Abstract—Cloud computing is a promising technology in which computing resources are delivered as services over the Internet. Cloud is a centralised computing environment. Though it provides alluring benefits yet it suffers from key loopholes such as data transmission overhead, proximity, security and jitter delay. To avoid these issues a new computing technology has been raised called as Fog computing, which was initiated by Cisco. Fog computing is decentralised architecture which aims moving computation and storage from cloud to the corner of the network edge devices also called as edge computing, which are located closely to data sources. Fog computing is an extension of cloud computing. These features of fog are very useful for rising IoT applications particularly for latency sensitive and mission critical services. This paper focuses on comparison of Fog computing with other computing services by displaying definition and architecture of Fog computing, attributes and challenges of FC.

I. INTRODUCTION

Cloud computing is a techno business disruptive technology, which is swiftly gaining attention of individuals and business organisations. It offers desired features like globally, on demand, broad network access, pay per use to a shared group of configurable computing resources. To obtain better operational and capital cost efficiency many SME (small and medium enterprises) are adopting cloud for maintenance the data. Cloud computing is convergence of many technologies such as virtualisation, web services, SOA, web technologies, autonomic computing and other which depends on web. Furthermore to make wireless data transfer easy with IoT devices Fog computing was introduced by Cisco. Figure 1 explains how Fog computing is correlated and dependent on clouds.

Although cloud computing paved the way for easy accessing, processing, and managing users information but still suffer from the risk of security. Traditional security methods such as string of passwords for authentication and authorization are not enough. In Fog computing, computing resources and applications are dispersed in any place along the way of network from clouds to data sources. The whole application process and services are arranged in simple 3 hierarchal layers as shown in figure 2.

The figure 2 depicts that each intelligent device is connected to fog devices which are interconnected and also connected with the cloud.

Moving from cloud to fog

There is a huge swift in IT industry from centralised computing like cloud towards decentralised computing away to the edge of network. The purpose behind moving is smart applications like independent driving, intelligent cities, smart agriculture, savvy homes which demands more interactions which is limitedly address by cloud. Issues such as small time delays, security, privacy and performance are extremely hard to be solved by
centralised computing. So Fog plays an important role in which the devices are dispersed densely to the edge of network. The word edge refers various nodes to which end user is connected also known as Edge computing. The whole idea is depicted in figure 3.1 and figure 3.2

Figure 3.1: Cloud architecture before Fog computing

Figure 3.2: Cloud architecture with Fog technology

II. RELATED WORK

Why we require fog as extension of cloud? What can we do by utilising Fog computing? These can be examined by reviewing few existing researches. The authors [9] presented how local processing and responses to users works for small computing works without utilising cloud by assessing performance with IOX platforms as a simulation tool. The authors of [5] displays a method for assessing cost on various cloud environments by utilising virtualisation. authors of [6] examined the benefits of Fog computing in several various domain such as smart grid, wireless networks etc. And proposed common problems in Fog like security, privacy, trust. The authors in [7] proposed effective structure and algorithms for provisioning resources in fog by utilising virtualisation methods. The authors in [8] proposed policy based management of resources to support secure and safe integrations and interoperability between requested resources in Fog by using eXtensible Access Control Markup Language(XACML). In this paper we present a study on Fog concentrating on ideas, applications and issues may encounter in designing and implementing Fog computing.

III. ATTRIBUTES OF THE FOG COMPUTING

Various attributes of Fog are listed below:

a) Heavy geographical distribution

The services and applications are widely distributed on heavy Fog nodes, as Fog computing follows decentralised architecture. For instance by having many fog nodes which are placed along tracks and highways ,high quality of streaming is provided to moving vehicles.

b) Close to end users

With Fog computing recording and processing is moved to the edge network of the continuum or in user end devices which reduces response time and network latency drastically.

c) Support for mobility

Several applications generally mobile applications needs response with less delay where the support for mobility is possible with Fog computing.

d) Heterogeneity

Fog computing is constructed mostly by using virtualisation technology which needs to support different devices and technologies. Compute, storage and networking resources are basic blocks of Fog and cloud.

IV. CHALLENGES

Though Fog provides great benefits it still has several loopholes which needs to be solved. Some of the problems are listed below:

a) Programmability:

Managing applications is big problem in cloud and Fog platforms. As Fog contains many small nodes which are to be placed in correct location for proper abstraction, which is big deal for programmers.

b) Finding/sync:

Some applications executing on Fog devices needs interaction among peer devices and as well as with centralised server or cloud. So finding devices and getting synchronisation is an issue.

c) Management:

Fog computing follows distributed model of computing by dispersing edge nodes geographically which are to be managed properly for efficient computing.
d) Compute/storage limitation:
In Fog platform numerous small nodes are used which may limit processing and storage capabilities for some applications which is still a problem.

e) Security:
The similar security concerns for virtualised platforms are applied to Fog which affects fog devices hosting applications. With secure sandboxes which gives new challenges for implementing fog applications are trust and privacy. As Fog supports third party infrastructure for processing and storing privacy is concerned as major issues.

f) Standardisation:
At present there are no common standards and rules are available which are mostly needed in software components.

V. FOG COMPUTING ARCHITECTURE
The vital elements are divided into three layers: Different physical resources, Fog abstraction layer, Fog service orchestration layer.

a) Different Physical Resources: Physical resources which are heterogeneous in nature scaling from high speed interconnects data centers the basic to various wireless communication technologies, 3G/4G, LTE, Wi-Fi etc.

b) Fog Abstraction Layer: This layer presents unique application programming interfaces for resource management like controlling, preparing, managing physical resources like CPU, storage, network and energy.

c) Fog Service Orchestration Layer: It gives policy based, dynamic management of Fog services. Managing huge quantities of fog devices is achieved with following innovations and elements:

VI. FOG COMPUTING VS CLOUD COMPUTING
To know the benefits of Fog various attributes are considered. Cloud computing attributes has restrictions regarding quality of service which is demanded by real time applications. Table 1 displays the difference between attributes in both environments.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Fog</th>
<th>Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographical Distribution</td>
<td>Decentralised</td>
<td>Centralised</td>
</tr>
<tr>
<td>Data Transmission</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Location of the application service</td>
<td>Edge of local network</td>
<td>Within web</td>
</tr>
<tr>
<td>Security</td>
<td>Can be defined</td>
<td>Undefined</td>
</tr>
<tr>
<td>Locality awareness</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Distance between users and servers</td>
<td>Single hop</td>
<td>Multiple hops</td>
</tr>
<tr>
<td>Mobility support</td>
<td>Supported</td>
<td>Limited</td>
</tr>
<tr>
<td>Real time interactions</td>
<td>Supported</td>
<td>Supported</td>
</tr>
</tbody>
</table>

VII. CONCLUSION
Fog computing is not replacement for cloud computing it is just an extension. It is distributed model by managing data on dispersed nodes. Fog computing is proposed to bring down the computing and storage to end of the network also called as Edge computing. The main advantage of Fog computing is to provide more interactions and more responsiveness for real time applications particularly in the domain of IoT. This paper defines Fog computing, attributes and also highlights different challenges observed when designing Fog computing Systems. Fog computing will rise with swift development in IoT, edge nodes, SDN, RFID, NFV, VM and mobile cloud. So finally with Fog computing user will get better experience by reducing latency and improving security.

REFERENCES


