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Fog computing and its role in development of Smart applications

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***Abstract*— In 21st century, Internet of Things (IoT) is playing an important role in developing Smart cities. With the growth of IoT, data is growing with acceleration. As the data is growing the need to store data is also increasing. More the data, the latency will be high to store and retrieve data from the cloud. The concept of fog computing was originated to diminish the latency for accessing the data to and from the cloud. Fog computing imparts the storage, computing as well as networking services at the end point of the network. Fog nodes also have limited computational capabilities. Due to some weaknesses, fog computing and cloud computing cannot sustain alone, so both these technologies are integrated to build smart IoT infrastructure for Smart city. Fog computing have a major role and supreme responsibility in development of a Smart city. This paper discusses various applications of fog computing and their implementations in a Smart cities. It also proposes a prototype for Waste management system in a city. Fog computing can help to govern the waste collection of the city in a smart way. On the basis of our review, several open concerns and challenges of fog computing are discussed, and the directions for future researchers have also been discussed.**

Keywords— ***Cloud computing, Fog computing, Internet of Things (IoT), Smart city, Waste management system, Load balancing.***

I. INTRODUCTION

In the modern computing age, use of IoT has been increased with a very high speed. IoT requires portability reinforcement and geo-distribution in addition to locality recognition and low latency. The numbers of edge devices providing computational services are three to four billion approximately. This evaluation is expected to increase to a trillion in coming years [1]. The IoT connect real world things to the internet and allow the connected device to exchange statistics with minimal human interference. In IoT architecture, sensors that are interconnected with some applications produce data and send it to nearest sensor nodes [2].

In the smart city environment, due to global deployment of sensors, extreme data is produced, which increased the need of an architecture which can fulfill the requirement of devices to maintain data. Cloud computing possess a genre which is known as *"Fog computing"*. This genre brings the services provided by cloud near to the edge devices. Fog computing not solely executes latency-sensitive operations but also execute latency-tolerant task at powerful computing nodes at the intermediate of network. The genre of Cloud computing was introduced to fulfill the requirements of distinct segments of IoT i.e. Internet of Everything (IoE), Internet of Me (IoM). For example wearable gadgets, commercial, customer, transportation, healthcare, buildings, energy, consortium [6].

The concept of fog computing was introduced by Cisco in year 2012[7].The initial target of fog computing is to enhance the productivity and to decrease volume of data which is transferred to cloud for processing. For ease management of all resources fog layer act as an intermediate among devices and cloud data centers. Fog computing can provide services in various areas i.e surveillance, transportation sector, intelligent cities, health care and smart buildings. Fog computing can be used in different types of IoT services [7][8]. First, Smart E- Health Gateway can be used for patients to monitoring their health status [10]. Second, Smart homes can be improved by detecting the changes in temperature and air conditioning system. Emergency alarm can be activated and send the warnings to the owner [11]. Third, Smart cities can monitor traffic and transport systems with the help of IoT and fog. Fourth, Smart waste management system can be developed with the help of fog computing which can diminish the problems of increasing waste in the cities. A fog based Electronic Data Interchange (EDI) is a comprehensive virtualized gadget equipped with the storage, transmission and computing capacity [7].

Further sections of the article are explained as follows: Section II contains Motivation of the study, Section III Fog computing introduction, Section IV explains the Layered architecture of fog computing, Section V discusses applications of fog computing, Section VI explains load balancing in fog computing environment, Section VII discusses Review of Literature, Section VIII contains proposed methodology, Section IX is about the open issues and encouragements and finally Section X conclude the paper and explains the Future Scope.

II. MOTIVATION

The motivation of this paper is to provide a smart waste management system which includes load balancing on the fog layer. This paper gives a brief discussion of the application areas of fog computing. The basic concepts of fog computing are discussed which includes advantages, disadvantages and architecture of fog computing.

Fog layer requires load balancing to achieve resource efficiency, avoid overload in the network, to improve system performance and also to protect the system against failures. There are various existing smart waste management systems, but no system includes load balancing at the fog

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layer. This paper also discusses various open issues and challenges faced in fog environment.

III. FOG COMPUTING

According to Cisco, fog computing is extension of cloud computing from network to edge devices. Fog computing is defined as a framework where a large number of heterogeneous devices collaborate with the network to execute a number of tasks without the intervention of arbitrator [3]. Satyanarayanan, et.al. [4] introduced the term "Cloudlets" for fog computing. But it was made known by Cisco as resourceful layer that is placed between the cloud and edge device. Fog brings the compute, communication and networking services near to the origin of data to speed up the process time and reduce the required cost.

1. *Attributes of Fog computing*

As the fog sector expands, virtualization is considered to be its key to success. There is requirement of fog to act as bridge between cloud and IoT devices because of few issues faced by cloud i.e. latency, versatility, security and transmission capacity. Concurrently, entire things cannot be executed from the edge due to capacity, reliability, energy consumption, overloaded nodes and security reasons. Fog computing is the emerging technology which has many characteristics. A few of them is discussed as follows:

- *Distributed architecture:* Architecture of Cloud computing is more centralized whereas architecture of fog is distributed. Nodes of fog can be arranged and can be accessed anytime within time, for example pipeline monitoring [5].
- *Reduced latency:* The fog layer provides less response time because fog nodes are available near to the edge device. So fog computing provides less latency as compared to the cloud computing.
- *One network node away from the edge:* The fog layer is just one hop away from the edge due to which less bandwidth is required [4].
- *Quick mobile application support:* Extension in storage and offloading in computation for various mobile applications are given support by fog computing. For example connected rail.
- *End-user support:* Fog nodes will be positioned at the edge device with heterogeneous end-user support [6].
- *Support for mobility:* Any movable device can become a fog node. i.e. cars, mobile phones etc.

2. *Need of Fog computing?*

In cloud computing the users have to store data in the datacenters which are located far away from them. The storage locations of datacenters are kept confidential from the users. It also took an abundance of time to store and retrieve from the server. IoT demands less latency and higher bandwidth for data transmission to and from the cloud. Sometimes there is network problem and we cannot access the cloud in the way we want to, then it is very hard to access the data in case of emergency. Fog computing is the term used to provide solutions to the problems faced in cloud computing. It provides the computing, storage and other facilities near to the user's end. Fog Computing is a genre of cloud computing that provides services to the edge device [9].With the help of network connectivity, fog nodes can be distributed everywhere:

- On industrial level.
- Above the power pole.
- Beside rail lanes.
- In the smart grids [10].

3. *Interface of Fog with the Cloud and IoT*

As fog layer acts as intermediate layer to the IoT and the cloud, so it is required to be known in advance, that which data is to be stored on which storage location. It should be known that which data should be stored in fog nodes, which data should be sent to cloud layer. The real time data that needs fast processing should be stored on the fog layer. In the same way bulk storage and heavy duty computational data should be stored on the cloud [13].

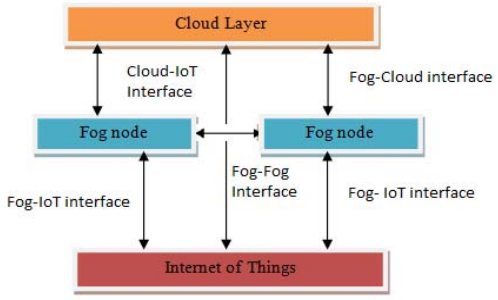

Figure 1 Fog interface with Cloud and IoT

4. *Existing computing technologies compared to fog computing*

Existing computing technologies that depend upon cloud and on end-user devices for their computing and storage have to face various challenges like security, latency, data storage and maintenance. Fog can provide effective ways to overcome many limitations of the existing computing technologies. Fog can be compared to the other technologies in terms of various Quality of Service (QoS) based parameters i.e. Latency, bandwidth, security etc. The table below shows the comparison of fog computing with the cloud computing and IoT.

Table 1: Comparison of Fog with other related technologies

Parameters	Cloud Computing	IoT	Fog Computing
Latency	High latency than fog	High	Fog brings all services near to the edge, so it provide low latency
Network Bandwidth	More bandwidth is required	Low	Low bandwidth is required
Security	Less secure	Less secure	High security
Access speed	High: depending upon virtual machine connectivity.	High	High
Capacity	Unlimited	Limited	Fog can store limited data, so filtered data is sent to cloud.

5. *Advantages of Fog computing*

Fog computing was introduced to overcome the problems faced by cloud computing, so it has some advantages that are listed below:

- *Concurrence to end users:* Fog is different from cloud by its concurrence to final-users.
- *QoS Services:* It provides reduced latency, location alertness, and boosts Quality of Services (QoS).
- *Real time applications:* Because of its low latency feature fog computing is used in real time applications i.e. municipal networks that hold vulnerable traffic and native data [15].

6. *Cons of Fog computing*

The main disadvantage of fog computing is the complexity it brings to the computation, storage, and networking as part of the overall architecture. Few disadvantages of fog computing is explained as bellow:

- *Security:* Fog computing faces security issue as malicious users can attack on the gateways. Sometimes unauthenticated user enters in the network and tries to thieve the important information.
- *Privacy:* The privacy issue deals with hiding the details from the unauthorized persons. Anyone can access the fog nodes because they are easily accessible due to presence on the edge, sometimes unauthorized person can try to temper the data.
- *Complexity:* Fog computing contains a web of nodes which increases the complexity of the system. In fog computing environment everything can become fog node, so due to large number of fog nodes in the system, it increase the complexity.

IV. LAYERED ARCHITECTURE OF FOG COMPUTING

The genre of cloud computing i.e. Fog computing have three layer architecture. The lower layer contains IoT devices. Fog layer is the middle layer. IoT devices are coupled to cloud layer via fog layer. Whole devices store their data on the cloud. The fog layer filters data, and the data which is not immediately required is redirected to the cloud. The frequently accessed data is stored on the fog layer. Layered architecture of fog computing is explained as below:

Smart IoT devices: The millions of sensors nodes and embedded systems having low bandwidth and very low latency are used at this layer. Smart devices like smart buildings, smart phones, laptops, smart electricity bulbs, smart cars etc. can be considered as IoT devices which collect the data and send this data to the fog layer[14].

Fog Layer: Network layer of fog is further subdivided into two parts: Fog network and Core network

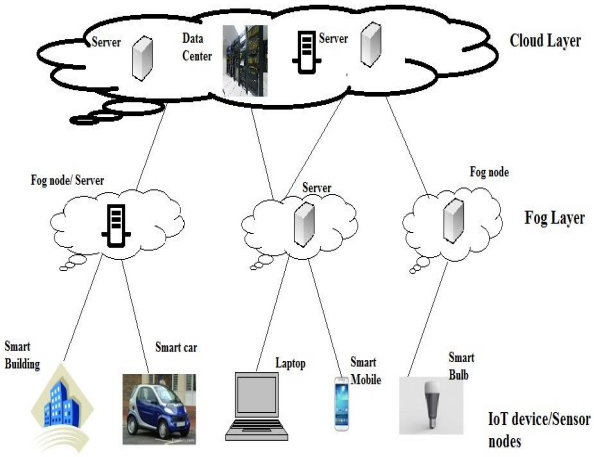

Figure 2 Architecture of Fog computing

- *Fog Network:* It includes 3G/4G/ 5G/ LTE/ Wi-Fi etc multi edge services that are used to connect different sensing devices with the fog nodes. Fog nodes are used to filter data gathered by way of IoT devices and not frequently used data is redirected to the upper layer i.e. cloud layer.
- *Core Network:* Multiprotocol Label Switching (MPLS), QoS, multicast and security are considered at this layer [15].
- *Cloud layer:* This layer includes a lot of datacenters and cloud hosting IoT analytics. The huge data gathered through different IoT devices are stored in the large data centers located at various locations in the world.

V. APPLICATIONS OF FOG COMPUTING

Fog works in distributed environment. It provides services to the final user at the edge device. Fog computing have various application areas that can be discussed as follows:

a) Smart Healthcare

Because of polluted environment various kinds of bacteria are being spread in the air which causes various diseases.

Every person is busy today because of fast lifestyles. Smart Healthcare is the smart IoT which keeps track of activities of people and measures various parameters of their body and keeps on uploading the data on the fog nodes, which are being observed by the doctors. The data stored on the fog nodes are being used by doctors to treat the patients within time. The people are wearing perceptive devices and these are further linked to fog nodes which are continuously sending the measurements of body parameters (temperature, blood pressure etc.) in order to the fog nodes. These intelligent wearable devices help to keep track of people's health [9].

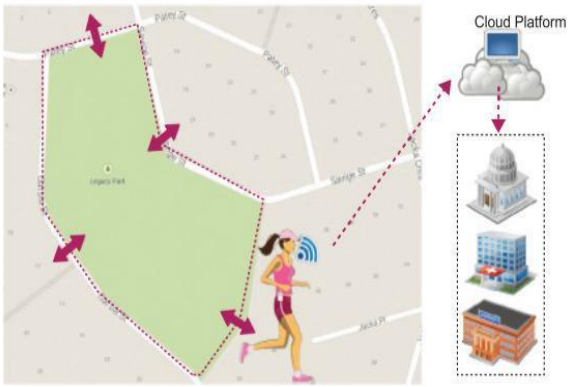

Figure 3 Smart Healthcare System [9]

b) *Smart Parking*

Due to much increase in transportation in the cities, more parking spaces are required. People have to wander here and there to find the appropriate parking space for them. Fog computing introduced a new idea of Smart parking. With the use of fog computing the parking slots can be installed with the sensors which keep on tracking weather the parking lot is empty or full. These sensors continuously keep on sending data towards the fog nodes which can be further connected to the smart vehicles. Vehicles can get indication through fog nodes about their nearby free parking space[14].

c) Smart Agriculture

Agriculture is the broad area to be given attention because this area is from where all the cities are getting food. Smart agriculture concept has been inaugurated in last few years. Smart sensing and computing are playing a significant responsibility in smart agriculture. A few smart agriculture approaches are invented in this area. Smart irrigation systems have been provided. Smart sensors are being fixed up in the fields [5]. Fog computing provides a platform for operating the sensors in the fields, which are continuously observing the crops. The sensors detect requirements of the crops and continuously store data in the fog nodes which send the alerts to the farmers about the requirements of the crops. The smart agriculture plays a crucial role for building a smart city.

d) Smart Waste management

The earth is degrading day by day, and to conserve the planet we require keen attention towards the natural resources. Now days, daily growing waste and water depletion from the earth seeks more attention. Smart garbage management system can be classified as the solutions for betterment of environment in this time. Such smart systems will be developed with the help of cloud as well as fog computing to collect and manage the waste more efficiently [10].

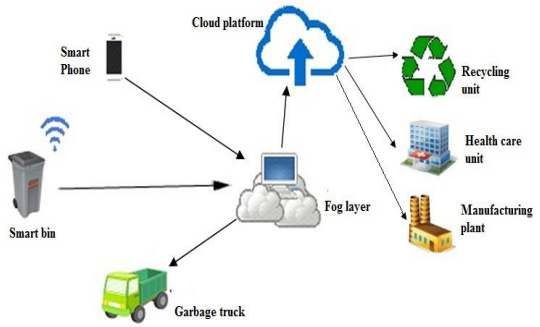

Figure 4 Waste management system

VI. LOAD BALANCING IN FOG COMPUTING ENVIRONMENT

In a network, few systems remain under-loaded at some time interval, while the others carry the entire load of the network. To maintain the load in a balanced scheme, "Load Balancing" becomes necessary. "Load Balancing strives to distribute the load in identical proportions throughout resources depending on recourse capability in order that every useful resource isn't overload or underutilized in a cloud device"[24]. Load balancing also required to be done to avoid deadlock and reduce the server overflow problem [25].

Some of the goals of fog based load balancing are discussed as below:

- In case of any system failure, load balancing provides the backup plans.
- Performance substantially can be improved.

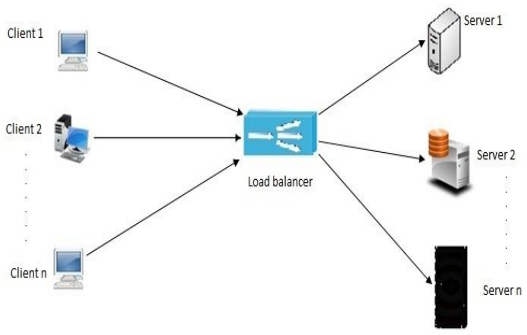

Figure 5 Load balancing

VII. REVIEW OF LITERATURE

This section includes the review of some researchers based upon introduction and architecture of fog computing, waste management system and load balancing in fog environment.

Simmhan et. al. [5] highlighted the gaps between capability and existence of fog computing, and diagnoses challenges that is required to be swamped for the sustainable resolution. They also discussed fog computing system architecture as well as resource characteristics of cloud, fog and edge computing systems. In the deployment of fog devices it is difficult to predict the user's demand and according to that determine the quantity of resources required at different locations. We can resolve this problem by optimally placing the fog devices at appropriate locations to serve the requests of nearby mobile users.

Charith Perera et.al.[14] has surveyed the various fog computing applications. They have discussed in detail about various applications and their implementation systems. According to them fog computing have scope in various areas like smart city, healthcare system, smart cultivation, Smart garbage management system and smart transportation etc. According to them sensing technology is improving day by day which is helpful in costs reduction. Sensing technology is helping in daily routine to build the smart city.

Chiang et.al.[15] summarized the fog research opportunities, concentrates essentially on context networking of IoT. According to them fog is a legitimate extension of cloud. They correlated cloud and its genre i.e. Fog in distinct factors like size, distribution and utilization and bandwidth.

Rajni [16] have studied about the variation in cost and makespan for execution of scientific applications due to increase in file size and network bandwidth. They also analyzed the impact of bandwidth; increased data file sizes, data transfer on total execution time and cost of scientific workflow application. They explained provisioning strategies and investigated the impact of Virtual Machine (VM) provisioning strategies by using different file sizes. The role of data and communication being interpreted here as other costs in case of scientific workflow applications has been taken here as a comprehensive study.

Aazam et.al.[25] presented Smart Gateway based architecture of fog computing. The concept was tested based upon the upload time delay, synchronization delay, bulk-data and jitter. They have explained Smart Gateway into two types i.e. Single-node and multi-node communication with the Intelligent Gateway. According to the article, trimming and pre-processing of the data before transmitting to the Cloud data center is very important for better and quick service furnishing.

Few of existing waste management systems have been reviewed as below:

Pooja V. Garach et al.[17] has developed a smart waste management system. They have advanced automated system in which ultrasonic sensor is being placed inside the trash cans and weight sensor at the bottom of trash cans. The sensors in trash cans detect whether the cans are empty or full, so that the collectors may get to know in advance about that. The data gathered through the sensors is then transferred to the cloud for storage and further use for various authorities. They have also surveyed algorithm implementation for Smart waste management (i.e. Dijkstra's Algorithm and Ant Colony System). They have also suggested shortest path route for the garbage collector to collect the discarded matter.

Dr. Latha Venkatesan et al [18] in their paper have developed smart alert system for garbage clearance by giving an alert signal to the cleaner. They have implemented real time waste management system to check whether the dustbins are full or not. They have used ultrasonic sensor along with arduino uno to check the level of garbage filled in the dustbin and also send alerts to the cleaners on their mobiles. People can get information through this system and can act accordingly. This system is implemented to reduce the cost, resource optimization and the traffic in the city.

Harshita Chugh et al. [19] developed an intelligence bin which can be used to monitor waste through sensors and send the related detailed information to the internet. They have installed sensors in the bins and these bins are connected with each other's, and they send data about the amount of discarded matter to the cloud from where higher authorities can take data to take suitable action about the discarded matter in the city.

G. K. Shyam et. Al [20] presented a waste collection management solution by developing intelligent waste bins, using an IoT prototype with sensors. These intelligent bins can read, collect, and transfer a large volume of data over the internet. Real GIS (Global Information System) data is used for the simulation results.

Table 2: Comparison of Existing waste management systems

Author	Work done	Evaluation and simulation environment	Algorithm used and methodology provided
Pooja V. Garach et al.[17]	Developed advanced automated system for waste management.	ifogSim	Surveyed Dijkstra's Algorithm and Ant Colony System and provided shortest path route algorithm
Dr.Latha Venkatesan et al [18]	Developed smart alert system for garbage clearance.	Ubidots, Arduino IDE software	Developed a program using Python language using the SMTP protocol to direct the message to cleaner.
Harshita Chugh et al. [19]	Developed an intelligent bin.	Android app	Provided algorithm to monitor the status of the bins.
G. K. Shyam et. Al [20]	Developed smart waste bins using IoT prototype.	Real GIS data is used for simulation	Shortest path spanning tree algorithm (SPST) is used.

Few load balancing based research reviews are given below:

B. Sotomayor et. al. [28] explained that Round Robin algorithm is used for load balancing in static environment. In this the resources are provisioned to the task on first-cum-first-serve (FCFS- i.e. the task that entered first will be first allocated the resource) basis and scheduled in time sharing manner. The resource which is least loaded (the node with least number of connections) is allocated to the task.

L. D. Dhinesh Babu [29] proposed an algorithm that is named as Honey Bee Behavior based Load Balancing (HBB-LB), which aims to achieve thoroughly balanced load across virtual machine. The proposed algorithm considers the priorities of the tasks which are assigned to VMs. The load balancing in VMs is based upon the honey bee's self-organized behavior of foragers in honey bee colonies.

D. Puthal *et al.*[30] proposed a novel load balancing technique to authenticate the Edge Data Centers (EDCs) and find less loaded EDCs for task allocation. An adaptive EDC authentication technique is proposed with the help of a centralized cloud data center. The proposed approach brings a sustainable and dynamic load balancing technique by considering the load of the destination EDCs. Breadth First Search method is used to design the proposed load balancing technique.

N. Song *et al.* [31] presented a framework in which cloud atomization technology is used to convert the physical nodes in fog computing environment into virtual nodes. They represented a graph model of fog computing in which the vertex of the graphs represents the various fog nodes and the edges represents the task dependencies and the bandwidth consumed. The layered model of fog and a graph repartitioning algorithm is created for fog computing with the use of cloud automation system. They also compared the operating time between the dynamic repetition algorithm and the classical hybrid strategy in terms of increasing number of tasks. With the increase of number of tasks in fog computing environment, the load balancing becomes mandatory.

X. Xu *et al.* [32] suggested a dynamic resource allocation method for load balancing in fog environment. They presented a system framework for fog computing and the load balance analysis for various types of computing nodes. They also designed resource allocation method in the fog environment through static resource allocation and dynamic service migration to achieve the load balance for the fog computing systems. The proposed method aims at high load balancing for all types of computing nodes i.e. cloud and fog nodes. They designed a global resource allocation strategy to enhance load balancing during the execution of the fog services.

VIII. PROPOSED METHODOLOGY

This article proposes a prototype of waste management system implementing load balancing at fog layer. The proposed prototype model contains three layers: Smart sensor devices, fog nodes/ servers, Cloud datacenters. Smart bins will be deployed which will contain the sensors. These Smart bins will be further tied up to the fog layer which filters the data to be passed to the cloud. Load balancer will balance the load on the fog nodes. It will divide the load equally on all the nodes. Fog nodes will generate alert messages to notify the garbage carriers to collect the waste. Security sensors will also be installed in the bins which will inform about the safety of the bins. If anyone will try to temper the bins then these sensors will start playing loud noise signals which can save the stealing of bins. The Smart bins will be connected through Wi-Fi, 3G/4G, LTE to the fog layer. An application will be generated to operate the whole scenario. Fog layer will further connected to the cloud. CloudSim will be used to manage the cloud and the fog nodes.

The subsequent figure shows the proposed prototype of waste management system

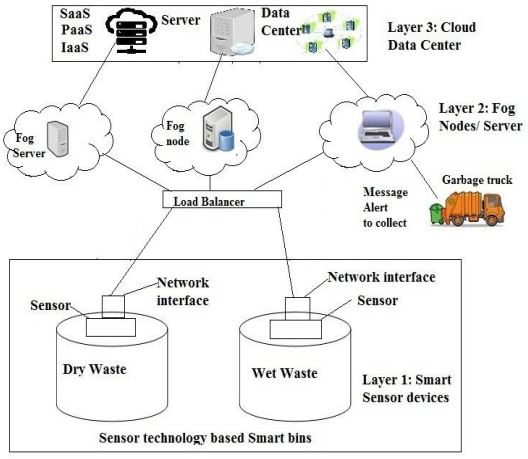

Figure 6 Prototype of Waste management system

Smart waste management system can help to develop a clean and green city.

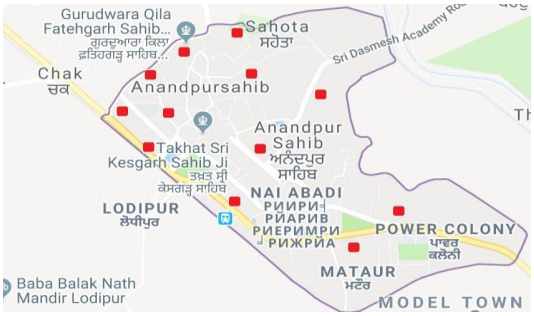

Figure 7 Proposed city to implement the prototype of waste management system

IX. OPEN ISSUES AND ENCOURAGEMENTS

In the preceding sections we have explained few application scenarios of fog computing. There are various research work have been done in the explained field. Both IoT and fog computing are developing fields. There are few limitations of existing systems.Therefore, a fog platform should be developed in a manner that anyone can compose approaches for backing of new applications. Now a days, mobile marketing apps and fog computing are similar. In a mobile

marketing app, number of apps are being designed to perform similar tasks but with the higher level of performance. Each application is different from each other. On the basis of requirement user can install or uninstall app at any time. Whereas mobile marketing apps, pays attention towards rules and guidelines which are worthy to be followed. Alike plug-ins to work consistently in fog platform, there ought to be some standardization, but applications should be accessible for resourcefulness.

There are various open challenges that can be further worked upon. The following can be further explored:

- *Communication between fog nodes:* It can be further explored to find an architecture through which fog nodes can interface with each others.
- *Detection of stolen Devices:* Smart devices are costly than the other simple devices in the market. These can be stolen easily. So further work is required to be done to protect these gadgets.
- *Security:* Security is the biggest challenge in today's world. Fog nodes need more security algorithms to be implemented.
- *Load balancing:* Load balancing is must in fog environment. Because it will cause problem if the few servers will be overloaded and the others will be under-loaded.
- *Energy Efficiency:* Energy efficiency can be a huge challenge in the fog computing. Power consumption of fog needs to be reduced.

X. CONCLUSION AND FUTURE SCOPE

Fog Computing can be efficiently used to construct Smart city scenario. The sensor technology has been developed nowadays, which can help us to generate smart things. All IoT devices send data to the cloud. Due to centralization of Cloud environment, it is becoming hard for different IoT devices to access data within time. Fog computing technology has been introduces which reduce the latency and provide the storage facilities at edge device i.e. near user device. Fog computing helped to create sustainable Smart cities. This research discussed about fog computing architecture and implementation of its applications in the Smart cities. This paper proposed a prototype for waste management system which includes the concept of load balancing on the fog layer. In further studies this prototype will be implemented to develop a smart city scenario, and energy consumption of fog nodes will be reduced. There are still more open areas for the future researchers i.e. Fog networking, resource provisioning, more advancement in transportation, security of fog nodes.

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