An Analysis to Empower IoT Devices through FOG Computing

Jyoti Anand   
Computer Science Engineering  
University of Engineering & ManagementJaipur, India  
anandjyoti136@gmail.com

Shivam Choudhary  
Computer Science Engineering  
University of Engineering & ManagementJaipur, India  
shivamkumar11062@gmail.comJyoti Khandelwal   
Computer Science EngineeringUniversity of Engineering & ManagementJaipur, India  
jyoti.khandelwal@uem.edu.in

Deepak Sethi  
Computer Science Engineering  
SRM UniversityDelhi-NCR, India  
deepaksethi@live.in

*Abstract*— Increasing numbers of physical IoT devices to the internet generates huge amount of data, further need to communicate to the preferred locality. Today, IoT has become an integral part of the people’s regular routine. Process, store and communicate the sensory data to the distant cloud center causes to be network congestion, high latency and power consumption. It couldn’t provide real time data analysis in critical scenarios like e-healthcare, military, smart traffic system etc. also. Using fog computing (FC) between cloud layer and end user devices is a way for empowering the IoT devices and provide real time feedback. It’s not a substitute for cloud, just enables data processing tasks at the edge of network. An offloading mechanism is used in FC to improve the lifetime of power constraints IoT devices. In this paper, we first facilitate a brief explanation about FC, its common framework, characteristics and challenges. Then a comprehensive survey of existing offloading algorithms of FC is provided with their scope and benefits.

Keywords— IoT, fog computing, network latency, offloading, power consumption.

# Introduction

Wide adoption of IoT technology, leads to an ever-growing presence of networked computing devices in public and private places as well. As per the information given by International Data Corporation (IDC), amount of digital data was 1 zettabyte and 2.5 exabytes in 2010 and 2012 respectively [1]. By 2025, approximate 75.44 billion physical devices will be connected to internet [2]. These IoT devices are constraints in nature, aiming to interact with environment and sense the physical phenomenon. Constrained devices impose low battery power, limited memory space and less processing capability [3]. Devices also need a proper internet connection for data transmission from source to the destination by the use of external gateway [4]. To store and process the sensory data, a data center is required on the distant cloud. Cloud computing make it possible, which is a traditional model and couldn’t fit to provide the real time feedback in large scale IoT environment [5]. It also causes to be increase network latency and maximum power consumption. Then concept of fog computing was developed to solve these issues, coined by Cisco [6]. It brings the computing, storage and processing services closer to the edge of network. Smart cities, smart grid, smart healthcare, video streaming, smart traffic etc. are the major areas where fog computing is widely used [7]. It is a decentralized architecture and fitted between the end devices and cloud computing. Fog computing comprises many numbers of fog SNs, fog servers and fog gateway etc. with sufficient memory and processing capabilities. Fog SNs are capable to process the huge amount of data released by different IoT devices instantly [8]. It facilitates real time services to the user more efficiently than cloud in milliseconds. Fog servers (also called nano data center) send some data to the distant cloud which require high computation power and more energy. Nano data center on fog layer takes less energy for data processing than centralize data center of cloud [9]. Figure 1 shows the common architecture for fog computing. It is a three-tier construction, details will be provided in next section of the paper. As discussed above, running computationally intensive application and handle massive amount of sensory data on power constraints IoT devices are major issues [2]. Offloading is a mechanism to save energy of SNs by executing the tasks on local server in FC. Fog gateway monitors the current situation of SNs and takes the decision whether to bid offloading or not [10]. Wireless Body Area Networks (WBANs) are needed to offload diagnostic related responsibilities to accompanying fog server.

Fog isn’t a replacement to cloud, but seen as a complement. Both computing models are differing to each other in terms of providing network services, described in table I. Section II elaborates a common architecture of fog computing. Then its characteristics over cloud computing are discussed. Even fog is deployed to minimize latency and energy consumption, some issues are discussed in section IV. Review part explores some offloading algorithms of fog computing, which manage the power consumption and network latency. Many authors have provided a systematic review on fog computing in their own way. Caiza et. al. gave ideas about fog computing at industrial level w.r.t architecture, latency and energy consumption of constraints devices [6]. Lastly, conclusion and future scope are deliberated to emphasize the ideas of this paper.

# Architecture of Fog Computing

Fog computing shifts the computing, network and storage services from the distant cloud to the edge of the network [11]. It is introduced as an intermediate layer between IoT devices (or, end devices) and cloud layers [12]. Figure 2 demonstrates the common framework of fog computing, which has three layers i.e., end devices, fog and cloud. As the bottom layer is consisting of all physical objects such as smart phones, smart watch etc. equipped with sensors and actuators, knowing as perception layer. It is nearer to the users. These devices capture information from the environment and send to the fog layer for further processing [9]. Numbers of fog SNs are available in form of routers, switches, fog server etc. on this layer [13]. Fog SNs are geographically distributed over the network and also aware to the location. They perform the data processing tasks on received input and maintain a fair connectivity between end user devices and destination. Fog layer is well suited for time critical applications of IoT such as healthcare, because it reduces network overhead and latency. It also takes the decision whether to process the data on the fog layer or send to the distant cloud. Only those data are sent to cloud which require high processing and more spaces in memory. Cloud computing provides high performances with huge storage capacity and more efficient computation than fog computing. Also, it has numbers of data centre to save the data for future use.

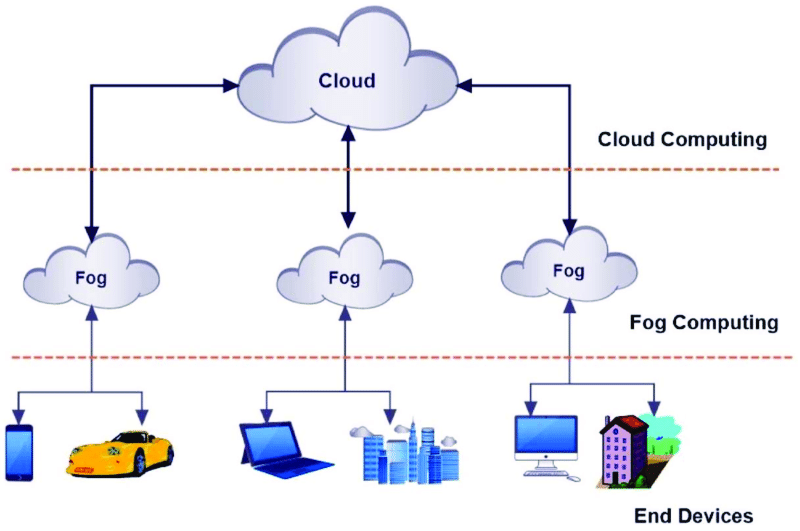


Fig. 1: A common framework for Fog Computing

# Characteristics of Fog Computing

As the fog layer is nearer to the end user, has lots of features. Negas et. al. characterizes the fog layer in comparison to the perception and cloud layers [14]. Perform computing services at the edge of the network is considered as the most prominent attribute of the fog computing. Prominent characteristics of fog computing are listed as follows:

1. *Low Latency & less energy consumption:* Fog SNs receive the sensory data from the IoT devices and process at the edge of the network in local area networks (LANs). It saves the travelling time of sensory data from the perception layer to the distant cloud layer. Henceforth, it achieves low latency and establishes actual interactions among them. Due to the proximity of fog SNs to the edge devices, doesn’t release too much heat. In this way, it saves energy of the SNs also and sustain more time in harsh environment.
2. *Location Awareness & Geographical Distribution of IoT devices:* Fog SNs are distributed across and at the edge of the network surroundings. These constraints SNs have the capacity to figure out the location of devices and take decisions in real time. They also address the functional and non-functional requirement of IoT devices such as mobility, security etc.
3. *Heterogeneity & Interoperability:* Fog SNs are existing in form of gateways, edge routers, base stations, fog server, access points etc. on an intermediate layer. These SNs are varying in storage capacity, processing power, energy consumption and may operate on varieties of operating system also. For that, it is required to upload different types of software to run them. Hence, fog computing is heterogeneous in nature. Consequently, fog SNs needs interoperability to communicate, cooperate and connect with a wide range of suppliers in order to maintain a wide range of services.
4. *Mobility:* Location awareness and large-scale geographical distribution supports the mobile necessities of IoT devices at the perception layer. Fog computing inherently linked the smart devices like vehicles, watches, phones etc. at the terminal tier. At the fog layer, some fog SNs are equipped with mobility and extensively used in traffic monitoring system, coffee outlets and moving vehicles etc.
5. *Bandwidth saving:* As the data processing is done on the edge of the network and restrict the data transmission to the distant server, fog saves the network bandwidth. In special scenario of IoT, fog execute decision making job at the local server rather than cloud.

Above mentioning, fog is a complement rather than substitute to the cloud. Hence at the last of this section, we are providing a brief view on cloud and fog computing models based on the above discussed characteristics.

Table I: Comparison between cloud and fog computing models [15] [16]

|  |  |  |
| --- | --- | --- |
| **Comparing Parameters** | **Cloud Computing** | **Fog Computing** |
| Network Latency | Maximum | Minimum |
| Power Consumption of devices | High | Low |
| Location awareness | Not possible | Yes |
| Geographical location | Centralized | Distributed |
| Mobility | No | Yes |
| Bandwidth Consumption | High | Low |
| Real time interaction | Less | More |

# Challenges in Fog Computing

Fog computing shifts the storage and processing services from the cloud to the edge of the network. Even it is deployed to minimize network latency and power consumption, has lots of issues. Estimating network resources on fog layer in an efficient manner is a tedious work due to the heterogeneous nature of IoT devices. The distributed architecture of fog arises following issues [3] [14]:

1. *Types of IoT Devices:* A resourceful computer or smartphone expect high quality services with quick response. Power consumption of constraints IoT devices became a critical issue here; hence services may be offloaded from such devices to the fog SNs. Fog also needs to aware during resource allocation and to monitor power consumption of SNs.
2. *Customers’ reliability and loyalty:* As IoT devices are dispersed widely and generating varieties of data, it would be very difficult to predict whether a requesting client will make the most of the requested resources. Reliability isn’t guaranteed in case of mobility. Hence, resource estimation should be performed on customer’s behavior and service utilization.
3. *Mobility (On Ground or In Air):* The number of mobile devices will increase in coming time. It is expecting that the entire transport system and aerial vehicles will adopt the internet facility to make it more convenient. Some e-commerce companies have already decided to deliver their products using drones. For this numerous SNs will be placed on them and processed under fog environment. For such scenarios, fog has to consider the behavior of SNs, transmission rate of data, mobile pattern of physical device while deciding about suitable resources.
4. *Security & Privacy:* Whenever fog is working for sensitive IoT applications like healthcare, military etc., sensory data need to be concealed before transmitting to the fog or cloud. It requires more processing and also consume energy. Therefore, fog has to estimate resources w.r.t data and communication security.

# Literature Review

Aazam et. al. presented a review on offloading scheme for executing tasks on behalf of the IoT or edge devices and send the feedback to the desired location [10]. Fog uses the machine learning algorithms along with data analytics tools to examine the data. It helps to optimize power consumption, minimize latency and perform load balancing as well among SNs. Offloading tasks have a direct impact on the scalability of IoT devices, as well as the service itself. In [17], fog computing is utilized to analyse and aggregate the data in smart healthcare. For data analysis, it distributes the processing work to the fog connecting edge devices using task scheduling algorithm. Then it considers schema mapping, duplicate detection and data fusion to aggregate the data. Schema mapping ensures meaningful movement of data. While redundant data is avoided via detection. Finally, information is collected and make a single entity in data fusion. Motivated by the prior concerns of IoT, a LoAd Balancing (LAB) algorithm is proposed to minimize the network latency [18]. It considers communication and computing latency for base stations and fog SNs respectively. IoT devices choose its base station based on updated advertised load information and uplink data rates. The tree-based fog computing (TBFC) model is proposed to minimize electric power consumption of SNs [12]. It modifies the speed of CPU of local devices for three different scenarios (adequate power mode, power saving mode and conservative mode). Thereafter energy consumptions are analysed for all separately. Results shown that power saving mode is working better than others. Paper [19] proposed a bi-objective offloading method based on firefly algorithm to find an optimal device. Firefly is a biological inspired optimization algorithm. It considers power consumption and computational time factors for selecting an optimal device. Paper [20] calculate energy consumption of consuming devices at fog and cloud layer separately. For this, time tolerance and maximum transmission power are utilized. Numerical analysis shown that energy consumption in mobile devices using fog is very less. An incentive driven Ad-Hoc IoT Cloud framework is proposed, which allow mobile devices to create Adhoc and flexible clouds using IoT and other computing devices [21]. An energy efficient and incentive aware task offloading called D2D fogging, is proposed to achieve energy efficiency [22]. Song et. al. devised a processing optimization mechanism of typed resources with synchronized storage and computation adaptation in FC [23]. It will become a boon to support storage and computational services for 6G networks [24] [25].

|  |  |  |
| --- | --- | --- |
| Author’s Name, Year | Proposed Work | Benefits |
| Oma et. al., 2018 [12] | Delivered tree-based fog computing (TBFC) model, where fog SNs are organized in balanced tree. | Minimize electric energy consumption of SNs |
| Paul et. al., 2018 [17] | Introduces task scheduling algorithm for data analysis and perform data aggregation with concerns to schema mapping, duplicate detection and data fusion. | Used in smart healthcare to detect the chronic diseases. |
| Fan et. al., 2018 [18] | Proposed workload LAB algorithm for IoT devices and base station | reduce network latency in IoT environment |
| Adhikari et. al., 2019 [19] | Proposed a bi-objective offloading method based on firefly algorithm and fitness function | Reduce power consumption along with computational time by 30% compared to others |
| Zhao et. al., 2017 [20] | Provided an offloading algorithm for mobile devices through energy calculation at fog and cloud layer as well | Fog consumes energy up-to 87% lesser than the cloud model |
| Hasan et. al., 2018 [21] | Mobile users can make an Adhoc cloud using proposed algorithm “AURA”. | Saves 34% energy, comparing to without offloading in fog |
| Pu et. al., 2016 [22] | Create collaborative environment for mobile devices | Save 30%, 23% & 18% energy in random, greedy and reciprocal schemes |
| Song et. al., 2018 [23] | Presented a processing optimization mechanism of typed resources with synchronized storage & computation adaptation | Minimize processing cost over network, computation & storage. |

# Conclusion

Fog computing is a decentralized intermediate layer between the cloud and perception layer, aiming to transfer the real time data with low latency to the end users. It’s possible due to the proximity of computation, storage and processing tasks to the edge of network. This review gives an idea of evolving and use of fog computing w.r.t to minimum energy consumption of IoT devices. Offloading is a way to minimize the energy consumption. In this regard, some algorithms are reviewed and summarizes in tabular form with its working principle and features. TBFC, AURA, bi-objective offloading etc. are the well-known power optimization algorithm in fog computing. In future, we shall study the use of machine learning and data analytics approach in fog computing to optimize data processing and save energy of SNs

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