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Cloud and Fog Computing Models for Internet of Things

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Abstract: IoT – A technological buzzword in the world of internet, enable interaction among billions of devices connected to internet through advanced communication technologies. It is a predominant research area which dragged the attention of researchers, scientist, academician, scholars etc., in recent years. IoT has expanded its use across multiple application areas ranging from home automation in domotics, industry automation in business sector to disaster/emergency control management in government projects. The amount of data involved in all of these applications are very huge, and IoT requires a computing model for its analysis and deployment. This paper presents an extensive review on two reliable computing models namely cloud and fog. The reliable services offered by cloud computing and fog computing to IoT are identified and discussed.
Keywords: Cloud computing, Fog computing, IoT, Data analytics.

I. INTRODUCTION

IoT is all about connecting smart devices and sensors (collectively called as objects) through communication technologies. This enables the objects to send and receive data. As the number of objects getting connected to IoT increases, the amount of data involves also massively increase. This brings in the concept of Big Data into IoT. Big Data is one another big thing in IoT computing and it generates values from very large data set. It basically describes large voluminous amount of data both structured and unstructured. Though big data is fairly a new term, the older way of gathering and storing data or doing analysis on those data with traditional computing/data management techniques and tools cannot be easily done [1]. There are few characteristics that describes why the traditional data management techniques cannot be applied to big data. They are the three V's – Volume, Velocity, and Variety. Volume means the quantities of data that reach unfathomable proportions. Velocity is the rate of measure of how fast the data flows in. Variety means the diverse set of data types. The analysis of this three V's is referred as Big Data Analytics. Analysis is the process of deriving value from the data. When big data is analysed with intelligent analytical techniques and algorithms it yields a feasible solution.

Data analytics in IoT is to derive intelligence from big data. Data analyst know they have the huge data to be analysed, but they have to filter unstructured data from the structured data. Since there is no standard framework or structured techniques, many IoT application systems cannot react fast enough to streaming data and have failed to improve time-to-decision over the past year. Even as analysts work with huge data volumes and perform more complex analysis, data-driven decisions need to be made faster [2]. IoT application need data management solutions and analysis that facilitate rapid decisions. It is known that, when there is voluminous data need to be analysed, it has to be stored in a data centre. The long run practised way of storing data or specifically IoT data is a cloud-based solution.

But it is proved from the literature that managing and analysing more and diverse kinds of data directly to cloud is a challenging and intricate task. For example, in a smart traffic management system, if the cars connected send 25 GBs of data to the cloud every hour, the challenges is to sense this data, identifying and analysing data that can be processed and quickly acted upon to derive actionable events. To overcome this issue of cloud based computing and to enhance the data management solutions, analysis and deployment, this paper also highlights on fog computing model. The rest of the paper is organized as follows: Section II describes in detail the cloud computing and its issues in IoT deployment. Section III introduce the fog computing and the services it offers to IoT deployment. Section IV depicts the quality of service offered by cloud and fog. Section V with conclusion and discussion.

A. Cloud Computing model for IoT

At a basic level, cloud computing solution provides a way for the IoT systems to connect to centralized data storage. This enables the IoT to manage all aspects of IoT deployment such as device location and management, and data analytics in it. This almost increases the benefits of binding IoT with the cloud in terms of integration, and flexibility to access the services through an interface. It also offers a model for convenient, on-demand use of network application, access to servers and storage services. One advantage of cloud computing platform is that it provides renting of business processes on a "pay-as-you-go" rather than managing private data center. The integration of IoT with cloud gives user the flexibility to access the services offered by the cloud provider [3]. The general service model offered by cloud includes Software as a service (SaaS), Platform as a service (PaaS), and Infrastructure as a service (IaaS). This research work has also identified a number services offered by cloud to IoT. It includes:

1) *Remote Processing:* It offers remote processing. As miniaturisation of devices and 5G connectivity is on the go, this service will offer developers offload remote processing in cloud.
2) *Virtualization:* Cloud virtualization in IoT enables cost-saving, hardware-reducing, and energy-serving techniques.
3) *Load Balancing:* Load balancing in cloud IoT is the process of distributing workloads across multiple computing resources. It reduces cost and provides maximum resources availability. It enables scalable traffic management. It also supports fault tolerance.
4) *On Demand Delivery***:** Cloud computing in IoT enable resources such as storage, and other software system made available to users as needed. It simply means access to resources only when there is a need. This service helps to overcome the problem of fluctuation on resources demands, and there by reducing the cost.
5) *Payment only on usage:* The user of IoT system is charged or measured only for the cloud resource used for the timeframe. In this context, payment only on usage is related to on demand delivery.
6) *Multitenancy:* This allow cloud resources to serve different IoT systems that are isolated from each other. For example, this allows two different IoT systems to use one cloud storage device, while each remains unaware that it may be used by others. With multitenancy or resource pooling, cloud resources are dynamically utilized based on the demands [4].
7) *Security :* Cloud provides security to IoT on Infrastructure and data storage. At infrastructure level, it provides security to network, host and application. The aspects of data security includes data at rest, data in transit, authentication, data lineage, data provenance and data remanence
8) *Data analytics:* Cloud supports massive parallel execution of data processing and analysis of IoT data. Traditional way of processing data across multiple servers can be overcome with the use of cloud data analytics for IoT application. Data analytics on cloud is done by simultaneous examinations of sensors data collected by IoT sensors therefore, it assures the quality and reliability of analysis.

Though cloud enables convenient, on-demand network use of computing resources, the heterogeneity and loosely controlled nature of the Internet makes cloud not more appropriate to deploy IoT systems. One such issue that affects the quality of service is network latency. With cloud model if the internet is very slow, the IoT user requests, data transmission and system responses have to propagate a large number of networks hops depending on the distance between the user and cloud system. This high latency of cloud will affect the time critical IoT systems where data-driven decisions need to be made faster. The next issue with cloud is its security and privacy. The high latency of cloud also give intruders a way to access the data while in transmission from user to cloud system. To overcome these flaws, a new model for analysing and acting on IoT data is required.

II. FOG COMPUTING MODEL FOR IOT

Fog computing enable some sort of data analysis and decision making to be done on nodes where the data is originally collected instead transmitting vast amount of IoT data to the cloud. In this way, fog computing is considered to be extension of cloud computing which provide added functionalities such as quick response time, low latency and reduced traffic. One advantage of fogging is time sensitive data is collected, stored and analysed at the network edge, while less critical data is sent to cloud.

Data analysis play an important role in determining what data needs to be collected, how it has to be analysed in closer to network edge.

A. *Services offered by Fog Computing*

1) *Energy management at the edge:* Energy management in fog is different from cloud model in terms, not all fog nodes have same computational power, memory and storage. They vary widely and most of the fog nodes are battery powered. Therefore, energy management at the edge of the network should provide scalable, cost effective, open architecture, local and remote monitoring of Cyber physical Energy systems. [7] AddressCPES – a new paradigm implemented in fog comprise of distributed generators, and energy storage than can transform the manually controlled systems to energy efficient smarter system. The energy management scheme proposed [7] attains the attributes above said.
2) *Security:* Fog offer many security features when compare to cloud model. As computing and control happens near the edge of the network in fog model, any abnormality or unusual activity can be identified and mitigated before they can happen. Data protection in fog node becomes easier since IoT data collected are stored in the edge. Fog also offer end user low-latency service. Therefore, the intruder may find it difficult to access the data while in transmission. With fog computing many decoy

technologies like honey pots, honey files, bogus information systems are used to overcome the security potholes [6]. It also provide security via encrypted and multipath traffic in the end-to-end network system

3) *Low latency service:* fog computing offer end user low-latency services. Analysing IoT data at the edge or where it is collected will reduce the latency. The time needed to transmit the data to data center is reduced and therefore increase the speed of decision making. This service plays a crucial role in IoT applications such as smart traffic management, surveillance, and disaster management where milliseconds even matter.
4) *Resource management:* Any number of devices (Eg: nodes, scanner) can join and leave the fog at any time instance. Therefore a rich resource management service will enable real time network monitoring and control. To ensure reliability of the data transferred between the devices, this service will identify the fault and anomaly occurred and report to management control [5].
5) *Bandwidth management:* At most case fog computing utilizes only less bandwidth since most of the data transmission happens between the nodes that are placed at the edge of the network. This service will allow the bandwidth to be used later for some other purpose. By this way, this service also avoid bottlenecks
6) *Location awareness:* Location service help in monitoring and tracking the fog nodes. This service will enable the distributed fog nodes to form a multicast group to facilitate rapid decisions for time critical application. To enable this, fog model maintain a location log list of neighbour nodes. To track neighbour nodes, it will need information like network address, ip address etc., and maps it with physical location.
7) *Edge analytics as a service:* Data is the foremost important thing than anything else in fog computing. Data management in fog plays a crucial role in determining what kind of data to be acquired and processed. Data analysis or mining at the edge can be performed in two different ways. Data to information, with information of long-term values are stored at cloud data centre [8]. Whereas, information that helps to act quickly to take decision on time critical systems are stored in fog node (local data store).

III.QUALITY OF SERVICE OFFERED BY CLOUD AND FOG COMPUTING TO IOT

Table. 1 depicts the quality of service offered by cloud and fog in IoT deployment

IoT Deployment features to be considered	Cloud Computing - Services handled at remote data center	Fog Computing – Services handled at the network edge
Quick data process	No	Yes
Enabling devices to make smart decision	Yes	Yes
IoT application where operations are time critical	Not-suitable to deploy	Suitable to deploy
Internet connectivity to deploy IoT	Strong	Strong
Response time	Slow – take minutes, days and weeks	Quick – milliseconds to seconds
Latency	High	Low
Data processing	IoT data collected is send to the cloud	Happens on nodes (edge of the n/w where the data is collected)
Data analytics	Data analytics done at cloud	Less data analytics at edge
Data storage	Inside the loud only	Data stored on device itself
Processing capacity	Require expensive, high power processing and storage	Require inexpensive low-power processing and storage
Persistence of data	Transient	Persistent for months or years
Data threat (Stealing of data)	High probability	Very low probability
Location awareness	Not provided	Provided
Distribution	Centralized	Distributed
Type of connectivity	Wired/wireless	Wireless
Mobility	Limited support	Fully Supported
Data service at edge	No	Yes
Risk factor	More – as data is outsourced to an external provider	Less – data is processed only at the edge of the network

IV. CONCLUSION AND FUTURE WORK

Cloud is an enormous heterogeneous network where the services are handled at remote data centre. Though cloud offer numerous services to IoT application, due to its heterogeneity and loosely controlled nature of the Internet makes cloud not more appropriate to deploy IoT systems. Though cloud computing model ensures data processing and analytics in an efficient way, the time critical IoT application demand on the fly analysis, which with cloud takes more amount of time for processing and sending the analysed data back to IoT application. An advantage with cloud is, it support pay-as-you-use. But, still using third party service provider does not guarantee complete security. Fog, on other hand overcome all the issues stated by enabling computing at the edge of the network. This does not mean cloud computing is not fully suitable for IoT. It can be concluded, fog is an extension of cloud that enable IoT data processing, analytics and deployment at the edge of the network or time sensitive and critical data can alone be processed and deployed on the servers or machine kept at the edge of the network. Whereas, the other IoT data can be processed and analysed at cloud level. Therefore, an IoT deployed at hierarchical computing model will utilize all the services offered by both cloud and fog computing. The future work of this paper aims to work on hierarchical and reliable models focusing on edge, fog and cloud computing.

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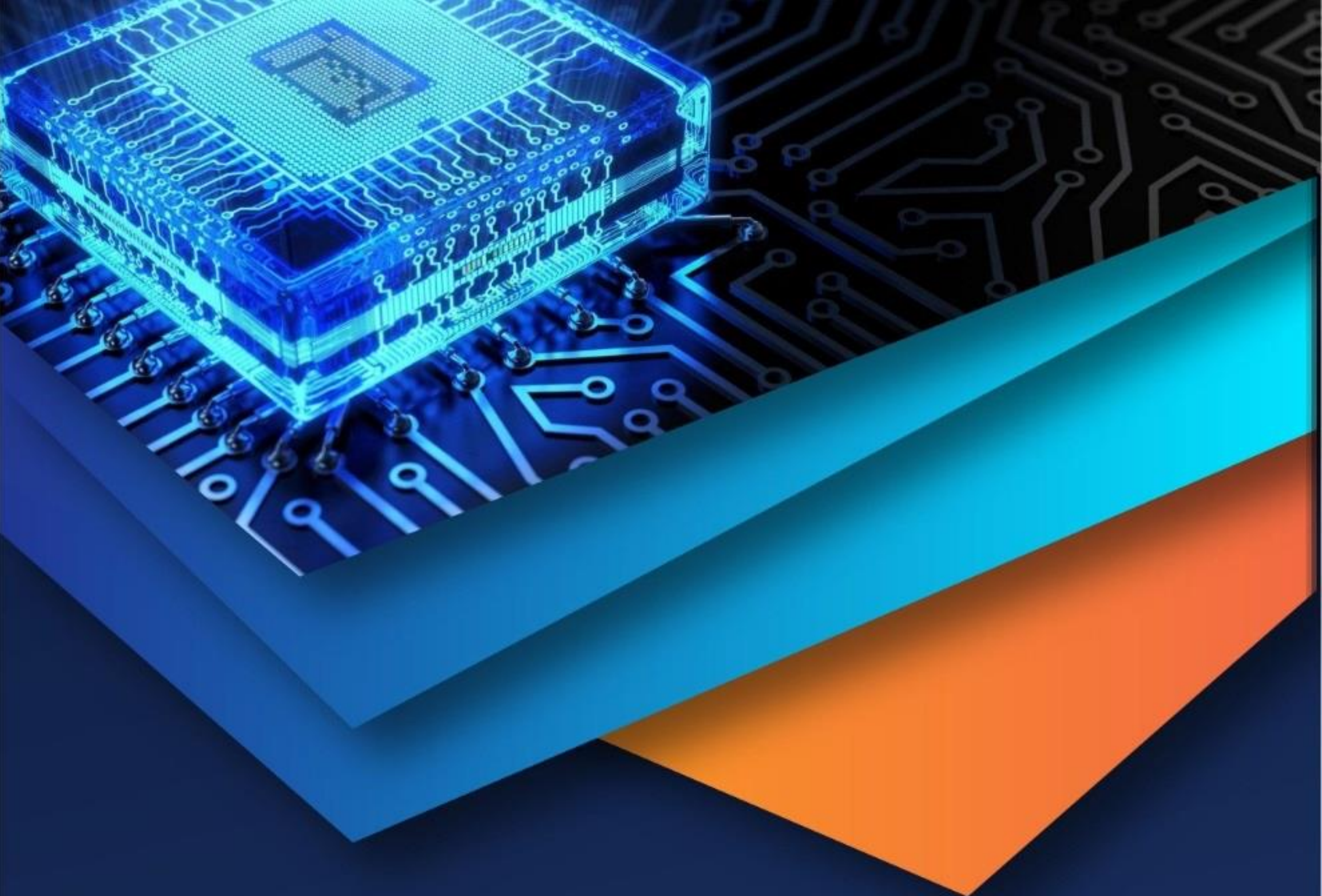

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