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THEORETICAL MODELLING OF FOG COMPUTING IN IOT APPLICATIONS

PRIYANKA N. CHANDAWAR
Assistant Professor,
Department of Computer Science
Prerna College of Commerce, Nagpur,
(MS) INDIA

ABSTRACT

The exposure of Internet of Things has permitted the interconnection and communication among large world things, that results in Data Explosions (associate unwanted generation of big and heterogeneous quantity of knowledge, referred to as information explosions.) On the opposite hand, the classic centralized cloudcomputing paradigm faces many challenges like high latency, low capability and network failure. Therefore, a new computing paradigm, referred to as fog computing, has been projected as a complement to the cloud answer. Fog computing extends the cloud services to the edge of network, and makes computation, communication and storage nearer to edge devices and end-users. In this paper, we will overview and summarize fog computing model architecture, key technologies, applications and challenges. Firstly, we will present the hierarchical architecture of fog computing and its characteristics, and compare it with cloud computing and edge computing to stress the similarities and variations. This paper provides a summary of the combination of fog computing with the IoT; this involves associate investigation of the fog progressive, characteristics and edges. The combination of the IoT with fog computing is additionally mentioned by highlighting the integration benefits, rising IoT applications and challenges encountered.
Keywords: *Internet of Things; cloud of things; fog computing; fog as a service; IoT with fogcomputing; cloud computing*

1 INTRODUCTION

The Cloud Computing model which provides “pay-as-you-go" is an efficient alternative to acquiring and managing private data centres (DCs) for customers facing Web applications and executing them. Several factors contribute to the economy of scale of mega DCs: higher predictability of massive aggregation,which allows higher utilization without degrading performance; convenient location that takes advantage of cheap power; and lower OPEX achieved through the deployment of homogeneous compute, storage, and networking components.Cloud computing frees the enterprise and therefore user from the speciation of many details. This bliss becomes a drag for latency-sensitive applications, which require nodes within the vicinity to meet their delay requirements. An emerging wave of Internet deployments, most notably the Internet of Things (IoTs), requires mobility support and geo-distribution additionally to location awareness and low latency. For this a new platform is needed to meet these requirements, and that platform we call Fog Computing. We also say that instead ofdisassemble Cloud Computing, Fog Computing enables a new kind of applications and services, and that there is a fruitful interaction between the Cloud and the Fog, particularly when it comes to data management and analytics.

1.1 Challenges of the Cloud of Things

The integration of the cloud with the IoT, referred as CoT, has many benefits. For instance, ithelps to manage IoT resources and provides less expensive and efficient IoT services. In addition,it simplifies the flow of the IoT data and processing and provides quick, low-cost installation and integration for complex data processing and deployment [1,3].

The CoT paradigm also introduces new challenges to the IoT system that cannot be directed by the traditional centralized cloud computing architecture, such as latency, capacity constraints, resource-constrained devices, network failure with intermittent connectivity and enhanced security[4].

In addition, the centralized cloud approach is not appropriate for IoT applications where operations are time-sensitive or Internet connectivity is poor. There are many scenarios where milliseconds can have serious significance, such as telemedicine and patient care. This is the equivalent scenario for vehicle-to-vehicle communications, where avoiding collisions or accidents cannot tolerate, the latency caused by the centralized cloud approach[2]. Therefore, an advanced cloud computing paradigm that improves the capacity and latency constraints is required to handle these challenges.Cisco suggested new technology called fog computing to address most of these challenges.

2. FOG COMPUTING

This section provides an overview of fog computing, its characteristics, benefits and architecture.

Fog computing is a disseminated computing infrastructure in which computing resources are located between the data source and the cloud or any other data centre. Fog computing is a model that provides services to edge user. The devices at the fog layer usually perform operations related to networking such as routers, gateways, bridges, and hubs.The term fog is often associated with Cisco, fog computing has been defined by manyresearchersandorganizationsfromanumberofdifferentperspectives.

2.1 Characteristics of Fog Computing

- . Heterogeneity: Fog Computing is a highly virtualized platform that yields compute, storage, and networking services between end devices and Cloud Computing Data Centers, typically, but not best located at the edge of network
- Edge location: The root of the Fog are often traced to early proposals to support endpoints with rich services at the edge of the network, including applications with low latency requirements (e.g. gaming, video streaming, augmented reality).
- Geographical distribution: In contrast to the more centralized Cloud, the services and applications targeted by the Fog demand widely distributed deployments. The Fog, will play a major role in delivering high quality streaming to moving vehicles, through proxies along highways and tracks.
- Large-scale sensor networks: To check the environment and therefore the Smart Grids are other examples of manifestly distributed systems, requiring distributed computing and storage resources.
- Support for mobility: It is essential for several Fog applications to speak directly with mobile devices, and thus support mobility techniques, like the LISP protocol, which decouple host identity from location identity, and require a distributed directory system.
- Real-time interactions: Important Fog applications involve real-time interactions instead of batch processing.
- Interoperability and federation: Consistent support of certain services requires the cooperation of different providers. Hence, Fog components must be able to interoperate, and services must be federated across domains.

Basically, fog computing is an extension of the cloud but nearer to the things that work with IoT data. As shown in Figure 1, fog computing acts as a middleman between the cloud and end deviceswhich brings processing, storage and networking services nearer to the end devices and thesedevices are called fog nodes. They can be situated anywhere within a network connection. Any devicewith computing, storage and network connectivity can be a fog node, such as industrial controllers, switches, routers, embedded servers and video surveillance cameras.

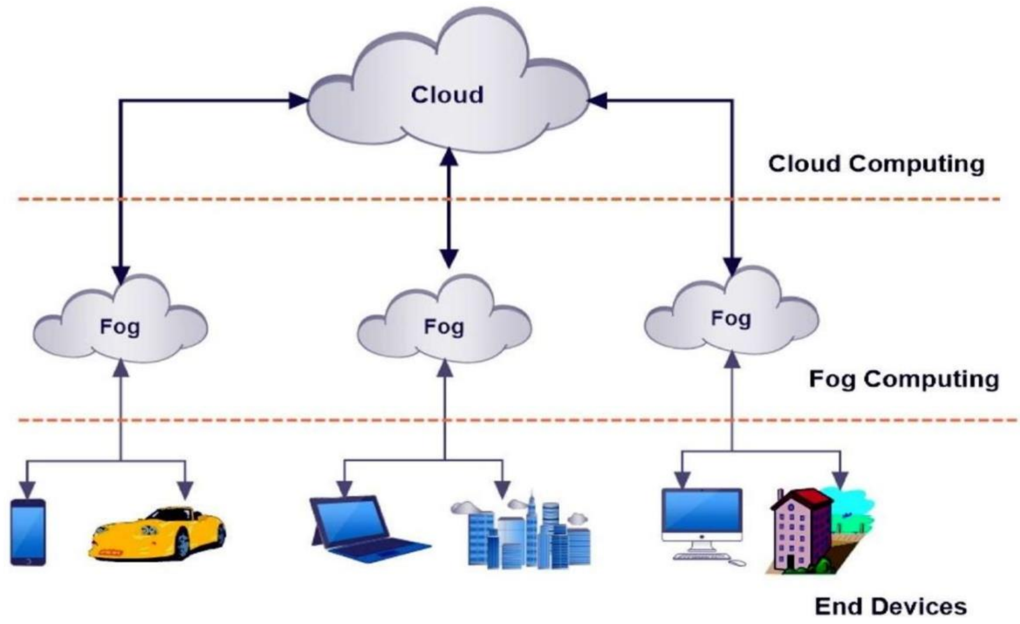

Figure 1. Fog computing is an extension of the cloud but closer to end devices [5].

2.2 Benefits of Fog Computing

Fog computing extends the cloud computing model to the edge of the network. It brings many benefits for IoT devices. These benefits can be summarized as follows:

- Greater business agility: With the help of the right tools, fog computing applications can be quickly developed and deployed. In addition ,these applications can program the machine to work according to the customer needs [8].
- Low latency : The fog has the ability to support real-time services (e.g.,gaming ,video streaming) [9]
- Geographical and large-scale distribution: Fog computing can provide distributed computing and storage resources to large and widely distributed applications [9].
- Lower operating expense: Saving network bandwidth by processing selected data locally instead of sending them to the cloud for analysis.
- Flexibility and heterogeneity: Fog computing allows the collaboration of different physical environments and infrastructures among multiple services [10].
- Scalability: The closeness of fog computing to end devices enables scaling the number of connected devices and services [9].

2.3 Architecture of Fog Computing

Fog computing is an approach that takes some of a data centre's operations to the edge of the network. The fog provides limited computing, storing and networking services in a distributed manner between end devices and the classic cloud computing data centres. The primary objective of fog computing is to provide low and predictable latency for time-sensitive IoT applications.

According to Mukherjee et al., Aazam and Huh and Muntjir et al the architecture of fog computing consists of six layers—physical and virtualization, monitoring, pre-processing, temporary storage, security and transport layer—as shown in Figure 2.

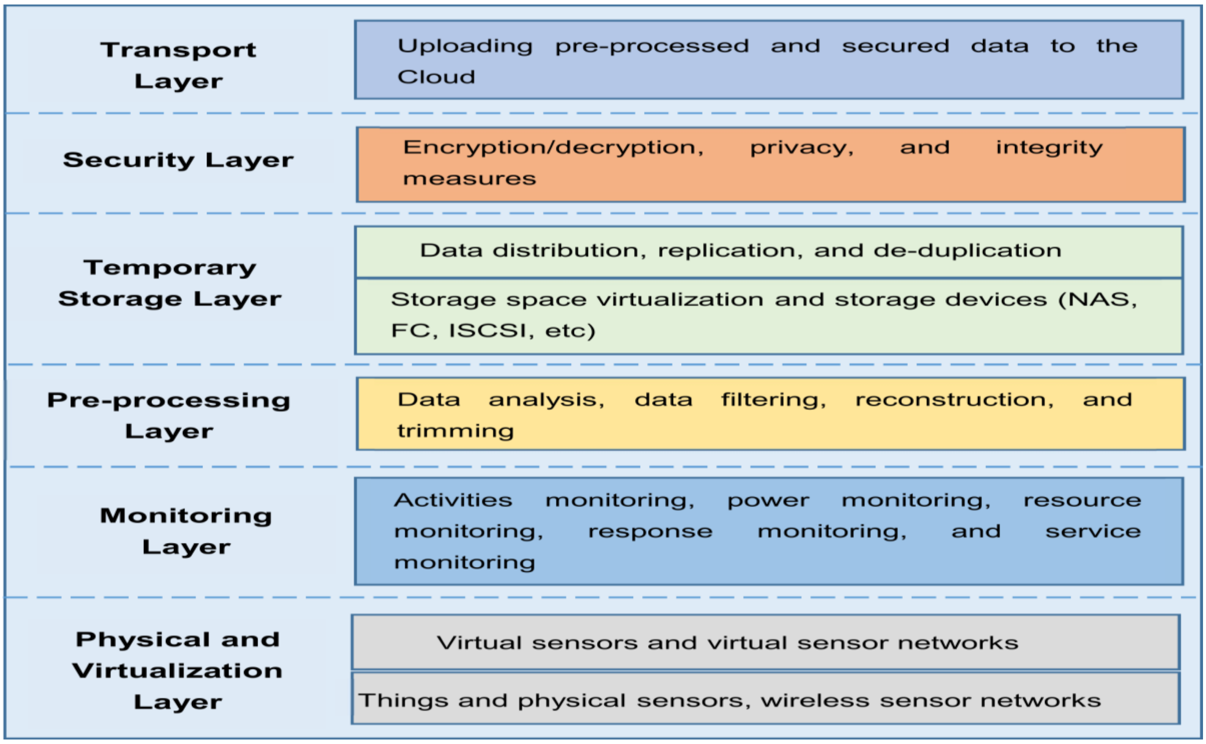

Figure 2. Layered architecture of fog computing [6].

The physical and virtualization layer involves different types of nodes such as physical nodes, virtual nodes and virtual sensor networks. These nodes are managed and maintained according to their types and service demands. Different types of sensors are distributed geographically to sense the surroundings and send the collected data to upper layers via gateways for further processing and filtering [12]. While at the monitoring layer, resource utilization, the availability of sensors and fog nodes and network elements are monitored. All tasks performed by nodes are monitored in this layer, monitoring which node is performing what task, at what time and what will be required from it next. The performance and status of all applications and services deployed on the infrastructure are monitored. In addition, the energy consumption of fog nodes is monitored; since fog computing uses many devices with different levels of power consumption, energy management measures can be both timely and effective [11].

The pre-processing layer performs data management tasks. Collected data are analyzed and data filtering and trimming are carried out in this layer to extract meaningful information. The pre-processed data are then stored temporarily in the temporary storage layer. When the data are transmitted to the cloud, they no longer need to be stored locally and may be removed from the temporary storage media [13].

In the security layer, the encryption/decryption of data comes into play. In addition, integrity measures may be applied to the data to protect them from tampering. Finally, in the transport layer , the pre-processed data are uploaded to the cloud to allow the cloud to extract and create more useful services. For efficient power utilization, only a portion of collected data is uploaded to the cloud. In other words, the gateway device connecting the IoT to the cloud processes the data before sending them to the cloud. This type of gateway is called a smart gateway. Data collected from sensor networks and IoT devices are transferred through smart gateways to the cloud. The data received by the cloud is then stored and used to create services for users [3]. Based on the limited resources of the fog, a communication protocol for fog computing needs to be efficient, light weight and customizable. Therefore, choosing the communication protocol depends on the application scenario of the fog.

3. FOG COMPUTING WITH IOT

The current centralized cloud computing architecture is facing severe challenges for IoT applications.

According to Cisco [14], provides a highly virtualized model of computation, storage and networking resources between end devices and classical cloud servers.

To increase the efficiency of IoT applications, most of the data generated by these IoT objects/devices must be processed and analyzed in real-time. Fog computing will bring cloud networking, computing and storage capabilities down to the edge of the network, which will address the real-time issue of IoT devices and provide secure and efficient IoT applications [16].

Fog computing is considered to be the best choice for applications with low latency requirements such as video streaming, gaming, augmented reality,etc. [17]

The integration of fog computing with the IoT will bring many benefits to various IoT applications. The fog supports real-time interactions between IoT devices to reduce latency, especially for time-sensitive IoT applications. In addition, one of the important features of fog computing is the ability to support large-scale sensor networks, which is a big problem with the ever-growing number of IoT devices, which will soon be counted in billions. Fog computing can provide many benefits to various IoT applications, as shown in Figure 3.

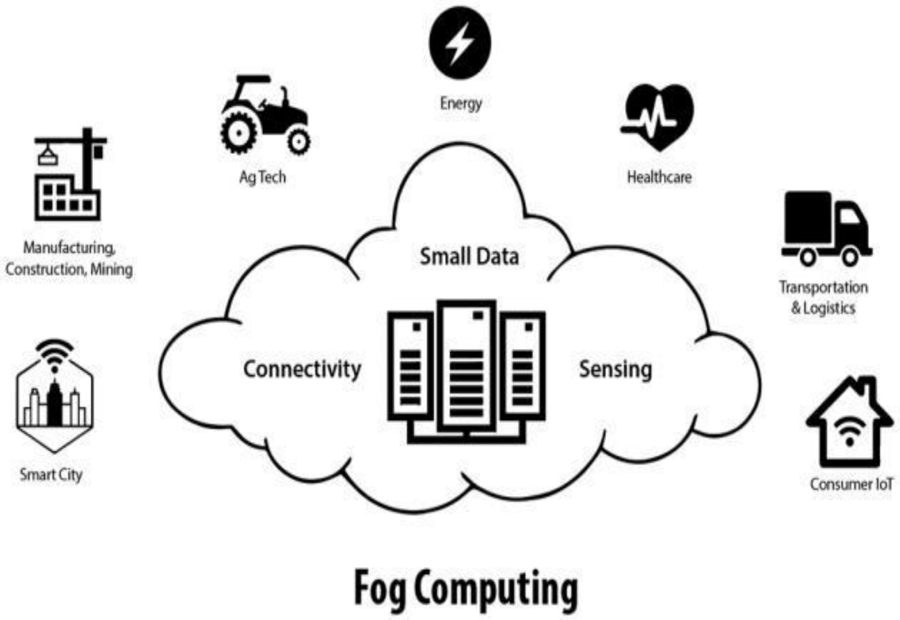

Figure 3. Fog computing in different services and applications [7]

Fog computing can provide effective ways to overcome many limitations of existing computing architectures that rely only on computing in the cloud and on end-user devices that are related to IoT devices.

According to M. Chiang and T. Zhang [10], fog computing can solve many of IoT challenges as described in Table 1.

IoTChallenge	How the Fog Can Solve the Challenge
Latency constraints	The fog performs all computation operation such as managing and analyzing data and other time-sensitive actions close to end users, which is the ideal solution to meet latency constraints of some of IoT applications.
Network bandwidth constraints	Fog computing enables hierarchical data processing along the cloud to IoT devices. This allows data processing to be carried out depending on application demands, available networking and computing resources. This, in turn, reduces the amount of data required to be uploaded to the cloud,

	which will save network bandwidth.
Resource-constrained devices	Fog computing can be used to perform operations that need huge resources on behalf of resource-constrained devices when such operations cannot be uploaded to the cloud. Therefore, this allows reducing devices' complexity, lifecycle costs and power consumption.
Uninterrupted services	Fog computing can run independently to ensure continuous services even when it has irregular network connectivity to the cloud.
IoT security challenges	Resource-constrained devices have limited security functions; therefore, fog computing acts as the proxy for these devices to update the software of these devices and security credentials. The fog can also be used to monitor the security status of nearby devices.

Table 1. Fog computing provides new solutions to many IoT challenges.

3.1 Applications of Fog with the IoT

There are many significant areas where fog computing can play a vital role in different IoT applications. This section provides an overview of various IoT applications that can benefit from fog computing.

3.1.1 Connected Car

According to Cisco, autonomous vehicles is a new trend for cars. There are many beneficial features, which depend on the fog and Internet connectivity, that can beaded to cars such as automatic steering and "hands-free" operation or self-parking features which mean that there is no need for a person behind the wheel to park the vehicle.

In the next few years, it is expected that all new cars will have the ability to communicate with near by cars and the Internet. Fog computing will be the most efficient solution for all Internet-connected vehicles, since it provides a high level of real-time interaction. In addition, it will allow cars, access points and traffic lights to interact with each other to deliver a good service to users.

With the use of the fog instead of the cloud, collisions and other accidents can be reduced as it does not suffer from the latency of the centralized cloud approach, enabling it to start literally saving lives.

3.1.2 Smart Home

The IoT has many sensors and devices connected within the home. However, these devices come from different vendors and have different platforms, making it difficult to urge them to cooperate with each other. Fog computing solves many of these problems. It integrates various types of platforms and empowers smart home applications with flexible resources.

3.1.3 Smart Traffic Lights

Fog computing allows traffic signals to open roads on the basis of sensing flashing lights. It senses the occurrence of pedestrians and cyclists and detect the distance and speed of the nearby vehicles. Sensor lighting turns on or off when it identifies movements.

Smart traffic lights may be considered to be fog nodes which are corresponding with each other to send warning messages to nearby vehicles. The interactions of the fog between the vehicle and access points are enhanced with WiFi, 3G, smart traffic lights and road side units.

3.2 Problems of Fog with the IoT

Although the fog computing paradigm offers number of benefits for different IoT applications, but at the same time it faces many challenges that stand in the way of its successful deployment. These challenges include scalability, complexity, dynamicity, heterogeneity, latency and security, as shown in Figure 4.

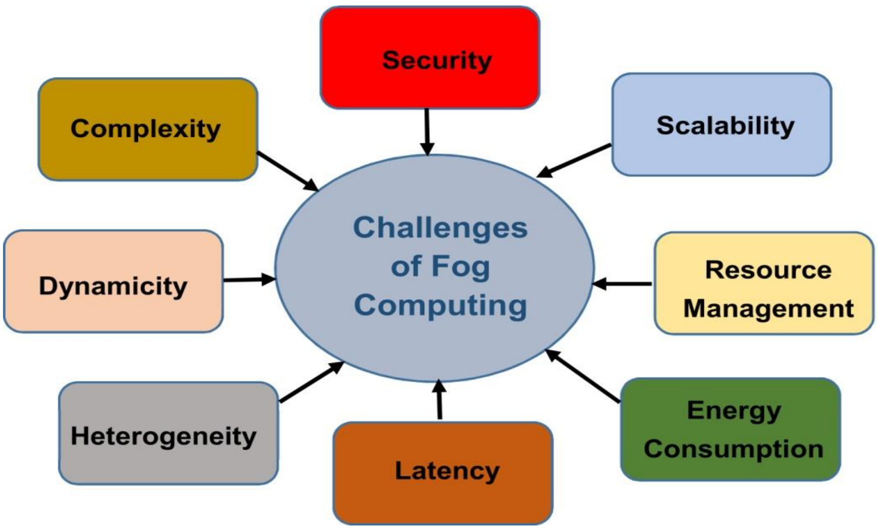

Figure4. Challenges of fog computing [15].

(1) Scalability: The number of IoT devices, which generates a massive amount of data and requires a vast amount of resources such as processing power and storage. Therefore, fog servers should be able to support all these devices with suitable resources. The real challenge will be the capability to respond to the rapid growth of IoT devices and applications.

(2) Complexity: Since there are many IoT devices and sensors intended by different manufacturers, choosing the ideal components is becoming very complicated, especially with different software and hardware configurations and personal requirements.

(3) Dynamicity: One of the important features of IoT devices is the ability to develop and dynamically change their workflow composition. Therefore, fog nodes will need automatic and intelligent reconfiguration of the topological structure and assigned resources.

(4) Heterogeneity: The management and coordination of networks IoT devices and sensors which are designed by different manufacturers with various proficiencies heterogeneous IoT devices and the selection of the appropriate resources will become a big challenge.

(5) Latency: One of the main reasons to substitute the cloud with fog computing is providing low latency, especially for time-sensitive applications. However, there are many aspects presenting a high latency of application or service performance on fog computing platforms.

(6) Security: Many research studies focus on cryptography and authentication to improve network security to protect against cyber-attacks in fog computing.

(7) Resource management: Fog end devices are often network devices equipped with additional storage and computing power. However, it is difficult for such devices to match the resource capacity of traditional servers, let alone the cloud.

(8) Energy consumption: The fog environment involves a large number of fog end devices; the computation is distributed and can be less energy-efficient than the centralized cloud model of computation. Therefore, reducing energy consumed in fog computing is an important challenge that needs to be addressed.

CONCLUSION

In recent years, the IoT has attracted the attention of both academic and commercial organizations. It is becoming an essential part of our lives. It has the ability to connect almost everything to everything else in our environment. IoT devices are dynamic in nature and have limited storage and processing capabilities. However, the traditional centralized cloud has many issues, such as high latency and network failure. To solve these issues, fog computing has been developed as an extension of the cloud, but closer to the IoT devices in which all data processing will be performed at fog nodes, by this means reducing latency, especially for time-sensitive applications. The incorporation of fog computing with the IoT will bring many benefits to different IoT applications. In this paper, we presented the state-of-the-art of fog computing, including a conversation of fog characteristics, architecture and its benefits. The discussion also attentive on different IoT applications that will be enhanced through the fog. Challenges of integrating the IoT with the fog are also discussed. In summary, the purpose of this paper was to provide a review in order to review up-to-date research contributions on fog computing and the IoT and its applications in our world, as well as demonstrating future research directions and open issues regarding integrating fog computing with the IoT.

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