A Review Paper on Fog Computing Paradigm to solve Problems and Challenges during Integration of Cloud with IoT.

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Abstract. In Today's world technologies such as Internet of Things, Cloud Computing as well as Fog Computing are growing at an exponential rate which depend upon each other directly or indirectly. The Internet of Things can be described as a network of substantial matter such as cars, washing machines, refrigerator which can interact with each other through internet. Billions of devices will be IoT enabled in near future and generate enormous amount of data but IoT devices has some limitations like storage capabilities, processing capabilities and utilization of resources which can only be handled by integrating it with cloud technology. Cloud model provide environment in which software, Infrastructure, sharable pool of configurable resources, virtual environment, sensors, hardware and database is provided as a utility for IoT devices and users. In cloud computing paradigm some limitations exist for example distance of the data source from multi-hop, geological unified structure, latency, heterogeneity and many more. To address such limitations, Fog computing approach can be used to bring computing assets nearer to IoT devices. Fog computing is an enhancement of the cloud-based Network and computing services. It provides computational and storage services of cloud proximate to IoT devices. This paper provides an overview regarding the cloud computing uses in IoT devices and issues or problems that occur during integration. Handling of problems that occurs during integration of cloud with IoT can be done through fog computing. The purpose of this survey is to understand the concept of fog computing to improve the existing system of Integration of Cloud with IoT

Keywords: Fog, nodes, Cloud Computing, Internet of Things, reliability, latency, heterogeneity

1. INTRODUCTION

This can be very significant to integrate IoT with Cloud as counting of IOT devices increasing rapidly and by 2020 various devices will be IoT enabled .In such scenario massive quantity of data will be produced by these devices and can only be stocked up or manipulated in a Cloud .It is extensively approved that utilization of Cloud computing is to be utilized for efficacy utilities in the upcoming time [1].This Cloud creates environment in which it provide software services, hardware
Cloud provides services which can be sharable on the internet. On another side, Internet of things is a association of substantial items that communicate with each other over internet but these devices have limited storage and computational capabilities [3]. This paper provides overview of integration of cloud with IoT devices where cloud can also provide sensors as a service in sensor-cloud framework for IoT devices. Open issues or challenges which can be occur during integration of these two technologies and proposed Fog framework to overcome these issues or challenges are also describe in this paper. Organization of remaining paper can be given as: Section - II depicts fundamental perceptions of Cloud computing, IoT as well as IoT which is based on Cloud paradigm. III Section depicts Literature survey. Section IV talk about the significance of integrating cloud with IoT. Section V discusses problems or challenges occurred during integration. Section VI discusses the implementation of fog in IoT. Section VII discusses proposed framework of FOG computing to overcome these issues. Section VIII compare cloud computing and fog computing in IoT infrastructure Section IX discusses future scope and conclusion and X section include references.

1. Basic Concepts

Basic concepts such as Cloud Computing, IoT, Sensor cloud, fog Computing are explained in this section.

A. **Cloud Computing**: Cloud Computing provide computing as a utility such as hardware resources, memory, workstations, processor. According to NIST Cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [7] compared to internet. Internet of things is an association of corporeal items which comprises of entrenched technology expertise for communication as well as sense or interact with external environment in which they are operating. Sensors and Actuators are the two basic building blocks of internet of things where sensor senses the physical environment like lighting conditions, temperature; humidity and passed information over network or cloud. Based on sensed information actuator perform action. In today world there are various IoT applications such as Structural health, Noise urban maps, Traffic congestion, Water flow, Smart roads and more.

Essential building blocks for IOT devices are given as:

(i)**Sensors**: They perform some input function by sensing or feeling physical changes in the environment or characteristics of system in response to stimuli such as heat is converted into electrical signals in temperature sensor and pressure is converted into electrical signals in Barometer.

(ii)**Actuators**: Actuator is mechanism by which control system act on environment. It requires control signal along with source of energy, and after getting control signal it responds by switching energy into mechanical motion. Various actuators can be used by IoT devices such as hydraulic actuators, pneumatic actuators, electrical actuators, thermal/magnetic actuators.

B. **Cloud based IoT**: IoT is a ubiquitous technology through which normal physical objects can also be able to connect with internet and communicates. But the main problem is that there will be lot of IoT devices which in turn generate lots of data and these devices have limited storage and computational capabilities [5]. Cloud based IOT means that model which helps IoT devices to fetch data and send data to cloud for storing and computation. Sensor cloud is an example of cloud based IoT in which sensor as a service (Se-aaS) provided to IoT devices. sensor cloud integration comprises of virtualization of sensor nodes due to which virtual instances of physical sensors are created on cloud.

C. **Fog computing**: This term invented by CISCO. Fog computing was initiated to broaden cloud closer to IoT devices for solving problems faced by cloud for data processing. By 2020, approximately 50 billion of devices shall be online and presently billions of devices bring into being enormous data every day. Device compactness is still escalating every day and present cloud computing representation is not capable to process that data. Another problem of latency is also unhandled by the cloud sometime. If time sensitive data is propelled through IoT devices to cloud and then there is a waiting situation for appropriate act so that afterwards it may direct to numerous of useless consequences. Fog can be seen as an intermediary layer connecting Cloud and IoT devices.
2. LITERATURE SURVEY

Renta et al. [12] describe the procedure for the storage of data that is received through distributed IoT devices to remote cloud. In this paper it is discussed that IoT devices are enabled to collect user data in real time through data management system. Cloud computing processed data in a faster way so those users subscribed to IoT devices get notification quickly. System also runs alert services on the basis of previous health policy. Chen et al. [13] describe the safety measures of medical data sharing through cloudlet. A model is developed for reliable destination such as hospitals, doctors etc. Data is divided into three different parts to accumulate within cloud. This system of detection of Intrusion works effectively to prevent malicious attacks in the whole process. Zhang et al [14] introduced one new patient – centric cyber physical system which is termed Health-CPS which mainly depends upon cloud computing and data analytics. Peddi et al. [15] suggests an e-health care system of calorie calculation on mobile which is based on cloud platform. In this system diverse food substance are classified out of the meal to calculate the overall calorie. These systems incorporate offloading mechanism from mobile application to cloud. In cloud system, there is a broker entity which employs dynamic memory allocation schemes to manage resources effectively. Muhammad et al [16] introduced Healthcare solution on the basis of IoT – Cloud technology for the monitoring of the user’s voice pathology. This solution proposes incorporate pathology detection system which applies binary pattern onto voice signal all the way through Mel spectrum technique. To conduct efficient pathology classifier based on machine learning is used. Author describe that connotation of cloud computing with IoT devices shows an improvement in the precision as well as ease of access of Healthcare solution. Gupta et al [17] discusses the IoT based on Cloud–empowered physical and corporeal activity investigation prototypical for the different users. The proposed model contains the entrenched sensors, Cloud computing and Web services of XML for quick as well as trustworthy communication. These model alert user for abnormal physical activity. Hosssain et al. in [18] discuss the impact of Health Industrial IoT for scrutinizing real time health concerns of matured people. In this paper proposed context gathers data of ECG via smart phones as well as sensors. Data collected will be sent to cloud through which it can be accessed through doctors effortlessly. Ahmad et al [19] projected a new Healthcare framework grounded on Fog which operate as an intermediary stratum in between cloud and IoT devices. This framework ensure confidentiality of data and its security along with Cloud Access security broker (CASB). This proposed structure also proficient of aggregate data from distributed sources and cryptographic evaluation. Dubey et al [20] suggested service leaning architecture of Fog computing to appraise sensed data related to raw health with the help of IoT devices. Various illustrations identify important patterns from health-related data and store those on cloud for its storage as well as processing. The foremost objective of this work is to draw attention to processing of big data with fog computing resources with low power.

3. SIGNIFICANCE OF INTEGRATING CLOUD WITH IOT

In today world IoT devices are increasing rapidly but there are some limitations like storage, computation, privacy, reliability, scalability, interoperability. Cloud technology can help IoT devices to overcome these issues. In Cloud model user of IoT devices can rent server, software, data center space of network equipment and cloud service provider offer resource management, PaaS, SaaS, database as a service and many more in response. There are some Essential characteristics of Cloud which provides benefits to IoT devices and are given as follows:

(i) Scalability and elasticity: Cloud provides dynamic scaling and large amount of resource allocation can be released in very short time period without any variation in system performance whether scale in or out.

(ii) Manageability and interoperability: In Cloud model client have total control of virtualized infrastructure resources and pre-configured facility for allocation of virtualized resources.

(iii) Availability and reliability: Stored data can be retrieved at any time without any failure and uninterrupted facility for computation and communication.

(iv) Performance and optimization: High utilization of physical resources among different clients and enable high computing power with large pool of physical resources using parallel processing.

(v) Real time communication: Data sharing and various applications are the two main components of cloud based IoT and applications that may be transmitted through IoT devices [7].
(vi) **Storage**: IOT devices are increasing at a very fast rate and generate enormous amount of data that is either structured or semi structured but due to limited storage capabilities they must be required to operate in Cloud environment [8].

(vii) **Computing or processing capabilities**: IoT devices have limited capability of processing the data and to achieve scalability they need some kind of infrastructure. On the other hand, Cloud provides unlimited virtual processing and on-demand model.[9]

(viii) **Models offering services**: In cloud computing there are various models used for providing services to IoT devices on-demand and are given as follows:

• EaaS (Ethernet as a Service) In the described mode cloud endow with omnipresent connectivity to their clients.

• SAaaS (Sensing and Actuation as a Service) that makes sensing and actuation service available online by creating virtual instance of physical sensors on cloud.

• IPMaaS (Identity and Policy Management as a Service), that makes strategy available to identify that the user which are accessing the cloud is authentic.

• DBaaS (Database as a Service) In Cloud computing there is huge capacity of storing data and provide DB as a service to their users.

• SEaaS (Sensor Event as a Service), this provides services of messaging available which are produced by events of sensor.

• SenaaS (Sensor as a Service), such service supervises the sensors located remotely.

• DaaS (Data as a Service), this makes everywhere access and acceptance of any form of data

The well-known architecture of IoT is having three layers which are first application, next perception and then network layer. Mostly presume that available network layer in architecture of IoT is the Cloud layer, that become conscious about the architecture of Cloud-based IoT, as illustrated within Figure 1[29].

![Figure 1: Cloud Based IoT architecture](image)

4. **PROBLEMS AND CHALLENGES OCCUR DURING INTEGRATION OF CLOUD WITH IOT DEVICES**

(i) **Authorization**: In Cloud based IOT lots of data can be transferred from real world to the cloud, but one important issue that need focus of many researchers that there must be some policies or authorization rules which ensure that only authorized user is permitted to access sensitive data generated by IoT devices [10]. Some other challenges like malware analysis, Distributed denial of service attack, Quality of service, session hijacking, virtual machine hacking need special focus of researchers.
(ii) Heterogeneity:
Cloud model is mainly found insufficient to handle many heterogeneous devices; Cloud services have proprietary interface and allow sharable pool of resources to their users or IoT devices based on cloud service provider[10]. On the other hand IoT uses different type of devices which are made by different vendors and made by different specifications, not follow common standard; One device uses one protocol and another devices uses another protocol, therefore handling or processing of data generated by these IoT devices by a Cloud is a big challenge for researchers.

(iii) Data processing or Latency:
By 2020 billion of devices will be connected to internet. IoT devices are heterogeneous and generate enormous amount of data in terms of volume, velocity and variety which cannot be processed by today Cloud model in a specified time period. Suppose in a "Smart car accident detection system" car automatically send signals generated by a device named accelerometer and other GPS sensor to the Cloud [6]. Time sensitive data is sent through IoT devices to cloud for its investigation and after that these devices stay for the proper action to be performed by the cloud.

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\text{Latency time} = \text{Time taken from device to cloud} + \text{Time for analysis of data} + \text{Time from cloud to device}. 
\]

If latency will be increased then accident may have already occurred in above detection system.

(iv) Data Filtering:
As we already discussed that lots of data will be generated by IoT devices in future and current cloud model unable to processed or store all data, it means data need to be filtered. Data can be divided on the basis of sensitivity and are listed as follows:

Time sensitive data: In smart health care system immediate response of cloud to IoT device is required for the treatment of patient sometimes, otherwise patient would be died.

Less time sensitive data: In smart health care system immediate response of cloud to IoT device is not urgently required when patient is not in critical condition.

Non - time sensitive data: In smart health care system there may be a possibility where patient condition is ok and just going under treatment for personal satisfaction.

It is a big issue which require attention of many researchers that how to identify the data which is time sensitive when it comes to real time approach.

(v) Operation Reliability:
The data which is generated by IoT devices is utilized to give solution of real time problems. It is meant that data integrity along with its accessibility should be sure, data unobtainability as well as altering may be risky.

(vi) Big data:
According to data analytics it has been predicted that by upcoming years Big data will reach approximately 50 billion devices. This is very essential that focusing on transportation, processing and storage of enormous amount of data that will be produced. It is very well-known fact that IoT is a core source of big data but Cloud framework is the only way to store this data over long period of time. Application whole performance is heavily depending upon characteristics of data management service. It is very big issue to manage massive amount of data.

5. IMPLEMENTATION OF FOG IN IOT
Implementation of fog computing paradigm in IoT shows in the Figure 2, example of fog network example has shown in the Figure 2 that is required to be implemented for building a smart city. The data which is received from peer nodes as well as lower-level nodes, fog nodes is required that much capability of its proceeding for doing various tasks. In the given figure fog nodes nearer to end devices uses cumulative data delivered via IoT devices for its transfer to the central fog node whose position is within a building or street. Fog nodes are accountable for controlling as well as managing scalability and extendibility of various IoT devices for various tasks whose requirement is low latency like biometric system, anti-collision system in train.
However, requirement of some processes is proportion of computational resource that cannot be processed by a single fog node as well as on cloud. Augmented reality is a prime example of such application which requires lot of computational resource and outcomes prerequisite is delivered in real time. Fog nodes require peer to peer connection in such situation.

6. PROPOSED FRAMEWORK OF FOG COMPUTING TO OVERCOME ISSUES

Fog computing as well as fogging both these terms are anticipated by CISCO and the awareness that was provided is the expansion of cloud more closely to IoT devices. Solving the problems is the principal aim of Fog computing that are faced by the cloud for data handling out. This is an intermediary between cloud & IoT devices. In real time scenario lots of data is generated by IoT devices which can be divided on the basis of time sensitivity as explained above. Sometimes cloud take too much time to respond to IoT devices due to which unwanted results may occur, the most important question arise that can we reduce this latency. By the end of 2020, 40% of the data of whole world will arrive from sensors, 90% from the overall data of world were produced firstly throughout the span of last 2 years. Overall expenses on IoT devices will be approximately 1.7$ trillion. Current cloud model’s ability is not that sufficient to grip the necessities of IoT devices. Billions of devices consuming bandwidth, if all devices become online, facilities to all the IoT devices will not be provided even by IPv6. To handle variety, volume, and velocity of IoT data upgraded model of computing is required to solve problems such as latency, network bandwidth, security issues, secure data across wide geographical areas under different environmental conditions [11]. Fog computing model requires when data need to be analysed within fraction of second, huge number of IoT devices, devices are separated by a large geographical distance, devices are needed to be subjected to extreme conditions

Fog and Cloud differ from each other in various parameters such as resource capacity, capability, bandwidth etc. Cloud based IoT Health care solution loose interoperability as soon as these are projected to dwell in fog. A cluster-based fog architecture has been proposed in [21] by Redowan Mahmud, Fernando Luiz Koch, Rajkumar Buyyah. In the cluster-based fog architecture (Figure 2) multiple nodes form cluster at similar or different fog level. Some nodes in the cluster execute application like healthcare and other manage database. Each cluster is dependable for meticulous health care solution. In this architecture all inter and intra node communication are handled by cluster head node. In this structural design individually a fog node may receive health related data through various linked node. On every occasion when node receive data from cluster, it checks importance of data and forward it to cluster head node.

Fog computing provide distributed environment for computing and networking amenities amid IoT devices as well as conventional cloud computing. In fog environment various omnipresent as well as distributed devices are proficient of performing various jobs independent way without any third-party intervention. It is a type of computing which can outspread its amenities provided through cloud data centers at IoT devices of the network. This environment can facilitate to store data within cloud data
centers as well as IoT devices. There are various applications which are based on fog computing framework and are listed as follows:

1. Health care:
A system assisted by fog computing was proposed and named as FAST in CaO [22]. The objective of this system was to monitor fall condition for stroke patient in real time. In this paper set of algorithms for fall detection using data such as measurement of acceleration, methods for time series analysis, algorithms for noise reduction were proposed.

2. Augmented reality:
Some applications which are grounded on the basis of augmented reality will not tolerate sometimes small amount of delay or latency in response as it can damage user experience. Augmented brain Computer interaction game was the proposal of Zao [23] which was on the basis on fog computing.

3. Caching and pre-processing:
Performance of website improves by usage of fog servers where user establishes a connection with internet via fog boxes and each user’s HTTP request is sent through fog devices [24]. Fog devices loading request on user page and perform many optimizations. Some techniques for saving the time like caching HTML components, organizing the configuration of web pages which helps in reducing the size of components in web.

![Generalized cluster-based fog architecture](image)

**Figure 3** Generalized cluster-based fog architecture [28]

According to this architecture fog computing explore new features which are given in **Table 1**.[28]

| Facts                      | Fog cluster | Cloud data center |
|----------------------------|-------------|-------------------|
| Alliance                   | Easy        | Tough             |
| Number of servers          | High        | Few               |
| nodes or servers inclusion | Flexible    | Tough             |
| contiguity to source of data (hop) | One/two   | Multi             |
| Topographical symmetry     | Dispersed   | Centralized       |
| Real time interaction      | Possible    | Hard              |
| Tolerance catastrophe      | High        | Low               |
| Link of Communication      | Adjustable  | Static            |
| Power usage                | Fewer       | High              |
| Preservation of Management | Simple      | Complex           |
| Subject to under /over provision | Less       | Higher            |
| Configuration              | Adjustable  | Rigid             |
| Cost                       | Low         | High              |

**Table -1**: Enhanced Feature of proposed Fog system
Fog and Cloud Computing Comparison in IoT Infrastructure are given in Table 2.

| Areas                  | Cloud                                                                 | Fog                                                                 |
|------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------|
| Computing Model and its location | In small data center it is centralized                               | It is very nearer to the user and distributed along large geographical areas. Controlling of nodes and system can be carried out by centralized node / distributed manner. |
| Size                   | Size of cloud data center is very high as compared to fog node and it contain thousands of servers. | Every fog node is comparable to single server machine and this is designed to meet the user demands |
| Deployment             | Exceptional and well-defined planning is required                     | Common of these don’t necessitate forceful planning, depends on the environment |
| Operation              | This is operated in fully controlled environment and exert teams are required for operation. | It is operated according to the demand of user. It can be operated by a company of any size and operate in an environment. |
| Network requirements   | Client need to connect with proper network while waiting for the user who want to access its services. Bandwidth prerequisite increases as overall quantity of data is increased which is generated by all clients. | Uninterrupted network services can be provided as it can operate autonomously within intermittent network connectivity. |

Table-2: Comparison of Cloud and Fog Computing in IoT infrastructure

7. ARCHITECTURE

Fog layer is proposed or designed amid of cloud as well as IoT devices and layered architecture of fog is given in figure 4. Arrangement of fog nodes is done in a distributed manner in ordered different fog levels. This node may be outfitted using memory, processing as well as storage space and bandwidth of network. The fog nodes at lower level which are very nearer to IoT devices and propose interface for associated applications. These nodes commonly known as application gateway nodes which sense health data and promote it to upper fog nodes. Resources can be virtualized as well as shared in the structure of Micro computing instances (MCI)
Working of Fog: Fog nodes work as per the type of data received by them and which can be decided by fog nodes on the basis of time sensitivity. In fog model data which is generated by various IoT devices transmitted to the fog node which can be router, switch or gateway. If data is Time sensitive then fog node processed it and revert response back to IoT device. If data is non time sensitive then IoT devices send the summary of data to the cloud for historical analysis and storage. If data is less time sensitive then fog node transmitted it to aggregate fog node which send the data summary for historical analysis along with storage to cloud. The whole process of working of fog model is given in figure 5.

Figure 5: Flow diagram of working of Fog model

8. FUTURE SCOPE AND CONCLUSION

Fog computing is an advanced variety of Cloud computing and with the help of fog model unwanted accidents can be reduced, latency can be decreased at some stage in decision making, enhanced privacy as all industry can analyze their specific data in the vicinity and accumulate secret and private data in its local servers, local server propel individually those data that is sharable with cloud. Fog computing model may be used in various applications such as Real time health analysis, Real time rail monitoring, pipeline optimization. In pipeline optimization gas as well as oils can be elated all the way through pipelines which require real time vigilance of pressure, flow and compressor. In this optimization terabyte of data is created and distribution fall such data to cloud for its scrutiny as well as storage space is not sufficient, latency of network will not be tolerable, which means that fog model will be the only way out.

In future the main problem that can arise on which many researchers would wish to work that how fog node be able to identify the data generated by IoT devices is time-sensitive or not. Various machine learning techniques can be applied in future at data generated by IoT devices to classify
according to its sensitivity. Researchers can make policies or offloading algorithms to store or processed time sensitive data at fog layer and non-time sensitive data at cloud layer.

The counting of IoT devices is increasing day by day at a very fast rate due to which large volume and variety of data is generated, but IoT devices has a restricted storage space and processing capabilities because of which integration of cloud is very essential for smooth functioning of IoT devices. In this paper, we presented significance of integrating cloud with IoT devices. Although fog computing is emphasized in this paper. In future work various machine learning techniques such as Naïve Bayes, SVM Classifier or deep learning techniques such as LSTM classifier, gated recurrent neural network classifier can be carried out at fog layer to predict real time data to classify the data according to time sensitivity so that all data which is produced by IoT devices not required be storing or processing at cloud layer.

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