Journal of Advanced Research in Computer Graphics and Multimedia Technology
Volume 11, Print Issue 1 - 2024, Pg. No. 12-17
Peer Reviewed Journal

Review Article

Navigating the Digital Mist: Unravelling in Fog Computing for Educational IOT

Simranjeet Kaur

PCTE Group of Institutes, Baddowal, Ludhiana, Punjab, India.

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E-mail Id:
simranjeetkaur@pcte.edu.in
Orcid Id:
https://orcid.org/0009-0007-8938-9022
How to cite this article:
Kaur S. Navigating the Digital Mist: Unravelling in Fog Computing for Educational IOT. *J Adv Res Comp Graph Multim Tech.* 2024; 11(1): 12-17.

Date of Submission: 2024-03-11
Date of Acceptance: 2024-04-17

ABSTRACT

In the ever-evolving field of education technology, the integration of Fog Computing into the realm of Educational Internet of Things (IoT) has emerged as a promising paradigm, promising enhanced connectivity, storage and real time data processing. This paper embarks on how fog computing technology can help in enhancing the operations of Internet of Things to make it fir and suitable for usage in educational purposes by exploring different hurdles and complexities inherent in this technological convergence. By using this, sensor data processing takes place at the edge devices of the network so that it can reduce the network traffic across the network layers significantly, safeguard the sensitive educational data, optimize computing resources and bandwidth offering a unique perspective on the challenges faced in this dynamic landscape. By extracting insights from case studies and real-world examples, this research illuminates practical scenarios that vividly portray the challenges faced by educators, administrators and technologists alike. The paper goes beyond identification of different fields providing a roadmap for potential solutions incorporating technological advancements, best practices and policy considerations. This study aims at contribution to the ongoing discourse on the intersection of Fog Computing and Educational IoT, offering a unique perspective on the challenges & opportunities faced in this dynamic landscape. As I unravel the complexities within this digital mist, I pave the way for informed decision making, ensuring the seamless integration of Fog Computing technologies into educational IoT.

Keywords: Fog Computing, Cloud Computing, Educational, Internet of Things

Introduction

The term "Fog computing" was first coined by Cisco and refers to the fog which is a cloud close to the ground to the concept of an easily accessible cloud to the edge of a network. Advancement in the field of science has unveiled various opportunities in various sectors such as health care, transportation, education and others. In contemporary times, technologies like AI, IoT, AR and VR have played a great role in enhancing operational efficiencies in various sectors. Apart from that, big data analytics and cloud computing help to store and analyse abundant sets of data and end-to-end encryption allow users various sets of information securely. IoT in recent years has gained huge significance because the features of IoT provide huge ranges of services which also offer a combination of other technologies to render top- notch experiences to the users. Fog computing architecture refers to the architectural experiments that emphasise combining physical and logical network elements for implementing a proper network.

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Despite the highly advanced features of the industrial Internet of Things, these technologies are not self-operable but require assistance from other technologies such as cloud computing, big data analysis, ML and others to process data for operational purposes. Fog is a layer of the distribution network which is highly accessible by the public and fog computing functions as a media which focuses on the requirement of data through cloud computing and the way can be analysed and interpreted locally. The concept of fog computing is heavily focused on increasing the capabilities of cloud computing to the end-side client. Apart from that, fog computing also focuses on offering better storage capacity and accessibility with better computation features. The importance of fog computing is that it offers better communication, and better encryption for end-to-end users as a part of security measurement and increases the network bandwidth which is highly important to equalise the latency sensitivity.

Current Market Study: An Initiative towards Fog Computing

IoT systems with a fog layer can be classified into two parts things layers, fog layers and cloud layers. The things layers refer to the layers which function in the area of generating information and data collection (Adel, 2020., p.7). The things layers contain sensor objects and devices which allow transmitting information through the IoT network to the end users. The fog layers are decentralised nodes that exist in each location where data will be transmitted. This layer focuses on the networks for data transmission and emphasises making sure that data is received by the user. This area focuses on request-response activities and controls data transmission activities to make sure that data is received by end users within time. In the last, the cloud layer focuses on allowing network access to the users conveniently and efficiently to generate user satisfaction across all spheres of the shared network. The cloud layer stage is a pivotal stage which serves as the topmost layer of the overall fog layer (Diao, 2020., p.248).

As the IoT networks use a lot of information to perform their duty, the cloud layer serves as storage of abundant information. The fog nodes are one of the pivotal features of fog computing that serves as the middle layer which serves as a bridge to streamline the inflow and inflow of information. Hence, fog nodes act as a gate to allow encrypted access, and delivery of information by the command of IoT device users. The fog nodes also work as transactional analysis to process data in a compatible way with cloud storage. Apart from assisting the IoT process, it can work as a traffic controller to tackle the overload balance in an automated way to help users for seamless experiences. Hence, this fog computing offers better management control for IoT devices (Patwary et al. 2021., p.10). In the education sector, fog computing is highly exceptional for implementation in educational institutes for access to a greater number of educational information.

Apart from that, sensory features of fog computing allow for building efficient getaways between IoT nodes and cloud computing to ensure better operational activities (Varghese et al. 2020., p.127). Fog computing is highly important to ensure the integration of all platforms related to the educational institutes as well as software to maintain the efficient working of IoT devices in that place.

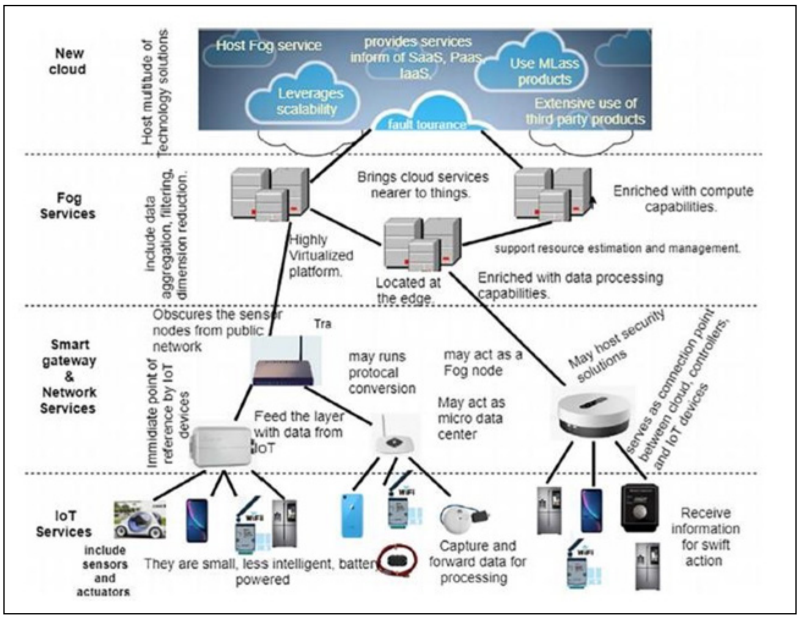

Figure 1.Fog computing service infrastructure

(Source:Adel, 2020.,p.7)

Fog computing is an important part of IoT devices which offer decentralised infrastructure to the devices which offer several activities such as data storage, transforming and modelling data and computation that allows users to obtain information as per command within little to no time. Fog computing functions imitate the capabilities of information technology which allows students trainees as well as teachers immediate access to a large set of information within a quick time (Zhang, 2020., p.630). Apart from that, fog computing helps students find a large set of data by applying a few keywords. It is a part of micro-data which facilities users with important access to information based on given keywords. As a feature of Industry 4.0, the major benefit of fog computing is to display accurate information within a few moments along sources and further suggestions based on the input that is given for educational purposes (Aggarwal & Kumar, 2023).

As educational institutes often rely on pre-determined learning management systems which control data and operations in a way, fog computing can bring important changes within them through understanding the negative aspects embedded within the present learning management system. Besides that, the components of computing help to ensure uniform flow to traffic within the LMS for swift operational activities. Previously, in most cases, handling large databases at any institute such as educational institutes or other places required the services of IT professionals to maintain such databases which may contain confidential data (Dong et al. 2020., p.43). In the case of fog computing, it has become simpler to handle databases for any kind of content retrieval availability through cross-examining the server. Downloading helps to store information within major devices for further usage of educational content at offline mode. But download time is still a major issue and fog computing faces challenges in that area. The implementation of fog nodes is highly important for acquiring data from the cloud server to improve the bandwidth of the network and store the cache of the file. Hence, fog nodes are highly important to improve access speed into the content delivery network or CDN and improve cache efficiencies which will allow educational personnel to make space for CDN (Hua, Guan & Kyriakopoulos, 2020., p.111). Additionally, many educational institutes suffer from the absence of data from educational classes as traditional education is based on word-of-mouth action. Hence, having a consolidated database allows access to more information. Another big issue faced by educational institutes is upholding the privacy of confidential data such as information about the students as well as other kinds of confidential data that require permission (Chang, 2021., p.55). The third issue of the educational system is to maintain authenticity as data originality requires a series of cross- checking through the assistance of tools. Hence, education material verification is a big challenge in the higher education system. To mitigate these issues, data engineering within the fog layer level helps to deal with data collection by using sensors to collect and resize information that is compatible with the industry 4.0-enabled devices.

Fog nodes help to gather large sets of data immediately as nodes enhance network reach (Sabireen & Neelanarayanan, 2021). Apart from that, fog computing helps to address the issue of disconnection and slow delivery of download speed by improving the algorithm mechanism that can track data history where disconnection was performed. After bridging the disruption, the problem of disconnection can be mitigated. As a result, fog computing can improve the architecture of databases by centralising all the information on cloud storage and students can access large et of information within no time which helps them to save time, resources and travel and increase the quality of education for the students.

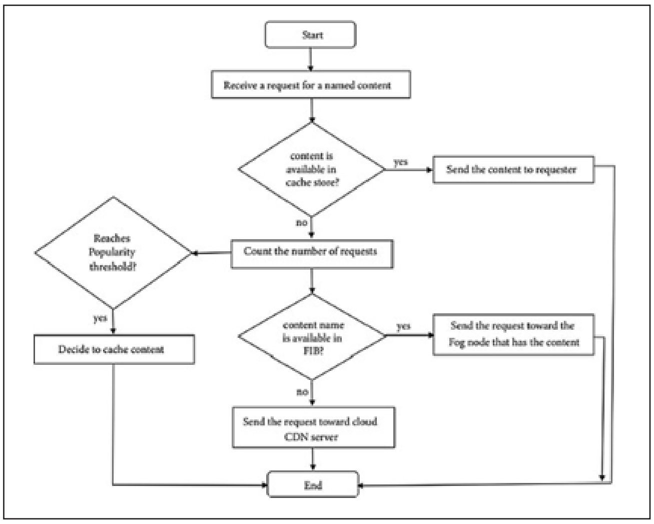

Figure 2.Flow chart of the fog content delivery

(Source: Adel, 2020., p.7)

Comparative Analysis of Traditional Cloud Computing and Fog Computing

Cloud Computing

Cloud Computing refers to a process for the delivery of several services through the Internet, it also includes the data storage of the device, the servers that are generally used for the Internet and the databases of the device. Advanced networking and software are also two components of cloud computing (Alzakholi et al. 2020, p. 45). In this digital era cloud computing has become one of the most useful applications for internet users due to the unlimited storage feature. Cloud computing can help users to have unlimited storage for their data, and it also enables backup support for the users for their valuable data.

Table 1.Features of Cloud Computing

Features	Cloud computing
Cost of Deployment	High
Size	The size of this model is large
Computing model	Centralised computing model
Optimisation of resources	Global
Mobility management	Limited support for device mobility
Location awareness	No
Operation	Limited heterogeneity support
Latency	Communication latency is high
Maintenance	Operated and maintained by the experts
Reliability	Support to computing
Applications	Higher inter-application

(Source: Self-developed)

Cloud computing helps users make the necessary data available anywhere through its effective features. A brief of features of cloud computing has been provided in the above table. The cost of deployment for cloud computing is naturally high for the users. The deployment of fully functional cloud computing requires a significant amount of the cost (Sunyaev & Sunyaev, 2020, p. 200). Apart from this, the model size of this has been large for cloud computing as well. Cloud computing has the ability to optimise the resources on the global stage. The mobility of cloud computing is significantly low for the devices. Cloud computing is unable to provide a location to the users (Atieh, 2021, p. 10). Hence location awareness is low for cloud computing. It has the support of limited heterogeneity for the operations but the communication latency is high. The maintenance of cloud computing generally is done by expert developers, the reliability of this technology is based on the support it provides to computing and it can be used for higher applications.

Fog Computing

It is considered as a decentralized infrastructure of computing that helps to locate data, storage, compute and applications. It is generally conducted between the cloud and the data source. Fog computing, like edge computing, brings the power and advantages of the cloud nearer to the place where data is acted and created upon (Atieh, 2021., p. 10). The below are some of the specific features of fog computing.

Table 2.Features of Fog Computing

Features	Fog Computing
Cost of Deployment	Low
Size	It is of a small size.
Computing Model	It consists of a spatially distributed model.
Optimization of Resources	Local method
Mobility Management	Full support towards device mobility
Location Awareness	Yes
Operation	Full support of device heterogeneity
Latency	Communication latency is low
Maintenance	No or less requirement of human interaction
Reliability	Real-time applications
Applications	Lower inter-application

(Source:Self-developed)

Fog computing requires a very low cost to deploy fog computing. Its small size generates both the accessibility and ease of integrating it in various activities. The spatially distributed model works as a ubiquitous access towards a shared continuum regarding scalable computing resources. This is a virtual, physical or horizontal paradigm of resource that exists between traditional data center or cloud computing and smart end-devices. The local method of resource optimization uses fog environments for the delivery of storage devices and computation and effectively manages decentralized resources. This method of computing generates full support to the mobility devices that consists of high processing power as well as large memory storages (Ning et al. 2020., p. 70). This enables the devices of low processing mobile for running the respective devices of computing. It has a considerable range of location awareness in the formation of geo-distributed nodes.

This is able in inferring its own location and tracking the end user devices for supporting mobility. The computing method generates a considerable range of support towards the heterogeneity of the devices. It is a geographically distributed architecture of computing that has a resource pool. The service deployment of fog computing generates low latency by processing local data in the near real time. This computing method does not need or hardly need any sort of human interaction as it is generally processed by gateways, sensors or devices. It relies on real time applications. It consists of inter-application isolation that is considerably low.

Primary Differences between Cloud Computing and Fog Computing

The comparison is this context has a considerable facet in terms of determining the diverse features of these two computing methods. Cloud computing has a high cost whereas fog computing maintains s a low cost (Al Masarweh et al. 2022., p. 84). The former consists of a considerably large size whereas the latter has a small size. The centralized computing model of cloud computing has the optimization capacity of resources whereas fog computing is spatially distributed model that works as a ubiquitous method. Cloud computing has global optimization resources while fog computing contains a local method. The mobility management supported by cloud computing is limited for supporting the device mobility. Fog computing, on the other hand, caters full support towards device mobility. The former has no location awareness, while the latter has considerable range of location awareness.

Operations through cloud computing are generally limited and it provides heterogeneity support to the users. On the other hand, fog computing also provides heterogeneity support to the users, however, the main difference between these two is cloud computing provides a limited approach and Fog computing provides complete support to the users. The latency of cloud computing is significantly high for the users while the latency for fog computing is significantly low for the users. Moreover, the users also can get significant maintenance support from the expert for cloud computing and on the other hand the maintenance support for the Fog computing does not need any human interaction often. Cloud computing generally provides reliability to computing and on the other hand fog computing supports real-time applications. Application for cloud computing is higher for the users and on the other hand, Fog computing provides a low inter-application for the users.

Open Research Challenges and Future Directions

Fog computing comes with several challenges and issues in the educational sector which can create an impact on the performance of computing.

Authentication

As intellectual property theft has become a bigger issue due to the high rise in the frequency of espionage attacks, hackers can attack cloud databases to steal confidential information related to student, and academic databases and sell them to the black market (Hou & Wang, 2020., p.98). Hence, safeguarding IP through authentic access is a big issue for the implementation of fog computing.

Privacy issues

The fog computing system works with networks and lack of protection will make the network susceptible to malicious attacks which could disclose private information to harbour privacy attacks (Fang et al. 2020., p. 26). Although data-to-data encryption increases safety, lack of protection is always prevalent.

The issue of network management

As fog nodes help to increase the coverage of the network, the main issue lies with managing fog nodes correctly to increase coverage and data transfer rate. Other than this the issues of latency and response time, network slicing and Quality of Service (QoS) and Interoperability and standardization are of major concern.

Operation cost

As IoT devices consume a large amount of energy at this stage, planning regarding energy constraints must be done in a pre-defined manner.

Cost versus usability

The development of IoT is also at the primary stages and devices that servers for building fog computing infrastructure come with a high amount of price which may become inexpensive in future times.

For using a fog commuting system, on latency and reliability of the systems must be assessed to mitigate issues that may require re-planning. Apart from that, a real-time data-driven response system needs more improvement for a better approach towards the educational system.

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