Pakistan Journal of Engineering Technology and Science (PJETS)
Volume 10. Issue. 1, PP. 46-56, JUNE 2022
https://doi.org/10.22555/pjets.v10i1.863

FOG COMPUTING IN INTERNET OF THINGS

M.Ali Bhutta[1*], Urooj Yousuf Khan[2]
[1]New Mexico Highlands University, USA
[2]Institute of Business management, Pakistan
[*]Corresponding author: mabhutta@nmhu.edu

Abstract: **Internet of Things envisions a talk able platform for heterogenous devices. It implies devices with heterogenous capabilities are communicating over a common platform. Many supporting technologies exist to complement this idea. One such technology is Fog Computing. Fog Computing indicates that there is a horizontal platform that sits between devices and the Central Cloud. This intermediary layer enhances system performance and provides immediate response to the connected modes for transactional operations, thereby reducing the network traffic that is routed towards the Cloud. This paper provides an overview of Fog Computing in Internet of Things.**

Keywords: ***Fog Computing, Internet of Things, 5G Networks***

I. INTRODUCTION

While driving and thinking about meeting in next 30 minutes at office, a thought came into your mind if you switched off heating system. IoT is where devices and systems are connected over internet for purpose of sharing and processing data. These devices and systems include simple home appliance to delicate industrial tools, where engineers control distantly. This network is becoming increasingly complex with an inclusion of more devises in network and resultantly, exponential growth in data is observed. [1].
Fog computing is a decentralized computing architecture that have data storage and processing units at edge of clouds. Fog computing can be seen as extension of cloud computing, in which infrastructure is decentralized in a way that data can be stored and processed in edges. It aims to provide faster response times, reduce network bandwidth usage, and improve the overall efficiency of data processing and storage [2].
Fog computing and IoT are closely related, as Fog computing can be used to support the processing and analysis of the massive amounts of data generated by IoT devices. Relation between IoT and fog computing reconceptualize the computing and data processing. By bringing the computing power closer to the Edge, Fog computing can reduce the latency and bandwidth required for data transfer, making it possible to process and analyze data in real-time [3].

Fog computing also enables IoT devices to operate more efficiently by offloading some of the processing tasks to nearby Fog nodes, reducing the workload on the devices and extending their battery life. This can be particularly useful in applications such as smart cities, where large numbers of IoT devices are deployed in a small area [4]. Overall, Fog computing and IoT are complementary technologies that can be used together to create more efficient and effective systems for processing and analyzing data in real-time, especially in applications where low latency and high reliability are critical [5].

The paper is structured as follows: Introduction and literature review is presented in the Section 1 and 2. The relation between the Fog Computing and IoT is presented in Section , followed by conclusion in last section.

II. LITERATURE REVIEW

-

A) Internet of Things (IoT)

The Internet of Things (IoT) is a term used to describe the interconnectivity of devices, objects, and people through the internet. The IoT is transforming the way people interact with technology, and it has the potential to revolutionize various industries. In this literature review, we will examine the current state of the IoT, its challenges, and opportunities, and explore some of the latest trends and developments in the field [6].The IoT is growing at an incredible pace. According to a report by Gartner, there will be 25 billion connected devices by 2021. These devices range from wearable technology, smart homes, and smart cities to connected cars, healthcare devices, and industrial IoT applications. The widespread adoption of IoT devices has resulted in a massive amount of data being generated every day, which has led to new challenges for organizations to process, store, and analyze the data [7].The architectural details for Internet of Things (IoT) is depicted in Figure 1.

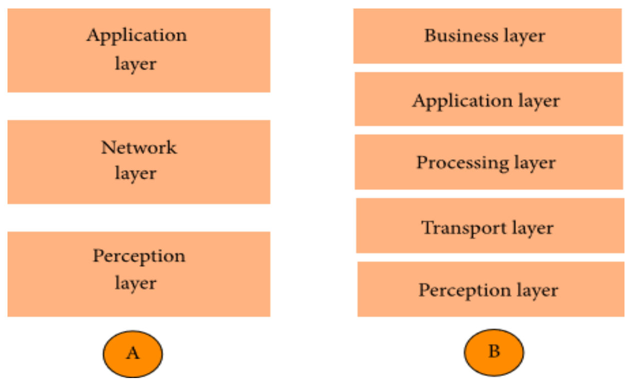

Figure 1: Layered Architecture of IoT [8]

Security in IoT is important of many challenges. The proliferation of connected devices has created a vast attack surface, making it easier for hackers to exploit vulnerabilities in the system. In addition, IoT devices are often deployed with little or no security measures, making them an easy target for cybercriminals. Another challenge is the standardization of IoT devices and protocols. With so many devices, it is difficult to create a unified protocol that can ensure interoperability between devices [9].

Despite the challenges, the IoT presents a significant opportunity for businesses and organizations. With IoT, businesses can gain valuable insights into their operations, improve efficiency, reduce costs, and improve customer satisfaction. In healthcare, IoT devices can improve patient outcomes, reduce costs, and provide better patient care. Smart cities can improve traffic flow, reduce energy consumption, and enhance public safety [10].

Edge computing is a recent development in the IoT. Instead of transferring data to a central location for processing, edge computing processes data at the network's edge, nearer to where it is generated. The amount of data that needs to be communicated across the network can be decreased, data security can be improved, and latency can be decreased [6]. The application of machine learning and artificial intelligence (AI) is a further development in the IoT. (ML). These technologies can help organizations to analyze the vast amount of data generated by IoT devices and gain insights into their operations. AI and ML can also help to improve the accuracy of predictions and automate decision-making processes [11].

The IoT is transforming the way people interact with technology and creating new opportunities for businesses and organizations. However, the rapid growth of IoT devices has also led to new challenges, including security, standardization, and data management. Despite these challenges, the IoT presents significant opportunities for organizations to improve efficiency, reduce costs, and enhance customer satisfaction. With the latest trends in edge computing, AI, and ML, the IoT is poised to become even more transformative in the years to come [12].

B) Enabling technologies for IoT (Internet of Things)

There are several enabling technologies for enabling IoT. Few notable ones are discussed below:

- *Wireless Sensor Networks (WSNs):* These networks are made up of low-cost, battery-powered, and wireless sensors that can be used to collect data from the environment and send it to a central location [13].
- *RFID ("Radio Frequency Identification")* technology*:* This technology uses radio waves to identify and track objects in real-time. RFID tags can be attached to objects, and the information they contain can be read remotely [14].
- *Cloud computing*: This technology provides a platform for storing, processing, and analyzing large amounts of data from IoT devices. It enables real-time data processing and analytics, making it an essential component of IoT [3].
- *Edge computing*: This technology makes it possible to process and analyze data closer to the devices that are producing it, at the network's edge. This makes it excellent for Internet of Things applications by lowering latency and bandwidth needs. [4].
- *Big Data Analytics*: This technology involves the use of advanced analytics tools and techniques to process and analyze large amounts of data generated by IoT devices. It enables real-time decision making and provides valuable insights into customer behavior and preferences [15].
- *Artificial Intelligence (AI):* AI algorithms can be used to analyze data from IoT devices and make predictions based on the data. It enables predictive maintenance, anomaly detection, and other intelligent applications [13].
- *Blockchain technology*: Security and transparency is of great importance in storing and sharing data. Blockchain technology assures security while storing and sharing data in computing structure. It enables secure transactions, data sharing, and identity verification [2].
- *5G Networks*: With the use of this technology, data may be processed and analysed closer to the sources of the data, at the network's edge. This is perfect for IoT applications since it lowers latency and bandwidth needs. It also enables the deployment of IoT devices in remote areas where traditional connectivity is not available [15].

These enabling technologies have a vital role in the development and deployment of IoT applications. By leveraging these technologies, organizations can build innovative solutions that improve business operations, enhance customer experiences, and drive growth.

C) Fog Computing

According to authors [16],Fog is a node closer to the source, which can improve latency, reduce bandwidth requirements and enhance the overall efficiency of distributed systems. The architectural details for Fog Computing are given below in Figure 2.

Pakistan Journal of Engineering Technology and Science (PJETS)
Volume 10. Issue. 1, PP. 46-56, JUNE 2022
https://doi.org/10.22555/pjets.v10i1.863

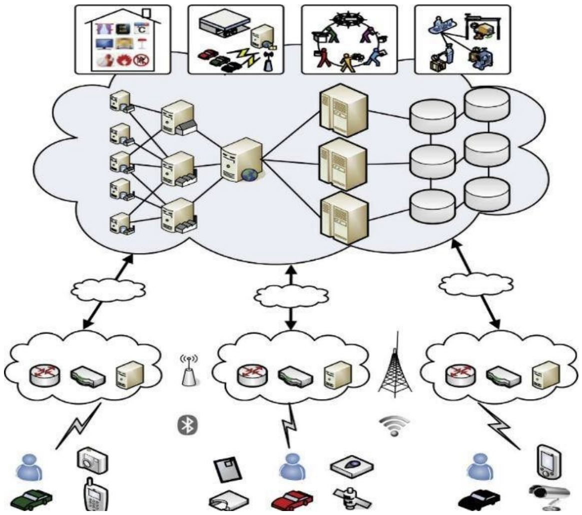

Figure 2: Three Layered Approach to Fog Architecture [17]

However, like any technology, Fog computing has its own set of challenges that need to be addressed to ensure its successful implementation. Few notable challenges are mentioned below:

- *Security*: One of the significant challenges [16]in Fog computing is security. In Fog computing, data is processed and analyzed at the edge, which means it is closer to the source and potentially more vulnerable to security breaches. Fog nodes, gateways, and sensors are susceptible to cyber-attacks. To secure the Fog computing environment, it is crucial to implement robust security measures at the edge devices and gateways. This includes securing data transmission, securing the hardware and software, ensuring the authenticity of the fog nodes and gateways, and protecting against malware and cyber threats.
- *Resource Management*: Another significant challenge in Fog computing is resource management. Fog nodes have limited resources compared to cloud servers, which makes it challenging to run complex applications on them. The lack of processing power, memory, and storage can make it difficult to handle data-intensive applications, leading to performance issues. To address this challenge, Fog computing requires efficient resource management techniques that can allocate and utilize resources effectively. This includes dynamic resource allocation, load balancing and task scheduling [15].
- *Interoperability*: Interoperability is another significant challenge in Fog computing. Fog nodes, gateways and sensors are often developed by different vendors, using different technologies and standards. This can create compatibility issues that can hinder the seamless operation of the fog computing environment. To ensure interoperability, Fog computing requires standardized protocols and interfaces that enable different devices to communicate and exchange data seamlessly [14].
- *Scalability*: Fog computing needs to be scalable to handle the growing demand for computing resources. As more devices are connected to the network, the volume of data generated increases, and the demand for processing power and storage capacity increases as well. To address this challenge, fog computing requires scalable architectures that can add and remove nodes dynamically and can scale up or down according to the demand [14].
- *Privacy*: Privacy is another significant challenge in fog computing. Fog computing involves processing and analyzing data at the edge, which can raise privacy concerns. The data collected by the sensors and devices at the edge can be sensitive and personal, and its analysis can reveal sensitive information about

Pakistan Journal of Engineering Technology and Science (PJETS)
Volume 10. Issue. 1, PP. 46-56, JUNE 2022
https://doi.org/10.22555/pjets.v10i1.863

individuals or organizations. To address this challenge, Fog computing requires privacy-preserving techniques that can protect the confidentiality of data while still allowing analysis to be performed [5].

Fog computing is a promising paradigm that can enhance the efficiency and performance of distributed systems. However, it is not without its challenges. Addressing these challenges requires a concerted effort from researchers, developers, and policymakers to develop robust security measures, efficient resource management techniques, standardized protocols, scalable architectures, and privacy-preserving techniques. By addressing these challenges, Fog computing can unlock new possibilities for the Internet of Things, smart cities, and other emerging applications.

III. FOG COMPUTING AND IOT

I. *Fog Computing as an Enabling Technology for Internet of Things*

Fog computing is a new approach to processing this data that is designed to take advantage of the growing network of edge devices in the IoT. Rather than sending all of the data generated by these devices to a central server or Cloud for processing, Fog computing distributes the processing across multiple Edge devices [18].

The benefit of fog computing is that it can lessen the quantity of data that needs to be transferred across the network, hence lowering latency and enhancing performance. As a result of the ability to process data locally on Edge devices, it can also assist in lowering the cost of data transmission. [12].

Fog computing and the IoT are both part of a larger trend towards distributed computing and Edge computing, which are changing the way we think about computing and data processing. As these technologies continue to evolve, they are likely to have a significant impact on a wide range of industries, from healthcare and manufacturing to transportation and energy [3].

Fog Computing and the Internet of Things (IoT) are two rapidly growing areas of research and development that are transforming the way we collect, process and analyze data.

II. *Their Complimentary Role*

One of the characteristics of the Cloud Computing is global centralization having single server. Low latency restricts many IoT applications, for instance video surveillance. Localization in fog computing enables low latency. Both localization and globalization, in fog computing and cloud computing respectively, are necessary for many applications, especially those involving analytics and Big Data. This topic was raised earlier in relation to smart traffic lights. Here, we focus on Smart Grid, whose data topologies provide as additional examples of this interaction.

The data produced by sensors at girds and devices is received by fog collectors placed at the edge. Some of this data refers to real-time processing-required protection and control loops. (from milliseconds to sub seconds). The data is gathered, processed, and control orders are sent to the actuators by the first tier of the fog, which is intended for machine-to-machine (M2M) communication. Additionally, it filters the data for low-level consumption and transfers the remaining data to higher tiers.

The second and third tiers cover systems and procedures, as well as visualization and reporting (human-to-machine [HMI] interactions). (M2M). These interactions, which are all a part of the Fog, occur at timescales ranging from seconds to minutes (real-time analytics), and even days. (transactional analytics). The Fog must therefore accommodate a variety of storage types, ranging from ephemeral at the lowest rung to semi-permanent at the highest tier. We also see that the geographic coverage is bigger and the time scale is longer the higher the tier.

The Cloud, which is utilised as a repository for data with a permanence of months and years and which serves as the foundation for business intelligence analytics, offers the most comprehensive, global coverage. This is an example of a dashboard or report in an HMI environment that shows key performance indicators.

The statistics below demonstrate the importance of Fog computing and the IoT and their potential to transform various industries. They also highlight the challenges and opportunities associated with these technologies, and the need for continued research and development in this field [19].

III. *Recent Statistis*

There are several statistics and reports that indicate that Fog computing is one of the key enablers for IoT. Here are a few:

- The global market for fog computing is anticipated to increase from USD 22.8 billion in 2019 to USD 92.4 billion by 2024, at a Compound Annual Growth Rate (CAGR) of 32.2% over the forecast period, according to a Markets and Markets analysis. This growth is attributed to the increasing demand for real-time computing for IoT applications [20].
- A survey conducted by Gartner in 2019 found that 75% of IoT projects are expected to include Edge computing and Fog computing by 2022. This indicates that organizations are increasingly recognizing the importance of fog computing in enabling IoT applications [21].
- A report by Grand View Research found that the use of Fog computing in IoT applications is expected to reduce network latency by up to 95%. This can significantly improve the performance and reliability of IoT applications, making them more suitable for real-time use cases [9].
- A survey conducted by Forbes in 2019 found that 72% of organizations believe that Fog computing is essential for IoT applications. This indicates that fog computing is widely recognized as a key enabler for IoT [22].

Overall, these statistics indicate that Fog computing is a crucial technology for enabling IoT applications. Its ability to provide real-time computing, reduce network latency, and improve the reliability of IoT applications makes it an essential component of the IoT ecosystem [23].

IV. CONCLUSIONS

This paper presents an overview of Internet of Things and its association with Fog Computing. The paper covers the importance of Fog computing and provides valid statistics to prove the fact that Fog computing will be one of the defining technologies in the Future. The paper also discusses the challenges faced by the Fog Computing paradigm and those faced by IoT. Major challenges faced while envisioning IoT can be successfully resolved by implementing Fog Computing.

ACKNOWLEDGEMENT:

We recognize the input from Abdul Hanan Sheikh, which helped to make this article worth and interesting for reader.

V. REFERENCE

[1] A. Yousefpour, T. Nguyen, K. Kadiyala, F. Jalali, A. Niakanlahiji, J. Kong and J. . P. Jue, "All one needs to know about fog computing and related edge computing," *Journal of Systems Architecture,* pp. 289-330, 2019.

[2] R. M. J. Z. S. A. Flavio Bonomi, "Fog Computing and Its Role in the Internet of Things," 19 June 2012. [Online]. Available: https://conferences.sigcomm.org/sigcomm/2012/paper/mcc/p13.pdf.

[3] A. A.-R. a. F. A.-T. H. Al-Rizzo, 13. A Survey on Edge andFog Computing for the Internet of Things:

Challenges and Opportunities, IEEE Communications Surveys and Tutorials, 2021.

[4] Z. Y. a. W. Z. H. Song, 15. "A Systematic Review of Fog Computing for the Internet of Things: Architecture, Applications, and Challenges", IEEE Internet of Things Journal, 2021.

[5] P. K. P. Sharma, "An Overview of Fog Computing: Concepts, Architecture, and Applications", 2021.

[6] O. Hersent, D. Boswarthick and O. Elloumi, The Internet of Things: Key Applications and Protocols.

[7] F. . A. Alaba, M. Othman, I. A. T. Hashem and F. Alotaibi, "Internet of Things security: A survey," *Journal of Network and Computer Applications,* vol. 88, pp. 10-28, 2017.

[8] U. Y. Khan and T. R. Soomro, "Envisioning Internet of Things using Fog Computing," *(IJACSA) International Journal of Advanced Computer Science and Applications,* vol. 9, no. 1, pp. 441-448, 2018.

[9] M. Kranz, Building the Internet of Things: Implement New Business Models, Disrupt Competitors, Transform Your Industry.

[10] A. S. Syed, D. Sierra-Sosa, A. Kumar and A. Elmaghraby, "IoT in Smart Cities: A Survey of Technologies, Practices and Challenges,," *Smart Cities,* vol. 4, no. 2, p. 429–475, 2021.

[11] S. Klein, M. Yadav and M. Leib, IoT Solutions in Microsoft's Azure IoT Suite: Data Acquisition and Analysis in the Real World.

[12] P. Hu, S. Dhelim, H. Ning and T. Qiu, "Survey on fog computing: architecture, key technologies, applications and open issues," *Journal of Network and Computer Applications,* vol. 98, pp. 27-42, 2017.

[13] R. K. R. B. Redowan Mahmud, "Fog Computing: A Taxonomy, Survey and Future Directions," 17 November 2016. [Online]. Available: https://arxiv.org/abs/1611.05539.

[14] R. M. P. N. a. J. Z. Flavio Bonomi, "Fog Computing: A Platform for Internet," 1 febuary 2019. [Online]. Available: https://cse.buffalo.edu/faculty/tkosar/cse710_spring19/bonomi-bdiot14.pdf.

[15] E. M. ,. F. L. ,. A. P. ,. O. R. Carlo Puliafito, "Fog Computing for the Internet of Things: A Survey," 02 April 2019. [Online]. Available: https://dl.acm.org/doi/10.1145/3301443.

[16] W. Shi, J. Cao, Q. Zhang, Y. Li and L. Xu, "Edge Computing: Vision and Challenges," *EEE Internet of Things Journal,* vol. 3, no. 5, pp. 637-646, 2016.

[17] U. Y. Khan and T. R. Soomro, "Fog Networks: A Prospective Technology for IoT," *International Journal of Advanced Trends in Computer Science and Engineering,* vol. 10, no. 3, pp. 1-5, 2021.

[18] W. YU, F. LIANG, X. HE, W. G. HATCHER, C. LU, . J. LIN and X. YANG, "A Survey on the Edge Computing for the Internet of Things," *IEEE Access,* p. 20, 2017.

[19] M. M. Inuwa, "A review on fog computing: Issues, characteristics, challenges, and potential applications," p. 20, 26 February 2023.

[20] S. Z. a. X. C. X. Tang, "Fog Computing for Industrial Internet of Things: A Comprehensive Review., IEEE Access, 2020.

[21] S. Bhattacharjee, Practical Industrial Internet of Things Security: A practitioner's guide to securing connected industries.

[22] L. F. Bittencourt, "The Internet of Things, Fog and Cloud Continuum: Integration and Challenges," p. 71, 2018.

[23] N. M. Abdulkareem, S. R. M. Zeebaree, M. A. M. Sadeeq, D. . M. Ahmed and A. . S. Sami, "IoT and Cloud Computing Issues, Challenges and Opportunities: A Review," *Qubahan Academic Journal,* 2019.