FOG COMPUTING IN IOT

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Abstract - Even though the demand of cloud computing is on rise, it involves an inherent problems related to very less mobility as well as location-awareness, along with unreliable latency. These drawbacks make cloud computing very unfeasible solution for applications like IoT. It is fog computing which addresses these difficulties as it provides very elastic resource as well as services till the end devices at the very edge of network, and cloud computing will take more care of fulfilling demand of resources distributed at the core of the network. Computer scientists and researchers had recently gained interest in this paradigm of remote computing as it provide computational efficiency of a cloud and bandwidth efficiency of a local network. This paper reviews the state of the art of FOG computing, its challenges, application and its comparison with cloud.

Keywords - Internet of Thing, Fog Computing, Cloud Computing

I. INTRODUCTION

More and more ubiquitously connected smart devices are coming in existence and becoming the main factor of computing. Various wearable devices, smart metering machines, smart home, smart city, smart vehicles, large-scale WSN, etc. are coming into existence. The Internet of Things (IoT) had been a popular research subject for many years and it will be considered as the future of Internet. Even after several attempts to augment IoT applications with the power of cloud, problems related to IoT applications like low latency, more mobility, geo-distribution, geographic location-awareness etc. are still a major concern[1]. Fog computing can address such problems and provides elastic resources and services to the end users residing at the edge of network so the cloud could focus more about providing resources distributed in the core network.

Internet of Things (IoT) is a network of interconnected objects embedded within everyday objects, which are equipped with ubiquitous intelligence. There are huge range of devices which could be wireless sensors and which can just sense data and provide a continuous stream of small amount of data or something as complex as smartphones, tablet, which can produce huge amount of data. These groups of sensors and along with small, low-power computational devices are called "things" and Internet of Things aims to develop a network infrastructure where these "things" communicate with each other. It will allow several parameters of different objects to be collected and several parameters to be controlled away from environment through the existing network of infrastructure so we can quickly integrate the real world along with computer simulation systems due to which it will increase efficiency, as well as accuracy and also economic benefit and reduce the amount of human intervention. The information gathered by these embedded systems are used for analysis of the environment, where they are deployed and use the results of the analysis to control the environment by sending commands to environment controlling objects i.e. actuators.

II. FOG COMPUTING

Fog Computing is a distributed platform which can provide computing, as well as storage and also networking services between the IoT devices and conventional Cloud Computing. Data Centers which either reside at the edge of network or as internal nodes of the distributed environment. Fog Computing is defined as a scenario where a several ubiquitous and decentralized devices are capable to perform varied tasks in wireless and sometimes autonomous manner can communicate as well as cooperate in between them through the network in order to perform tasks of processing and storing data even without any intervention of third party. These tasks can vary from supporting basic network functions or some new service and applications that run in its virtual environment.

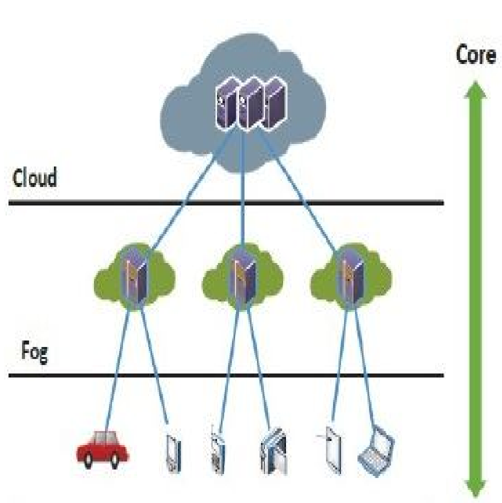

Fig 1 Fog Computing [7]

Fog computing is a paradigm of distributed computing which extend its services given by the cloud datacenters at the IoT devices of the network. Fog computing will also give facility like automating management of computing, as well as networking and storing of data in between the cloud data centers and IoT devices. Fog computing consists of several components of such applications which can run both on the cloud as well as in edge devices between sensors and the cloud. Fog computing provides features like mobility, computational resources, network and communication protocols, interface heterogeneity and connectivity to the cloud as well as data analytics of distributed network which takes care of many requirements of many applications having demands like low latency along with wide as well as dense geographical distribution. Following are few of the applications using fog computing.

1. **Healthcare:** An analytics system assisted by fog computing called FAST was proposed in Cao [2] is able to monitor fall condition for stroke patients. They developed a set of fall detection algorithms, which uses data like measurements of acceleration and time series analysis methods along with data noise reducing algorithms to allow increase in efficiency in detecting fall condition. It detects fall condition in real-time and it was based on distributed network of fog computing.
2. **Augmented Reality:** Applications based on augmented reality cannot allow even minor latency as even very small delays in response can potentially damage the user experience. Fog computing will be one of the major players of augmented reality domain due to its distributed computing capabilities. Augmented Brain Computer Interaction Game proposed by Zao [3] is based on Fog Computing and Linked Data, it will collect raw streams of data created by EEG sensors and then it will be classified to detect the brain state of the user while playing a game, which uses augmented reality [5]. Brain state classification is one of the most computationally heavy signal processing tasks, which needs to be carried out in real-time.
3. **Caching and Preprocessing:** Zhu[4] improves website performance by using edge servers where users used to connect with internet by "fog boxes" where each of user's HTTP request goes through a fog device. The fog device on user's page loading requests, to reduce its amount of time, performs various optimizations. It will have some general time saving techniques like caching HTML components, reorganizing the composition of webpages as well as reducing the size of elements in the web. The edge devices could also perform different optimizations that will analyze the user's behavior and internet conditions. For example, when there is congestion in network, the device at the edge then sends low resolution graphics and photos to the user so that response time can be under acceptable limit. Also, the performance of the client machines are monitored by the edge device and send graphics of appropriate resolution taking care of rendering time required by the browser.
4. **Software Defined Networks (SDN):** SDN is an important concept based on computing and networking. SDN along with fog computing together will be capable to resolve some of the main issues related networks of vehicles, intermittent nature of connectivity, high collision rate and high rate of packet losses. Augmenting the vehicle-to vehicle as well as vehicle-to infrastructure communications along with main control supported by the SDN does this. It would split the control and communication layers where controlling will be done by central server and server would decide the communication path for nodes.

III. ROLE OF FOG COMPUTING IN IOT

The Internet of Things (IoT) promises to make many items which including devices of consumer electronics, appliances used in home, devices used in medical, different kinds of cameras, and many all types of sensors to be a part of the Internet environment. This will be opening the door wide to innovations which will be facilitating many new kinds of interactions among humans and things and it will also be enabling us to realize of smart cities, as well as smart infrastructures and smart services that will be enhancing the quality of life. Fog is such an architecture that can distribute computation, communication, control and storage closer to the end users along the cloud-to-things continuum.

A. Demands of Internet of Things (IoT)

Just like all other technologies, even IoT has its own demands. These demands vary for different devices as there are tons of devices, which are used to create and develop IoT network. Following are the few demands, which are necessary for any IoT device to work efficiently and fulfill our requirements.

1. **Ubiquitous Devices:** Huge demand of IoT devices will increase the number of devices getting connected over the network. The increase of this is mainly due to these two factors: devices used by users as well as the micro-sensors and various actuators. Wearable computing devices (smart watches, glasses, etc.), smart-cities, various intelligent metering devices used by energy suppliers to analyze power consumption at an individual house, etc. will be the major cause for increase in demand of these devices [1]. SPP-lightweight and efficient strong privacy preserving authentication scheme for secure VANET communication.
2. **Physical Dimension and Power Consumption:** Production cost is an important factor due to which device should be as small as possible. This increases the portability of device and reduces power consumption, which can be crucial in some contexts (for example, cell phones or battery operated

fire detectors in a remote forest). Packaging and energy management technologies aims in creating smaller and autonomous devices that can run for long time at low price. Even though convenient packages improve energy consumption, it may not be enough to last longer. IoT devices require long lasting sensors that may not be connected to a regular power source. Lithium-ion batteries are used today for all kinds of portable devices. Even so, batteries working on electrochemical reactions will become a limiting factor in future developments.

3. **Network management:** As all the IoT devices need to communicate with each other, networking infrastructure between them plays a crucial role. Most of the devices have very less network bandwidth to spare for transmission as well as to receiving data from other devices. Also, some devices need a connection with very less latency of just few milliseconds like actuators to take controlling decisions dynamically. Sensors on the other hand transmits few kilobytes of data per second, but it is sent continuously round the clock equating it to several gigabytes of data transfer within a single day.

B. Need for Fog Computing in IoT?

Distributed structure of the IoT networks across many different varieties of industries is very vast in scale and it will be going to be critical to ongoing economic growth. Their requirements are operational efficiencies with zero downtime as well as ultra-low latency. Also, enormous amount of data loads coming from billions of streaming devices require processing power that is closer in proximity to the "things". Following are the ways how fog can fill this gap between cloud and things.

1. **Assignment of Functions:** Fog computer effectively distributes the allocation of functions in IoT networks, unlike other resources. This is able to simplify as well as standardize the basic operations related to the global level of IoT network, such as configuration and administration.
2. **Distributed Architecture:** Fog networks are able to distribute as well as integrate the computing, as well as communication, also the storage and control very flexibly along continuum of cloud for the device. This will also provide a common methodology for meeting the basic requirements of IoT, such as computation as well as storage. The distributed design provides worth across the complete network not simply on the edge.
3. **Immersive distribution:** The distributed fog network architecture provides an "immersive distribution", unlike the cloud, which offers centralization. Immersive distribution means that fog resources are available throughout the network. This allows management flexibility and ease of integration with existing IoT environments. Fog can do this by interacting not only with the cloud, but also with other fog devices, IoT and 5G devices, and with end-user input.
4. **SCALE:** SCALE (Security, Cognition, Agility, Latency, and Efficiency) is an acronym developed by OpenFog. These features are main factors of fog differentiation. IoT differs from others by resource demands as it has high value applications but significant network bandwidth limitations and peripherals with limited resources. Interrupted services or intermittent connectivity to the cloud are not tolerable.
5. **Low Latency :** The fog services have small latency[10] that enables it to perform in real time computations of systems such as AI (Artificial Intelligence), VR(Virtual Reality), real-time Safety control loops, analytics of streaming of data, etc.

IV. FOG IMPLEMENTATION IN IOT

There are various implementations of fog computing in Internet of Things (IoT) where it had helped in leveraging the benefits of it. Figure 2 shows an example of fog network which can be implemented to build a smart city. Each fog node is capable of performing resource intensive task from the data it gets from its peer nodes as well as from the lower level nodes or IoT devices.

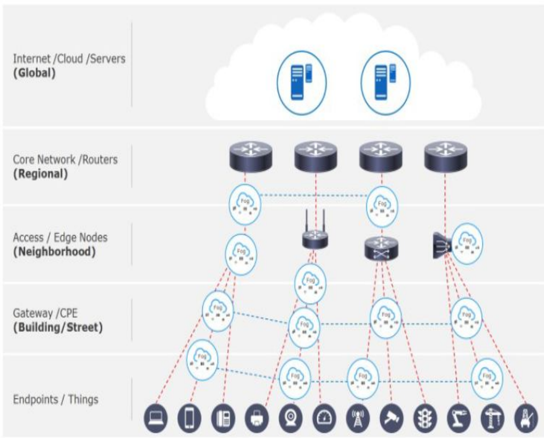

Fig. 2 Fog network implementation in a smart city [9]

Figure. 2 shows the fog nodes residing at the endpoints aggregate the data provided by IoT devices before it is sent to the central fog nodes deployed into a building or a street. This helps in minimizing the amount of data transfer and avoids the problems of network congestion at the upper layers of the hierarchy. The fog nodes are also responsible to manage control and scalability of the IoT devices for tasks which require very low latency such as biometric identification for which user authentication need to be done within few seconds or anti-collision system in trains which need to take decisions in real time.

Some processes may require lot of computational resource which a single fog node may not be able to fulfill alone as well as it cannot be processed onto a cloud for e.g. applications related to augmented reality requires huge amount of computational resource as well as the results need to be delivered in real time. In such a situation the fog nodes also need to have a P2P (peer-to-peer) connection by which it can achieve load balancing, network resilience, fault tolerance, etc.

V. COMPARISION OF FOG COMPUTING AND CLOUD COMPUTING OVER IOT

Even though fog computing gives great advantages to the IoT infrastructure, however cloud computing is one of the emerging solution and it is already in use in many different areas. Also lot of research and development had already happened into cloud computing compared to fog computing. Fog and cloud are both good solutions but they are complement of each other in the form of providing service. Table 1 shows comparison of Fog and cloud computing.

Areas[9]	**Cloud**	**Fog**
Location and model of Computing	Centralized in a small number of data centers	Distributed along large Geo-graphical areas and it is closer to the user. Fog nodes and systems can be controlled by a centralized node or in distributed manner.
Size	High Each cloud data center is very large in size consisting of at least thousands of servers.	Each fog node can be equivalent to a single server machine. It’s designed to meet the user demands.
Deployment	Require sophisticated deployment planning	Depends on the environment. Majority of them don’t require intense planning.
Operation	Operated in a fully controlled environment with technical expert teams by large companies.	Operated in environment where it primarily depends on user demands. They are not operated directly by a person. It can be operated by any size of company.
Applications	It can support predominantly cyber-domain applications. The applications mainly suffer high latency.	Can support cyber-domain, cyber-physical applications. It suffers very less latency and hence useful for time critical applications.
Network requirements	Require clients to have network connectivity until the user wants to access its services. Bandwidth requirement grows with the increase in total amount of data generated by all the clients.	Can operate autonomously to provide uninterrupted network services even with no or intermittent network connectivity. Bandwidth requirement depends on the total amount of data need to be sent to cloud after filtered by fog.

Table 3.1 Comparison of Fog and cloud

CONCLUSION

Fog computing has benefits in many domains, and provide the solutions for security problems in current paradigm. Future research can expand the paradigm of fog computing in smart grids. This provides us a vision to for fog to be a platform of unification made enough for a brand new breed of rising services and modify development of latest devices and applications. However this study suggests that with the emergence of fog, cloud computing can not become an obsolete concept. As it was seen that, even if fog computing continue to develop in future, it has to go hand-in-hand with the cloud computing. Fog computing is just a bridge which connects the gap between the demands of IoT infrastructure and the computational capabilities cloud could provide. By creating a harmony between these two complementary techniques of remote computing, various targets can be achieved, which are once just a dream for us.

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