Integrating IOT and Fog Computing for solving time sensitive Applications: The need of the hour

B.Indira[1] and M.V.Ramana Murthy[2]

1. Assistant Professor, Dept. of MCA, CBIT(A), Hyderabad

2. Professor & Head, Dept. of M&H, MGIT, Hyderabad.

Abstract: With the quick advancement of Internet and Cloud technologies, many numbers of physical objects are linked to Internet and are communicated with each other to solve many real-world problems without human intervention. It delivers great benefits to cater the needs of our daily life and in turn significantly improves the quality of our life. Millions and trillions of devices are connected together which generates a very huge data and a platform is required in order to process this large amount of data generated by these massively connected devices. Technologies like Cloud computing and Big Data Analytics can be employed to address this problem. But, the traditional Cloud Computing Paradigm faces some challenges like high latency, bandwidth, Network failure and reliability. In order to address these challenges, the concept of Fog Computing paradigm is introduced. Fog Computing extends the Cloud Computing services to the edge of the network. Fog computing is a virtualized platform that provides storage, compute and other network services between end devices and cloud computing. The Fog Computing paradigm utilizes local computing resources and minimizes latency, conserve network bandwidth, address security concerns and operate in reliable and secure environment. Cloud Computing fails in most of these requirements. Fog Computing reduces the amount of data that needs to be transported by filtering the data and thereby improving the efficiency. In this context Fog Computing provides a pragmatic and viable solution to most of real world and time-sensitive applications like autonomous vehicles, smart grids, wireless sensor and Actuator Networks (WSANs), smart Homes or buildings, smart traffic lights, Healthcare monitoring etc. This paper provides state - of – the – art of Fog Computing including the architecture characteristics and benefits. An attempt is made to address the challenges of integrating IOT with Fog Computing and this paper also presents some real world, time sensitive IOT applications and future directions of integrating Fog Computing, Cloud Computing, Big Data Analytics and Internet of Things.

Keywords: Internet of Things, Fog Computing, Cloud Computing, Big Data Analytics Smart grid, Autonomous cars, Fog as a Service, Smart Home, Health monitoring WSAN.

Introduction:

The revolution in manufacturing of hardware devices and various types of sensors and actuators has started a new era in providing many automated applications in order to help human beings. It is recognized that 127 new devices are getting connected to the internet for every second. It is estimated that by 2025 there will be 75 billion devices connected to the Internet. The applications such as smart buildings, self-driving cars, health care, smart agriculture, smart parking etc ., have made the life of humans comfortable and easy. But this convenience is also introduced many new challenges including security, storage, distribution, privacy of data. The connectivity among the devices in IIOT is possible through various wireless communication technologies like 3G, 4G, Wi-Fi, Blue tooth. The use of smart devices in all these applications generate a huge amount of data and this data has to be transferred to cloud over Internet for further analysis. This data has to be transferred to cloud for further processing, while transferring the data, security issues like integrity, privacy and security breaches may be raised.

The new advancements in electronics, sensors and actuators, connectivity and processes has led to a new era of intelligent applications and these applications generate an enormous amount of data that has to be processed and analyzed at the right time in order to make the right decisions at appropriate time. But these end devices cannot process the data and they have very limited resources and this huge amount of data must be transferred to the cloud for further processing. This introduces many problems like data tampering, Data integrity.

In addition to security and privacy problems Cloud Computing also faces some challenges like high latency, bandwidth, network failure and reliability. In order to address these challenges, the concept of Fog Computing paradigm is introduced. Fog Computing extends the Cloud Computing services to the edge of the network. Fog computing is a virtualized platform that provides storage, compute and other network services between end devices and cloud computing. The Fog Computing paradigm utilizes local computing resources and minimizes latency, conserve network bandwidth, address security concerns and

operate in reliable and secure environment. Cloud Computing fails in most of these requirements. Fog Computing reduces the amount of data that needs to be transported by filtering the data and thereby improving the efficiency. In this context Fog Computing provides a pragmatic and viable solution to most of real world and time-sensitive applications like autonomous vehicles, smart grids, wireless sensor and Actuator Networks (WSANs), smart Homes or buildings, smart traffic lights, Healthcare monitoring etc.

HP conducted a research study and exposed that 70% of most commonly used IOT products have some sort of security vulnerabilities [1]

IOT and Fog Computing

As per the statistics given in the website of safeatlast[2], it is recognized that 127 new devices are getting connected to the internet for every second and at present there are 26.66 millions of active IOT devices. It is estimated that by 2025 there will be 75 billion devices connected to the Internet. Many applications such as Healthcare, smart buildings, process automation, driverless car (autonomous cars), and traffic management required quick response time in order to improve safety and quality of service, which is not possible with the help of cloud computing models. The cloud computing paradigm mainly achieves high scalability and availability and suffers from high latency and poor response time. Further to transfer this huge volume of data to the cloud it needs a high bandwidth, which in turn introduces the security and privacy issues. So there is a need for a better computing paradigm.

With respect to all these constraints the idea of Fog Computing was introduced by Cisco. Fog Computing is a new model that extends Cloud Computing to the edge of the network, often interchangeably using the term edge computing although there is a little difference between the two terms. Fog Computing is a distributed computing paradigm that acts as an intermediate layer in between cloud data centers and IOT sensors.

The deployment [3] of fog structural networks at the edge is essential to perform intelligent computation fog notes provide computational flexibility better communication storage capacity and much more services the concept of Fog Computing was first introduced by Cisco in 2012 to address challenges of IOT applications in conventional cloud computing [4]

Fog Computing facilitates location awareness, achieves low latency support, real time applications, improves Quality of Service (QoS), scalability, high bandwidth, better navigation and interoperability . Previously Fog Computing was known by many different names like Omnipresent Cloud, Distributed Cloud, Infinite Cloud, Mobile Edge Cloud, Edge Computing etc. [5]

Fog converges a set of techniques that were developed over the years and represent their integration into a single scenario with requirements such as device ubiquity, agile network, efficient Service Management and data privacy [6]. Fog Computing and Cloud Computing provide similar set of services in terms of processing and storage. Fog has some additional advantages compared to Cloud Computing as it is close to the user and also has dense Geographic coverage. Basic element of fog architecture is fog node, the extra layer between remote cloud server and IOT devices.

Any device with storage capacity, computing power and network connectivity such as routers, switches, and controllers can be a fog node [7]

State-of-the-art Fog Computing

Hany f Atlam [8], presented state-of-the-art of Fog Computing and its integration with IOT by highlighting the benefits and its implementation challenges.

Abdul Rauf [1], discussed IOT, Fog Computing, relationship between IOT and Fog Computing, their security issues. And proposed a risk-based trust management model for the smart Healthcare environment to cope with security and privacy related issues.

F.Bhoomi [9], proposed Fog Computing platform to support resource-constrained IOT devices.

Gollaprolu Harish [10], discussed ideas of Fog Computing, challenges, supported observations, future directions for analysis.

N. Peter [11], provided a summary of opportunities for Fog Computing in real time applications and the strategy for resolving problems related to two congestion and latency.

Ramanpreet Kaur [12], focused on integration of fog and IOT and analyzed the need of integrating them, application areas that are benefited from this integration, the challenges deriving from such integration and implementation of this integrated environment in the field.

Yogesh Kumar [13], discussed a framework to improve performance via a collective role amongst fog knots to attain the best load and job distribution. He measured Fog Computing as an extremely virtualized stage of source pool that delivers calculation,

storage and networking facilities to adjacent end consumers.

S. Khan [14], provided a review of Fog Computing applications to identify common security issues

Julien Gedeon [15], summarized current research efforts, describe applications where Fog Computing is beneficial and identified future challenges that remain open to bring Fog Computing to a big breakthrough.

Mahmud [16], provide a taxonomy of Fog Computing according to challenges and features of Fog Computing.

Deepak Puthal [17], discussed three layered architecture and highlighted potential security threats and solutions at each layer and also discussed open research issues at all three layers of fog hierarchy.

Fog versus Cloud

Requirement /feature	**Cloud Computing**	**Fog Computing**
Latency	high	Low
Proximity	low	high
Distance between client and server	Multiple Hops	One Hop
Security	undefined	Can be defined
Location	No	Yes
Awareness		
Geographical distribution	centralized	Distributed
Heterogeneity	low	high
Context awareness	no	Yes
No.of server nodes	few	Very large
Delay Jitter	high	Very low
Deployment	Fixed, static	Dynamic, opportunistic

Fog architecture

Fog Computing extends Cloud Computing by deploying all the resources such as data storage, computing and communication resources and Data Analytics closer to the end user. Physical and logical network elements and software are arranged in order to implement a task in Fog Computing architecture. Fog Computing market opportunity will exceed dollar 18 billion worldwide by 2022.[18]

The main component of fog architecture is a fog node. Fog nodes play a vital role in Fog Computing and they collect data from multiple sources and process it.

Fog nodes are distributed and deployed across the network.

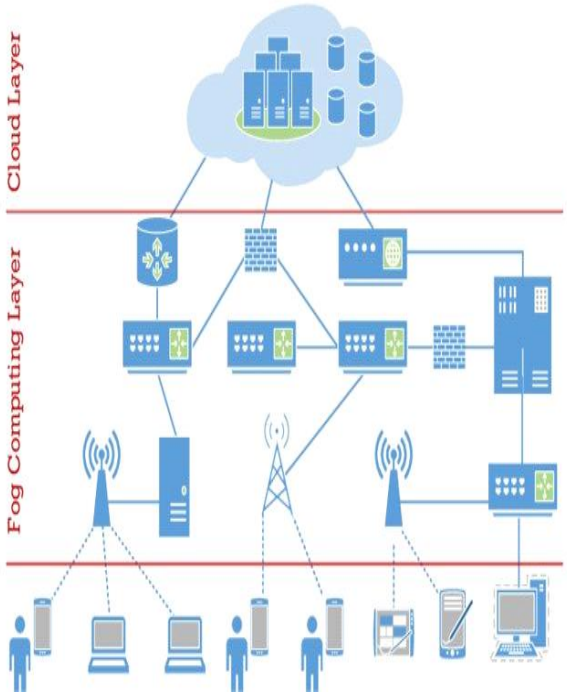

Fig. 1. Architecture of Fog Computing

Layer 1: Things: this layer mostly deals with sensing and capturing. This is the basic layer of fog architecture which includes devices like mobile phones, sensors, Smart cards etc. These devices, which are distributed across various locations capture the data. These devices will be working in a heterogeneous environment.

Layer 2: fog layer: This layer includes fog nodes, which are devices such as routers, gateways, Fog servers, base stations etc. Fog nodes are located at the edge of the network, placed in between cloud data centers and end devices. Fog nodes can compute, transfer and store data temporarily and provide services to end devices.

Layer 3: Cloud layer: This layer provides large storage and high performance servers. This performs computation analysis and stores data permanently. The cloud layer provides resources on demand basis. It acts as a backup and provides permanent storage for data in fog architecture.

Benefits of Fog Computing

Fog computing support IOT applications with fast response time and low bandwidth usage by moving computation from Cloud to EDGE devices. Fog Computing provides the following advantages.

- improve quality of operating system
- compliments cloud
- parallel processing operations at the edge of core network
- perform intelligent computation at the edge
- provides computational flexibility
- better communication
- viable solution to video streaming in vehicles
- reduce user traffic and latency problems

- content is closer to the user
- Increased performance
- provides basic services to the network edge
- speed up time sensitive applications
- computing resources closer to IOT devices
- low bandwidth usage
- minimize latency
- increase scalability
- reduced response time in time critical applications
- reduce power consumption and other operational costs
- provide reliability
- mitigate resource constraint problem
- improve speed of live video streaming
- load balancing and proper resource allocation
- Time sensitive applications are better executed
- greater business agility
- lower operating expenses
- provide uninterrupted services
- provide promising solutions
- use IPV6 Protocol to handle large number of smart objects
- use of GPS enables to use location based context

Characteristics of Fog Computing:

- geographical distribution
- large-scale sensor networks
- real time interactions
- very large number of nodes
- support for mobility
- support for online Analytics
- Interoperability
- wireless access
- Heterogeneity

Challenges of computing:

- Security : The fog environment is vulnerable and less secure than cloud computing authentication has to be increased to protect against cyber attacks
- Complexity: Wide variety of IOT devices are produced by different manufacturers, so choosing the best components is very difficult and complicated
- Scalability: Billions of IOT devices are generating a very huge amount of data that require large processing power and storage.
- Heterogeneity and Coordination: There are a vast variety of devices with different communication

capability and thus need a proper coordination and management of these devices.

- Privacy: unsecured fog nodes can allow intruders to collect sensitive data of users.
- ResourceManagement:Smart management of resources is the need of the hour.
- Dynamic: dynamical nature of workflow makes it difficult to perform the operations.
- Energy Consumption: Reduction of energy is a very vital challenge as multiple fog devices are distributed at different locations.
- Keeping track of objects: IOT is an integration of millions of devices. Many devices will be added to IOT network and keeping track of these devices is a main challenge.

Applications

Health care system: Health care systems face enormous challenges that will increase due to aging populations and the rise of chronic diseases, shortage of nursing staff, wastage of time due to manual measuring of biometric parameters and transfer of data among systems. Real time processing plays an important role in Healthcare applications and data has to be processed at a faster rate. In fog based Healthcare Solutions, fog nodes are distributively arranged in hierarchical fog levels. Fog nodes are placed very close to IOT devices. Fog nodes will receive Health related data from sensors and other connected devices and check for the relevance and any other risk associated with patients by processing the data and immediately can notify invoke an event who can take care of the problem immediately.

Smart car/ connected car/ automatic car: Smart car is a driverless car. This car will be able to communicate with other cars and can drive safely on its own. They will also generate a huge amount of data and have to sense other cars, people, cyclists and other objects and also traffic lights and must take the decision immediately based on sensed data. So fog computing plays a key role in this smart car application.

Smart home: requires unified interface to integrate all the home appliances. Smart home application requires communication and coordination between all the devices to provide better services such as providing security measures, maintaining room temperature, managing power consumption etc. All this is done again with the help of sensors and Fog Computing.

Conclusion and future scope

With Rapid growth in hardware, IOT is integrated in our day-to-day applications. In this paper we discussed Fog Computing, its architecture, features, benefits and some applications. This exponential growth of IOT applications requires a new and specialized form of computing known as Fog Computing, which is the need of the hour address some challenges faced by IOT applications. But before adopting fog computing, organizations must have deeper insights regarding the service levels, resource management, and architecture, virtualization, safety and privacy issues. As a whole, fog computing will play a vital role in time-critical IOT applications and provide improved services.

[1] Abdul Rauf, Riaz Ahmed Shaikh, Asaduallah Shah, "Security and Privacy for IOT and Fog Computing Paradigm", 978-1-5386-4817-918-$31.00@2018 IEEE

[2] Li, Shancang, T. Tryfonas, and H. Li. "The Internet of Things: a security point ofview."InternetResearch 26.2(2016):337-359.

[3] Muhammad Rizwan Anawar , Shangguang Wang , Muhammad Azam Zia,Ahmer Khan Jadoon, Umair Akram, and Salman Raza, "Fog Computing: An Overview of Big IoT Data Analytics", Hindawi Wireless Communications and Mobile Computing Volume 2018, Article ID 7157192,22pageshttps://doi.org/10.1155/2018/7157192

[4] Redowan Mahmud, Ramamohanarao Kotagiri and Rajkumar Buyya, "Fog Computing: A Taxonomy, Survey and Future Directions", © Springer Nature Singapore Pte Ltd. 2018 B. Di Martino et al. (eds.), Internet of Everything, Internet of Things, https://doi.org/10.1007/978-981-10-5861-5_5

[5] William Tärneberg, The confluence of Cloud computing, 5G, and IoT in the Fog, Doctoral Dissertation Electrical Engineering Lund, March 2019

[6] Lina Husain Kazem, "Efficient Resource Allocation for Time-Sensitive IoT Applications in Cloud and Fog Environments", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-3, September 2019.

[7] Tianyi Chen , Student Member, IEEE, Qing Ling , Yanning Shen , Student Member, IEEE, and Georgios B. Giannakis, "Heterogeneous Online Learning for "Thing-Adaptive" Fog Computing in IoT", IEEE Internet Of Things Journal, Vol. 5, No. 6, December 2018, pp 4328-4342.

[8] Hany F. Atlam , Robert J. Walters 1 and Gary B. Wills , "Fog Computing and the Internet of Things: A Review" Big Data Cogn. Comput. 2018, 2, 10; doi:10.3390/bdcc2020010 www.mdpi.com/journal/bdcc

[9] Flavio Bonomi, Rodolfo Milito, Jiang Zhu, Sateesh Addepalli, "Fog Computing and Its Role in the Internet of Things", MCC'12, August 17, 2012, Helsinki, Finland. Copyright 2012 ACM 978-1-4503-1519-7/12/08... $15.00., pp 13-15

[10] Gollaprolu Harish, S.Nagaraju, Basavoju Harish, Mazeeda Shaik, "A Review on Fog Computing and its Applications", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue-6C2, April 2019.

[11] Peter, N. FOG Computing and Its Real Time Applications. Int. J. Emerg. Technol. Adv. Eng. 2015, 5, 266–269.

[12] Ramanpreet Kaur, "Integration of IoT and Fog: Need of the Hour", International Journal of Engineering Technology Science and Research IJETSR www.ijetsr.com ISSN 2394 – 3386 Volume 5, Issue 1 January 2018,pp 1104-1109.

[13] Dr. Yogesh Kumar, Dr. Manish Mahajan, "Intelligent Behavior Of Fog Computing With IOT For Healthcare System", International Journal Of Scientific & Technology Research Volume 8, Issue 07, July 2019 ISSN 2277-8616, pp 674-678

[14] Khan, S.; Parkinson, S.; Qin, Y. "Fog computing security: A review of current applications and security solutions." J. Cloud Comput. 2017, 6, 19. [CrossRef]

[15] Julien Gedeon, Jens Heuschkel, Lin Wang, Max Muhlh ¨ auser, "Fog Computing: Current Research and Future Challenges", Fog Computing: Current Research and Future Challenges, conference paper, march 2018.

[16] Mahmud, R.; Kotagiri, R.; Buyya, R. Fog Computing: A Taxonomy, Survey and Future Directions. In Internet of Everything: Internet of Things (Technology, Communications and Computing); Springer: Singapore, 2016; pp. 103–130.

[17] By Deepak Puthal, Saraju P. Mohanty, Sanjivani Ashok Bhavake, Graham Morgan, and Rajiv Ranjan, "Fog Computing Security Challenges and Future Directions", A bottom-up view to the fog system hierarchy, pp 1-6.

[18] techblog.comsoc.org. visited in May, 2020.