ISSN 2278-3091
Volume 10, No.4, July - August 2021
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse021042021.pdf
https://doi.org/10.30534/ijatcse/2021/021042021

A Review of Fog Computing Architecture and Cloud Computing Architecture

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ABSTRACT

Cloud computing is utilized in today's world in all the applications. The scope of the Cloud is defined from the storage of the data of the mobile devices to storage and manipulation of gigantic amount of data generated from the social and commercial websites like Amazon, Google, Flipkart etc. Hence, the tremendous amount of data is transmitted to/from the Cloud servers at the same time for preprocessing, analysis and backup purposes. This may cause delay in the transfer of data due to the physical distance or network limitations. Hence, an intermediate layer of Fog computing can help to analyze and process the data before it is sent to the Cloud for further processing. Thus, the data received by the Cloud servers are already analyzed and preprocessed that leads to saving in time, improved abilities, establish data transmission capabilities, improved security and reduced latency. Hence, the introduction of Cloud computing and Fog computing as well as their comparative studies are discussed in this review paper. The architectures of both Cloud and Fog computing are presented along with the explanation of working of Fog nodes. Lastly, both the computing technologies are compared based on the parameters viz. latency, architecture, transmission, data processing, connectivity, response time, number of nodes, analysis and security.

Key words: Fog, Cloud, computing, latency, bandwidth.

1. INTRODUCTION

In the last few years, Cloud computing is being used in real-time IoT applications for research purposes. Client can access data from anywhere anytime using this technology. [1] Cloud provides many facilities like to store data, manage those data, handle processing, automatic software integration, easy access of data. But now this data are increasing day by day. As per the Jupiter Research, the number of IoT devices, sensors, and actuators connected together will be over 46 billion that is triple as well as gigantic amount as compared to the existing [3]. That's why to handle this data we need to implement such a technology that can help to preprocess data before reaching the Cloud. For this purpose, Fog computing is a promising technology that helps to improve latency, bandwidth, volumes, security, mobility and the efficiency of communication between IoT device and the Cloud. Hence, in this chapter, the Cloud computing and the Fog computing are discussed in detail. The difference between the architecture of Cloud computing and the architecture of the Fog computing are compared showing the characteristics and benefits of Fog as compared to Cloud. Lastly, two time-sensitive case studies are presented to show the applicability of Fog computing to handle critical situations with lower latency.

2. CLOUD COMPUTING

In Cloud computing technology, numerous devices, computers and servers are connected via the Internet to create a network. Cloud computing provides three different types of services as follows [6]:

- Infrastructure as a service (IaaS):
  For some small companies it's hard to manage data storage and hardware, using this online infrastructure they can use according to their needs and need to pay for it.[5]

- Software as a Service (SaaS):
  This service allows to use and rent software and applications without installing them on user's machine. We can use software and hardware on online platform that's why it's easy to manage. [5]

- Platform as a Service (PaaS):
  A platform is given to user on which they can upload their work. User can deploy their code on this platform and can program software on this too. [5]

2.1 Architecture of Cloud computing

As shown in figure 1, Cloud architecture is having two layers. One is Cloud server and another is IoT devices means

hardware level. IoT devices can be mobile, laptops, routers, computers, sensors which can pass data to the Cloud. A Cloud server is having different data centers where all these data can be stored. They are having good processors to process and store the data.

IoT devices are connected with the Internet and they send information to the Cloud to process the data. Now the Cloud is having much data to process so this process will take some time to review the data and to give a response back. However, a longer response time and unnecessary delays are observed in Cloud computing due to overwhelming data, physical distance and network related issues. When data and its analysis as well as decision making are time-sensitive, this may cause issues or life threating incidents in the domain like healthcare. Majorly, the problems occur because of the time delay that increases the latency and hence, the communication performance may be degraded.

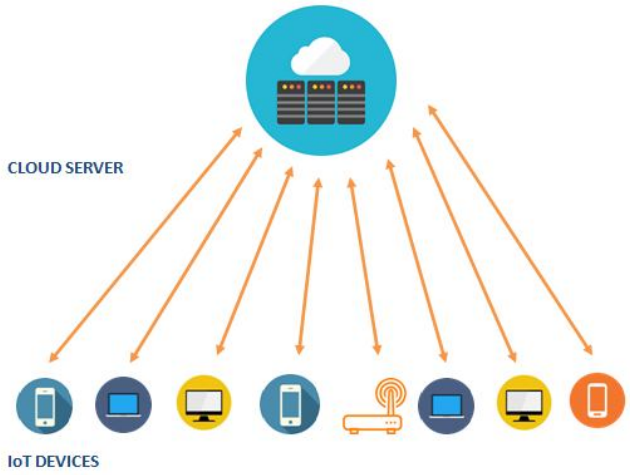

Figure 1: Cloud Architecture

For example, different IoT devices are deployed on the Cloud. Now different IoT devices send data to Cloud for data storage and future analysis. IoT devices have constraints on bandwidth, processing, memory and energy. Cloud can handle processing but it cannot handle bandwidth, energy and memory limitations of the devices. In this case, lots of data will be there in between Cloud and IoT devices leading to tremendous communications going to happen in between Cloud and IoT devices. That will consume bandwidth and energy. To reduce the unnecessary delays in communication and for faster communication and processing of the data, the Fog computing technology is developed as discussed in next section [6].

3. FOG COMPUTING

CISCO has introduced the name Fog computing. The purpose of Fog computing is to bring Cloud closer to IoT devices. Thus, the Fog computing is presented with an aim to solve the problems faced by the Cloud computing, especially in transfer and management of the data. Fog technology stands between Cloud and IoT devices.

3.1 Architecture of Fog computing

The Cloud and IoT devices are main part of Cloud architecture. IoT devices sends data to the Cloud and then getting a response back or getting the data back from the Cloud if it is required for further actuation of whatever details. This is the only way through which IoT devices and Cloud can communicate with each other. Hence, an alternate way or approach is required for this communication of Cloud and IoT devices. So we want essentially something like this so traditionally we had Cloud and now we are talking about Fog architecture which is inside the Cloud architecture.

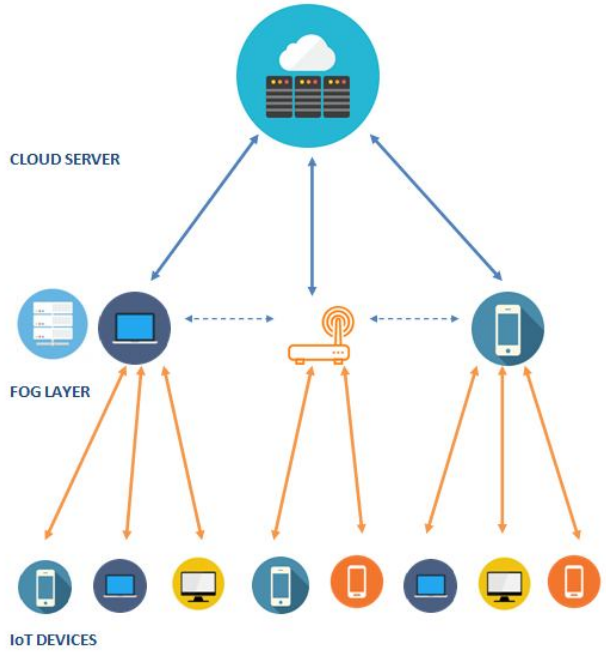

Figure 2: Fog Architecture

As shown in figure 2, we have these different IoT devices and data being sent and response received either response or even the data can be fetched. The Cloud would take care of the processing the data plus storing the data. Processing could even include things like running different analytics right. This is the traditional model now the problem over here is that latency means it takes much time to transfer data from IoT device to Cloud and then data need to process over data and give response back to IoT devices. So, this generates huge delay during this process. Fog will have the Cloud we will have the Fog layer. Here Cloud and Fog very closer to the IoT devices. Some of the data are going to be processed at the Fog layer and some of the data would be sent to the Cloud directly to be processed and stored. In some cases, we need to have computations only in that Fog. In some cases, you know some basic processing will be done in the Fog and other data would be sent to the Cloud.

3.2 Fog nodes

Fog nodes can be routers, computers, embedded servers, switches, video surveillance cameras, etc. which can be developed anywhere inside the network. Each Fog node has its aggregate Fog node.

3.2.1 Characteristics:

There are three main characteristics of Fog nodes: Storage, Network connectivity and computing facility.

- Data Storage
  Fog computing provides temporary data storage to client to process the data.
- Faster computing
  It transfers data to Fog and data is processed at Fog level. It takes quick actions for most time sensitive data and responds back as fast it can.
- Establishing Network
  IoT devices can easily connect with different Fog nodes and Clouds using internet.

3.2.2Working of Fog nodes

These types are based on time sensitivity. There are three types of data: Most time-sensitive data, less time-sensitive data and data which are not time-sensitive.

- Most time-sensitive data
  Data which should be analyzed within factions of a second.
  Data is analyzed at the nearest node only.

- Less time sensitive data
  Data which can be processes and analyzed in seconds or minutes.
  Data are sent to cluster of nodes for analysis.

- Data which are not time sensitive
  Data which can be wait for hours, days, years.
  Data are directly sent to Cloud for analysis and storage.

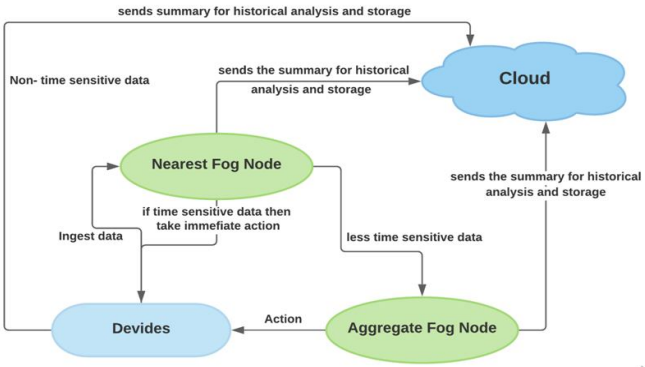

Figure 3: working of Fog nodes

As shown in figure 3, diagram is having IoT devices which communicate with Fog nodes and Fog nodes communicate with Cloud. Now for different time sensitivity of data the flow of data works differently. For most time sensitive data, IoT device sends data to closest Fog node. Closest Fog node process the data immediately and responds back to IoT device and then sends data to Cloud for future analysis and storage. For Less time sensitive data, IoT device sends data to closest Fog node and closest Fog node sends data to cluster of Fog nodes. That processes the data and give according actions to IoT devices and sends data for future analysis and storage. For non-sensitive data, data will send to Cloud for further processing and storage.

3.2.3 Advantages of Fog

The advantages of Fog computing are as follows [7,8,11]:

- Security
  Provides better security than Cloud.

- Latency
  The unwanted accidents that are going to happen if the IoT devices are implemented in some safety critical platforms like industry where there is industrial safety a prime concern in such case such it is required to process fast. Latency will be reducing during decision making. Using Fog computing quick decisions can be taken.

- Mobility support
  Nodes can be mobile, laptop, computer, routers and these nodes can connect and disconnect the network at any time.

- Privacy of data
  It is preferable for industries to analyze their own data locally and store the confidential data in this Fog approach in the local servers and only those data that can be shared with the others and not very confidential can be sent to the Cloud.

- Data handling
  Bandwidth will be consumed for handling the data. Data can be analyzed locally and that would reduce the risk of latency.

- Business agility
  Fog applications can be easily developed according to tools available. It can be deployed anywhere we needed and programmed according the customer's needs. That way the costumer's satisfaction can be improved supporting nobility here in this Fog model.

- Bandwidth
  Data are preprocessed and analyzed in the Fog nodes before sending to the Cloud so that way the

bandwidth is also reduced. Most important is that faster response time quickly the actions that are determine through the analysis can be executed in this kind of model.

- Deployment in remote places
  Fog platforms can be deployed in remote places and they can be subjected to harsh environmental conditions. Different types of harsh environmental conditions snow fall, rain fall hill storm, under sea, railway tracks, vehicles, factory, etc.

3.2.4 Challenges

Despite various advantages offered by the Fog computing, the challenges of using it are as follows [8, 9, 10]:

- Data security
  The nodes which are generating data are distributed. An authentication and authorization of whole system nodes is difficult.
- Power consumption
  Fog uses additional nodes. Power consumption is higher than the centralized Cloud and these are low power devices we are talking about and everything is done at the Cloud so that is the reason why power consumption has to be taken care of.
- Reliability
  It's hard to maintain data availability and integrity for each node. If one node fails it's not gone harm the whole system.
- Fault tolerance
  In case any node is failed that needs to be get fixed immediately.
- Real-time analysis
  For minimizing latency real-time analysis is must require. By using dynamic analysis, we can reduce danger and increases output. Analyze the huge number of nodes is quite difficult.
- Programming architecture
  Fog nodes can be mobile, routers, computers, laptops, etc. These Fog nodes can connect and disconnect the network according to requirements.

4. COMPARISON

The comparison of both the Cloud and Fog computing based on different parameters are given in table 1for a better understanding of both technologies [2][10].

Table 1: Comparison of Cloud computing and Fog computing

Parameters	**Cloud computing**	**Fog computing**
Latency	High	Low
Architecture	Centralized	Distributed
Transmission	Device to Cloud	Device to Device
Data processing	Far from source to destination	Close from source to destination
Connectivity	Internet	Various protocols and standards
Response time	High	Low
Number of nodes	Few	Large
Analysis	Long	Short
Security	Lower	Higher

5. CASE STUDY

Fog computing is preferable for implementation instead of Cloud computing to increase latency, bandwidth and security of the application.

The effectiveness of fog computing over Cloud computing is observed in the healthcare domain [11]. In healthcare domain, it's used to alert and emergency management where alert notifications are generated in case of any emergency. This can be helpful while giving emergency notification to victim's family too. In mobile system, application fog captures user and mosquito sensor data and it is beneficial for quick identification of any newly infected use or risk site. This system is useful for monitoring of patients suffering from chronic diseases and other health services. By monitoring this kind of patients, it collects data and can be used for future analysis where fog will aggregate and analyze data collected by edge devices and distribute processing tasks to edge devices. Dynamic distribution and scheduling of health tasks is also possible using fog computing. Fog performs computation tasks to reduce application delay and costs [12].

Fog computing is also helpful in vehicular transport system in different ways [12]. In intelligent transportation system, vehicular fog computing is used. By using fog computing, two vehicles can communicate with each other through automation system. This is helpful to improve traffic efficiency and road safety in cities. It also reduces energy consumptions. Using fog, vehicles can be informed about traffic status instantly and redirect to other roads instantly. Traffic lights and signals both can be handled as per the traffic situations using fog. Fog gives real time communication to transfer data and take quick actions. It can also get information of public transport systems that can track live location and get arrival and departure time for users.

6. CONCLUSION

Fog computing is a subset of Cloud computing. It is an intermediate layer between IoT devices and the Cloud layer to help IoT applications in the different ways. It gives solutions to the primary problem that is faced by the Cloud while handling IoT data (specifically time-sensitive) as it reduces the overall latency. This is one of the most promising and important benefits of the use of Fog technology. The benefits can be extended from an individual person to the huge organizations by means of Fog technology. Thus, this technology provides a real-time analysis and monitoring. So, the use of Fog in Cloud computing is preferable for improved latency, bandwidth, security, volume and privacy.

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