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Focusing on Mobile Users at Edge and Internet of Things using Fog Computing

PROF. RAKESH SURYAWANSHI[1], GANESH MANDLIK[2]
[1]HOD, Dept of MCA, A. C. Patil College of Engineering, Kharghar, Navi Mumbai, Maharashtra, India,
Email: rakeshsuryawanshi@gmail.com.
[2]PG Scholar, Dept of MCA, A. C. Patil College of Engineering, Kharghar, Navi Mumbai, Maharashtra, India,
Email: ganesh.g.mandlik@gmail.com.

Abstract: New advancements in Mobile devices and technology (Smart phone, Tablets, laptop and wearable devices) are increasingly becoming an essential part of human life as the most effective and convenient communication tools not bounded by time and place. With convergence of cloud computing and mobile computing, Mobile users are experiencing high end user friendly applications and facilitated video streaming, cloud gaming etc. Mobile users intensively and ubiquitously use these mobile applications because of that there is an explosive growth in the mobile data traffics. Also an Internet of Things (IoT) device generates large amounts of data. Transmitting this huge amount of data to the clouds and cloud retransmitting that data back to user or user's device requires a good bandwidth, this requires a considerable amount of time otherwise it will suffer from latency. Therefore, to accommodate this kind of traffic yet provide the guaranteed quality of service (QOS) to mobile users represent a key issue for the next generation networking. This encourages the emergence of Fog computing as a solution tailored made to serve this kind of mobile traffics. Fog aims to take services, workloads, applications and large amounts of data and deliver it all to the edge of the network. Fog computing distributes data and moves it closer to the end-user to eliminate latency and numerous hops, and support mobile computing and data streaming. Today's mobile users are asking for more data access from any device, any time, from anywhere. This means that the future of the cloud must support the idea of the "Internet of Thing (IoT)" That's where Fog Computing comes in. In this paper, we outline the main features of Fog computing and describe its concept, architecture and design goals. Lastly, we discuss on the potential research issues that needs to be study for the betterment of fog computing.

Keywords: CISCO, Fog Computing, Cloud Computing, Internet of Things.

I. INTRODUCTION

Over the past few years, advancement in the field of network based computing, technologies and applications on demand have led to an explosive growth of application models such as cloud computing, software as a service, community network, web store, and so on. The mobile devices have evolved from mere voice calls only devices to smart devices that enable the user to access value added services anytime, anywhere. The growth of mobility has changed our lives fundamentally in an unprecedented way. According to Cisco IBSG, close to 80 percent of the world's population has access to the mobile phone and new devices like the iPhone, Android Smartphone, palmtops and tablets have brought a host of applications at the palms of people's hands. Smartphones represented only 29 percent of total global handsets in use in 2014, but represented 69 percent of total global handset traffic. In recent years, the Internet has shifted to the cloud-based architecture. Notably, cloud computing has already evolved as the key computing infrastructure for Internet services with full-fledged service models and applications. Cloud technology has revolutionized the way services are delivered to end-users. The advent of truly mobile computing in the form of smartphones and tablets has also driven the demand for Cloud resources in order to compensate for the inherent lack of local resources on these devices. As reported in Cisco Global Cloud Index (2013-2018) [1] by 2018, global data center traffic will reach 8.6 zettabytes per year and 76 percent of all data center traffic will come from the cloud.

According to CISCO three out of four data center workloads will be processed in the cloud. The recent proliferation of smartphones has substantially enriched the mobile user experience, leading to a vast array of new wireless services, including multimedia streaming, web-browsing applications, socially-interconnected networks, social networking, navigation, and internet-of-things applications including E-healthcare, smart home and community, etc., The intensive use of mobile applications, wearable devices and Internet of things application finally leads to the surge growth of the mobile data traffic. As reported in Cisco Visual Networking Index (2013-2019) [2] Global mobile data traffic will increase nearly tenfold between 2014 and 2019. Modern 3G and 4G cellular networks simply aren't fast enough to transmit data from devices to the cloud at the pace it is generated, and as every mundane object at home and at work gets in on this game, it's only going to get worse.

Therefore to accommodate the mobile data traffic in a scalable and efficient approach represents an urgent goal. From the user's perspective, acquiring desirable mobile applications with guaranteed service quality at any time anywhere is an important determinant of life quality. The cloud centralized approach of information storage, retrieval and management, and mobile devices over the years became the major destination of information; the successful integration of cloud computing and mobile computing therefore represents an important task. However, due to the large distance between the cloud and mobile devices, the enjoyable high-rate data exchange between cloud and mobile user is still a hurdled by fundamental engineering challenges. This makes high-quality cloud-based mobile computing still a far end to achieve, and motivates the emergence of Fog computing as an effective solution towards the smooth convergence of cloud and mobile computing. Also an emerging wave of Internet deployments, most notably the Internet of Things (IoTs)[3], requires mobility support and geo-distribution in addition to location awareness and low latency.

Therefore we think a new platform is needed to meet these requirements; a platform fog computing was first proposed by Cisco in 2012 also known as edge computing. However, the research on Fog computing and related systems is in a very early stage. The goal of this research is to investigate on the key features of Fog computing and identify its main design goals and open research issues accordingly from the networking perspective and also the role of fog computing in Internet of thing that while improve the mobile users life. In the rest part of this paper, we unfold our journey by first describing the basic system architecture of Fog computing and showcase fog computing incorporating Internet of things Applications. After that, we discuss on the fundamental motivation behind the Fog computing and its comparisons with existing cloud computing networking systems. Lastly, we discuss on the potential research directions and conclude this paper.

II. FOG COMPUTING

Fog computing, a term coined by Cisco, involves bringing more intelligence to the network edge to allow for more efficient data handling and faster, local decision making. Fog Computing is a paradigm that extends Cloud computing and services to the edge of the network. Similar to Cloud, Fog provides data, compute, storage, and application services to end-users. The distinguishing Fog characteristics are its proximity to end-users, its dense geographical distribution, and its support for mobility. Services are hosted at the network edge or even end devices such as set-top-boxes or access points. By doing so, Fog reduces service latency, and improves QoS, resulting in superior user-experience. Fog Computing supports emerging Internet of Everything (IoE) applications that demand real-time/predictable latency (industrial automation, transportation, networks of sensors and actuators). Thanks to its wide geographical distribution the Fog paradigm is well positioned for real time big data and real time analytics. Fog supports densely distributed data collection points, hence adding a fourth axis to the often mentioned Big Data dimensions (volume, variety, and velocity).

Unlike traditional data centres, Fog devices are geographically distributed over heterogeneous platforms, spanning multiple management domains. Cisco is interested in innovative proposals that facilitate service mobility across platforms, and technologies that preserve end-user and content security and privacy across domains. Fog computing, also known as fogging, is a model in which data, processing and applications are concentrated in devices at the network edge rather than existing almost entirely in the cloud. That concentration means that data can be processed locally in smart devices rather than being sent to the cloud for processing. Fog computing is one approach to dealing with the demands of the ever-increasing number of Internet-connected devices sometimes referred to as the Internet of Things (IoT).

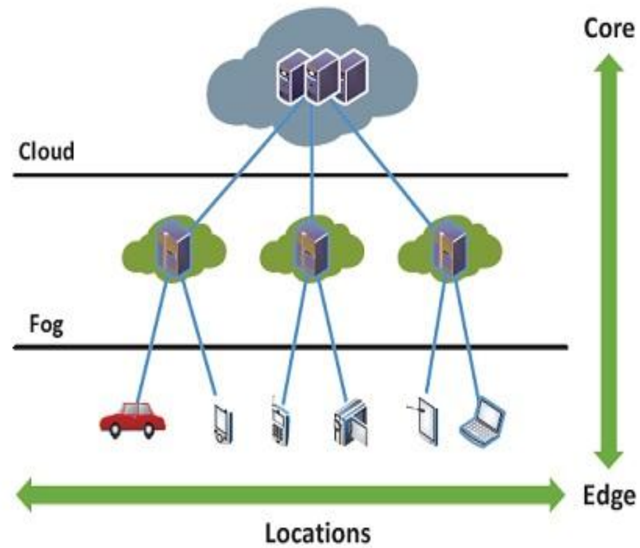

Fig.1. Fog Architecture [13]

A. Characteristics of Fog Computing

- Bringing data close to the user. The volume of data being delivered via the cloud creates a direct need to cache data or other services. These services would be located closest to the end-user to improve on latency concerns and data access. Instead of housing information at data centre sites far from the end-point, the Fog aims to place the data close to the end-user.
- Creating dense geographical distribution. Fog computing extends direct cloud services by creating an edge network which sits at numerous points. This, dense, geographically dispersed infrastructure helps in numerous ways. First of all, big data and analytics can be done faster with better results. Then, administrators are able to support location-based mobility demands and not have to traverse the entire WAN. Finally, these edge (Fog) systems would be created in such a way that real-time data analytics become a reality on a truly massive scale.
- True support for mobility and the Internet of Everything (IoE). As mentioned earlier, there is a direct increase in the amount of devices and data that we use. Administrators are able to leverage the Fog and control where users are coming in and how they access this information. Not only does this improve user performance, it also helps with security and privacy

issues. By controlling data at various edge points, Fog computing integrates core cloud services with those of a truly distributed data centre platform. As more services are created to benefit the end-user, edge and Fog networks will become more prevalent.

- Numerous verticals are ready to adopt. Many organizations are already adopting the concept of the Fog. Many different types of services aim to deliver rich content to the end-user. This spans IT shops, vendors, and entertainment companies as well. Let's take Netflix for example. With so many users all over the world, centralizing all of the content within one or two data centres would make the delivery process a nightmare. To deliver large amounts of streamed services, Fog Computing can be leveraged by placing the data at the edge; close to the end-user.
- Seamless integration with the cloud and other services. The idea isn't to replace the cloud. With Fog services, we're able to enhance the cloud experience by isolating user data that needs to live on the edge. From there, administrators are able to tie-in analytics, security, or other services directly into their cloud model. This infrastructure still maintains the concept of the cloud while incorporating the power of Fog Computing at the edge.
- Real-time interactions. Important Fog applications involve real-time interactions rather than batch processing.

B. Motivating Scenarios of Fog

We elaborate on the role of Fog computing in the following 9 motivating scenarios. The advantages of Fog computing satisfy the requirements of applications in these scenarios.

1. Smart Grid: Energy load balancing applications may run on network edge devices, such as smart meters and micro-grids. Based on energy demand, availability and the lowest price, these devices automatically switch to alternative energies like solar and wind. As shown in Figure 2, Fog collectors at the edge process the data generated by grid sensors and devices, and issue control commands to the actuators. They also filter the data to be consumed locally, and send the rest to the higher tiers for visualization, real-time reports and transactional analytics. Fog supports ephemeral storage at the lowest tier to semi-permanent storage at the highest tier. Global coverage is provided by the Cloud with business intelligence analytics.

2. Smart Traffic Lights and Connected Vehicles: Video camera that senses an ambulance flashing lights can automatically change street lights to open lanes for the vehicle to pass through traffic. Smart street lights interact locally with sensors and detect presence of pedestrian and bikers, and measure the distance and speed of approaching vehicles. As shown in Figure 3, intelligent lighting turns on once a sensor identifies movement and switches off as traffic passes. Neighbouring smart lights serving as Fog devices coordinate to create green traffic wave and send warning signals to approaching vehicles. Wireless access points like Wi-Fi, 3G, road-side units and smart traffic lights are deployed along the roads. Vehicles-to-Vehicle, vehicle to access points, and access points to access points interactions enrich the application of this scenario.

3. Wireless Sensor and Actuator Networks: Traditional wireless sensor networks fall short in applications that go beyond sensing and tracking, but require actuators to exert physical actions like opening, closing or even carrying sensors. In this scenario, actuators serving as Fog devices can control the measurement process itself, the stability and the oscillatory behaviours by creating a closed-loop system. For example, in the scenario of self-maintaining trains, sensor monitoring on a train's ball-bearing can detect heat levels, allowing applications to send an automatic alert to the train operator to stop the train at next station for emergency maintenance and avoid potential derailment. In life saving air vents scenario, sensors on vents monitor air conditions flowing in and out of mines and automatically change air-flow if conditions become dangerous to miners.

4. Decentralized Smart Building Control: The applications of this scenario are facilitated by wireless sensors deployed to measure temperature, humidity, or levels of various gases in the building atmosphere. In this case, information can be exchanged among all sensors in a floor, and their readings can be combined to form reliable measurements. Sensors will use distributed decision making and activation at Fog devices to react to data. The system components may then work together to lower the temperature inject fresh air or open windows. Air conditioners can remove moisture from the air or increase the humidity. Sensors can also trace and react to movements (e.g., by turning light on or off). Fog devices could be assigned at each floor and could collaborate on higher level of actuation. With Fog computing applied in this scenario, smart buildings can maintain their fabric, external and internal environments to conserve energy, water and other resources.

5. Internet of Things (IoT) and Cyber-physical systems (CPSs): Fog computing based systems are becoming an important class of IoT and CPSs. Based on the traditional information carriers including Internet and tele-communication network, IoT is a network that can interconnect ordinary physical objects with identified Addresses. CPSs feature a tight combination of the system's computational and physical elements. CPSs also coordinate the integration of computer and information centric physical and engineered systems. IoT and CPSs promise to transform our world with new relationships between computer- based control and communication systems based control and communication systems, engineered systems and physical reality. Fog computing in this scenario is built on the concepts of embedded systems in which software programs and computers are embedded in devices for reasons other than computation alone. Examples of the devices include toys, cars, medical devices and machinery. The goal is to integrate the abstractions and

precision of software and networking with the dynamics, uncertainty and noise in the physical environment. Using the emerging knowledge, principles and methods of CPSs, we will be able to develop new generations of intelligent medical devices and systems, 'smart' highways, buildings, factories, agricultural and robotic systems

Fig.2. Smart Grid [13]

6. Software Defined Networks (SDN): As shown in Figure 4, Fog computing framework can be applied to implement the SDN concept for vehicular networks. SDN is an emergent computing and networking paradigm, and became one of the most popular topics in IT industry. It separates control and data communication layers. Control is done at a centralized server, and nodes follow communication path decided by the server. The centralized server may need distributed implementation. SDN concept was studied in WLAN, wireless sensor and mesh networks, but they do not involve multi-hop wireless communication, multi-hop routing. Moreover, there is no communication between peers in this scenario. SDN concept together with Fog computing will resolve the main issues in vehicular networks, intermittent connectivity, collisions and high packet loss rate, by augmenting vehicle to vehicle with vehicle-to-infrastructure communications and centralized control. SDN concept for vehicular networks is first proposed in [12].

7. Shopping Center: Assuming that a number of Fog servers are deployed inside a multi-floor shopping center, which collectively forms an integrated localized information system. The Fog servers at different floors can pre-cache floor related contents, such as the layout and ads of stores on a particular floor. The Fog servers can deliver engaged services including indoor navigation, ads distribution and feedback collections to mobile users through Wi-Fi.
8. Inter-state Bus: Greyhound has launched "BLUE" [4], an on-board Fog computing system over inter-state buses for entertainment services. A Fog server can be deployed inside the bus and provides on board video streaming, gaming and social networking services to travellers using Wi-Fi. The on-board Fog server connects to the cloud through cellular networks to refresh the pre-cached contents and update application services. Using its computing facility, the Fog server can also collect and process user's data, such as number of travellers and their feedbacks, and reports to cloud.

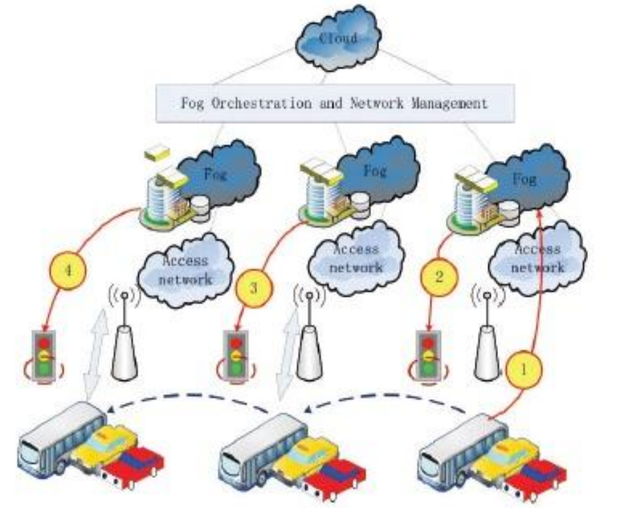

Fig.3. Smart Traffic Lights and Connected Vehicles [13]

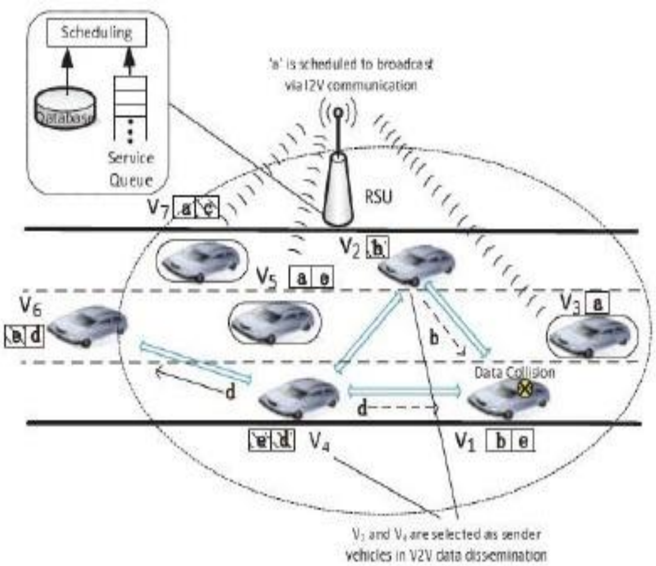

Fig.4. Software Defined Networks (SDN) [13]

9. Smart Transportation: Fog computing concept along with Internet of things (IoT) devices like sensors or accutors etc can be used for the betterment of transport bus services in big cities by providing location of the bus to its commuters by message on their phone. Because of that commuters spend less time while waiting for a bus on bus stop. Also bus company can do survey on how many commuters travel on particular routes, peak hours etc., in order to improve the transport service. Toll booths on highways with help sensors and ETC tags in vehicles can be used to avoid long queues at booths. Also allows government agencies and toll collectors to find out how many vehicles run on the highways, busy time, average traffic speed based on this future decision can be taken.

III. FOG COMPUTING AND BIG DATA

According to Steve Hilton of MachNation [14], Fog computing allows Business organisation to drive business success by delivering right information at the right time to the users on any device. There's an elephant in the big data room. Many organisations are using outdated technology and policies to collect and analyse data. These organisations are missing opportunities to extract the maximum valued information from their data. With the advancement of the Internet of Everything (IoE) and fog computing, organizations can deliver the right valued information at the right time to user on any device, driving business success.

The traditional data analytics model involves a centralized data warehousing and manual data manipulation and investigation. With the IoE, enormous amounts of data send in can make it difficult to find and act upon the right data if it is stored in centralized data warehouses. In much of the cases, centralized data processing requires high bandwidth to get information or data from point A to point C for analysis purpose. Moving gigantic amounts of data around the centralised cloud can result in lower reliability and higher network latency.

On the other hand, According to Cisco Business Insights-fog computing promises to unleash actionable data in real time at the network edge through mobility support and knowledge of aspects such as location awareness and geographical distribution. For example if a whether company uses the fog computing to transform the big data into competitive advantageous Information. Data collected in from a variety of sources: sensors, aircrafts, autonomous marine vessels, automobiles, nano satellites, drones, and weather enthusiasts around the globe. Their technologists cooperate with other executives to analyse this data based on that company can deliver accurate weather forecasts and content, creating a competitive advantage. And with The Weather Channel television network, website, and mobile application, the company is reaching more customers and expanding the business. In the above example, The Weather Company's, requires intelligence at the edge of the network, where colossal amounts of data are beginning to pour in from sensors and "things." In the internet-connected world of the IoE, innovation is accelerating in ways and speeds never before seen, because people are accessing the right information at their fingertips.

Much of the infrastructure to accomplish this—data centers and cloud-based computing is already established. There's just one thing is needed: a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional cloud computing data centers that is now referred to as fog computing. Typically, the fog platform filters big data and pushes relevant data to the cloud and then supports the real-time, actionable analytics and play processes wherever people Emerging fog computing and data virtualization technologies are helping companies to overcome the challenges of centralized data processing. Data virtualization software makes it simple and seamless to manipulate and view data, no matter where it is stored. Fog computing constructs a highly virtualized platform that extends cloud resources to the edge of the network. This reduces latency by providing compute, storage, and networking services throughout the network.

According to Steve Hilton of MachNation, "Fog computing has three main benefits:"

1. Data is processed and accessed more rapidly than in traditional, centralized computing architectures.
2. Data can be accessed more efficiently from a network perspective, not always requiring the high bandwidth that is necessary for communications with a central data center.
3. Datasets are processed and accessed reliably in the most logical location, minimizing the risks of latency.

To secure these benefits, Hilton suggests a systematic review of a company's business processes in each functional area. There are numerous processes that would benefit from the use of fog computing, including logistics management, warehousing services, retail services management, field services management, and others, After reviewing business processes, organisations can create a common architectural approach to deploy fog computing with its ancillary technology components: networks, hardware, platforms, software, and services.Data virtualization and fog computing helps in bring intelligence and analytical capabilities to the data. The result is the ability to extrapolate value and act on large quantities of diverse data, as it flows into the network, from any number of sources. IT decision makers, Operations decision makers, and line-of-business leaders need to work together to determine their fog-based analytics needs. The simple question to answer is whether fog-based analytics increases the speed, efficiency, and reliability of processing and accessing large amount of data. If the answer is yes, then these stakeholders should determine how to implement a fog solution.

There is an economical advantage of using fog computing. The organisation needs a simple solution (or multiple solutions) to train models and send them to highly optimized and low resource intensive execution engines that can be easily embedded in devices, mobile phones and smart hubs/gateways. To achieve this goal, fog computing is done best when it is done by machine learning models that gets trained on a fraction of the data stored on the cloud. After a model is considered good enough or adequate, then it is pushed to the devices. Algorithms like decision tree or some fuzzy logic or even a deep belief network can be used locally on a device to make a decision that is cheaper than setting up an infrastructure in the cloud that needs to deal with raw data from millions of devices.

IV. DIFFERENCE BETWEEN FOG COMPUTING AND CLOUD COMPUTING

Table I: Difference between Fog Computing and Cloud Computing

Fog Computing V/S Cloud Computing		
Parameters	Fog Computing	Cloud Computing
Target User	Mobile User	General Internet User

Service Type	Limited localized information services related to specific deployment locations	Global information collected from worldwide
Hardware	Limited storage, compute power and wireless interface	Ample and scalable storage space and compute power
Distance to Users	In the physical proximity and communicate through single-hop wireless connection	Faraway from users and communicate through IP Networks (Multiple Hops)
Working Environment	Outdoor(streets, parklands, etc.) or indoor (restaurants, Shopping malls, etc.)	Warehouse-size building with air conditioning systems
Deployment	Centralized or distributed in regional areas by local business (local telecommunication vendor, shoppingMall retailer, etc.)	Centralized and maintained by Amazon,Google , etc.
Latency	Low(Locality)	High(eventual consistency)
Control	distributed/hierarchical (partial control)	Centralized/ hierarchical (full control)
Location Awareness	Yes	No

Table I describes the difference between fog computing and cloud computing in terms of hardware used, location awareness, latency, service type etc.

V. FUTURE RESEARCH TOPICS

Issues related to communication, security, privacy and system integrity in the FOG Environment is definitely a topic for research and has to be explored. Therefore we need to do a research on the Interplay between- mobile devices and fog, fog and cloud and between fogs. And also need to do research on the security and privacy.

A. Communications between Mobile and Fog

Fog servers have limited storage and deliver limited localized services only, another key design research issue is how to optimally select the desirable information contents to cache at each Fog server and determine the appropriate service applications which cause the least service failure rates to mobile users. The solution needs to consider the predictable pattern of mobile service requests, available storage and compute power of a Fog server. The Fog computing can also be incorporated with the 5G cellular networks. In this case, by making the cellular base station a Fog server with on-board storage and compute facility, the entire Fog system can provide greater coverage and dedicated services to cellular users.

B. Communications between Fog and Cloud

The cloud performs two roles in the integrated Fog computing system. First, the cloud is the central controller of Fog servers deployed at different locations. With each Fog server focusing on the service delivery to mobile users at specific locations, the cloud manages and coordinates the geo-distributed Fog server clusters at different regions. Second, the cloud is the central information depot. The Fog servers at different locations select the information contents from the cloud and then deliver the copied contents from its cache to the mobile users. With above two roles, the design goal of the communications between fog and cloud can be two-fold: 1. how to enable the reliable and scalable control of Fog servers at the cloud; and 2. how to develop the scalable data routing scheme from cloud to Fog server for content updates.

C. Communications between Fogs

Fog servers belonging to different owners may locate at close distance to each other and serve the similar mobile users, it is thus possible for separate Fog server clusters to collaborate for joint service delivery. For instance, the Fog servers across the city collaborate for the distribution of similar contents to vehicles. In addition, since Fog servers co-located in the same region may be connected to the Internet through the same Internet service provider with the high-rate low-cost connections, to enable efficient collaborations among nearby Fog servers can alleviate the traffic between cloud and Fog servers, and improve the system performance with saved bandwidth cost and enhanced data rate.

D. Security

The same security concerns that apply to current virtualised environments can be foreseen to affect fog devices hosting applications. The presence of secure sandboxes for the execution of droplet applications poses new interesting challenges: Trust and Privacy as users are becoming increasingly concerned about the risk of having their private data exposed. Before using other devices or mini-clouds in the network to run some software, isolation and sandboxing mechanisms must be in place to ensure bidirectional trust among cooperating parties. The fog will allow applications to process user's data in third party's hardware/software. This of course introduces strong concerns about data privacy and its visibility to those third parties. For that reason some kind of mechanism or technique needs to be research in order to keep users privacy. Fog computing provides security to information by using Decoy technique and User Profiling in case of insider attack or Man in the middle of attack as it describe in [8][9][10][11].

E. Need for Standardisation:

Today no standardised mechanisms are available so each member of the network (terminal, edge point...) can announce its availability to host others' software components, and for others to send it their software to be run. So there is clear necessity to discover standard protocols, architectures and APIs in order to facilitate the interconnection among heterogeneous Internet of Things (IOT) smart objects and the creation of enhanced services that will fulfil the users' needs.

VI. CONCLUSION

This paper proposes Fog computing, a new networking technology dedicated to serve mobile users at edge. By providing reserved compute and communication resources at the edge, Fog computing controls the huge intensive mobile traffic using local fast-rate connections and reduces the long back and forth data transmissions among cloud and mobile devices. This significantly enrich the quality of service (QoS) perceived by mobile users and, more importantly, largely save both the cost of transmission bandwidth and consumption of energies inside the Internet backbone and also result in less battery consumption of mobile devices while fetching information from cloud. Therefore, Fog computing provides a scalable, sustainable efficient and quality solution to enable the convergence of cloud based services over the Internet and the mobile computing. The purpose of this paper is to research on the major motivation and design goals of Fog computing from the networking's perspective. We stress that the emergence of Fog computing is inspired by the increased predictable service demands of mobile users, and to incorporate fog computing with Internet of Things applications. Fog computing is thus mainly used to service the localized service requests. As a Fog server owns a hardware resources in three-dimensions (storage, compute and communications), this three-dimensional service-oriented resource allocations is the key of Fog computing. Moreover, with the three-tier Mobile-Fog-Cloud architecture and rich potential applications in both mobile networking and Internet-of-things, the Fog computing may also help in broad research issues on network management, traffic engineering, big data and novel service delivery. Therefore, we think a bright future of Fog computing.

Software Defined Networks (SDN): As shown in Figure 4, Fog computing framework can be applied to implement the SDN concept for vehicular networks. SDN is an emergent computing and networking paradigm, and became one of the most popular topics in IT industry. It separates control and data communication layers. Control is done at a centralized server, and nodes follow communication path decided by the server. The centralized server may need distributed implementation. SDN concept was studied in WLAN, wireless sensor and mesh networks, but they do not involve multi-hop wireless communication, multi-hop routing. Moreover, there is no communication between peers in this scenario. SDN concept together with Fog computing will resolve the main issues in vehicular networks, intermittent connectivity, collisions and high packet loss rate, by augmenting vehicle to vehicle with vehicle-to- infrastructure communications and centralized control. SDN concept for vehicular networks is first proposed in [12].

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