-time response [3] [7] [9].

International Conference on Smart Systems and Advanced Computing (Syscom-2021), December25–26, 2021
EMAIL: sainitaruna0@gmail.com (A. 1); sudhakar@ccet.ac.in (A. 2); manrajsingh16447@gmail.com (A. 3); tarunvats1807@gmail.com (A. 4)
ORCID: XXXX-XXXX-XXXX-XXXX (A. 1); XXXX-XXXX-XXXX-XXXX (A. 2); XXXX-XXXX-XXXX-XXXX (A. 3)

This paper introduces cloud computing and edge computing technology, highlighting their differences and applications. The methods of integrating edge computing with cloud computing are listed along with their challenges, opportunities, and future trends.

2. What do you mean by Cloud and Edge Computing?

Cloud computing is a term used to describe a type of data storage and processing technology. Cloud computing refers to centralized, distributed, and parallel computer systems that are dynamically provided [20]. Data analytics, or the analysis of data, is greatly aided by cloud computing. Big Data Analytics refers to data analytics performed on large amounts of data [22].

Edge computing refers to technology that enables computation near data sources at the network's edge. On behalf of cloud and IoT services, it works with both downstream and upstream data [23][24]. Computational or networking devices that lie between cloud-based data centers and information sources are known as edge devices. A mobile phone, for example, might be placed between cloud and body sensors, or a cloudlet or mDC could be used to segregate a mobile device from the cloud [2].

Edge has the ability to supply a host of advantages in real-world applications. Researchers have already shown that offloading computing operations for wearable assistance systems which are cognitive, utilizing cloudlets enhance reply time by 80 to 200 milliseconds while reducing energy consumption by 30 to 40%. Thanks to edge computing, CloneCloud technology improves reaction time and energy consumption by 95% for evaluated applications [2].

A number of challenges, including system reliability, should be considered by anyone working with edge computing. Insufficient wireless connections or limited battery life may also cause energy-constrained edge devices to fail. Developers should nonetheless allow the system to perform its fundamental operations in these circumstances. [23]. Security and privacy are other important factors to consider. Edge computing, on the one hand, safeguards data better than cloud computing because preparation takes place near the source. Due to network topology, the vast number of low-cost personal smartphone equipment in the system, and sensor inconsistency, edge computing makes security and privacy more difficult [31][32].

3. Contrast between edge computing technology and cloud computing technology

The methods of storing and processing information are comparable with respect to Cloud Computing technologies and Edge Computing technologies. The differences among these techniques are dependent on the location of storing and processing and time of response as shown in Figure 1. Because of such differences and challenges, some computer technologies open up opportunities for others, and vice versa. Thus, this compares the challenges and potential in Cloud Computing and Edge Computing using various key variables chosen based on Data Analytics requirements presented in Table 1 [23].

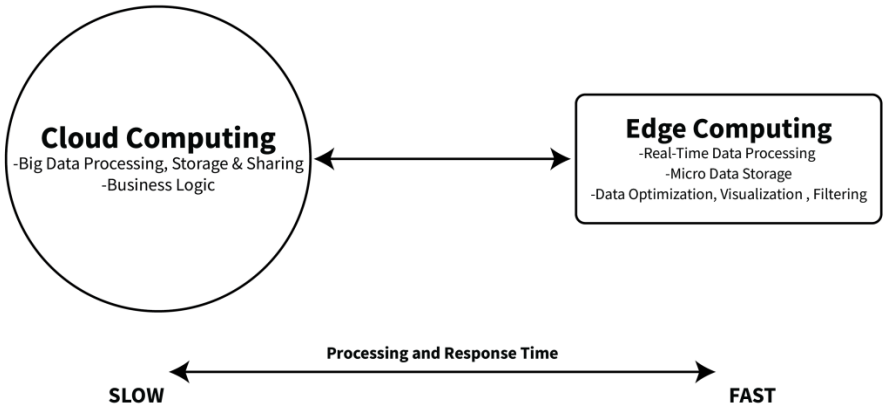

Figure 1: The structure of contrast between edge computing technology and cloud computing technology

Table 1
Differences between Cloud Computing and Edge Computing

Comparison areas	Edge Computing	Cloud Computing
Storage	Micro data storage	Big data storage
Processing of data can be done	Data is in small quantity	Preparation of Big Data
Computational Power	It has less power	It has more power
Reaction time	Reaction is faster	Reaction is slower
Network/ Data Safety	Safe	Not Safe
Annual Cost	It is less costly	It is more costly

4. Edge Computing's Challenges and Cloud Computing's Opportunities in Data Analytics

The development of Edge Computing technology is still in its early phases. Foundations such as AWS, Azure, and App Engine [11] [13], unlike Cloud Computing, are still in their early phases. As Pan and McElhannon mention, most edge computing structures use special kinds of physical edge servers devoted to performing major processing and storage, or elementary ports with minimal virtuality support. The very most significant resistance to this computing is the limited amount of data available. Edge Computing systems are limited in their ability to store large volumes of data due to memory constraints. This technology is used for the storage of Micro Data in the case of edge computing devices. On the other hand, the volume of data is always expanding in the context of Industry 4.0. As a result of the increase in data, the concept of edge computing systems should enable many kinds of storage, from ephemeral storage, which is at the lowest level to, permanent permanency, which is at the highest level, encompassing a wide variety of local regions over a long period of time.[6]. Cloud computing, on the other hand, delivers monthly and annual data coverage around the globe. As a result, cloud computing solutions are built for Big Data storage, with data organized into logical pools that users may access remotely [15] [17].

The power of Edge Computing will process a limited amount of data because data storage and processing are done in the same location. Devices based on Edge Computing are designed to perform the processing of data on small databases as a result. However, in the case of Industrial 4.0, where large amounts of data are generated on a daily basis, data analysis requires additional computational capacity, which can be brought about by Cloud Computing technology. The data processed amount is directly proportional to computing power, and Edge Computational technology lacks sufficient computing energy for data processing due to hardware hindrance. Notably, Cloud Processing has the ability to provide greater computing capacity, resulting in cloud computing jobs being more efficient. Standardization is the process of creating an open environment in which industry and academia can

collaborate on a common platform [34]. However, as a novel technology, Edge Computing is not completely adopted because of the unavailability of a standardized IoT ecosystem that will result in an uninterrupted and proficient homogenization of all devices through a defined agreement inside the environment of Industry 4.0 [19] [21].

5. Edge Computing Integrated with Cloud Computing

Edge computing was introduced for increasing the efficiency of cloud computing. With the help from edge computing, cloud computing performance can be increased in the following ways:

- Decreased response time - When the data is produced at the source, it is processed/ prepared at the edge, and this decreases the response time and thus, increasing the processing efficiency and reduction of pressure on the network [1][29].
- Making IoT popular - Cloud computing alone cannot handle large amounts of data. Edge computing helps in overcoming this limitation, thus enabling more and more devices to be connected to the IoT [1].
- Data consumer and data producer from data consumer - Instead of uploading large data requiring a lot of bandwidth directly on the cloud, it could be uploaded to the network's edges [2].

6. Future of Edge Computing

The Internet is fast-moving, looking ahead "Internet of Things," which might link billions or perhaps hundreds of trillions of edge devices to create massive amounts of data at a high rate, with certain applications requiring extremely low latency.[25] Due to the compact computer storage, and network connectivity for the few numbers of data service centers, as well as across long distances between peripheral devices and secluded data service centers, typical cloud architecture will face a number of challenges. To address this issue, edge computing and edge cloud appear as viable options, since they bring assets near to assets-constrained edge IoT projects and may help to foster the latest IoT ecosystem, i.e. open innovation. New developing technologies, such as software-defined networking (SDN) and network functions virtualization (NFV) made this possible. Figure 3 depicts a basic depiction of the link between open innovation, SDN, and NFV.

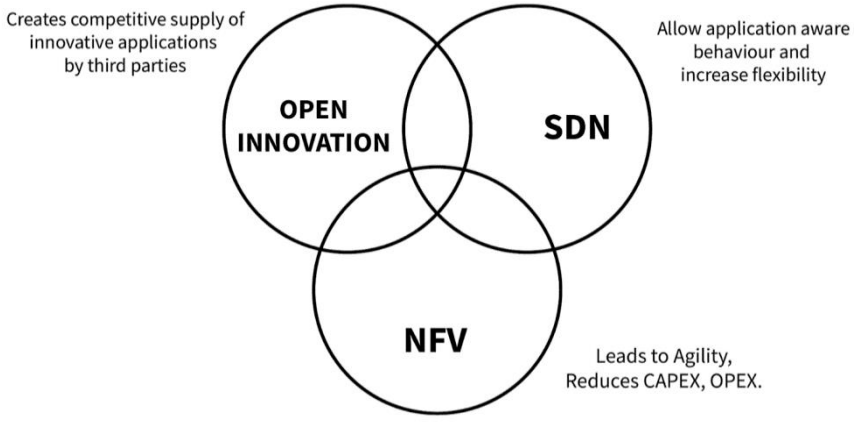

Figure 2: NFV and SDN convergence in open innovation

NFV and SDN are extremely complementary from a technological standpoint for edge cloud potential. Software vendors, device suppliers, ASPs, and ISPs are among non-technical players in the upcoming edge cloud and market of application. Upcoming 5G technology and the "Network Softwarization" trend put NFV and SDN integration into a larger perspective. By 2024, 5G networks are expected to provide greatly upgraded and programmable network architecture, with video traffic

dominating cell networks, IoT and large data processing, Virtual Reality (VR), and exploding being widely available and delivered with minimal latency [8] [12] [14] [24].

7. Future possibilities with Edge Computing

To further adorn our vision of edge computing, we provide several real-world examples where edge computing can be applied very efficiently and meaningfully.

- **Concept of cloud offloading:** In a typical cloud computing model, the majority of calculations are performed in the cloud environment, which implies that requests and information are handled in a centralized environment. Because the edge possesses specific computation resources, edge computing enables a portion of the burden to be offloaded from the cloud. This is because the content provider, as has been the case for decades, makes the data available on the Internet. At the edge, the IoT generates and consumes data.[2][24]. As a result, in the edge computing model, data along with data processing tasks are cached in the edge only. The edge computing model can be used very beneficial in online purchasing businesses, as an example.[2]
- **Video Analysis:** Due to high data transfer, privacy, and latency problems, the concept of cloud computing is no more preferable for video analytics implementations. Consider the case of a city-dwelling child who has gone missing. A request to search for a child could be issued in the cloud and could be delivered to everyone in a required region using the edge computing paradigm [24]. Each object, such as a smartphone, can reply to the call and examine the data of its local camera before transmitting the conclusions to the cloud. Hence, this model, as opposed to solitary cloud computing, allows you to use data and processing resources across the board and achieve results considerably faster.[2] [18]
- **Smart Home:** Smart lighting, smart TVs, and robot vacuums are examples of items that have been developed and are now available on the market [24]. These gadgets would generate a lot of data, which should be utilized mostly at home to reduce the data transportation burden and ensure privacy. Because of this aspect, the cloud computing paradigm is incompatible with a smart home [2][23]. Edge computing, on the other hand, is excellent for building a smart home since it allows items in the house to be easily connected and monitored, data to be processed locally to save internet bandwidth, and services to be hosted on the ‘edgeOS’ for simple and easy management and deliverance.
- **Smart Cities:** The concept of edge computing could be scaled out starting with a single home to a neighborhood or a city possibly. Edge computing promotes computing that can be as close to the source of data as possible. Edge computing, which analyses data at the network's edge, could be a cost-effective solution in this situation.[23] Edge computing is a great model for those applications which need low latency and are predictable, like public safety or health emergencies, because it can cut data transmission time and simplify network topology.[10] [26]

8. Open Challenges and Issues

Edge Computing, along with Cloud Computing provides many applications and future opportunities. However, over time, many challenges and issues have developed. Some of them are as follows [16] [27]:

- Benchmark Rules: Mobile Edge Computing, or the MEC, has evolved over time. Some standards are needed with the help of industrial collaboration and the agreement of researchers.

- Well-planned implementation: With efficient MEC deployment, it is possible to reduce latencies by making the best use of bandwidth. However, because of the reliance on complex system components, optimizing spectrum consumption is challenging.
- Availability and Security: For assuring consistent service delivery, server capacity and wireless access medium are the most important factors to consider. Along with availability, physical steps should be taken to protect data and applications from intruders [28] [33][34][35].

9. Conclusion

Cloud computing and Edge computing basically complement each other and are interdependent on each other, thus benefiting one another mutually. The challenges faced in cloud computing can be solved using edge computing. Similarly, the limitations of edge computing can be overcome using cloud computing. The accession problem of Big Data and data storage and processing through the cloud can be solved with the help of these technologies. Detailed analysis and real-time feedback can be provided at the user end while performing complex functionalities on the Cloud on a remote basis [5].

10.Acknowledgements

We wish to acknowledge the help provided by the technical and support staff of the CCET ACM Student Chapter and the Department of Computer Science & Engineering, CCET (Degree Wing), Chandigarh. We would also like to show our deep appreciation to our supervisors who helped us in the finalization of our research paper.

11.References

[1] Mittal, S., Negi, N., & Chauhan, R. (2017, November). Integration of edge computing with cloud computing. In 2017 International Conference on Emerging Trends in Computing and Communication Technologies (ICETCCT) (pp. 1-6). IEEE.

[2] Sunil Sharma, Sunil Singh, and Subhash Panja, “Human Factors of Vehicle Automation”, in Autonomous Driving and Advanced Driver-Assistance Systems (ADAS), Taylor & Francis Group (CRC Press), Chapter 15, 2021.

[3] Edge Computing: Vision and Challenges Weisong Shi, Fellow, IEEE, Jie Cao,Student Member, IEEE, Quan Zhang, Student Member, IEEE, Youhuizi Li, and Lanyu Xu, IEEE INTERNET OF THINGS JOURNAL,VOL. 3, NO. 5, OCTOBER 2016

[4] Sunil Kr. Singh, R. K. Singh, M.P.S. Bhatia, SP Singh, “CAD for Delay optimization of Symmetrical FPGA Architecture through Hybrid LUTs/PLAs”, ACIT, Vol. 178, Page 581-591, Springer, 2012

[5] Bajic, B., Cosic, I., Katalinic, B., Moraca, S., Lazarevic, M., & Rikalovic, A. (2019). EDGE COMPUTING VS. CLOUD COMPUTING: CHALLENGES AND OPPORTUNITIES IN INDUSTRY 4.0. Annals of DAAAM & Proceedings, 30.

[6] S. K. Singh, R. K. Singh and M. Bhatia, "Design flow of reconfigurable embedded system architecture using LUTs/PLAs," 2012 2nd IEEE International Conference on Parallel, Distributed and Grid Computing, 2012, pp. 385-390, doi: 10.1109/PDGC.2012.6449851.

[7] Nikolic, B.; Ignjatic, J.; Suzic, N.; Stevanov, B. & Rikalovic. (2017). A. Predictive Manufacturing Systems in Industry 4.0: Trends, Benefits and Challenges. in 28TH DAAAM International Symposium on Intelligent Manufacturing and Automation, pp.769–802. doi:10.2507/28th.daaam.proceedings.112’

[8] R Madan, SK Singh, N Jain, Signal filtering using discrete wavelet transform,International journal of recent trends in engineering 2 (3), 96, 2009

[9] Tamás, P. (2016). Process Improvement Trends for Manufacturing Systems in Industry 4.0. Acad. J. Manuf. Eng.14, 7.
[10] Sunil Kr. Singh, Ajay Kumar, Siddharth Gupta, Ratnakar Madan, "Architectural Performance of WiMAX over WiFi with Reliable QoS over Wireless Communication" in International Journal Advanced Networking and Applications (IJANA) [EISSN: 0975-0282], Page 1016-1023, Vol. 03, Issue 01, July 2011.
[11] Khan, W. Z.; Ahmed, E.; Hakak, S.; Yaqoob, I. & Ahmed, A. (2019). Edge computing: A survey. Futur. Gener. Comput. Syst., Vol. 97, pp. 219–235.
[12] SK Singh, RK Singh, MPS Bhatia, "Performance evaluation of hybrid reconfigurable computing architecture over symmetrical FPGAs" , International Journal of Embedded Systems and Applications 2 (3), 107-116, 2012 .
[13] Varghese, B.; Wang, N.; Barbhuiya, S.; Kilpatrick, P. L. & Nikolopoulos, D. (2016). Challenges and opportunities in Edge Computing. in IEEE International Conference on Smart Cloud, pp. 59–70. doi:10.1007/978-3-030-02083- 5_5
[14] SK Singh, RK Singh, MPS Bhatia, "System level architectural synthesis & compilation technique in reconfigurable computing system", International Conference on Embedded Systems and Applications (ESA10) WORLCOMP-2010, pp 109-115, July 12-15, 2010.
[15] Bonomi, F.; Milito, R.; Zhu, J. & Addepalli, S. (2012). Fog Computing and Its Role in the Internet of Things. in Proceedings of the first edition of the MCC workshop on Mobile cloud computing, pp. 13–16. doi:10.1145/2342509.2342513
[16] SK Singh, K Kaur, A Aggarawal, "Emerging Trends and Limitations in Technology and System of Ubiquitous Computing", International Journal of Advanced Research in Computer Science (IJARCS), 5 (7), pp 174-178, 2014.
[17] Kadhim, Q. K.; Yusof, R. & Mahdi, H. S. (2018). A Review Study on Cloud Computing Issues Related content. in 1st International Conference on Big Data and Cloud Computing (ICoBiC) 2017, pp. 1–11. doi:10.1088/1742- 6596/1018/1/012006
[18] Aggarwal, K., Singh, S. K., Chopra, M., & Kumar, S. (2022). Role of Social Media in the COVID-19 Pandemic: A Literature Review. In B. Gupta, D. Peraković, A. Abd El-Latif, & D. Gupta (Ed.), Data Mining Approaches for Big Data and Sentiment Analysis in Social Media (pp. 91-115). IGI Global. http://doi:10.4018/978-1-7998-8413-2.ch004
[19] Mach, P. & Becvar, Z. (2017). Mobile Edge Computing: A Survey on Architecture and Computation Offloading. IEEE Commun. Surv. Tutorials, Vol. 19, pp. 1628–1656.
[20] Sudhakar Kumar, Sunil Kr Singh, Naveen Aggarwal, Kriti Aggarwal, "Evaluation of automatic parallelization algorithms to minimize speculative parallelism overheads: An experiment", pp 1517-1528, 2021 Journal of Discrete Mathematical Sciences and Cryptography, Volume 24, Issue 5 , Taylor & Francis, (2021)
[21] Hu, P.; Dhelim, S.; Ning, H. & Qiu, T. (2017). Survey on fog computing: architecture, key technologies, applications and open issues. J. Netw. Comput. Appl., Vol. 98, pp. 27–42.
[22] Chopra, M., Singh, S. K., Aggarwal, K., & Gupta, A. (2022). Predicting Catastrophic Events Using Machine Learning Models for Natural Language Processing. In B. Gupta, D. Peraković, A. Abd El-Latif, & D. Gupta (Ed.), Data Mining Approaches for Big Data and Sentiment Analysis in Social Media (pp. 223-243). IGI Global. http://doi:10.4018/978-1-7998-8413-2.ch010
[23] Bajic, B[ojana]; Cosic, I[lija]; Katalinic, B[ranko]; Moraca, S[lobodan]; Lazarevic, M[ilovan] & Rikalovic, A[leksandar] (2019). Edge Computing vs. Cloud Computing: Challenges and Opportunities in Industry 4.0, Proceedings of the 30th DAAAM International Symposium, pp.0864-0871, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-22-8, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/30th.daaam.proceedings.120
[24] W. Shi and S. Dustdar, "The Promise of Edge Computing," in Computer, vol. 49, no. 5, pp. 78-81, May 2016, doi: 10.1109/MC.2016.145.

[25] J. Pan and J. McElhannon, "Future Edge Cloud and Edge Computing for Internet of Things Applications," in IEEE Internet of Things Journal, vol. 5, no. 1, pp. 439-449, Feb. 2018, doi: 10.1109/JIOT.2017.2767608.
[26] J. Ren, G. Yu, Y. He and G. Y. Li, "Collaborative Cloud and Edge Computing for Latency Minimization," in IEEE Transactions on Vehicular Technology, vol. 68, no. 5, pp. 5031-5044, May 2019, doi: 10.1109/TVT.2019.2904244.
[27] Shahzadi, S., Iqbal, M., Dagiuklas, T., & Qayyum, Z. U. (2017). Multi-access edge computing: open issues, challenges and future perspectives. Journal of Cloud Computing, 6(1), 1-13.
[28] Gou, Z., Yamaguchi, S., et al. (2017). Analysis of various security issues and challenges in the cloud computing environment: a survey. In Identity Theft: Breakthroughs in Research and Practice (pp. 221-247). IGI global.
[29] A. Dahiya (2021), Integration of Cloud and Fog Computing for Energy Efficient and Scalable Services, Insights2Techinfo, pp.1
[30] A Dahiya, B. Gupta (2021), Edge Intelligence: A New Emerging Era, Insights2Techinfo, pp.1
[31] Mishra, A., Gupta, N., & et al. (2020). Security threats and recent countermeasures in cloud computing. In Modern principles, practices, and algorithms for cloud security (pp. 145-161). IGI Global.
[32] Gupta, B. B., Yamaguchi, S., & Agrawal, D. P. (2018). Advances in security and privacy of multimedia big data in mobile and cloud computing. Multimedia Tools and Applications, 77(7), 9203-9208.
[33] Zheng, Q., Wang, X., Khan, M. K., Zhang, W., Gupta, B. B., & Guo, W. (2017). A lightweight authenticated encryption scheme based on chaotic scml for railway cloud service. IEEE Access, 6, 711-722.
[34] Negi, P., Mishra, A., et al. (2013). Enhanced CBF packet filtering method to detect DDoS attack in cloud computing environment. arXiv preprint arXiv:1304.7073.
[35] Singh, K. S. (2021). Linux Yourself (1st ed.). Routledge.