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Review Article

IOT ENABLED CLOUD BASED HEALTHCARE SYSTEM USING FOG COMPUTING: A CASE STUDY

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Abstract
Fog computing or fog network is designed to support distributed and decentralized computing platform by reducing the burden on cloud computing. Using IoT infrastructure many devices are connected to the fog network to send and receive data. The three layers of fog network are used to sense the data from the IoT devices, to process the data and finally to present the data in the application layer. There are many applications of fog computing such as e-commerce, mobile services, mobile networks, agriculture, smart buildings, self-driven auto mobiles, smart grids and cities, healthcare and image processing etc. This paper gives overview of the fog architecture, hierarchy of different layers, applications, challenges and research directions. A better IoT enabled cloud based healthcare system using fog computing model is discussed in this paper to assist patients in an efficient manner.

Key Words: Fog Computing, Cloud Computing, Healthcare, Internet of Things

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INTRODUCTION

Fog computing is treated as an extension of cloud computing. It is aplatform of heterogeneous and decentralized devices to form edge of the network. Fogging or for network is used to provide and handle various services to the devices using cloud service provider to support and provide IoT infrastructure. The objective of fog computing is to assist with cloud computing to reduce the burden of processing. This computing infrastructure provides automation of real time devices to support data analytics by using automation controller. The main advantages of fog computing platform are: reduced latency, decentralization of computing resources and decreased usage of resources [1].

ARCHITECTURE OF FOG COMPUTING

Architecture

The architecture of fog computing environment is shown in the following figure 1. There are mainly three components in this namely cloud computing environment, fog network and IoT. Various devices with unique identification numbers are connected via network to send and receive data with machine to machine interaction. There exist a variety of devices which are connected by using IoT such as computing devices, digital devices, mechanical devices etc. The second module is fog network in which there are three layers. There is a layer in fog network which is given direct access to the devices connected in IoT. The data of heterogeneous devices in IoT platform is taken by sensing network of fog network. This data is being analyzed by edge computing nodes. Intermediate computing nodes network is used to interact with the cloud computing environment to access and deliver the requested services. Cloud computing environment contains number of data centers to satisfy the demands of the consumers. This computing model has many advantages like elasticity, availability, privacy, security, low cost model, demand driven and reliability [2].

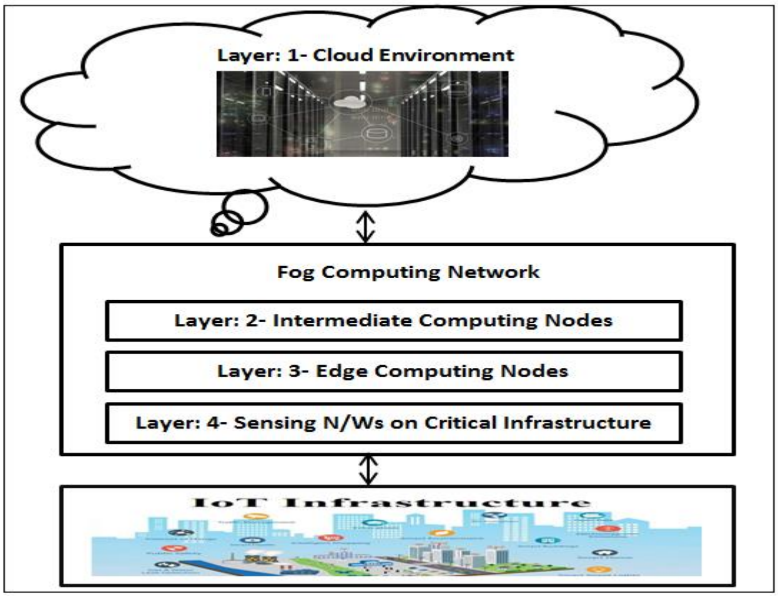

Figure 1: Architecture of Fog computing environment

Hierarchy
The hierarchy of fog network is shown in the figure 2. The first layer in the hierarchy is fog sensing or IoT plane which contains two layers datalink and physical. The second layer in the hierarchy is fog middleware or communication and networking plane which contains two layers transport and network. The third layer in the hierarchy is fog server or fog plane which contains two layers business and application.

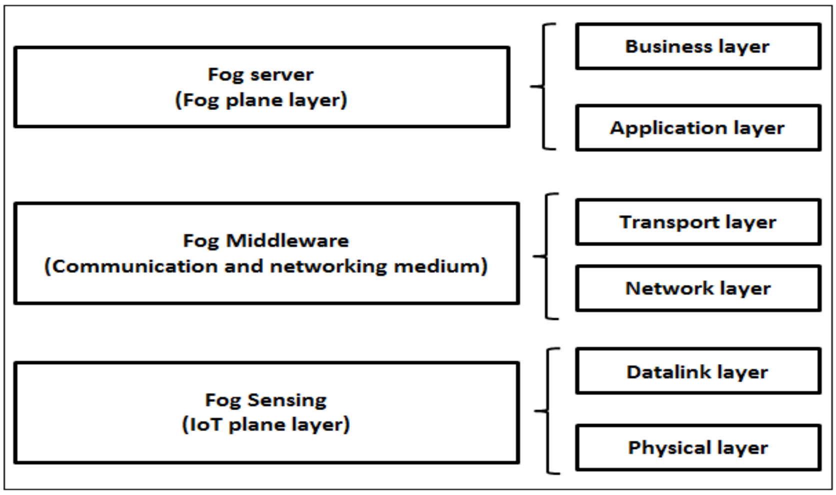

Figure 2: Hierarchy of fog network

Challenges of fog computing
The challenges of the fog computing environment can be listed in an abstract way as shown below [3-5]

Privacy
Fog network is a wireless network of heterogeneous systems (fog nods) in a decentralized and distributed computing environment. Since the data is being transferred between these fog nodes, privacy preservation of this sensitive data is important. Necessary care should be taken such that it can be accessed only by the end users of that service.

Security
Fog computing allows many devices to be connected in a distributed environment via gateways. There is a possibility to hack these fog nodes which gives rise to security issues in fog network.

Energy consumption
Lot of research is happening to reduce the energy consumption of fog nodes present in the fog environment. IoT platform generates lot of data and processing of this massive data is being happening in fog network and this is resulting high energy consumption.

Cost
To deliver the services based on the demand, fog computing platform is providing number of servers. By making use of these servers the big data analytics is being performed efficiently and effectively to meet the consumer demands. In this regard, to maintain number of fog servers maintenance cost may increase invariably.

Authentication
Since many heterogeneous devices through IoT platform are connected to the fog network, large scale data processing and service offering may cause scalability problems. To maintain high scalable services this platform requires robust infrastructure.

Flexibility
Service providers of cloud or internet and sometimes fog users are also service providers of fog computing. Due to this flexibility present in the fog network the architecture of fog computing may become complex.

Applications of fog computing
The world is revolving around data, to get connected with the data fog computing offers various services. These services include storage like storage and processing of data, network facilities, computing power and decision making capabilities [6-8]. Due to these advantages, fog computing infrastructure is having many applications as shown below:

Smart buildings
In inspect the progress of various operations in construction and management of smart buildings, fog computing or edge computing technique is been widely used. Various sensors which are deployed for this purpose are monitored regularly to identify and execute necessary actions. Building monitoring such as lighting control, water control, electricity control and many more activities are initiated by using this network.

Self-driven automobiles
Self-driven automobiles produces lot of data, using which real time traffic has to be estimated and driving decision command has to be given through the fog nodes. Quick data collection, data analysis and processing are possible due to the concept of connected vehicles.

Smart grids and cities
Both remote data and real time data from various sensors is collected due intelligent infrastructure of smart grids and smart cities. To efficiently make use of various resources to achieve sustainable environment, edge computing developed the concept of smart grids and smart cities.

Big data analytics
The data transfer is made easy with the fog computing environment. Real time analytics such as manufacturing may produce overload on cloud computing environment. Fogging allows collecting big data from numerous sensors and analyzed to take immediate actions.

Healthcare
Various health monitoring systems are been used in healthcare enabled by fog network. Real time prediction to handle various patients based on their data patient information system is made possible by using fog network. Various devices such as wearables, sensors and equipment are used to record patient information. Many IoT enabled wireless wearable devices are used for health record analysis to take necessary actions. In real world, such devices become a part of

edge computing to monitor health records of various patients [9-10].

Agriculture

Best management strategies are achieved in agriculture by using satellite data. In precision agriculture, the data is collected, processed and analyzed with the help of GPS or any other global tracking system to measure various parameters required for agriculture. In smart agriculture, all farming activities are being traced and managed by using IoT technology to analyze crop growth. These two approaches in agriculture are made possible by using fog computing paradigm.

Enhanced quality in mobile services and networks

5G mobile services and emerging applications in mobile services can be implemented by using fog computing environment. In mobile and wireless networks the technologies like SDN and virtualization enables the users to get services with higher capacity bandwidth and quality.

Comparison between cloud computing and fog computing

The comparison of cloud computing and fog computing can be illustrated as shown in the following table 1 [11].

Table 1: Comparison between cloud and fog

Parameter	Cloud computing	Fog computing
Latency	Usually high	Comparatively low
Service response time	In minutes	In milliseconds
Processing	Now and then	In a dedicated place
Service's location	In cloud data center	In edge network
Space between user and server	Multiple hops	Single hop
Architecture	Centralized	Distributed
Service mobility	Limited	Highly mobile in nature
Number of server nodes	Limited	Large in nature
Real time interaction	Supports	Supports
Network delay in packet spacing	Relatively high	Less
Awareness of location	No	Yes
Security	Relatively less	High
Privacy	Relatively less	High
Attack on network	Relatively high probability	Less probability

Security threats and solutions of fog computing

As we have mentioned in hierarchy of the fog computing there are three layers in it namely sensing layer, middleware and fog server. Security threats and solutions in each hierarchy of edge network are shown in figures 3,4 and 5.

Fog application layer	
• Security Threats	• Solution
• Node capture	• Authorization
• Device tampering	• Cryptography
• Spoofing	• Steganography
• Signal jam	• Image processing
• Malicious data	• Spread spectrum
• Denial of Service	• Jamming report
• Node outage	• Error correcting
• Reply attack	• Collision detection
• SYBIL attack	

Figure 3: Fog application layer security threats and solutions

Fog middleware layer	
• Selective forwarding	• TSL/SSL protocols
• SYBIL attack	• Ipsec protocols
• Blackhole attack	• Firewall
• Wormhole	• Link layer encryption
• Hello-food attack	• Auth broadcast
• Acknowledge flooding	• Multipath routing
• Heterogeneity	• Identity verification
• Data disclosure	• Packet authentication
	• Password management
	• Periodic change of password

Figure 4: Fog middleware layer security threats and solutions

Fog sensing layer	
• Sniffer/Loggers	• Safe programming testing
• Phishing attack	• Antivirus software
• Injection	• Cache development
• Session hijacking	• Data verification
• DDoS	• Access control
• Node identification	• Selective disclosure
• Information privacy	• Session inspection
• Social engineering	• Boundary inspection
	• Data encryption

Figure 5: Fog sensing layer security threats and solutions

Future directions of fog computing
The future directions of the fog computing can be listed as shown below [12].

Security
In fog computing, many devices are connected and globally distributed over the network. Some of the IoT devices are malicious and it is very difficult to identify such devices and to avoid security problems.

Limitations of sensing layer: All network connections which are made using IEE.802.15.4 is not highly secure. Lot of research is under progress to increase the secure communications using this standard.

Hardware limitations: Hardware limitations such as adding low cost machines (Analog to digital) may have limited restricted range of access.

Data routing and processing in IoT: The devices present in IoT can send and receive the data. Data routing and processing from these devices can be improved.

Communication limitations: The infrastructure can be improved to avoid the limitations of the communication and makes the process faster.

Data privacy protection: The data is collected from the IoT devices and guaranteed security mechanisms are to be used to improve data privacy

Protocols to protect fog systems: There are many protocols which are sued by the fog systems and the research is happening to improve the performance of the protocols.

Improvement of DTLS to protect CoAP communications: There is a need of improvements of DTLS to protect CoAP communications in fog computing environment to improve the efficiency.

Efficient task scheduling model in fog computing
The scheduling models in cloud computing enables the platform to schedule the incoming tasks efficiently to reduce the processing time and cost. In literature many scheduling algorithms are proposed to achieve better quality of service. All submitted tasks are kept in queue, based on online mode the tasks are been scheduled by using objective functions. These algorithms can be used in fog computing environment to immediately handle and process the client requests by using efficient resource allocation policies [13-17].

IoT enabled cloud based healthcare system using fog computing-a case study
Proposed model
IoT enabled cloud based healthcare system using fog computing is shown in figure 6. It has four modules namely client module, data filtering module, data processing module and event handler module. IoT enabled healthcare device is connected with the client module using sensors. The device has a direct connect with the client module. The raw data is being collected by the client module and is sent to the data filtering module. The data is filtered by the filtering module and the filtered data is sent to data processing module. The data is processed by the processing module and is sent to event handler module. Based on the processed data, the event handler module raises an appropriate event and the respective response is sent to client module. Actuator is responsible to take respective action.

Advantages
Using this infrastructure, large scale IoT based healthcare and monitoring devices can be operated efficiently. The health record of a patient can be monitored in a real time basis and immediate decisions and actions can be taken. Under different climatic conditions, seasons, living place and patient condition the fog network enables to process the data and predictions are forecasted beforehand [18-21]. The research is in progress to improve the healthcare services in IoT enabled network using fog computing.

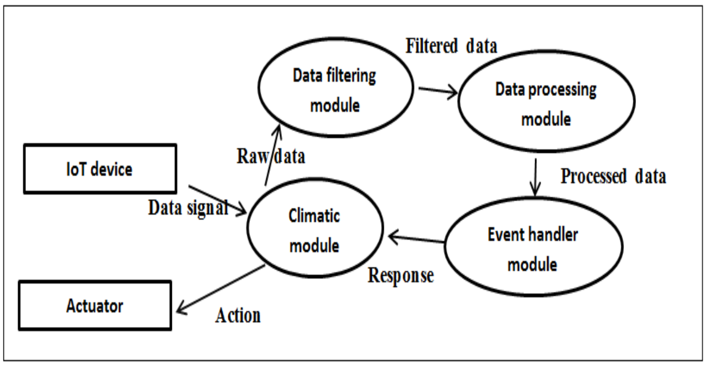

Figure 6: IoT enabled cloud based healthcare system using fog computing

CONCLUSIONS AND FUTURE WORK

Fog computing or edge computing is a computing platform to process the requests now and then within the edge/ fog nodes. Due to this response time of the fog network is typically in milliseconds. The services are highly mobile in nature and supports real time applications by supporting IoT efficient task scheduling. In this paper we have discussed about fog architecture and hierarchy in different layers, fog applications, challenges and research directions. A better IoT enabled cloud based healthcare system using fog computing model is discussed in this paper to improve the medical services in the healthcare. In future, the model can be implemented and results can be published to prove the proposed hypothesis.

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