Fog Computing for IoT: A Comparative Review

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***Abstract*—Internet of Things(IoT), has been one of the most grossing technologies that have opened up the door of newer possibilities of interactions among things and humans in order to improve the quality of living. With the help of cloud and fog computation environments, IoT is emerging every day. All the computations of IoT are done in the intermediate nodes of fog and in the data centers of the cloud. These nodes are millions in number yet the resources are limited and to continue this process for a long period of time it will get costlier. The necessity of managing resources in a fog environment is a challenging topic to which many researchers have contributed. This paper discusses the fog computing paradigm, resource management issues in terms of cost minimization, low latency, new architecture, routing, inter-layer approaches, and electricity consumption.**

***Index Terms*—Fog Computing, Energy-efficient IoT, Resource Management, Communication Models, Energy Balancing, Low Latency**

I. Introduction

IoT applications and services have been one of the most emerging technologies in our daily life. These services have provided new interactions between end devices and humans that have made life easier. But the rapid development of the IoT environment comes with new challenges in the technology such as energy efficiency, cost efficiency, data privacy, latency. As people are engaging with more IoT devices frequently, these devices are producing a large amount of data. It is becoming a challenge for IoT devices to maintain this large amount of data by themselves. In this regard cloud computing emerges as a new environment for analyzing, processing, and storing data provided by IoT devices. Though cloud computing can provide security and data privacy to some extent, some processes of IoT devices need real-time results. Cloud computing falls behind in some cases where real-time results are necessary. That is where the fog layer comes in. Fog Computing plays an important role in the cloud-IoT environment. The fog environment acts as an intermediate layer between IoT and cloud layers. fog computing also comes with data processing, analyzing, and data storage for IoT environments. By acting as an intermediate layer, fog computing provides the real-time process required by the IoT devices. In this paper, our main objective is to provide a brief discussion of fog computing architecture and its issues and challenges.

The rest of the paper is structured as follows, section 2 briefly discusses Fog computing in IoT. The architecture of fog computing is also described in this section. Section 3 discusses the issues and challenges of the fog environment. Related works and comparative analysis are provided in section 4 and finally, we conclude our review in section 5.

II. Fog Computing

A. Background of Fog Computing

A Fog environment is a three-tier architecture. The three individual tiers are consist of the IoT device tier, the Fog tier, and the cloud tier illustrated in Fig 1. The IoT tier is consists of different types of IoT devices, sensors, and actuators. The data generated for the IoT devices through sensors are collected and sent to the fog tier for further processing. In the fog tier, some data processing is executed in order to reduce time and latency. The fog tier is consists of several intermediate devices known as fog nodes. These fog nodes are linked to the cloud data centers through cloud gateways and resend the data to the cloud tier. The cloud tier is composed of different high-level servers and storage centers. The storage centers provide high-end processing for the data collected from the IoT devices. Thus the workload is divided into three tiers in order to reduce latency and bandwidth. The core application of fog layer is to collect data from edge nodes, process the data to some extent, store some necessary data and overheads, route the data to the cloud servers [1]. Traditional heterogeneous network architectures are incapable of handling the massive amounts of data traffic and computational demands posed by billions of IoT nodes [2] [3]. As a result, fog computing is seen as a promising architecture for meeting the service requirements of these IoT nodes. Cloudlets or fog nodes are intermediary devices with plenty of storage, communication, and computing capabilities. Fog networking, also known as fog computing, is a concept that uses these tools for the edge nodes to get the cloud closer to the IoT devices in a decentralized manner.

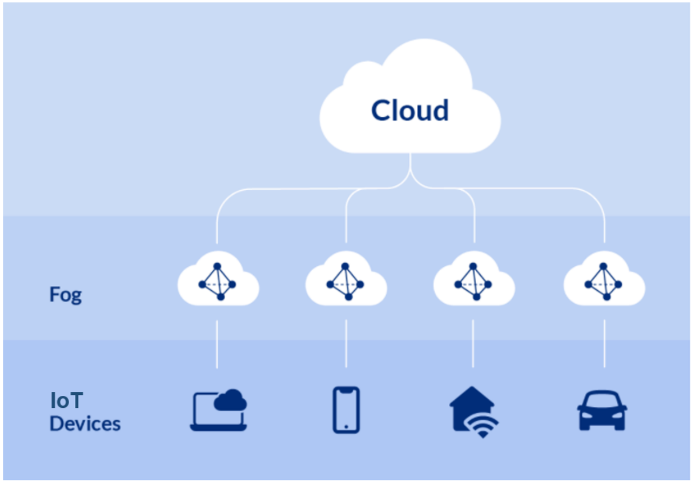

Fig. 1. Three Tier of Fog Landscape

B. Architecture

Physical and Virtualization layer, Monitoring layer, Pre-processing layer, Temporary storage layer, Security layer, and Transport layer are the six layers that make up the Fog architecture [4]. In Fig 2, The primary task of the physical and virtualization layers is to collect data from the edge nodes. The Monitoring layer performs node monitoring related to various tasks, where fog nodes are checked for power consumption and current state. The pre-processing layer is responsible for data analysis and redundant data removal.

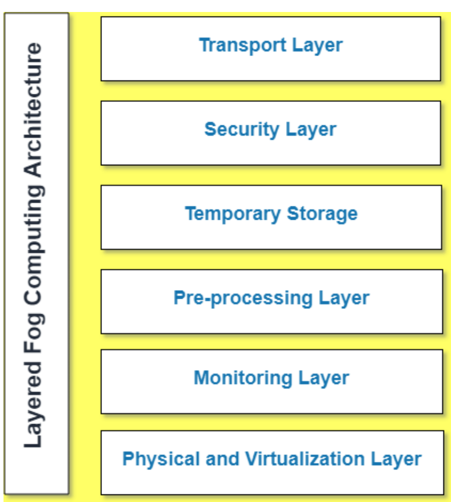

Fig. 2. Fog Architecture

This layer compiles analysis of massive amounts of data collected from end devices. The temporary storage layer is associated with data distribution and replication in the short term. Once the data is uploaded in the cloud, data is removed from this layer. The integrity, encryption, decryption and privacy is maintained in the Security layer. This layer ensures the preservation and security of the data collected from the fog nodes. Lastly, the transport layer securely uploads the final or partial data to the cloud for permanent storage. Smart gateways are used to refine the data before uploading to the cloud.

III. Issues & Challenges Of Fog

Considering real-time computation, fog computation is quite reliable. But considering resource management, implementation of algorithms and fog architectures in IoT, there are some major issues that we can discuss [5].

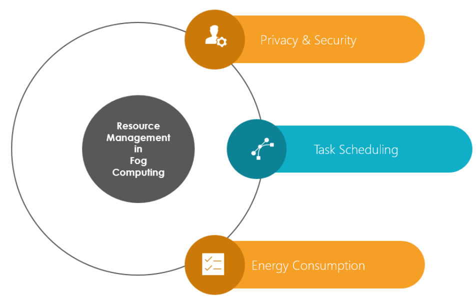

Fig. 3. Issues in Fog Computing

A. Privacy & Security

Privacy and security of the data is one of the issues in fog computing. As fog nodes will be dealing with sensitive and personal data, authentication and privacy protective algorithms need to be developed. Without proper data security measurement the fog nodes are subject to external threats.

B. Task Scheduling

Scheduling is another issue that needs to be addressed. Fog nodes typically have limited storage and computational control, despite the massive volume of data they are expected to handle. The difficult part is allowing scheduling for fog nodes with unpredictability in relinquishment probability and then making optimal use of the available resources. But without proper scheduling fog nodes will fail to handle enormous amounts of data.

C. Energy Consumption

Energy consumption is another issue in fog computing. Fog computing consumes a lot of energy because there are a lot of fog nodes in the fog environment that need energy to work. Without supervision over data transfer, potential drainage, and bandwidth management, fog nodes will consume excessive amounts of energy.

TABLE I
COMPARATIVE STUDY ON ISSUES AND CHALLENGES IN FOG COMPUTING

Citation	Challenges / Issues	Proposed Model / System	Performance Metric	Outcome	Weakness
M. Ali at al. []	IoT application and implementation	Improved Game Theory	Latency, Cost	Minimized cost	Time was not analyzed.
R. Oma at al. []	Energy efficiency in IoT system	Binary Tree Approach	Energy Consumption, Latency, Process Rate	Lower energy consumption, minimum delay, less processing overhead	Time complexity of proposed algorithm was not evaluated, no mention of evaluation tools.
T. Hsu at al. []	Real-time processing in IoT application in agriculture sector	Inter-Layer Approach, Communication, Agent Management	Latency, Cost, Storage	Reduced cost and storage size	Agricultural implementation was not evaluated, low scalability, proper evaluation tools and simulation was not provided, Proposed Algorithm was not clearly explained.
J. Luo at al. []	Communication efficiency, security issues in Fog Computing	Container-based architecture, Resource scheduling	Energy balance	Effective balancing among all terminal device, reduced time, increased transmission rate	Energy consumption was not evaluated.

IV. RELATED WORKS AND COMPARATIVE ANALYSIS

M. Ali at al. in [], introduced an algorithm to solve the many-to-one matching game which helps to resolve the optimization problem for joint cloudlet selection and latency minimization in a fog network. It has been modeled as a many-to-one matching game where IoT Nodes and cloudlets are considered as players. They also have suggested a distributed and self-organizing approach for solving the matching game, which improves the network's overall sum rate. Their research have solved the issues of energy cost efficiency, data privacy and latency. In their concluding remarks, the authors have compared their model with Random Association and Maximum (RSSI) based association. In their results, it has shown that the proposed method outperforms both of the existing models.

R. Oma at al. in [], discussed about the existing model of fog computing how it consumes a significant amount of electric energy and time to perform the basic tasks. They also have identified the problem of data being centralized and the processing overhead problem in the exciting architecture. Later on, the authors have proposed a tree-based fog computing model to deploy processes and data to fog nodes efficiently. So that the total electric energy consumption of nodes can be reduced in the IoT. The authors have measured the overall electric energy used by fog nodes and a server node, as well as the total execution time of an existing cloud computing model. They also have measured the same vectors of the proposed tree-based model. To conclude, they have also demonstrated how the overall electric energy consumption of nodes and the execution time of nodes can be minimized exponentially by using their proposed method.

T.Hsu at al. [], have proposed a decentralized calculation method. In their design, the nodes can analyze and have judgment capabilities to construct both cloud-side and fog-end-to-cloud mutual service. In the design phase, this study established a Creative IoT Service Platform mechanism to design an innovative service architecture platform model. Next, they have proposed a decentralized computing method through fog computing technology to distribute computing, communication, control, and storage resources and services to users or devices and systems close to users. They have also proposed a hardware design with creative platform and software design for IoT platform. The main design principle was to establish the IoT communication service agent and construct the agent management mechanism including hardware device communication, network data transmission and application service system installation and operation.The research successfully validated an innovative networking service architecture and thinking method, providing a computer-based approach to creative services. Improving the dilemma of passive management of networked operations, and in the future, different field models can be derived for experimentation.

J. Luo at al. [], have discussed about the limitations of the traditional architecture of fog computing and identify one of the major problems of Energy Internet, limited capacity of battery power. Later, they have proposed two solutions for the above-mentioned problems. First, they have suggested a multi-cloud to multi-fog architecture and develop two types of service models using containers to increase the resource usage of fog nodes and reduce service latency. Second, they have presented a task scheduling algorithm for energy balancing which is capable of reducing service latency, improve fog node efficiency, and prolong WSNs life cycle through energy balancing. Now, In the architecture of fog computing, they have proposed 3 roles as follows: 1. infrastructure provider (InP) which construct fog nodes for service developers and terminal devices, 2. service developer (SD) which develop services that can run in the fog nodes and 3. terminal device (TD) which use the service via submitting a request to a fog node and paying for it. Furthermore, In the multi-cloud to multi-fog architecture, they have divided 3 tiers in a fog node. They are: 1. The infrastructure tier, 2. The control tier and 3. The access tier. Here, in multi-cloud to multi-fog architecture, they have used some components based on containers. They are: Resource manager, LTSM, TSM, Cloud Agent, Request Queue, Access Controller. On the other hand, for energy balancing for terminal devices They have proposed 3 models. Such as, 1. Energy model of TDs (Terminal Device), 2. Fog execution model, 3. Cloud execution model. Additionally, they have proposed a task scheduling algorithm to reduce the delay of data transmitting. To conclude, they have proposed the energy cost and task scheduling in TDs and fog nodes, respectively, and have showed that the algorithm introduced in this paper will efficiently balance the energy of TDs in the network.

V. Conclusion

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