Review on Edge Computing for IoT applications

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Abstract With the advent of technology, there has been a great increase in the number of Internet of Things (IoT) devices out there. Consequently, these devices led to a gathering of huge amount of data, which has caused problems such as slow response speed, high bandwidth cost and latency rate in cloud computing models. Because of these problems, edge computing paradigm, which does computation at the edge of the network, has gained popularity as it has the potential to solve these problems. In this paper, we will review edge computing and compare it with cloud computing while looking at the advantages of edge computing. In addition, this paper also discusses applications and recent research done on edge computing.

Keywords: Cloud computing, Edge Computing, IoT

I. INTRODUCTION

With rapid shift towards digitalization, the number of devices has increased by a lot. Due to this, a new computing paradigm, Edge computing has been made widely available to several people. Arriving in this post-cloud era, edge devices have entered our daily life and have found its applications industrially.

According to Cisco, there will be a great increase in number of devices by 2023. By 2023 there will be 29.3 billion devices available according to the report, an increase of about 10.9 billion devices compared to 2018. In addition, there will over 14 billion Internet of Things (IOT) devices, also referred as Machine-to-machine (M2M) connections, in 2023 [1].

IOT devices are any device which are connected to the Internet and can communicate with other device. The devices are embedded with sensors which can gather data. Many devices like, a swart watch, fitness band, bulb which can be turned on using a phone and driverless car come under IOT devices. These devices are used to gather and send data. The term Internet of things is used to describe the network of such IOT devices as described above.

As the number of devices increases, the data generated from these devices will increase proportionally. This can cause problems in cloud-based model as they are not efficient enough for such large-scale data. Some devices or applications might need a high response time or real time feedback, while some devices will send a huge amount of data which can stress cloud computing models. Thus, to solve these problems, edge computing has come to the forefront.

Edge computing considerably reduces the distance needed to travel by the data as it is closer to the devices which are data source. With 5G and advancement of Internet of Things (IOT), Edge computing is finding more usage in day-to-day activities.

In this paper, we will do a survey of edge computing. Edge computing will be introduced followed by learning the benefits of Edge computing. Finally, we will learn about the applications and research in Edge Computing.

II. EDGE COMPUTING AND ITS BENEFITS

In this section, we will learn about the basics of edge computing and learn about the advantages edge computing has.

a) What is Edge computing?

In Edge computing, data is computed at the edge of the network. It means that the data is being computed close to the data source. This is not possible in case of cloud computing. Satyanarayanan described edge computing as “a new paradigm in which substantial computing and storage resources like cloudlets, micro data centres, or fog nodes are placed at the Internet’s edge in close proximity to mobile devices or sensors” [2]. There are many such definitions of edge computing and all focusses on the proximity of edge devices where source data originates to the place where computation takes place.

Edge computation allows computing data on both downstream data and upstream data in replacement of cloud services and IOT services respectively. W.shi et al. defines edge, where the computation takes place (edge of the network), as any resources belonging to computer and network along the path in between of data sources and cloud data centre [3].

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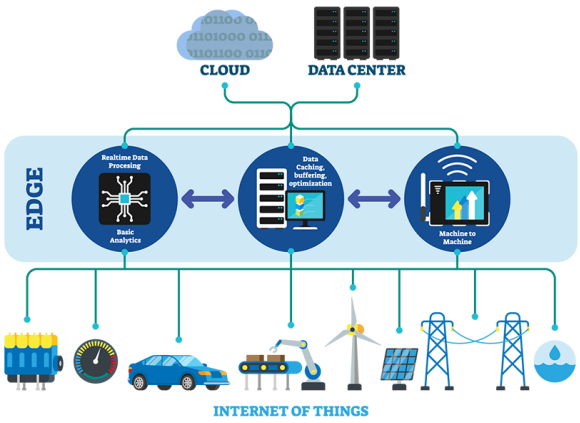

Figure 1: Concept of edge computing

As we can see in the figure above, in edge computing the data is processed closer to the edge devices. Instead of sending all the data to the cloud, data is sent to Edge servers first. Here the data processing and other tasks which require higher response rate, low latency, results in real time and better security can be performed. Edge servers work as complimentary to cloud servers, making sure the cloud servers are not burdened with all the data generated by IOT devices.

Thus, the main concept of edge computing is doing computations at the edge of network, closer to the source.

b) Why edge computing?

Edge computing can lower the latency. As the data is computed at the edge instead of being sent long distance to cloud servers, the response rate can be reduced by a lot. This is good for applications or devices which require high response time or real time feedback since there will be less delay compared to send data to cloud servers.

As stated earlier, according to Cisco, there will be over 14 billion IOT devices available in 2023 [1]. These devices will generate a lot of data which will be a big load on traditional cloud computing models. There will be high bandwidth costs as well. Thus, to avoid it, edge computing is needed.

There can be leakage or loss in data in cloud computing when data is uploaded to it. Thus, there is always a risk to security and privacy. This can be avoided in edge computing as the data is processed at edge. Therefore, data does not need to be uploaded to cloud and the risks can be avoided. [4]

Using Edge computing, companies can save a lot of money. Companies can save lot of bandwidth by switching to edge since all the data no longer needs to be transmitted for cloud computing. This can save the companies money they spend on bandwidth.

Table 1: Approach to edge computing

Internet of Things (IoT) Critical Cases for Edge Computing	• Data Center Loads and Complementing. • Evolution of Cloud Computing. • Network bandwidth limitations and cut costs. • Security Concerns. • Compliance and Regulation. • The immediacy of Analysis, e.g., To check machine performance. • Predictive Maintenance. • Energy Efficiency Management. • Flexible Device Replacement. • Having low latency, e.g., Closed-loop interaction between machine insights. • The high cost of transferring data to the cloud.
Benefits of Enabling Edge Computing for the Internet of Things (IoT)	• Computational Efficient • Costs and Autonomous Operation • Lesser Network Load • Reduced Data Exposure • Security and Privacy • Zero Latency
Future Directions of Computing for the Internet of Things (IoT)	• Edge-to-Cloud data exchange capabilities • Common-on-Edge data exchange capabilities • Streaming Data Analytics and Batch frameworks and APIs • Controlled rolling and Versioning upgrades of applications • Status of application monitoring from an Ad-Hoc Cloud Dashboard • Cloud-Based Deployments of Edge Computing Applications

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Edge Computing Importance	• Application Programming Interface. • Centralized Management. • Costs of Licensing. • Easier configurations. • Hacking Potential is increased. • Increases Extensibility. • Load on Network is reduced. • New Functionalities are offered. • Support and Updates. • The load on the server is reduced.
Advantages of Enabling Edge Computing	• Hacking issues are reduced. • Random issues are reduced. • Reliability is increased. • Speed is increased. • The compliance issue is reduced. • The random issue is reduced.

c) Where is it used?

In this section, we will discuss some of the real-life applications where edge computing is used.

1) Autonomous Vehicles: Autonomous vehicles generate a lot of data per second. It can take time to send all the data to cloud server. This can be fatal if the vehicle needs to make a quick decision, for example avoiding a pedestrian or another vehicle. Using Edge computing, autonomous vehicles achieve faster response time and can make appropriate decisions. In addition, vehicles will also be able to communicate with each other because of low latency, which is another benefit for edge computing.

2) Monitoring Health: Using Edge technology, healthcare workers can get immediate alerts from the wearable devices worn by patients. In addition, Edge technology can ensure data privacy of patients as data can be processed at the Edge device instead of sending data to cloud servers. Further, Edge technology can be significant in surgeries performed with the help of a robot. The robot can quickly process and analyze the data and make immediate decisions in the surgery instead of transmitting the data to cloud servers and wait for the decisions.

3) Smart Home: Smart homes are filled with Internet of things (IOT) devices and these devices generate a lot of data. These can increase cost and cause delay issues, latency and data security in traditional methods. Using Edge, we can solve this problem by brining processing closer to the IOT devices. Since the processing is closer, there will be low latency and data security will be ensured as data will be processed locally.

4) Augmented Reality (AR): Augmented Reality devices using Edge computing. Certain devices need ultra-low latency which cannot be provided by cloud-based architecture since in cloud-based architecture, all data will have to be sent to a centralized cloud server first and then the AR device will have to wait for the cloud servers to add digital element to data before sending it to the AR device. In addition, communication is more reliable as well in Edge servers as compared to cloud-based servers. Even data security is ensured as the data from the device does not transfer over a public network [14].

III. APPLICATIONS AND CURRENT RESEARCH ON EDGE COMPUTING

Here we will review some recent research and applications on edge computing.

Table 2: Review on edge computing

Edge Computing	Title	Domain	Summary
[5]	'Intelligent Edge Computing based on machine learning for smart city'	Machine Learning	This paper proposes a method to decrease the computing pressure on single mobile edge computation (MEC) mode when there is an increase in data. Machine learning is applied to distributed task scheduling algorithm in MEC and distributed device coordination algorithm for machine learning tasks. The final, distributed task scheduling algorithm is based on Stackelberg game algorithm, which achieves fast algorithm convergence and good stability in large scale network when tested and distributed device coordination algorithm is based on alternation direction method of multipliers (ADMM), which has good scalability and achieves fast convergence when tested.

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[6]	AI-Enhanced Offloading in Edge Computing: When Machine Learning Meets Industrial IoT	Artificial Intelligence	In this paper, a computer architecture is proposed using edge and cloud computing. In addition, the paper also proposes an AI driven offloading framework, with server accuracy as a metric, which sends traffic to edge and cloud computing intelligently. This increases the server accuracy.
[7]	Offloading Optimization in Edge Computing for Deep Learning Enabled Target Tracking by Internet-of-UAVs	Deep Learning, Convolutional Neural Network (CNN)	In this paper, a novel offloading framework is proposed where mobile edge computing is used in smaller unmanned aerial vehicle (UAV) models, such that, the higher level of CNN is handled by MEC while lower levels are embedded in UAV. This framework fulfills the timely processing of video images while keeping in account of the constraints faced.
[8]	An Internet of Medical Things-Enabled Edge Computing Framework for Tackling COVID-19	Deep Learning, Internet of Medical Things (IOTM)	This paper develops a system using IOTM incorporated with deep learning. The system generates reports and alerts with the help of deep learning. By using edge computing, the system achieves low latency, security and user- data privacy.
[9]	Mobile Edge Computing Enabled 5G Health Monitoring for Internet of Medical Things: A Decentralized Game Theoretic Approach	Internet of Medical Things (IOTM), 5G	In this paper, a 5G health monitoring system is developed using MEC such that the system wide cost is reduced, and more people benefit from it. To achieve it, intra-wireless body area network (WBANs) is used where bargaining game is used as bandwidth scheduling problem, and beyond – WBANs is used with a weighted potential game-based approach.
[10]	An Effective Training Scheme for Deep Neural Network in Edge Computing Enabled Internet of Medical Things (IoMT) Systems	IoMT, Deep Neural network (DNN)	This paper proposes a training scheme in edge computing called ETS-DNN model for DNN training. This model collects data timely and using the patterns in data, timely decisions are made
[11]	Intelligent Cooperative Edge Computing in Internet of Things	Artificial Intelligence	In this paper, an intelligent cooperative edge (ICE) computing architecture is introduced. A basic cloud-based AI is trained using public data which is then compressed and then decompressed at edge. The model at edge achieves a lower latency and a higher caching ratio.
[12]	Convergence of Blockchain and Edge Computing for Secure and Scalable IIoT Critical Infrastructures in Industry 4.0	Blockchain	The author in this paper proposes a layered architecture converging blockchain and edge computing. The architecture makes edge computing secure and scalable
[13]	Mobile Edge Computing in Unmanned Aerial Vehicle Networks	UAV	In this paper, three UAV enabled Mobile Edge Computing architectures are review. In addition, it also lists the implementation issues.

IV. CONCLUSION

In this paper we reviewed Edge computing. Edge computing was introduced, followed by learning the concept of Edge computing and then learning why edge computing is used and its importance. This is followed by learning the applications of Edge computing, that is, where Edge computing is used. The paper then also reviews the recent research and recent applications of edge computing, where Edge computing is used with different domains like Machine Learning and Blockchain. Edge computation provides computing at the edge of the network thereby, increasing response time, lowering the latency and reducing the cost and energy spent on bandwidth since the data is not sent to cloud servers. Edge computing has gained popularity because of the benefits it provides. The paper provides guide to newcomers learning Edge technology so they can carry out further research in it.

REFERENCES

[1] "Cisco Annual Internet Report (2018–2023) White Paper," Cisco, 2018.

[2] M M. Satyanarayanan, "The Emergence of Edge Computing," in Computer, vol. 50, no. 1, pp. 30-39, Jan. 2017, doi: 10.1109/MC.2017.9.`

 DOI : 10.35291/2454-9150.2021.0555 © 2021, IJREAM All Rights Reserved.

[3] W. Shi, J. Cao, Q. Zhang, Y. Li and L. Xu, "Edge Computing: Vision and Challenges" in IEEE Internet of Things Journal, vol. 3, no. 5, pp. 637-646, Oct. 2016, doi: 10.1109/JIOT.2016.2579198.

[4] K. Cao, Y. Liu, G. Meng and Q. Sun, "An Overview on Edge Computing Research," in IEEE Access, vol. 8, pp. 85714-85728, 2020, doi: 10.1109/ACCESS.2020.2991734.

[5] ZhihanLv, Dongliang Chen, Ranran Lou, Qingjun Wang, "Intelligent Edge Computing based on machine learning for smart city" in Future Generation Computer Systems, vol. 115, pp. 90-99, Feb. 2021, doi: 10.1016/j.future.2020.08.037

[6] W. Sun, J. Liu and Y. Yue, "AI-Enhanced Offloading in Edge Computing: When Machine Learning Meets Industrial IoT," in IEEE Network, vol. 33, no. 5, pp. 68-74, Sept.-Oct. 2019, doi: 10.1109/MNET.001.1800510.

[7] B. Yang, X. Cao, C. Yuen and L. Qian, "Offloading Optimization in Edge Computing for Deep-Learning-Enabled Target Tracking by Internet of UAVs," in IEEE Internet of Things Journal, vol. 8, no. 12, pp. 9878-9893, 15 June15, 2021, doi: 10.1109/JIOT.2020.3016694.

[8] M. A. Rahman and M. S. Hossain, "An Internet of Medical Things-Enabled Edge Computing Framework for Tackling COVID-19," in IEEE Internet of Things Journal, doi: 10.1109/JIOT.2021.3051080.

[9] Z. Ning et al., "Mobile Edge Computing Enabled 5G Health Monitoring for Internet of Medical Things: A Decentralized Game Theoretic Approach," in IEEE Journal on Selected Areas in Communications, vol. 39, no. 2, pp. 463-478, Feb. 2021, doi: 10.1109/JSAC.2020.3020645.

[10] I. V. Pustokhina, D. A. Pustokhin, D. Gupta, A. Khanna, K. Shankar and G. N. Nguyen, "An Effective Training Scheme for Deep Neural Network in Edge Computing Enabled Internet of Medical Things (IoMT) Systems," in IEEE Access, vol. 8, pp. 107112-107123, 2020, doi: 10.1109/ACCESS.2020.3000322.

[11] C. Gong, F. Lin, X. Gong and Y. Lu, "Intelligent Cooperative Edge Computing in Internet of Things," in IEEE Internet of Things Journal, vol. 7, no. 10, pp. 9372-9382, Oct. 2020, doi: 10.1109/JIOT.2020.2986015.

[12] Y. Wu, H. -N. Dai and H. Wang, "Convergence of Blockchain and Edge Computing for Secure and Scalable IIoT Critical Infrastructures in Industry 4.0," in IEEE Internet of Things Journal, vol. 8, no. 4, pp. 2300-2317, 15 Feb.15, 2021, doi: 10.1109/JIOT.2020.3025916.

[13] F. Zhou, R. Q. Hu, Z. Li and Y. Wang, "Mobile Edge Computing in Unmanned Aerial Vehicle Networks," in IEEE Wireless Communications, vol. 27, no. 1, pp. 140-146, February 2020, doi: 10.1109/MWC.001.1800594.

[14] Y. Siriwardhana, P. Porambage, M. Liyanage and M. Ylianttila, "A Survey on Mobile Augmented Reality With 5G Mobile Edge Computing: Architectures, Applications, and Technical Aspects," in IEEE Communications Surveys & Tutorials, vol. 23, no. 2, pp. 1160-1192, Secondquarter 2021, doi: 10.1109/COMST.2021.3061981.

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