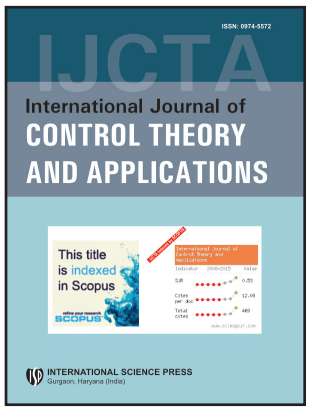

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A Comprehensive Survey of Fog Computing with Internet of Everything (IoE)

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Abstract: Fog computing is a prototype that augment cloud services onto edge of the network, this can support INTERNET of EVERYTHING (IoE) and also accomplishes the usual tasks performed by the cloud computing. The essential objective of fog computing is to provide Low Latency for IoE applications and mobility support. This paper mainly presents the characteristics, benefits and challenges of fog computing, it also explains about Internet of Everything and their integration with Fog, applications of IoE, goals and Challenges of IoE.

Keywords: Cloud Computing, Fog Computing, Internet of Everything (IoE), Fog Node, Fog Server.

1. INTRODUCTION

Over the years cloud computing[1] has gradually taken a significant and prominent role in terms of storage and computation. It has been introduced as a "pay-as-you-go" model, where the stored data can be accessed from any remote location. It is a shared pool of resources which meets the end user requirements in many aspects. Though cloud computing has many advantages, it also falls short in few scenarios known as security issue s, location awareness, limited control, flexibility and Bandwidth. In order to triumph over these problems a new paradigm named as FOG COMPUTING [2]. Fog computing is named as an extension of cloud computing which provides an edge network for real time statistic analytics and processing [3] it is also known as fog networking or fogging[4] which also supports an emerging concept INTERNET of EVERYTHING (IoE).

As the exploration on fog computing is in early stages, there is no standard architecture for fog computing as of now. Fog computing is a system level architecture which supplements the cloud to edge of the IoE network. It provides an intermediate layer between cloud and the end user (mobile, IoE) as shown in the Figure 1[6] [8]. Earlier as mentioned there is no standard architecture for Fog computing, hinged on the definition the below Figure shows the architecture overview. Fog layer is composed of geo distributed fog nodes where each nodes are virtualized devices which enables the storage, compute and communication resources and each nodes are connected to fog servers which transmit data from fog node to data centre or cloud service provider (CSP). Fog

provides the data at edge of the network to end user devices which gives Quality of Service (QoS) for the end user by reducing data traffic in internet etc….[5][7][9] [37].

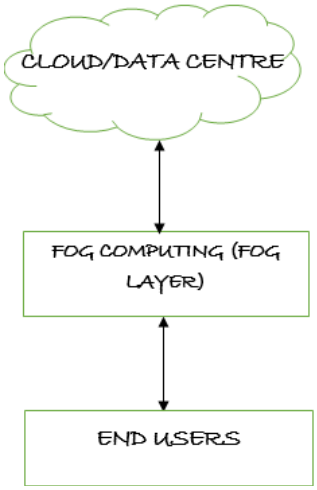

Figure 1: Fog computing overview

The crucial intention of FOG COMPUTING is to rampart the relevance's which requires less latency, location awareness and mobility to make these possible. We have to deploy the fog systems in a widely distributed manner. Fog nodes are easily deployed and widely distributed for the end users. It also enables the new services and applications for connected vehicles. Fog nodes collects the real time data and analytics of the IoE device and also enables the response time of IoE devices to millisecond. All the generated data will be sent to Cloud with a periodic data summaries [9] [7] [36].

2. CHARACTERSTICS AND BENEFITS OF FOG COMPUTING

Earlier as mentioned FOG COMPUTING doesn't differ the cloud computing, it is mainly introduced to address the applications and services which don't or limitedly fit by the cloud paradigm [9] [10].

2.1. Characteristics of Fog Computing

- ***Low Latency:*** It provides finest end point services at edge of the network.
- ***Wide Spread Geo Distribution***: Deployment of fog nodes globally provides an efficient services for end users and also decreases bandwidth.
- ***Support Mobility:*** Support virtuous and transparent access to shared files in reach of a mobile environment whilst sustaining data consistency.
- ***Heterogeneity:*** Fog nodes can be easily deployed in different kinds of environment.

2.2. Benefits of Fog Computing

Super-Imposed cloud immediate to everything that generate lots of data in a daily activity from which we get benefited in the following ways: [11] [12]

- ***Better Security:*** It provides better security for the data in motion and rest from the unauthorized user for this it has to monitor the entire data continuously: before, during and after. It also protect the fog nodes by using some security mechanisms to protect the IoE.
- ***Deeper Insights with Privacy Control:*** Evaluate perceiving data nearby from the fog nodes before sending to cloud.

- ***Lower Expenses:*** We can cheaply develop and deploy fog nodes dynamically to analyse a data before transmitting to cloud this results a lower expense to an organization
- ***Maintain Network Bandwidth:*** In a daily activity we are generating lots of data through different scenarios, these data can't be transmitted thoroughly from edge devices to cloud and it also falls short in storage and processing at critical analysis.
- ***Real-Time Analytics:*** Capturing the huge amount of data from the IoE devices in real time and perform analytics, based on the analysis we may pretend and also distribute the data between edge devices.

3. INTERNET OF EVERYTHING WITH FOG COMPUTING

IoE is an evolution of mobile, home and embedded applications that are being connected to the internet. It is a novel paradigm gaining a lot of buzz in modern terms of wireless telecommunications and also other smart objects. IoE is based on four pillars named as: People, Data, Process and Things. The main object of this paradigm is spreading widely throughout the network for variety of things such as Radio Frequency Identification (RFID), mobile, sensor network etc.… This results to large expanse of data that have to be accumulated, refined and conferred in a seamless and virtuous manner. As of now cloud computing provides the virtual infrastructure but the cloud itself can't connect and analyse the huge amount (thousands and millions) of data spread over large areas. To achieve these problems a new paradigm was introduced named as FOG COMPUTING which provides an efficient platform for the INTERNET of EVERYTHING.

In IoE for smart connectivity we were using network resources with the flourishing potentiality of Wi-Fi, 4G LTE wireless Internet access and the latest buzz is by using 5G we may achieve efficient performance to the end users or devices. INTERNET of EVERYTHING generate lots of real time data managed by virtue of on time refining. As cited FOG COMPUTING can provide low latency and mobility, also discuss about IoE with FOG as well as the architecture. IoE architecture mainly consist of these components end users, fog nodes, fog server and Cloud as shown in the below Figure 2[13] [15].

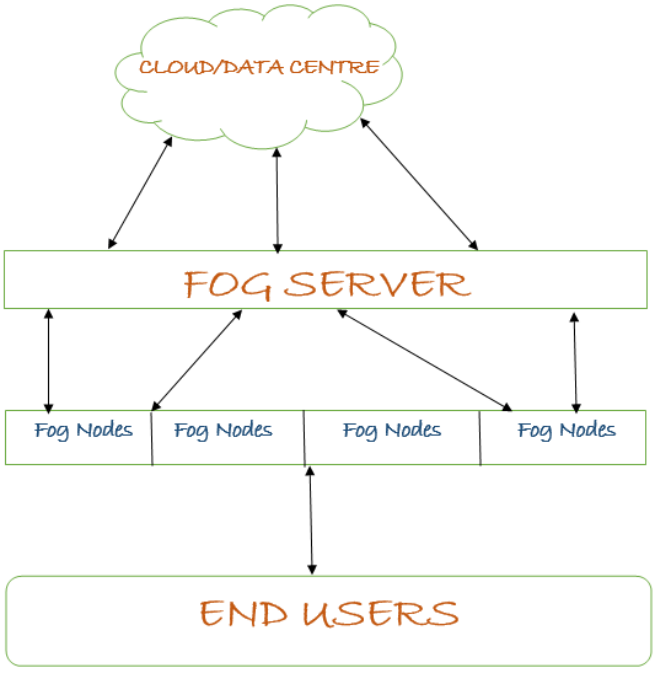

Figure 2: IoE with fog computing architecture

3.1. Architecture of IoE with Fog Computing:

- ***FOG NODE:*** Fog Node receives the real time data from the various heterogeneous sensors/end users by using some protocols such as Radio Frequency Identification (RFID), Wireless Interface for Frequent Interface (Wi-Fi), Near Field Communication (NFC), 6LoPAN, ZigBee, GPS, Sub-Gig, Bluetooth vs Bluetooth Low Energy (BT / BTLE). It provides volatile storage frequently for every 1-2 hours.
- ***FOG SERVER:*** Fog server is as same as cloud which provides a virtualization concept to store, process and analyse data from the IoE devices. Fog servers are deployed at edge of the network and it also provide on-demand services.
- **CLOUD:** All the data received by the fog nodes will be transfused to the fog server, from the fog server these data will be stored in cloud whereas cloud provides a permanent data storage for all IoE applications and also perform analytics on real time data[14].

The main goal of INTERNET OF EVERYTHING is smart connecting (Homes, Retail, Energy, Computing, Marketing, Consumer Electronics, Healthcare, Entertainment), vehicular Transportation, creating closer connection and efficient video streaming to the end users[16].

4. CHALLENGES OF INTERNET OF EVERYTHING

- ***Discover:*** We need to discover the nearby devices for communication purpose.
- ***Identify:*** *W*e admit that services of the other devices are running or not.
- ***Adaptability:*** There are many devices which are getting communicated with each other's here we have to address adapt of devices coming and going.
- ***Manage:*** Need to manage some protocols to diverse transport of the data between end users or end user to cloud.
- ***Interoperate:*** Able to be work across the different operating systems.
- ***Exchange:*** The exchange of information and services between two heterogeneous or homogeneous end user devices to provide efficient communication in the middle.
- ***Secure:*** Admit to secure devices from the bad or unauthorized users, so that we have to investigate the entire network thoroughly [16].

5. STANDARD PROTOCOLS OF INTERNET OF EVERYTHING

This section will discuss about IoE standard protocols and also the IoE ecosystem or communication stack. INTERNET OF EVERYTHING (IOE) protocols were differ by layers of the IOE ecosystem or communication stack. There are five layers in IOE communication stack named as Physical Layer, Data Link layer, Network/ Transport Layer, Session Layer and Application/Data Layer. Each layer consists of different types of protocols which are shown in the below table. Let us mainly discuss about the session/ communication protocols and their function briefly.

- ***CoAP:*** Constrained Application Protocol was specially designed to communicate the resource devices over the internet using UDP. It enables low power sensors and devices over the internet for the communication purpose. CoAP consist of two sub layers as message and request/response one provides reliability and the other is for communication purpose.

- ***MQTT:*** Message Queue Telemetry Transport (MQTT) is similar to CoAP but the design of the MQTT is light weight packet structure which conserve both memory usage and power. Provides communication between applications of one sides and network to the other side. It is mainly used to convert telemetry data in the form of messages later communicate to the server.
- ***DDS:*** Data Distribution Service (DDS) is designed for machine-to-machine communications for integrating intelligent machines. It relies on broke-less architecture and also provides reliability, security, priority, durability, etc..,
- ***XMPP:*** Extensible Messaging and Presence Protocol (XMPP) is used to communicate with the people to devices. It enables real time communication of wide range applications and also exchange the data between people and device such as voice, video calls, XML data, etc.., the main advantage of XMPP protocol is decentralized nature.

Table 1
Standard Protocols of Internet of Everything [31] [31] [32] [34] [35]

NAME OF THE LAYER	*PROTOCOLS OF THE LAYER*
PHYSICAL LAYER	USB, PLC, Wireless, etc.,
DATA LINK LAYER	CDMA, RFID, Bluetooth, ZigBee, etc.,
NETWORK/TRANSPORT LAYER	IPv4, 6LoWPAN, IPv6, RPL
SESSION LAYER/COMMUNICATION LAYER	CoAP, DDS, XMPP, HTTP,MQTT, etc.,

6. INTERNET OF EVERYTHING APPLICATIONS

There are several applications which will be supported by INTERNET of EVERYTHING (IoE) using the domain FOG COMPUTING. In this section we demonstrate about these scenarios: Connected Vehicles, Augmented Reality, Any Wearables, Big Data Analytics, Smart Grid, and Smart Health etc.…

6.1. Connected Vehicles

Connected vehicle uses wireless technology to connect vehicles to each other and also to Infrastructure. Connected vehicle technology can improve our transportation system by enabling safe wireless communication network among the vehicle infrastructure and personal communication devices. It is named as two types one is V2V and the other is V2I, these establish a connection with pedestrians, bicycle, Road Side Units. There are two types of primary connectivity known as Cell-Based [Point-to-Point] and the other is Dedicated Short-Range Communication (DSRC) [Broadcast] both uses the GPS positioning. We may overcome the crash types for vehicles by using the connected vehicle technology V2V with DSRC connectivity. DSRC connectivity improves the mobility, Safety and environment efficient. It provides a security network which requires a dedicated spectrum at 5.9GHz allocated by Federal Communication Commission (FCC). The only disadvantage with DSRC is both vehicles to be equipped with DSRC technology to get connected each other.

We eventually use Vehicular FOG COMPUTING (VFC) which extends a Vehicular Cloud Computing (VCC) and also has the common features with FOG COMPUTING. Fog is localized and provides low latency communication. Connected vehicle is equipped with Internet access and also uses wireless local area network. Connected vehicular system grow vigorously based on real time communication in midst of the other on-road vehicles as well as road-side access points. All the vehicles are harnessed with varied sensors and compute the circumstances of road, traffic congestion and consign all the collected data to the server. These communications will alight over Wi-Fi, 3G, 4G or LTE infrastructure, and according to the latest buzz 5G may provide a rich and efficient performance compared to past technologies in terms of communication[17][18][19].

6.2. Augmented Reality

Augmented Reality (AR) the term was first originate by a researcher Tom Caudell in 1990. AR is an emerging technology which adds a real world environment augmented with the computer generated data. AR extend our bodies with digital devices instead of the other way around, we can easily deploy AR applications. AR promises to make these dreams of Sci-Fi innovation more real than they have ever been. AR allows for virtual objects to be placed in the real world in real time. The virtual concept was originate by MILGRAMS in 1994. AR and Virtual Reality (VR) are the same but both only separated in terms of Hardware and with Augment we can view any product in the real world environment in real time through a mobile device. AR was first introduced by Google in the form of Google Glass later many companies had taken path into it. FOG COMPUTING plays a major role in AR Applications or Areas which provides a low latency, real-time analytics and also mobility. It can be applied to many markets, they are: Employee Testing and Training, Military Aircraft, Health Care/Medical, Theme Parks, Simulation Exercises, Navigation, Sports and Environment, Entertainment, etc.… [20][21][22]

6.3. Smart Grid

Smart Grid is a paradigm being proposed to expanse the intelligence of energy distribution and control system from some central core to abounded off-base nodes, in such a way of empowering extended authentic monitoring of energy losses together with innumerable rigorous control and adaptation. Electricity and information can be reciprocated amid utility and the consumer by employment of this two way dialog digital technology. Based on the demand of energy and low cost, these smart devices can switch to other new technologies like wind and solar energy production and also plug-in electric vehicle charger.

Bulk Generations, Transmissions, Distributions, Consumers, Markets, Operations and Service Providers are the seven domains that are part of an intellectual model interpreted by the NIST originated from the intellection of Smart Grid. Communications of the Smart Grid are mainly based on wired and wireless network technologies and the protocols are Zigbee, WiFi, Homeplug, power line carrier, GPRS, WiMax, LET, Lease line and Fibers. Managing electricity desolation in real time by the grid operators is facilitated by the exhaustive erudition from this technology and as a consequence this control truncates outages and diminishes the exigency for peak power. In control across, the grid engineers will be facile to counsel electricity production more absolutely by diminishing the power plants. Major benefits of Smart Grid are reliable, greener, national security, efficient transmission, low cost, availability renewable energy and less energy disturbances. Smart Grid runs on network edge devices and the generated data will be collected by fog nodes. These data provides the real-time reports, transactional analytics and visualization about consumption of energy. [23][24][25][26]

6.4. Smart Wearable

Smart Wearables are playing a prominent role in now-a-days for both personal and business usage. Google is the company originated smart wearable by the name of GOOGLE GLASS in 2009, later many other companies started introducing smart wearables in different sectors such as Medical, Security, Communication, Wellness, Fitness, etc. The key attributes of wearables are power efficient, connected, secure, accessible, long battery life, stylized and accurate sensor. Wearables can gather data from the device (connected wearable) and provides the information all these data will be stored for further references. It uses wireless internet connectivity technology for embedded device which connects every day by using these protocols Wi-Fi, Bluetooth and NFC. Wi-Fi protocols is used to connect Home applications and the other low products are used to connect with Bluetooth and NFC protocols. We use 3G/4G networks, for efficient output we may prefer 5G for wearables mainly in medical sector to know about chronic disease management, Heart (ECG), Blood Pressure, brain/eye movement. FOG COMPUTING supports an end-to-end latency and also provide mobility to the end users for an efficient usage and reliable access storage, it also performs real time analytics of sensor data to improve better decision making. [27][28][29][30] [38]

Table 2
Different IoE Applications/Services, Protocols and Sensors[15]

Applications	*Protocols*	*Sensors*
Connected Vehicles	Cellular	Accelerometer
Wearable	NFC	Magnetometer
Smart Tags	BT/BTLE	Gyroscope
Smart Parking	Wi-Fi	Pressure
Smart Health	RFID	Altimeter
Smart Grid	GPS	Temperature,
Smart Homes	ZigBee	etc.,
Smart Retail	Homeplug	
Augmented Reality (Entertainment)	6LoPAN	
Big Data Analytics	Sub-Gig	
	LTE	

7. CONCLUSION

Over the past few years cloud computing falls short on few constraints in Internet of Everything (IoE) applications. This paper proposes a new paradigm named as fog computing which has driven the cloud services to edge of the network and also enabled the wide spread appropriation of devices and applications in IoE. Fog also provides security to data generated by things and devices. The future enhancement in fog computing is to provide security for the fog nodes (Platform Security, Physical Security, Network Security) from the illegitimate users and also propose a non-volatile storage to fog server for better and efficient usage.

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