FOG COMPUTING AND RECENT RESEARCH TRENDS WITH APPLICATIONS

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Abstract:- Fog is a computational device or data collector and it acts as a bridge between cloud server and IoT devices. Sometimes, it is considered as substitute of cloud computing but actually it is the extension of cloud computing and so, the new technology named fog computing is not the replacement of cloud computing. Fog computing provides cloud layer services to the edge of the network for IoT devices. Fog nodes reduce the latency time of computation of IoT applications which maximize the performance of IoT devices and execution speed of IoT applications. The fog provides cloud services like storage, data processing or computation to end devices. We have focused on fog architecture, research trends, issues and applications of fog. In this paper, we have also discussed the concept of computation offloading in fog computing for better execution of data in IoT framework and the fog can be extended to work with Software Defined Networking (SDN) for faster execution of different services. At the end, various use cases are represented to show the importance of fog computing in real environment.

Keywords:
fog computing, edge computing, fog applications, fog recent trends, fog architecture, edge services to IoT, fog with SDN

1. INTRODUCTION

Cloud computing is a technology, in which; user need not worry about physical hardware, software or platform to do programming. It is pay-as-you go model, just you have to pay some amount of money to the service provider and you will get your specific service which is basically IaaS, PaaS or SaaS type. Cloud computing has reduced IT cost as well as provides scalability, flexibility of work and also provides almost unlimited storage space to the user [15]. But there are some issues in cloud computing like availability, confidentiality, access control, data security, more latency time and some other issues and due to these limitations, it is demanded for new technological advancement which can reduce latency time, compensate bandwidth overhead, and provide faster execution and security aspects [15].

Internet of things - IoT it is an innovation which made life easy and given number of advantages to our society. IoT devices reduced our human efforts by using sensors like manually entry of data or information, now these types of data collected by IoT sensors as well as it gives permission to store data automatically and also do processing of all these kind of data [1].

IoT suffers from major issues like greater performance and security [1]. IoT deal with cloud is known as Cloud of Things (COT) which solves many issues [1]. IoT device applications generate huge amounts of data from sensors. Cloud server needs very high network bandwidth to analyze these large amounts of data. In today's life we want IoT (internet of things) devices which can provide great performance and fast response. The same is only possible, when technical advancement can find the middle-layer which can work cloud services at micro level for multiple IoT devices. The fog computing is able to provide micro cloud services at the edge of networks.

Fog computing is a technology which is intermediate layered of IoT devices and cloud servers. Fog servers or Fog nodes provide us computation at the edge of network of IoT devices. There is not required to compute applications at cloud level. Fog layer servers and nodes reduce the latency time of computation of IoT applications which can speed up the performance of IoT applications. IoT with fog has just begun making its route into different parts of our lives with innovations in smart homes, smart cities, nature and the environment, industry and farming, efficient power vitality, medicine and health care, food emergency, disaster management, media transmission and many more [1].

Cloud and fog have same number of features, but fog have some extra features like low latency, computation at edge of IoT devices, location awareness, large number of nodes in distributed manner. Fog can provide following advantages [3]:

- It provides faster response to IoT applications which are time sensitive.
- It also supports collection of data from different devices.
- It provides privacy and security for personal data such as private medical information.
- It also provides location awareness for user.

Fog provides distributed points for gathering data created by the IoT devices. This is done through access points, proxy servers, and routers situated at the network edge or close to the sources. Fog computing is an extensive solution for cloud computing issues. Fog layer provides cloud services closer to IoT devices to provider fast response and better experience to the end users. In this paper, we have briefly shown the architecture of fog computing in section 2. The section 3 is focused on reviews of different applications for computational offloading and SDN. In the last section, section 4, we have shown different uses cases of fog computing to understand real world problems better way.

2. FOG COMPUTING ARCHITECTURE

In Figure 1, fog computing architecture is shown. It has mainly three layers: i) IoT devices ii) fog layer and iii) cloud layer. Fog-based architecture introduces a fog computing coordinator to better coordinate fog nodes. In particular, the coordinator gathers information of fog computing nodes in the same area periodically. In addition, the coordinator is also in charge of job assignment to fog computing nodes to collaborate on complex tasks.

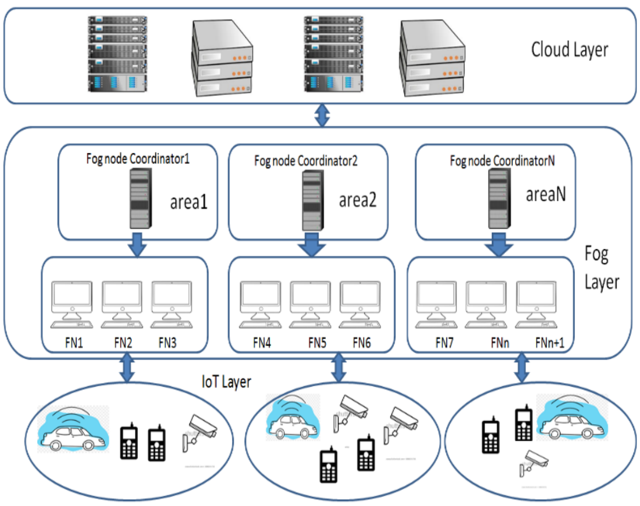

Figure I: Fog computing architecture [18]

Fog devices are placed between IoT layer and cloud layer. Fog computing brings networking services to the edge of IoT devices such as data storage, computation of applications and also provides security and privacy measures. Data stored in fog is mostly on temporary basis. If required to do long time storage then cloud is much preferable way. The fog layer also supports security and privacy methods to protect the data before sending it on public channel. As we see from fog architecture fog layer contains fog Coordinators and their fog nodes which are arranged as distributed manner in different areas. Fog coordinators coordinate different nodes.

3. REVIEW ON FOG ENABLING TECHNOLOGIES

A. Computation Off-loading in FOG Computing

The computational offloading process is able to work with different sensors and tasks are offloaded to nearby servers. This process of offloading can give smoother execution of data on fog servers and it can extend the battery life of IoT devices.

Fog computing in smart homes

Author in [6], a hybrid computation offloading algorithm (HCOA) was proposed for smart home automation in mobile cloud computing by utilizing the cloudlet. Due to the absence of computation asset in cloudlet, the queuing idea exists in the cloudlet and it brings about offloading mobile service of open cloud improving as a technique. They defined the mobile service scheduling issue as a discrete constrained optimization issue. The simulation tests results demonstrated that HCOA was affected by the waiting time in cloudlet and could accomplish an increasingly proficient vitality lessening objective contrasted with BCOA. Authors have not implemented their algorithm on real mobile service to evaluate its performance in real time environment.

Fog computing to approximate effect of externalities

Author in [7] said that effective balancing among centralized and local computing, storage, and network management in developing fog computing infrastructure requires representing externalities made by offloading choices made by individual end clients. Be that as it may, overhead connected with evaluating "long-range" externalities might be unsatisfactorily high. To relieve this trouble, they have proposed an Extended Network Utility Maximization [7] (ENUM) structure, which reduces this overhead by taking into consideration surmised valuing of "long-range" externalities at the expense of some loss in framework execution.

Storage off-loading in fog computing

Author in [8] proposed an algorithm and said that offloading all the computing and storage to cloud, the end clients lose the task capacities for private information. In this paper, they have designed an increasingly effective and secure cloud storage dependent on fog computing. By offloading some portion of the computing and storage work to the fog servers, the information protection can be ensured. In addition, to diminish the communication cost and, decrease latency time, they designed a differential synchronization algorithm [8]. There is a typical marvel that the new file is frequently somewhat unique in relation to the past form by one time of adjustment. Also they said that if they transfer the whole new file to the cloud server without fail, the overheads will be huge. Differential synchronization gives a feasible solution, yet, it builds the remaining task at hand on the clients' gadgets and the cloud server. By offloading some portion of the work to the fog server, the whole effectiveness will be improved.

Fair task offloading in fog computing

In [9] authors said that existing looks into for energy consumption in fog computing network principally center on the total energy consumed by processing a task. In any case, fair offloading among different fog nodes while keeping up a low task delay is of extraordinary hugeness particularly for the battery-controlled fog nodes. In this paper author proposed an analytical system of the fair task offloading for fog computing networks. Task delay and the relative energy consumption are defined. At that point, a fairness scheduling metric is built for each fog nodes. A two-step Fair Task Offloading (FTO) scheme is proposed at long last, which chooses offloading fog nodes as indicated by the fairness metric and afterward offloads tasks to the chose nodes dependent on a standard or rule that limit the task delay. Numerical simulation and comparisons demonstrate the acceptable performance of the proposed task offloading scheme for keeping up a relatively high fairness index for energy consumption and low task delay in the fog computing systems.

Hierarchical Fog-Cloud computing for IoT system
Author in [10], had studied the computing asset portion in a progressive fog cloud computing environment. They had planned a QoE maximization issue dependent on which they proposed a computation offloading game to demonstrate the competition between IoT clients. They demonstrated the presence of pure NE and built up an algorithm that can achieve the equilibrium [10]. They additionally gave an upper bound on the balance productivity loss of the diversion. To alleviate the time multifaceted nature of acquiring the NE, They further proposed a near– optimal resource algorithm and demonstrated that it comes to a - Nash equilibrium in polynomial time. They investigated the proposed algorithm through numerical experiments. Their results show that by utilizing the proposed algorithms, the IoT users can obtain a higher QoE [10]. Results also show that the computation time of delay-sensitive IoT applications reduces significantly when utilizing the computing resources of fog nodes. This demonstrates the ability of fog nodes in providing low–latency computing services in IoT systems. They further showed that the number of users that find the computing services beneficial increases by up to 20% when using the proposed mechanism in comparison to an existing algorithm in the literature.

Multi objective optimization for computation offloading
Author in [11] investigated the problem of joint energy consumption, delay and payment cost (E&D&P) [11] minimization for the MDs in a fog computing heterogeneous network. They had optimized the offloading probability and transmission power for the MDs to jointly minimize the energy consumption, delay performance and cost. They derived analytic results on energy consumption, delay performance and payment cost assuming three different queuing models at mobile devices, the fog node and central cloud and explicit consideration of the wireless channel. By leveraging the obtained results, a multi-objective problem with various constraints is formulated and addressed by using an IPM-based algorithm [11]. The performance evaluations were presented to illustrate the effectiveness of the proposed scheme and demonstrate the superior performance over the existing schemes.

In this paper, authors have demonstrated offloading concept in various way like offloading in smart homes, offloading in storage, offloading to minimize energy consumption, delay and payment cost (E&D&P), offloading in hierarchical fog – cloud computing to maximize QOE for end users.

B. Fog computing with Software Defined Network (SDN)/Network Function Virtualization (NFV)

SDN is an innovative idea for networking compared to existing distributed network. It provides data security and control mechanism of network packets with efficient network management.

Virtualized SDN based End-to-End reference architecture
Author in [12] had proposed architecture for fog computing dependent on SDN and NFV to full feel current network needs, for example, overcoming on dramatically growth of user traffic. These challenges cause significant issues, for example[12], lukeward reliability , jittered latency, low-granularity , location - awareness, standardized protocol communication and management, worldwide perspective of the network and dependency on the communication infrastructure for mobility support. In this proposed architecture, the highly dynamic networks are managed using global view of the federated SDN controllers for dynamic granularly network settings and multi-tenancy client assignments and also network and server virtualization techniques is used to create a dynamic, agile and flexible virtual fog networking components [12].

SDFog: Software defined computing architecture for QoS aware service orchestration over edge devices
Author in [13] had proposed a service-oriented middleware that distributes service hosting throughout the fog environment, making all the nodes in the resource continuum - from the edge to the cloud - capable of hosting services. Their proposed system performed QoS aware orchestration by scheduling flows between services that satisfy specified QoS constraints. QoS preserving virtual network functions (VNFs) [13] are used for establishing healthy user experience, which are allowed to run on the same infrastructure used by user applications and access resources of the underlying devices through a hypervisor. The aim of the author is to extend the concept of SDN to the application layer, and into a ”Software Defined Fog” (SDFog) [13], which is able to execute data- plane functions dealing with compute, storage and network resources on fog nodes. We demonstrate the uses of SDFog architecture with the help of a use case from smart home paradigm, and analyze the effectiveness of this architecture through a small-scale prototype implementation.

4. USE CASES IN FOG COMPUTING

We are going to represent various use cases in fog computing environment and these are discussed below:
Challenge in health care

Healthcare frameworks in many nations face number of difficulties that will increment because of maturing populace and the ascent of incessant illnesses. Numerous nations additionally experience a developing nursing staff lack. Simultaneously, there is a request to diminish costs while keeping up great consideration to patients. Today, much time is wasted in clinics by physically estimating biometric parameters and moving the information between frameworks.

Remote checking will spare time for guardians. Different upgrades incorporate automated supervision that can replace manual supervision. Another region is the improvement of procedures inside the medical clinic. Numerous procedures are arranged physically, and along these lines done consecutively, rather than utilizing assets more successfully. Also, sensors will make it less difficult to pick up right data about the present status and area of hardware, guardians and patients. Sensors will likewise give an increasingly exact picture of patients, as they can catch information continuously and permit knowledge into expanding variety of biometric parameters. This will reform diagnostics and treatment. When this new picture of patients is coordinated with analyzed methods, new experiences will change early detections, diagnostics, prescription furthermore, treatment of infections.

Fog computing in mobile devices
A model for the mobile deployment situation is the observing framework for chronic obstructive pulmonary disease (COPD) patients in [5]. A cell phone goes about as portable base unit and gathers information from a few detecting devices, forms it and sends it to a back end server. The motivation behind placing fog computing on the cell phone is to expand battery life of the wearable sensor device.

Fog computing in Home Treatment
The Parkinson speech analysis solution in [5] is a model for the home deployment situation. A fog node is set on the LAN in the network hierarchy. Like in the mobile scenario, fog computing is utilized to gather, store and process crude information, prior to sending it to the cloud for permanent storage. The primary inspiration for fog computing is to diminish network traffic and latency time. Another case of a home deployment scenario is where information from patient and natural sensors are utilized to recognize if a patient falls, and raise alerts about gas leaks and flames [5].

Fog computing in Hospitals
In [5] we see a typical example of setup of fog computing utilized in the clinic organization. Smart shirts, combined with signals, are utilized to screen physiological information and the area of patients. Fog computing is distributed among a several hubs. The data acquisition and processing board (DAPB) gathers process and combines information from the sensors, and sends them to the wireless transmission board (WTB). The WTB gathers information from the beacon point (BPs), consolidates them with the information from the DAPB and sends them in a single packet to the administration subsystem, situated at LAN level. The board subsystem utilizes the information from the DAPB and BPs to screen the medical parameters of the patients, finds the patient inside the medical clinic and checks if an alert has been initiated.

Fog computing in Non-Clinic Premises
The real time epileptic seizure detection system in [5] is a case of the non-clinic sending situation. A three-tier design is proposed, where filtering, preprocessing, feature extraction, feature selection and classification of EEG examples are performed on the cell phone cloud, which is set in the center level. Two favorable circumstances of utilizing fog computing are referenced: Providing sub-second real-time responses with negligible correspondence overhead, furthermore, diminishing traffic between the LAN and the seizure detection system situated in a cloud center.

Fog computing in Emergency Vehicles
The author in [5] depict how physiological and, relevant information can be gathered in a crisis circumstance from a patient wearing a medicinal gadget, and how this data can be copied and shared between various gadgets on location, in the emergency vehicle and in the emergency clinic. Fog computing is just worried about the gathering and sending of information, the complexity lies in the distribution of information among many fog hubs.

There are more number of use cases like portable mobile devices which gather information of COPD patient and send to fog server, used for home treatment to reduce network traffic and latency time, used in hospitals which uses smart shirts which sends physiological information and the area of patients and it is also used in emergency vehicles which gathers patient's data from patient's wearable gadget.

5. CONCLUSION

In this paper, cloud computing and fog computing are discussed and how fog can serve the IoT applications better way compared to cloud is shown. As we have seen services of fog computing can solve number of issues like reduces the latency time, computation at the edge of network, location awareness, and more number of nodes which are arranged in distributed manner. As we discussed, different research papers are shown the fog and computation off-loading with various applications like smart home, for data storage with security, fair task off-loading, hierarchical structure of fog-cloud to maximize QoE issue, minimization of energy consumption, delay performance and payment cost. It is also discussed SDN/NFV with fog computing in which highly dynamic networks are managed. SDN based fog also provides QoS aware service orchestration over edge of IoT devices. The fog is widely used in healthcare system like in hospital, non hospital premises, emergency vehicles like ambulance etc. The fog has better performance with the implementation of computational offloading in real architecture. In future, fog based security can be discussed to resolve the security aspects in fog computing.

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