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Fog computing system for internet of things: Survey

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Annotation

The Internet of Things is one of the most popular topics in the last decade, which has facilitated human tasks and daily tasks. In the IoT system, connected devices generate large-scale data to communicate with each other and perform the necessary tasks, which makes one of the challenges of using the IoT to manage the data generated through it. Cloud-based IoT systems are challenged by high latency, heterogeneity, and large scale. One of the proposed solutions to this problem is to transform data management and analysis by a computational and integrated model by the network called Fog computing. Compared to traditional cloud computing, Fog computing reduces energy consumption and is very suitable for delay-sensitive services with low traffic density, thus making it more efficient to use resources and perform better for bandwidth, energy consumption, and latency. This article investigates the concept of the Fog computing model and its architecture and its features, and then an extensive review of the proposed work on fog computing in the Internet of Things will be done.

Keywords: fog computing , Internet of Things (IoT), Fog benefit, IoT Application

Introduction

Over the past decade, the use of the Internet of Things and cloud computing has become very popular and plays a very important role in human life. The Internet of Things can connect physical objects to each other or people at any time and place. In this field, data is collected from the environment and shared via the Internet to be processed for various purposes. This process of connecting physical objects to the Internet results in the production of large-scale data, which introduces the concept of "big data", which requires efficient and intelligent storage [1].

Using traditional methods of existing hardware and software is not able to manage and process this large amount of data in an acceptable time. [1] Therefore, according to the cloud computing model, this big data is usually considered that cloud technology leads to the use of large resources remotely and at a reasonable cost. [2]. As the size of the cloud increases, network latency will increase as much as it is not acceptable for critical Internet applications [3]. There are limitations to using cloud technology, and one of the most fundamental limitations is the connection to the cloud and end-to-end devices on the Internet, which are not suitable for some sensitive applications.

Also, cloud-based applications are usually multi-component and distributed, which makes it common to deploy separate application components on multiple clouds, which is greatly delayed due to overhead due to cloud communication [4]. One of the solutions that have been introduced to address these limitations of cloud computing is an extension of cloud computing called Fog computing, which is a good example for many IoT services [5]. Fog computing is an example that has been introduced to address these limitations. The Fog computing architecture extends computing to the edge of the network and distributes computing, processing, and data storage to end-users [6]. In studies such as [7] [8], it has been widely stated that cloud computing is not suitable for most IoT applications and Fog computing is an alternative method in this situation. Fog computing is a marginal computational example that reduces the problem of high latency (or propagation delay) by building smart gates [9]. Because gateways are smart, they can decide to process incoming data or send it to the cloud-based on delay limits [10]. Fog computing can provide a mechanism for marginal devices to operate for a reasonable time without interruption, even if the cloud connection is

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lost, as well as protecting confidential information and sensitive data. It also provides a better real-time response than other cloud-based models [12]. Compared to cloud computing, Fog computing has relatively small computing resources such as memory, processing, and storage, however, it can process data generated from different devices [7].

Fog computing is basically a cloud extension, but it is closer to objects that work with IoT data. Figure 1 shows the Fog computing architecture in the IoT [13] The top layer is the cloud layer that does the processing, the bottom layer is the sensor layer, which produces the data. Fog computing acts as an intermediary between the cloud and end devices, bringing processing, storage, and network services closer to the ultimate tool itself. These devices are called fog nodes. A Fog layer consists of multiple Fog paths that provide limited storage and processing capabilities for data processing to end devices. They can be deployed anywhere with a network connection. Any device with calculation, storage, and network connection can be a node such as routers, embedded servers, and video cameras, etc. [31, 32]. The fog gate can be connected to another cloud connection gateway via wired or wireless. These gateways are smart and can make decisions about data transfer or processing [10].

A key difference between cloud computing and Fog computing is that cloud computing tries to optimize resources from a global perspective, while Fog computing organizes and manages this locally.

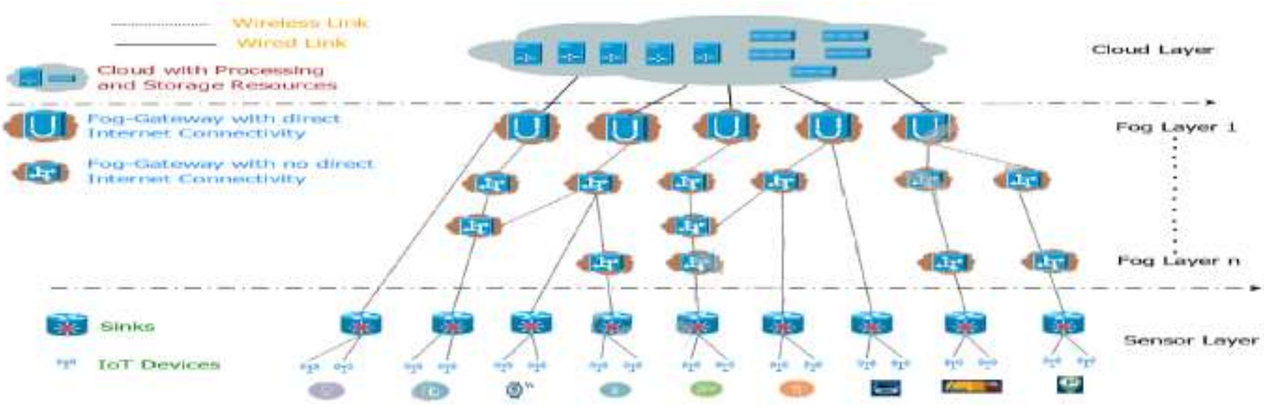

Figure 1 - Fog computing architecture [13]

The main protocols for communication between cloud and Fog, Fog computing, and IoT devices are shown in Figure 2. Communication between Fog computing and the Internet of Things is done using CoAP, MQTT, and XMPP protocols [14].

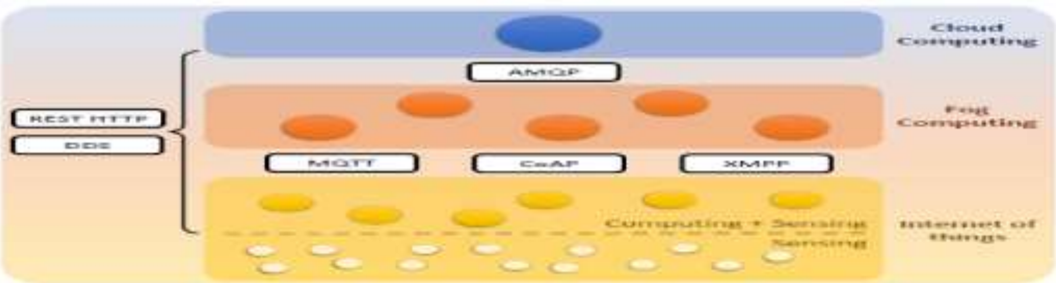

Figure 2 - Application protocols on the Internet, Fog, and cloud networks [14]

The rest of the article is organized as follows: Section 2 examines the IoT architecture and the motivation for using Fog computing. Section 3 examines the main shortcomings of IoT-based cloud integration. Section 4 provides a more comprehensive review of Fog Computing. We then provide a summary of Fog computing studies and suggestions in the Internet of Things in Section 5, and the conclusions are presented in Section 6.

I. IoT Architectures and Motivation of Fog Computing

One of the factors for the success of a system is its efficient architecture, and since the architecture of the Internet of Things is a field of research, many researchers and institutions have tried to create an efficient architecture, some of which are presented in [15]. The proposed architectures are 3-layer or 5-layer, as shown in Figure 3 [16].

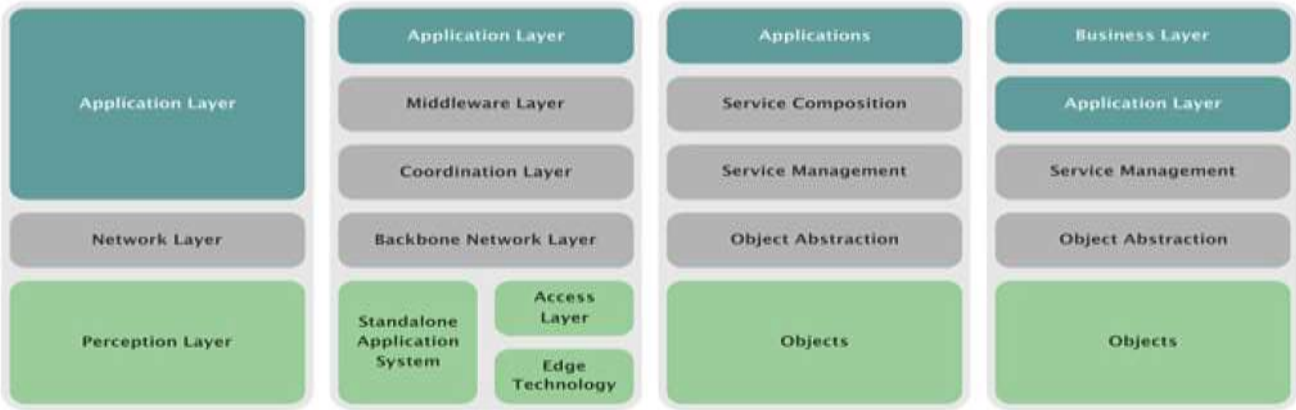

Figure 3- IoT architecture proposals (three layers and five layers) [16]

In three-layer architecture, sensors in the perceptual layer, by collecting data and transmitting through the network, reach the applied logic. In 5-layer architecture, additional layers help to provide device integration services at the perception layer. IoT devices usually have limited resources, as well as different communication protocols and data formats. After the logical separation of the functional components that results in three or five layers, we can map the logical components to the physical computational layers. We know that in a client-server approach, many components (shown in Figure 3) participate in the server in a cloud. Unfortunately, this approach does not address all of the requirements discussed above, so we need to go for an alternative computing hierarchy that works well for the Internet of Things. Fog computing is introduced as the middle layer between the perception layer and the cloud and gives more flexibility in choosing the architectural components of the IoT system. Figure 4 shows how Fog computing is placed between the perception layer or sensors and the cloud layer [17].

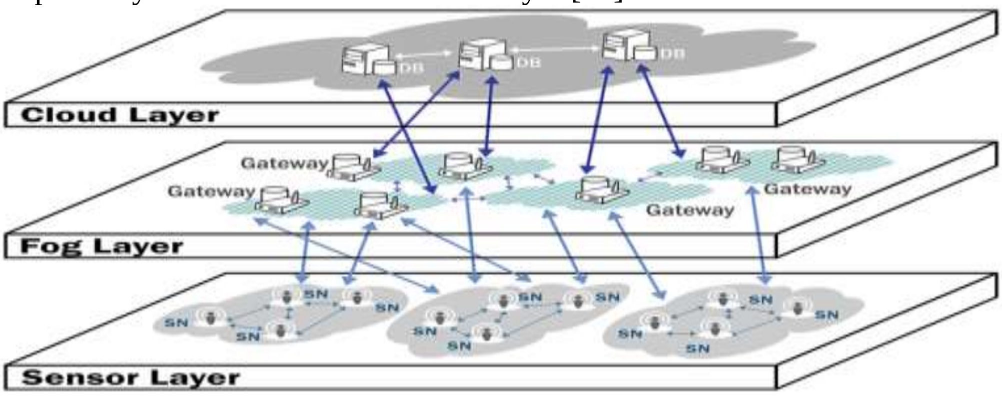

Figure 4- High-level overview of fog based IoT[17]

II. The most significant disadvantages of IoT-based cloud integration

The main disadvantages of IoT-based cloud integration due to the large distance between the cloud and the IoT devices are as follows: [23] [25] [24] [30][26] It has been said:

Latency: Very low and predictable response times are very important in some areas of IoT applications. According to the reference [20], road safety and independent driving services require a delay of fewer than 50 milliseconds, while smart grids have strict requirements up to 20 ms, with lags ranging from 250 to 10 ms Fog computing networks are parsed and Data analyzes are performed near the data collection site and actions are taken, which allows for a predictable reaction time.

Bandwidth consumption: Data obtained from IoT devices is increasing and can be known as big data. A network with fog computing transmits good information to the adjacent layer and acts as an interface between objects and the cloud, further reducing information, and this effective management of large data volumes significantly reduces bandwidth consumption. [27] .

Privacy: The use of mobile devices leads to the inevitable collection of sensitive data that requires adequate protection. Sensitive data is sometimes stored locally instead of being sent over the Internet in general, and when the cloud requires access to sensitive information. They are transmitted through fog due to privacy issues.

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Context awareness: Context in reference [21] is defined as "any information that can be used to determine the status of an entity". Provides background knowledge, improved service delivery, and resource utilization [22]. The Fog computing layer is adjacent to IoT equipment and improves texture awareness. Utilization of background information improves services and/or optimizes resource usage.

Hostile environments: Some IoT devices are used in critical areas (eg, traffic and emergency management) where the environment and public safety are key concerns. In such scenarios, the availability of services and data must be constantly guaranteed. However, there are areas where hostile environments in which the Internet is down performed very poorly, or are simply not available [23]. Fog computing can always guarantee availability. Fog computing is an example with limited capabilities such as computing, storage, and network services in a method distributed between different end tools and computing in the classical cloud method. This method provides a good solution for IoT applications that have latency [31]. Although the term was originally coined by Cisco [24], Fog computing has been defined by many researchers and organizations from several different perspectives.

As shown in Figure 5, the lowest layer in the hierarchy contains the final devices and. The higher layers lead from the edge of the network to the core, and their number and composition depend on the actual application purpose [28]. Finally, the top layer of the cloud is FC, which does not replace the Cloud but cooperates with it, because many services require Fog and Cloud features [29].

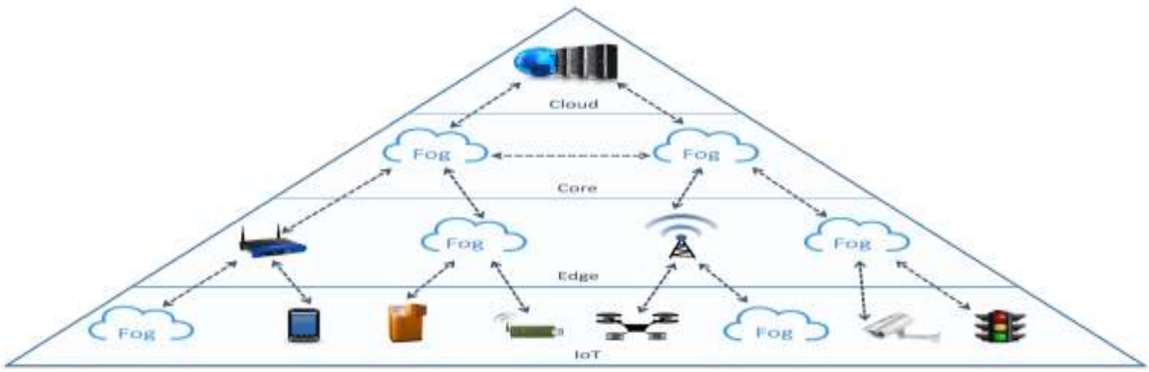

Figure 5. FC hierarchical organization

Interactions in such hierarchical systems can be of any type, both in one layer and between nodes belonging to different layers [28]. Each node has its share in the overall service and the nature of its role depends greatly on its position in the pyramid. Their integration has been investigated in [29, 24, 28].

III. Fog Computing

The Fog Computing layer is closer to the perception layer where the sensors reside and provide computing, networking, and storage services. To adapt these services and address the requirements of IoT systems, the fog layer provides the specifications discussed in the following. They establish. At the Fog layer gateway, the network interface is an important component to enable support for various wireless network protocols. According to Mukherjee et al. [36], Aazam and Huh [38, 37] and Muntjir et al. [39], 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 6.[40]

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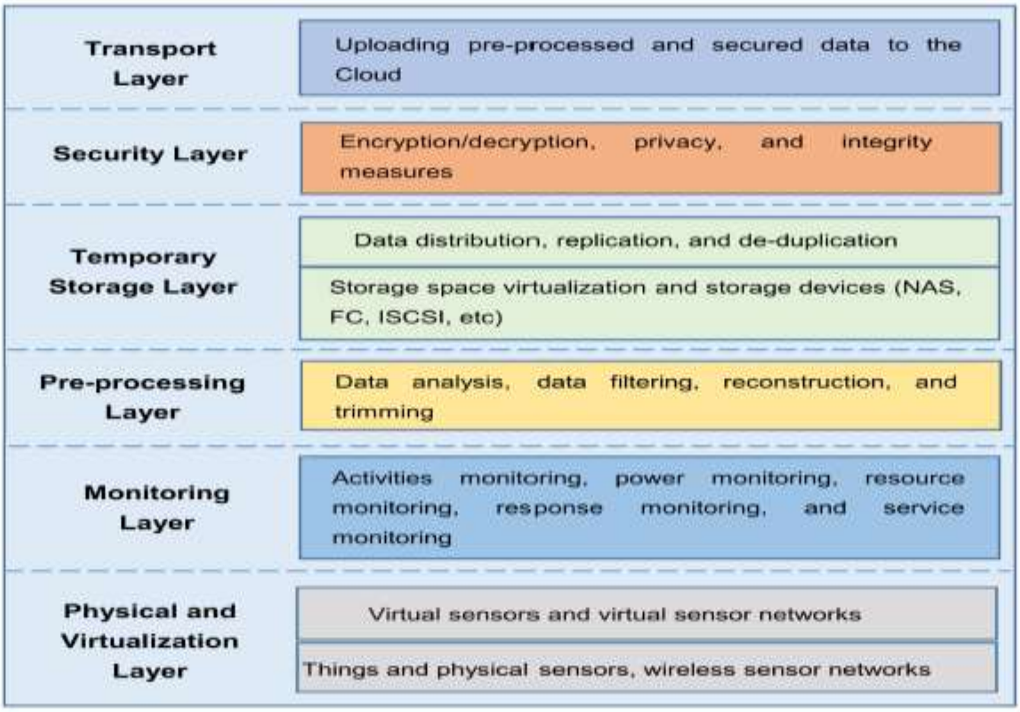

Figure 6- Fog computing layered architecture

The physical and virtual layers include various types of nodes such as physical nodes, virtual nodes, and virtual sensor networks. To better understand the environment, these nodes are geographically distributed and are responsible for sending data collected through gateways [32]. In the monitoring layer, the use of resources, the availability of sensors and Fog nodes, and network elements are monitored. This layer is responsible for controlling energy consumption and performance and tasks performed by nodes and Fog and programs and services located in infrastructure [36]. The preprocessing layer performs data management tasks. It is responsible for data processing to extract meaningful information, then the extracted information is temporarily stored in the temporary storage layer. Once transferred to the cloud, they no longer need local storage and may be removed from temporary storage media [38, 39].

At the security layer, data is encrypted/decrypted for protection. Finally, at the transfer layer, preprocessed data is loaded over the cloud to create more useful services [38, 39] Based on Fog's limited resources, a communication protocol for Fog computing must be efficient, light, and customizable. Therefore, the choice of communication protocol depends on the Fog application scenario [25].

Fog computing has the following features: [7]

- Low latency and location-awareness
- Supports geographical distribution
- End device mobility
- The processing capacity of a large number of nodes
- Wireless access
- Real-time schedules
- Heterogeneity

Despite similar sources and features almost similar to cloud and Fog, Fog computing has many advantages for IoT devices [24]. These benefits can be summarized as follows:

- Rapid development and deployment of Fog computing applications and machine programming based on customer needs [24].
- Ability to support full-time services with low latency [34].
- Distribution of computing resources and distributed storage in large-scale applications [34].
- Lower operating costs by saving network bandwidth by processing selected data instead of sending it to the cloud for analysis [24].
- Ability to work with heterogeneous physical environments and infrastructures [2].
- Increasing the number of devices and connection services due to proximity to devices [34].

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Possible services in the Fog layer are organized as computing, storage, and network services as follows:
Computing Services: There are several configurations for dividing computing loads between different layers in an IoT-based system, and processing requirements may vary based on actual work.

Storage Services: The solution for large-scale data storage is to filter and store data in the middle Fog layer [18] [19]. In combination with the computing service, stored data can be filtered and analyzed, and compressed for efficient transmission or training of local information related to system behavior.

Communication Services: The Fog layer is strategically located to organize these wireless protocols and connect them to the cloud layer. Also, the Fog layer provides visibility for IP-based devices to be accessible via the Internet [18].

IV. Fog-Computing in Internet of Things

In this section, we review the work related to Fog computing with the Internet of Things, which has been presented by various researchers in recent years. These research articles cover various aspects of Fog computing.

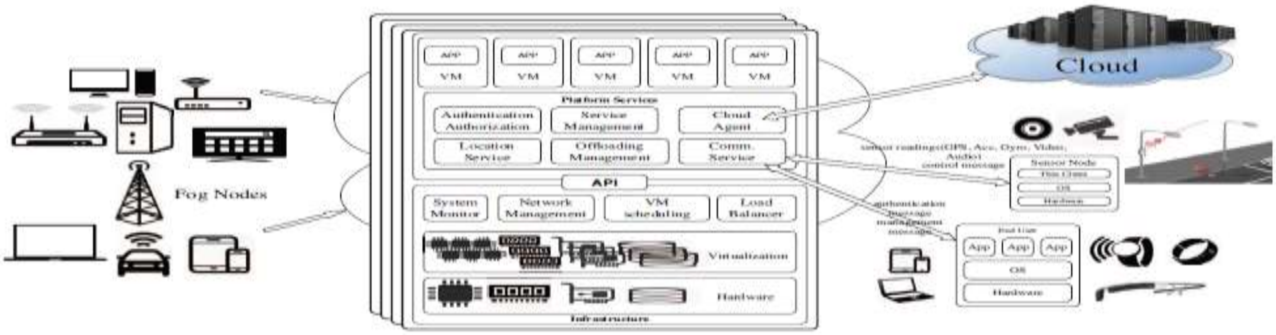

Figure 6 - Components of the Fog computing platform

Kumar et al. [41] discuss the features and benefits of using Fog computing and finally provide a survey of Fog computing compared to cloud computing.

N.peter et al. [42] discuss Fog computing and its immediate applications.

Yousefpour et al. [56] provide an overview of IoT-fog-cloud applications aimed at reducing IoT service latency and then develop an analytical model for evaluating the proposal.

C. Puliafito et al. [43] focused on mobile devices and examined the main challenges of mobile support, and identified and explained the three integration scenarios of Fog computing and the Internet of Things.

Dastjerdi et al. [9] proposed a reference architecture model for Fog computing, which helps IoT requests in local Fog instead of involving the cloud. In the proposed reference architecture, the central Fog service is placed in a software resource management layer.

Bonomi et al. [8] examined the integration of IoT with Fog computing and, besides, proposed a hierarchically distributed architecture.

Aazam et al. [37] have proposed a model for resource management through Fog computing that uses a dynamic approach.

Skarlat et al. [44] proposed a framework for the delay-sensitive application of Fog computing resources, and the evaluation result showed that the proposed model has less latency compared to existing models.

RANESH KUMAR et al. [45] Overview of Fog computing Research trends and technical differences between Fog and the cloud. Then, in the Fog computing architecture, the components of these structures are examined in detail. Finally, they presented a classification of Fog computing according to the requirements of the Fog computing model.

MITHUN MUKHERJEE et al. [46] examined security and privacy challenges in Fog computing and reviewed work done to provide a comprehensive summary of research programs to address various security challenges in Fog computing.

Ola Salman et al. [47] have introduced the use of SDNs and Fog computing as an evolution of the IoT to achieve an IoT architecture to meet the challenges of the Internet of Things.

PeiYun Zhang et al. [48] discuss and analyze the structures of Fog computing and the issue of security, and discuss various challenges in this area.

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Shanhe Yi, et al. [49] have also examined security challenges such as secure data storage, secure computing, and network security, and Fog computing privacy, and in [52] discuss Fog computing with similar concepts, and design and challenge Examine the future of Fog computing and highlights issues such as resource management, security, and privacy. In [53], after examining the definitions of Fog computing and the challenges of the Fog computing platform, They implemented and evaluated the initial Fog computing platform, the components of which are shown in Figure 6.

Geetanjali Rathee1 et al. [50] proposed a secure transmission mechanism to prevent an attack by examining the degree of trust and degree of each Fog node. A trust manager is created between the Fog layer and the IoT layer that can destroy node Fog and And Fog node services are provided through a trusted route.

Weidong Fang et al. [51] propose a Gaussian Distributed Comprehensive Trust Management System (GDTMS) for F - IWSN called TMSRS and also make the gray decision to achieve a secure routing plan with a balance between security (trust value), energy ((Residual energy) and transfer (transfer performance).

S. Prabavathy et al. [57] have proposed an intelligent intrusion detection method based on Fog computing using a sequential extreme learning machine called OSELM. By distributing cloud intelligence to local Fog nodes, it can detect IoT attacks faster.

Mohammad Aazam et al. [11] introduce the IoT architecture of version 4.0 and discuss how to integrate firmware such as Fog into different industry scenarios in this architecture.

Flavio Bonomi et al. [7] expressed the main features of Fog Computing and new services and applications at the edge of the network and concluded that the features of Fog computing are a good platform for IoT systems.

Srini et al. [13] present a complete set of topology control (TC) techniques in two phases of construction and maintenance to create and manage a network with Fog computing for the smart city, which in the construction phase of the Hungarian algorithm based on the construction algorithm (HTC) And use the Locator Identification Algorithm (CLI) to create a set of optimal locations to the gateways with the number of resources required, and in the maintenance phase of the holiday-based resource allocation algorithm and dynamic resource allocation (VRA)) Optimize the misuse of resources in the system.

Zahmatkesh et al. [55] review the applications of Fog computing for smart cities in IoT environments. They also review airborne control (UAVs) and machine learning (ML) techniques in FOG computing IoT systems that present opportunities and challenges. They also check the available ones.

Alhaidari et al. [55] provide a comprehensive review of the security of the Fog and CoAP protocols and the classification of review articles to better understand existing techniques. In fact, in this review, Fog's main security mechanism proposed to ensure the CoAP protocol is architecture, Security, and performance evaluation have been reviewed.

Conclusion

The Internet of Things (IoT) requires accurate time calculation for real-time application processing. Connected IoT devices generate large amounts of data that are generally processed in a cloud infrastructure due to the services required and the scalability features of the cloud computing model that are not time-sensitive. To address this, Fog computing, which exists between cloud devices and the Internet, was suggested to be responsible for intermediate computing and storage. The use of fog computing in the Internet of Things can solve many of the challenges of the Internet of Things as we have examined in this study, and there are many benefits to using it. The Fog computing model is one of the research topics that is still in its infancy. In this study, we review the motivation for using Fog computing in the Internet of Things, its features and benefits, and at the end, we review the research that covers various aspects of Fog computing.

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