A TRANSITION IN PROCESSING IOT DATA FROM REMOTE DATA CENTERS TO EDGE DEVICES

[1]Samreenfayaz,[2]ZahoorAhmadNajar
[1]MtechStudent,[2]Assistantprofessor
[1]Department of IT Central University of Kashmir
[2]Department of IT Central University of Kashmir, J&K, India

ABSTRACT

This paper describes the concept of cloud computing and how traditionally, it has been used for operating Internet of Things (IoT) data. But most of the IoT applications claims to have real-time reaction which cannot be attained through Cloud Computing mainly because of inherent latency. Fog Computing figures this problem by providing cloud-like services at the edge of the network. The computationally potent edge devices have put up with to discover this idea. Evidencing the exponential rise of IoT applications, Fog Computing deserves an in-depth exploration. The motive of Fog cloud is to perform low-latency computation/aggregation on the data while routing it to the central cloud for heavy computations. This paper displays the requirement for Fog Computing for processing IoT data. Readers will be able to achieve a fair comprehension of the various aspects of Fog Computing. The benefits, challenges and applications of Fog Computing with respect to IoT have been discussed. An architecture for IoT data processing is demonstrated. A thorough comparison between Cloud and Fog has been depicted. Also, an intricate discussion has been depicted on how the IoT, Fog, and Cloud interact among them.

Index Terms – Fog computing , IoT(internet of things), QoS(quality of service), WSN

I. INTRODUCTION

Cloud computing is a service delivery model based on Internet for providing on-demand access to the shared pool of computing resources (software/hardware). In the computing world, cloud computing evolves to provide everything-as-a-service based on pay per usage. It allows the consumers to concentrate on their primary objectives rather than worrying about their computing infrastructure requirements because infrastructure requirements of the cloud users are fulfilled by the cloud service provider. Cloud computing has emerged as a large scale distributed computing paradigm that provides the situation that services can be dynamically delivered and configured on demand [1]. Cloud computing has some featured goals, according to the National Institute of Standards and Technology (NIST) “Cloud computing is a model for enabling 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. This cloud computing model promotes availability and scalability and is composed of five essential characteristics, three service models, and four deployment models” [2].On-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service are some of the essential characteristics of cloud computing [3]. The main goal of cloud computing is the better use of distributed resources and use them to achieve a higher performance, throughput, and solving large scale computing problems. Mostly speaking, on the bases of NIST definition of cloud computing we can say that best use of available shared resources with best effort for offering the on demand services is one of the most important goals of this model. Cloud computing and storage solutions provide users and enterprises with various capabilities to store and process their data in third-party data centre’s. [1] It depends on sharing of resources to acquire coherence and economy of scale over a network. Due to the advantages like cheap cost of services, high performance high computing power, scalability, accessibility and availability cloud computing has become demanded.

Fog computing is a term created by Cisco that refers to extending cloud computing to the edge of an enterprise's network. Also known as edge computing or fogging, fog computing facilitates the operation of compute, storage, and networking services between end devices and cloud computing data centers. While edge computing is typically referred to the location where services are instantiated, fog computing implies distribution of the communication, computation, and storage resources and services on or close to devices and systems in the control of end-users.[4,5]The Fog architecture may either be centralized or distributed. Else, it can be a combination of both. In centralized architecture, every Fog node works under a central node. Managing a centralized Fog is easy but when the number of connected device increases it becomes a challenge. In a distributed architecture, Fog devices interact in a P2P fashion. The processing loads are shared across multiple Fog devices. Each Fog node communicates to each other for several purposes (e.g. job distribution, self-organization, peer discovery etc.)Fog computing is a medium weight and intermediate level of computing power. Rather than a substitute, it often serves as a complement to cloud computing. National Institute of Standards and Technology released a definition of fog computing as Conceptual Model, that defines fog computing as a horizontal, physical or virtual resource paradigm that resides between smart end-devices and traditional cloud computing or data center.[6] This paradigm supports vertically-isolated, latency-sensitive applications by providing ubiquitous, scalable, layered, federated, and distributed computing, storage, and network connectivity. Thus fog computing is most distinguished by distance from the edge. As per the theoretical model of fog computing, nodes are physically and functionally operative between edge nodes and centralized cloud.[7]Fog computing is also considered to be more energy efficient as compared to cloud computing.[8]when Cloud descends to the ground, it is named as Fog. Similarly, when the computation has been shifted from remote Cloud to the system that is close to the data source is termed as Fog Computing. Cisco used Fog computing for representing edge computing in which the processing is done at the devices that reside at the edge of the network. The edge devices include routers, switches, Wi-Fi access points, set-top-boxes, base stations etc. These devices no longer are used merely for data transfer but they are incorporating significant capacity of computing and storage. So, the computing jobs, which otherwise had to be carried to some remote Cloud set-up, can be accomplished locally. This minimizes the processing time and in turn the response time. This is beneficial especially for those applications that demand real-time response. And as services are hosted locally and close to the end-users, it caters the users better, thus improving the QoS significantly.

Internet of Things (IoT) is the network of physical things, connected together to share data among themselves and other computing devices. The 'things' may be sensors, automobile, kitchen appliances, electronic devices, building, elevator or other devices. These interconnected 'things' collect and exchange data to share their state information. With an application of intelligent middleware, 'things' will be transformed into intelligent entities thereby blending the physical and virtual world together making the machine and human interactions very personalized. According to IBM : The IoT is expected to make the physical world every bit as easy to search, utilize, and engage with as the virtual world [9]. The sole objective of IoT is automation and monitoring, automating every activity which involves digital interventions.

In terms of practical realization, IoT applications in real time produce huge data within a time lag of fraction of second as a constant stream. To process the data, further, it requires high-speed data processing in continuum for data analysis to find the valuable insights. This puts a lot of strain on traditional private data centre's owns by individual businesses in terms of network load management, centralized high data storage, processing, scalability etc

Typically, IoT devices are attributed to very limited computation and storage capacity. To get over this limitation, Cloud Computing has been the most favored platform for processing IoT data, which provides on-demand and scalable resources for computing and storage. The sensor data are transported to the Cloud data centre, where they are processed, and the outcome is sent to the subscribed applications. Furthermore, the datacenters may store the IoT data, if necessary for analysis to extract further knowledge which helps in business decision making. The Cloud platform has become popular for IoT data processing mainly because of economic reason. By opting Cloud Computing, organizations have freed themselves from the hassle of establishing their own computing setup and maintenance. But as we are heading towards the smart world for a smart living, uses of sensors and wireless networks locally has been on the rise, and the data generated locally is increasingly consumed locally [10].In other words, instead of at the remote centralized Cloud data centre, the data gravity is shifting more and more towards the neighboring to the data source or, formally what we call, the edge of the network. For these applications, it is extremely crucial to be facilitated by low and predictable communication latency for real-time interaction, location awareness, and support for mobility and large-scale networks [9]. The traditional Cloud Computing architecture lacks in these aspects. IoT requires a different computing architecture that enables distributed processing of IoT data with mobility support and quick response whenever and wherever wanted. Fog Computing perfectly befits this scenario. Fog Computing is particularly suited for applications that demand real-time response with predictable and minimal latency [9]. The edge devices such as set-top-boxes, access points, routers, switches, base stations etc. are becoming ever more powerful in terms of computing, storage and networking. Hence, they are being considered as capable candidates to perform computational jobs. Considering that, Fog Computing can play a big role in processing the huge amount of data generated from billions of distributed IoT sensors. Fog Computing is not to replace the Cloud Computing rather it augments Cloud Computing by extending its services to the edge of the network. Principally, both Cloud and Fog serve the end users by providing data, computing resource, storage, and application services. But Fog is differentiated from the Cloud with respect to its proximity to the source and sink, its distribution irrespective of the geography and last but not the least its support for mobility [11]. In the case of Cloud-based IoT data processing, every single bit of data would have to be shipped to the data centre. When the size of data to be processed grows enormously (and that is the exact case of IoT), it becomes very expensive to move them around. Since in Fog Computing data are being processed locally, the burden of transporting these data is lessened. The processed data are sent to the Cloud only if they are to be stored for further analysis and historical purposes. Also, since the data are processed very close to the source, the end-user service becomes very prompt which is very crucial for maintaining QoS in real-time and machine-to-machine (M2M) applications. Handling services in the Fog provide better user experience and more efficient and effective applications of IoT data. The other half of paper describes various scenarios as section2 describes operation of IoT data in cloud. Section 3 discusses operation of IoT data in Fog. Section 4 shows comparison of cloud and Fog. Section 5 explains the issues with traditional paradigm.Section6 discusses about dealings among Things ,Fog ,Cloud. Section 6 describes the conclusion.

II. OPERATION OF IOT DATA IN THE CLOUD

Typically, IoT devices are attributed with very limited computation and storage capacity and as a reason, Cloud Computing is there as a choice of platform for processing IoT data for quite a long time. IoT produces huge data and needs huge storage and real-time processing. Comprehending the current contextual situation of ‘things’ by analyzing the present and past data is inherently complex. The current contextual information or the data insight may help in decision making to take current action and future predictions. The objective of Cloud Computing is to establish a high-performance scalable virtual system with enormous data capacity and virtually capable of serving all type of processing jobs. This environment gives facility to all business enterprises and start-ups in revolutionarily cost reduction for what being spent on putting up computing infrastructure like private data centres. These two technologies are completely different, where IoT act a platform and Cloud as a service. Though these technologies are conceptually independent still they are complementary to each other. IoT generates huge data, where Cloud provides a way for these data to reach their destination (storage, processing – data analytics).Even though Cloud-based IoT model is a suitable solution, the deployment of IoT application has many challenges originated from economic consideration, social concern, technical limitation and administrative issues. In this perspective, Cloud Computing is a possible solution, offering IoT-based applications the advantage of huge data storage and computational power to process out the complex computation and other software services in dynamic, scalable and virtualized manner at a very low cost[12] .The mechanism for IoT data processing through Cloud is straightforward. Cloud linked to wireless sensor node (WSN) through gateways (Cloud gateway and sensor gateway) incorporated at both ends of the link. These gateways would allow data collection, aggregation and flow management. The sensor gateway collects the huge data streamed from sensors, compresses it and sends it to Cloud gateway. Whereas the Cloud gateway further decompresses the sensor data and store it in large Cloud storage servers [12]. There are several advantages of Cloud-IoT model, which had earned this model reputation in all respects. The advantages are described as follows [12]:

Scalability: The large routing architecture of Cloud model allows the IoT-based application to scale up in the Cloud as the need for new computing resources and services arises. This enables existing IoT-based application to scale up to large sizes based on new requirements without having to invest heavily in the new resources added.

Increased Data and Processing Power: Cloud provides enormous storage facility and processing power. Organizations can keep IoT sensor data easily in the Cloud without the hassle of creating its own private data storage. The huge processing power helps to process big complex data for the large-scale application.

Collaboration: Cloud enables huge IoT data stored in storage server to be shared among different IoT application and group of users.

Multi-Tenancy: The multi-tenancy attribute of Cloud allows instances of IoT applications toshare the same service infrastructure of Cloud in a varying manner. Further, Cloud allows integrating several services (Infrastructure, platform and software) from different service providers available on Clouds and Internet to meet the tailor-made demand of the user.

Flexibility: Cloud provides flexibility to support IoT applications to scale up based on the business requirement and IoT-based application development and other required services through Cloud's customizable software services. The Cloud flexibility can be realized in terms of scalability, storage option, control choice and security. Scalability allows Cloud to support dynamic workload of IoT. Whereas storage option gives flexibility of choice to store data based on business model into private, public or hybrid storage. Cloud gives the flexibility on how the IoT application get controlled by Cloud[13].

Agility of Services: By accommodating changing business demands Cloud allows rapid application development, testing and deployment. In this perspective, IoT can gain access to more resources (expensive hardware and software/applications) very rapidly as well as relinquish them to Cloud when the task finishes. The Cloud agility thus efficiently allows IoT applications to adapt to the rapidly changing business need and policies in a very cost-effective manner [14].

Analysis: The huge scalable processing power of Cloud and other data processing services available make data analysis job easy. This makes Cloud very attractive for various kinds of data analysis jobs over the accumulated sensor data to get valuable data insight into the future decision making.

Dynamic Provisioning of Services: Cloud provides varying services which allows processing the relevant information dynamically whenever and wherever they are needed. The API available in Cloud for various services enables the IoT applications to communicate with the data source. Cloud maintains 99.99% uptime, making its services available practically to anywhere and anytime as long as the IoT's have Internet connection [22].

Resource Optimization: IoT Cloud model enables resource optimization by enabling resources (infrastructure, platform and software) sharing among several numbers of application. This reduces the cost of operation and gains in the service quality. The IoT and cloud model is benefited to all size of organization- small, medium or big by the concept of resource sharing based on requirement and pay for use scheme thus optimizes the resource use.

Visualization: The Cloud provides tools (visualization API) that help to visualize sensor data pattern in terms of the diagram and allows applying statistics to predict the future data pattern.

III. OPERATION OF IOT DATA IN THE FOG

IoT produces an enormous amount of data. To maintain the quality regarding real-time data processing, probably Cloud is not the best solution for IoT. It is very clear that IoT needs a different kind of architecture which addresses the IoT's latency and mobility issues. In this regard, Fog Computing architecture typically suits IoT data processing. Fog has extended Cloud Computing, bringing it closer to IoTs. The computing services which have been upheld by the Cloud will be carried out locally by numerous other computational devices near IoTs. Network devices like routers, switch, modem and other control devices have a good amount of processing speed and memory. These devices can act as data processing unit for IoT's, thereby offloading data processing burden from the Cloud. These Fog devices, capable of producing and processing IoT data,are termed as Fog nodes. nodes. The Fog nodes may include a range of devices having the processing and storage nodes. The Fog nodes may include a range of devices having the processing and storage capacity like industrial controllers, set-top boxes, switches, routres ,embedded servers and video surveillance cameras etc.These devices can be resource-poor machines suchas set-top-boxes, access points, switches or resource-rich machine such as Cloudlet [15].Based on the business policies and application requirement (like real-time application) decisions are taken on where Fog nodes are to be deployed. In practice Fog nodes are kept on the network edges close to the 'things', to reduce latencies.

Even though Fog and Cloud are conceptually and technically different, Fog is merely an extension of Cloud in terms of data processing and control specificity. Fog is the virtualizations of Cloud making 'things' assume it as Cloud. Fog Computing incorporates virtualization to 'things' therefore introduces a new layer of abstraction to computing .This makes user/'things' concern-free, where the data is going and where it is stored. To the end-user, the abstraction blurs the distinction between the Fog and the Cloud. Fog Computing evolved from the research experience of many other similar computing paradigms, and do "balance" well the centralization and decentralization issues of IoT computing. In this view, the architecture on how IoT data is processed is significant.
Fog provides data service to IoT data, the data service include:
Data Filtering: Removing noisy data and other irrelevant data and thus separating the data of interest.

Segregation: Since Fog allows a multi-tenancy model, multiple IoT application shares the same resources. Segregating involves distinctly identifying and separating which data belong to which application

Aggregation: Aggregation involves collecting or gathering the same application data over a time span to get the data insight.

Data Encryption: To maintain privacy and security parameters, plain raw data obtained from the sensor/ 'things' are encrypted.

Caching: Fog provides enough amount of storage space, this allows data to be stored near user rather at a remote/distance data centre.
Fog is a natural extension to the Cloud, where both are interdependent on each other. Fog connected to Cloud can take the advantage of the highly capable services and application tools of the Cloud. Fog collects and aggregates data for Cloud. Fog sent the relevant/critical information to the Cloud for further processing and storage. Fog pre-process the data before it is sent to Cloud.

Some key characteristics of Fog Computing have been identified as follows [16]:

Processing Close to the Source: Because Fog devices are placed nearby to the IoT devices (within the same local network , in case of on-campus),the IoT data is processed close to the source.

Proximity to End-Users: The Fog devices are not only close to the IoT devices, they are close to the end users as well.

Faster Response: Since the data do not have to travel longer for processing and the effect is delivered to the nearby entities, rendering quick response is achievable.

Location Aware: Since the Fog devices are deployed locally (close to the sensing devices) and in small scale, they are location aware.

Support for Mobility: A majority of the IoT devices are mobile. Fog supports this mobility by having the Fog devices also mobile.

Massive in Size: As the number of IoT devices, distributed over wide geospace, is growing enormously the Fog end-points also run in billions.

Predominantly Wireless Communication: Wireless communication is predominant in connecting the IoT devices with the Fog nodes which makes the Fog architecture flexible and ubiquitous.

Support for Real-Time and Interactive Application: Fog applications, generally, are intended for real-time interactions although batch processing applications can also be well carried by Fog.

Support for Online Data Analytic: Fog not only can process real-time data, it can also have the capability for online data analytics.

Support for Heterogeneous Devices: Ideally Fog architecture supports various heterogeneous IoT devices. Also, the Fog devices themselves are heterogeneous.

IV. COMPARISON BETWEEN CLOUD AND FOG

The major differences between Cloud Computing and Fog Computing can be tabulated as follows:

	CLOUD	FOG
Architecture	Centralized	Distributed
Communication with devices	From a distance	Directly from the edge
Data processing	Far from the source of information	Close to the source of information
Computing capabilities	Higher	Lower
Number of node	Few	Very large
Analysis	Long-term	Short-term
Latency	High	Low
Connectivity	Internet	Various protocols and standards
Security	Lower	Higher

Table: comparison between cloud and fog

V. ISSUES WITH THE TRADITIONAL PARADIGM

IoT-based applications and associated sensors produce huge data. For large-scale IoT application or the expanding ones, the increase in sensor numbers causes data blast. The increasing rate of data would consume a lot of Cloud storage space and may cost high to organizations. Besides, the overwhelming data relaying toward Cloud put tremendous pressure on the network. This led to network latency and thus delays.

Among all the data which IoT produces, some are useful and need storing while others not. A faulty

Sensor may produce wrong information or data and thus floods the network with it. This raises the question whether it is necessary to send all the data to cloud, if not how to check the data before sending it?

To control and balance the data flow and address the intrinsic issues of IoT, a platform is needed in between 'things' and Cloud. The platform would retain the characteristics of Cloud-like flexibility and agility and provide a virtualized Cloud environment to 'things'. Local devices having the properties of high-speed processing and memory can be used to check the data flow that is needed to be sent to the Cloud[17]. Cisco came up with a new technology called Fog Computing, where local devices have some of the data processing capacity which reduces the network latency by not sending everything to the Cloud. Fog Computing has been introduced as a practical and efficient solution to fulfil the need of IoT [18].

The characteristic features of IoT which necessitate the use of Fog Computing are given below[19]:

The Huge Volume of Data: The magnitude of data produced by trillions of devices or 'things' connected to the Internet is astronomical. Managing and transferring this voluminous data to Cloud can incur issues like bandwidth consumption, network congestion and latency. In automation process, all the data need not necessarily be sent to the cloud for processing but can be processed and analyzed locally, near the source of the event with only relevant information is sent to the cloud.

Geo-Distribution and Need of Cooperation: IoT applications are evolving and its applications have been widespread globally across different domains like Industrial production, mining, traffic management, building and home automation, elevators, transportation and logistics, retails market etc. The rise of IoT applications has increased the use of sensors or IoT nodes globally in trillions. The sensor has limited resources need a platform which can manage and control the different IoT application and further maintaining consistency.

Latency Minimization: As the distance between data/event source and processing platform widens, the network latency also increases IoT application based on real-time systems are stringent to network latency for less than a fraction of millisecond increase in network latency may lose the instantaneous interaction requirement of the user or other applications. This issue can be eliminated by processing data at the network edge, removing the need of sending data to a distant location (Cloud). Processing data close or locally to the data source or user would eliminate network latency.

High-Mobility Applications: Mobile IoT application requires sensing, processing, and analyzing data on transit or move. For example, the driverless automatic car produces huge sensory data at the very high speed and demand instant decision making. Application of Cloud to wirelessly acquire and process the huge and high velocity data is far beyond the effectiveness of cloud. These types of mobile IoT applications demand virtual Cloud kind of service on the move which can process data and make a decision with or without Internet connectivity (in absence of Cloud).

Security Issues: Security issues are the prevailing concerns for all Internet-based applications. The security vulnerability of data increases with multiple hops. As the data crosses multiple network nodes and goes away from the user, of data corruption, cyber-attack etc. also increase. Thus, it is necessary that data processing should be carried out as close as possible to the user to prevent the chances cyber-attack. Computing on the network edge close to the data source can evade of the security vulnerabilities.

Scalability: Another characteristic of IoT-based application is scalability. With changing and expanding Business requirement, the number of devices or 'things' connected to the Internet may increase. With growing number of IoT application, the IoT network widens horizontally. The increasing sensors or 'things' demands software updates regularly to support data encryption/decryption and communication protocols. It becomes quite unrealistic for Cloud to take care of each node and manage them. Thus, it is necessary for a new architecture which would locally and closely manage the scalability factor of IoT.

DRIVING FORCE

In the last couple of decades, the price per unit memory and processing cycle has drastically fallen. The rapid advancement in memory and processing capacity reflects a huge improvement in performance .In comparison, networking technology lags in improvement in terms of computing and storage price performance. Sensor, processors and storage memory are seeming to evolve very rapidly than the increase in network bandwidth [9].

Today with IoT technology becoming a practical reality, billions of unlike devices including PCs, tabs, mobile devices, IP camera, elevator, cars, health devices, kitchen appliances, entertainment units, thermostat and others like building, industry and machinery, business sectors, etc. are all connected to the Internet to communicate and share data. Cisco estimated that by 2020, 50 billion devices will be connected to Internet [20]. The estimated data consumed globally around a day is in hundreds of exabytes .Devices producing an overwhelming wave of data on Internet has outpaced the network bandwidth. The rate at which data produced incapacitate the network infrastructure and may lead to stall the network service. The increasing number of sensors and data processing units has escalated the data production and consumption rate exponentially. It is estimated that AT&T network communicates 200petabytes a year in 2010, US smart grid produces 1000petabytes of data each year, US Library of Congress generates about 2.4petabytes of data a month and Google communicates about 1petabyte each month [19].

In Cloud-IoT model, sensors produce huge data and consume most of the bandwidth causing significant network latency. The sense of automation which IoT brings based on real-time event detection, processing, and decision making may not be realized if the network latency is high. The data feed on sensor all the way to Cloud and then the processed output back to actuation can take a long-time due to heterogeneous and multi-hop network structure. This may loosen the actual necessity of real-time data processing. To fasten up the data processing Cisco believed that instead of sending all the data to Cloud at a far distance, it can analyze and processed near the source of data so that real-time effect can be gained [9]. Fog Computing is an extension to Cloud Computing which allows data processing and analyses locally at the edge of the network much closer to the source of data. It is not worth sending all the data to the Cloud but the delay tolerant ones to maintain the load balance over the network. Much of the IoT data computing need to be performed locally in real time in the areas of mining, disaster management, etc. which elevates the need for Fog.

To summarize, the critical technical factors which act as driving forces advocating Fog Computing for future IoT-based computing are [9]:

- Increasing use IoT device
- Production of Cumbersome volume of data
- Network Latency
- Reliable (zero downtime) network communication
- Localized data processing

Benefits of Fog Computing Over Cloud

Fog Computing,in comparison to its contemporary technologies, provides real advantages to what is a need for IoT to work effectively. The Fog Computing advantages are [19]:

- Real-time processing.
- Homogeneous support to all varying kind and make of IoT device.
- Support rapid scalability.
- Secure IoT data while in transit from network edge to Cloud using sophisticated encryption algorithm.
- Rapid development and deploy of Fog applications.
- Fog Computing provides a pool of resources locally, near IoT.
- Fog Computing can balance the network load and computing by taking a decision where to best analyse the sensor data. Based on time sensitivity, privacy requirement and business policies, Fog Computing can decide whether sensor data need to be stored locally or on Cloud.
- Fog Computing automatically controls and manages IoT nodes dispersed geographically apart [21].

VI. DEALINGS AMONG THINGS, FOG, AND THE CLOUD

Fog is an extension of Cloud, prevailing data processing in a continuum ranging from network edges to core of the Internet. It basically bridges the gap between the Cloud and the 'things' bringing the services closer to the consumer. Since Fog resides on the edge of the network, it is advantageous to IoT in terms of locality-based computation, low bandwidth consumption and near-to-zero network latency, and flexible management and control of 'things'. Fog has its own limitation too, as a reason all the data are not analyzed in Fog some is sent to Cloud for further analytics and storage. To get over the limitation of Fog, the assistance of Cloud services is taken into consideration. The selection of Cloud and Fog is not binary. These two technologies together make mutually beneficial and interdependent continuum. Fog devices over a network, for the same IoT application or different, may collaborate with each other for data intelligence and sharing resources like processing power and memory. The architecture of IoT application decides "who does what and what time scale" [10]. Basically, three kinds of interactions are found in an IoT-Fog-Cloud model (Figure 2):

1. **Fog-to-Thing Interaction:** Fog provides most of the services to 'things' in resource efficiency and secure way. Among the services include data filtration, segregation and aggregation. Besides this, it provides storage, analyses and decision making. The different tasks which Fog nodes perform for IoT application are:
    - .**Data Processing:** Data filtering, segregation, and aggregation.
    - **Intelligence:** Data analysis and decision making.
    - **Storage:** Fog allows data to be stored for a long or short time, depending upon the application requirement.
    - **Control and Management:** Fog communicates with different 'things' for data gathering ,feeds and firmware update by using suitable protocols.
    - **Data Encryption and Decryption:** Data collected by 'things' are vulnerable to security threats and hence raise concerns for data protection. Fog node ensures data protection by encryption technology, data are encrypted before it is stored and relayed to other places.

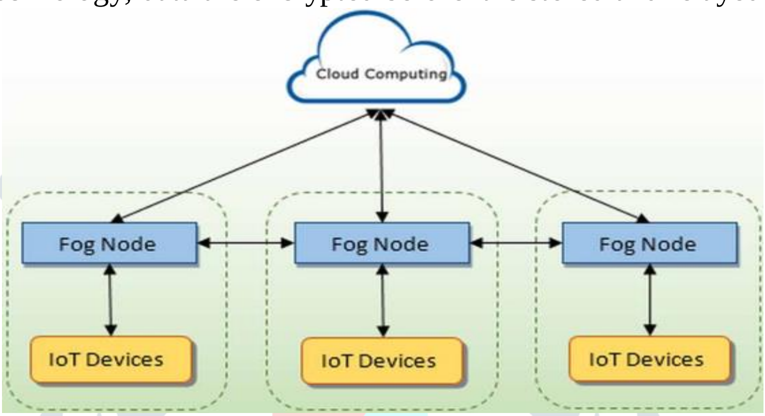

Figure 1: dealing between iot, fog and cloud

2. **Fog-to-Fog Interaction:** Fog to Fog interaction leads to data sharing, data backup, a collaboration of software and computations among the Fog nodes. Fog nodes are often resourced poor with limitations seen in terms of processing power, software capabilities and storage capacity. The Fog of Fog interaction, leading to Fog to Fog cooperation for resources (software and hardware), may help to overcome individual node's limitations. For example, the Fog nodes over the network edges for an IoT application may collaborate with each other to share the data storage and processing capabilities. Data gathered from a node with low memory is relayed to other nodes having high storage capacity. Similarly, nodes having high processing capacities collaborate with each other to provide an aggregated form of local data processing platform. Furthermore, while talking about the location-based application running over an IoT network, the data resources are often distributed or scattered. Collective data gathering for data analysis job will be accumulating data from scattered nodes. Fog of Fog interaction allows multiple Fog systems to share the data storage, software service and other computing tasks for one or multiple users or applications. Through the mutual collaboration, they serve as a backup for each other.

3. **Fog-to-Cloud Interaction:** Fog is a virtualized version of Cloud, sustaining all the features of Cloud. Fog is a kind of job handler of Cloud, with limitations of its own like resources and processing capabilities. It cannot substitute Cloud, as it has its own dependencies on Cloud in terms of software and Infrastructural support. Fog and Cloud exchange data with each other. The critical data gathered from 'things' are sent to Cloud and the then processed information is returned from Cloud. Cloud distributes and manages various services onto Fog; in a way Cloud services areavailed to 'things' (end users) through Fog.

VII. CONCLUSION

As the number of IoT devices are accelerating tremendously it is to be trusted this trend will endure to further edit the Internet. These devices produce a gigantic data .Cloud computing is used to handle such data in order to process, store, and analyze them. But big share of IoT applications are going to be real time that

are delay sensitive, this demand a new computing model that will process the data near to the source, instead of delivering it to the remote data centre. Thus the promising solution is offered by the Fog computing model which provides facilities similar to the Cloud, in small scale, at the edge of the network. Fog computing supplements and prolongs the Cloud computing thereby bringing the decentralized form near the IoT. Fog computing is imperatively the better deal for real-time and time-constrained applications as the data processing happens closer to IoT devices which has significantly decreased the network latencies. The appreciation of Fog has abstracted the heavy weighted cloud, bringing influential computing closer to the user. The peculiarity like support for mobility, geographical distribution and locality awareness has assisted much context-aware computing which would have been very demanding in cloud computing. Even though Fog computing has many challenges in terms of load distribution, supportability to heterogeneous devices, handling huge data and limitation to computing power and memory capacity, but its advantages are overwhelming. Fog Computing would also be the other stepping stone
in realizing Cognitive IoT, whereby physical world and the virtual world would blend together as one.

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cloud-computing-and-how-your-business-can-benefit-from-themings (IoT) is the network of physical things, connected together to share data among