Fog Resource Sharing to Enable Pay-Per-Use Model

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Abstract. Advancements in the Internet of Things and Information Communication and Technologies have increased the demand for real-time services. Thus computing resources are migrated from the cloud to fog networks to give the users near real-time experiences. Fog computing resources containing storage and networks that are shifted from core to edge to minimize the latency while using the applications-application implementation nearest to fog nodes that reduce the latency however burden leans on the density of users. The fog network performance degrades because of the over-subscription of fog nodes. In this work, we have proposed a method that depends on alliance establishment for resource management while using the model that will charge according to the usage of network resources. We assume that the cluster contains one prime node with several fog nodes. Firstly, the customer needs information regarding the application requirement for the clusters then the prime node evaluates the capacity of the fog node, which fulfills desired demands of the end user. According to end-user requirements, the prime node among the cluster selects the specific symmetry batch nodes. Additionally, in this work, we have suggested an extension of resource handling regarding fog networks, combining end-user demands for the service and allocating individual nodes against the batch application.

Keywords: Fog computing · Pay-per-use model · Coalition formation · Game theoretic approaches

1 Introduction

The Internet of Things (IoT) has completely replaced the regular communication between the physical and digital frameworks that define the different IoT devices. IoT devices are contributing more than 11 zettabytes of total data worldwide. The fog/edge computing moderates the demand for the utilization of cloud data centers for IoT instances. The perception of the fog/edge computing domain consists

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of computing resources like servers, the processor in terms of cores, data centers, and network devices like routers, switches, bridges, hubs, etc. In fog networks, nodes are highly distributed as compared to cloud setups. On the other perspective, cloud architecture is extended to the edge by fog networks while the fog networks use the properties that are being employed in the cloud architecture [13].

The pay-per-use model allocates the network's resources against end-user requests to avail of the service. Existing literature did not consider fog networks regarding business models. The fog networks have offered a platform to cope with the end-user application requirements. For optimization of resources as it was used earlier in the presence of a single cluster where researchers have offered the model to turn down the latency of service provisioning.

Existing literature considers distinct fog network parameters like fog node capacity, reliability, and delay. However, the work-related business perspective does not exist in fog networks [3]. We suggested the model which charges the price according to the use of network resources. The fog network provides support for designing and managing resources, which is essential for the fog network. In general, fog and cloud are different networks because one is distributed while the second is centralized, so both networks cannot use common schemes.

In this paper, we presented a pay-per-use model which depends on alliance establishment for resource management in fog networks. There is a partnership between fog nodes in the same cluster but non-cooperative behavior between individual groups. The customer desires to get a trade-off between delay and price against the services. This paper assumes that the collection contains one master node with multiple fog nodes. Firstly, the customer needs information regarding the requirement of the application then the master node evaluates the fog node that fulfills the end-user resource requirement [12].

The master node selects the local balance subset of fog nodes according to end-user requirements. After that, to reduce the price to be paid and service delay, the applicant selects the specific symmetry batch nodes of the fog network. Additionally, we suggested a resource-handling extension in fog networks. At the same time, the pay-per-use model is used to allocate the network's resources against end-user requests to avail of the application services [11].

The rest of the document is organized as follows: Sect. 2 presents a review of the literature, whereas Sect. 3 gives a system model for the pay-per-use model along with the problem statement. Section 4 explains the pay-per-use model. Next, Sect. 5 presents the experimental results, and finally, Sect. 6 concludes this paper following the direction of future work.

2 Literature Review

The existing literature focuses on reducing the latency in fog networks. However, the authors suggest a scheme that allocates the resources by using a fog network, so this is the combined problem for setup. The authors Nguyen, Bao-le, and Bhargava suggest a scheme to allocate the resources that is a purchaser-retailer game in which the services behave like purchasers while resources of fog network behave like distinct products [10].

The researchers assess the symmetry of each service while formulating curvilinear problems. Management of resource of fog network Abedin, Aslam, and Hong focusing the quality of service needs ultrareliable low latency communication with increment in broadband services [2]. The authors designed a combined customer alliance and scheme for resource deployment by using bilateral parallel games that verify a strong coalition between the infrastructure of fog networks and IoT devices.

In previous work, researchers discussed related resources deployment depends on pay-per-use for diversified services of fog network. Farooq and Zhu presented a scheme that relies on the price for deployment of implicit storage in which researchers focused on diversified services [6].

In the sensor cloud paper, Misra and Chakraborty suggested a technique comprising a pricing model related to the distribution of resources that focuses on service reliability. In another research, Misra and Chakraborty proposed a game theoretic resource allocation scheme for sensor cloud [9]. Researchers observed system deploys resources to the customers depending on the price that is finalized by a centralized system, also known as the cloud. The authors proposed an alternate scheme for sensor records. In another paper authors, Aazam proposed a resource deployment technique based on user requirements that depend on factual documentation [1]. Therefore, all these schemes have used a centralized approach for resource allocation that is not applicable in distributed fog networks.

In Fog prime paper, Misra and Mondal suggested a technique for deploying resources that depend on the dynamic cost to explore the bargain between the service delay and related price [8]. The authors used a game that is an active corporation - generation to finalize the deployment of resources technique regionally inside the cluster.

Hence, there is a need for a scheme regarding the deployment of resources in the fog network that uses the model that is pricing based to provide service of the fog network. In this work, we have presented an extension for the resource handling-related fog networks which combines end-user demands for the service and allocates individual nodes against the batch application. In this research, we used dynamic corporation-generation to finalize the deployment of resources technique regionally inside the local cluster. Another point is that in the proposed solution, authors have operated a profitability game that finalizes nodes and focuses on the tradeoff.

In the existing literature, the authors mainly covered unlike features of fog networks. The researchers discussed issues related to mobility and implications regarding mobility in terms of fog networks. Therefore, the authors did not discuss connected fog networks that are based on the price to be paid against the usage of network resources. We have suggested that policies related to pricing play a vital role in fog networks for resource allocation as in cloud networks. Additionally, a centralized approach is used as a resource allocation scheme in a cloud environment. So the centralized approach is not applicable in distributed fog networks. Finally, there is a need of a system that deploys the fog network resources that depend on price according to the usage of resources to provide service. Every cluster contains one coordinator node, which is known as a prime node.

3 System Architecture

This proposed solution suggests a system that depends on a fog network that contains several nodes with several customers. The nodes of the fog network are distributed over the terrestrial area and formulate clusters. One node in each cluster performs as an administrator who is known as the Prime node, as shown in Fig 1. Constraints like computation capacity and residual energy must be fulfilled by a node to become a leading or prime node. When the selection of the prime node is completed, every fog node joins the cluster based on the nearest leading or prime node. The node remains in the ownership of the service provider, but end users just utilize the services according to their requirements by using a pay-per-use model.

Table 1. Resource allocation features of fog networks

Resource allocation on the bases of pricing	Features of fog networks				
	Decentralized	Heterogeneous	Dynamic configuration	Fog	Cloud
Chakraborty [4]	No	No	Yes	No	Yes
Farooq [6]	No	No	Yes	Yes	No
Abedin [2]	Yes	Yes	Yes	Yes	No
Nguyen [10]	No	Yes	No	No	Yes
Chanra [5]	Yes	Yes	Yes	Yes	No
Halima [7]	No	No	Yes	No	Yes
Zhang [14]	Yes	No	No	Yes	No
Aazam [1]	No	No	No	No	Yes

3.1 Problem Statement

This model contains three layers one is the cloud, the second is fog, and the third is the end user. The fog layer is the middle that consists of hardware and software resources and provides communication between the end user and the cloud. The fog layer consists of fog nodes, and the node is basically a device or system that contains a processor, memory, and storage. There are multiple clusters in the middle layer. Each set includes one prime node and multiple fog nodes. The prime node of every group is responsible for allocating the resources to the end user according to the customer's request.

Before allocating resources, there will be an agreement between the end user and the owner of the fog network regarding the service being offered and its charges as well as the duration of the service. The ultimate consumer will be levied according to the consumption of fog network resources. In this paper, we focus on the middle (fog) layer to improve the network's performance by using the pay-per-user model. We present an extension of resource management in fog networks while combining the end-user demands for the service and allocating individual nodes against batch applications, as this problem is not discussed in previous literature.

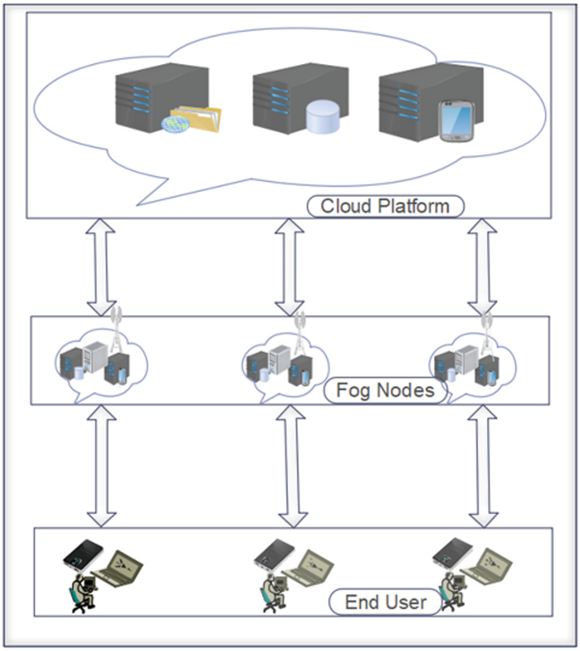

Fig. 1. Schematic Diagram of Fog Resource Sharing to enable pay-per-use Model architecture.

3.2 Selection of Prime Node and Creation of Cluster

The method which was suggested in previous studies was described in a set of equations. In this paper, some of the equations of earlier studies have been used according to the needs of this paper. We applied the Master Node Selection, and Cluster formation Method [8] that is abridged below. We assume that the prime node is elected based on the satisfaction of the Following condition as shown in Eq. 1.

$$C_f \geq C_{th} \quad \text{also} \quad E_f \geq E_{th} \tag{1}$$

Here C_f denotes the computation while E_f is the remaining energy of fog node f, sequentially. In another way, Cth and Eth are the threshold values of C_f and E_f and the selection of prime node based on Cth and Eth as given in Eq. 2.

$$I_{mi,mj} = \sqrt{(\frac{C_{mi} - C_{mj}}{C_{th}})^2 + (\frac{E_{mi} - E_{mj}}{E_{th}})^2} \tag{2}$$

C denotes the number of prime nodes or clusters, and C is selected by the prime node by using the p-dispersion technique. Two prime nodes, mi and mj have the dispersion index that shows Euclidean distance in the two-dimensional x-axis and y-axis. Prime node optimize the fn(C) and $fn(C) = minI_{mi,mj} : 0 < i < j < |F|$. When the group of a prime node is confirmed, then every fog node joins the cluster that contains the geographically closest prime node. After receiving the confirmation from the end-user prime node deploy the applications.

In this work, we assume that t is used to denote the time instant and end-user denoted by n that belongs to N, which is the group of end users.$A_n(t)$ Denote request to offer the group application from the prime node of the cluster. Based on the end-user request prime node finalize the suitable fog node f and then confirm to the end user n. End users accept the offer from the prime node according to its requirement and price of services. After finalization of the fog node, the end user confirms to the cluster's respective prime node. When the applications are deployed, then the end user will be charged an amount $p^{a_n}_{max}$ against the application that is being served to the end user $a_n \in A_n(t)$. So the following equation must be fulfilled as represented in Eq. 3.

$$p^n_a(t) \leq p^{a_n}_{max} \tag{3}$$

Where $p^n_a(t)$ denotes the price that is paid against the deployed application by the end user. The cluster's prime node is responsible for avoiding the over-subscription of the fog node by using Eq. 4s.

$$\sum_{a \in A_n(t),} x_{a,f} m_a \leq M_f and \sum_{a \in A_n(t),} x_{a,f} c_a \leq C_f \tag{4}$$

Where $x_{a,f}$ is the binary variable that shows the relation between fog node f and application a. The variable $m_a and c_a$ shows the application's memory and central processing unit resources.

$$X_{a,f} = \begin{Bmatrix} 1, \text{if application deployed to fog node f after confirmation from the end user} \\ 0, \quad \text{otherwise} \end{Bmatrix} \tag{5}$$

This works on the first come, first serve model (FIFO) to process the applications, but it can be well managed by redistribution of applications that are being done.

4 Pay-Per-Use Model for Resource Administration

This model communicates between the prime node and fog nodes that reside in the same cluster. In this proposed solution, there is the urge for scheme-related pricing comprised of resource allocation in fog networks which use models to provide service regarding fog networks. In this paper, we present an extension that resource management and, on the other hand, integrate the service request from the ultimate consumers, equipping a single fog node for each subgroup of application. Dynamic alliance game is being used in research which further streamlines resource allocation plans in local clusters. Furthermore, we employ a utility game for selecting fog nodes and also focus on tradeoffs.

Dynamic coalition gameplay a vital role in the social group of players to communicate between them. This also applies to different environments, and fog nodes handle every application for a limited time. We assume that there will be random changes regarding active applications and the requirement for resources. That is why a dynamic coalition game is an appropriate option.

In this paper, the prime nodes work as team leaders that confirm the cluster performance of the fog network regarding contentment of the fog nodes, detain, and under or over the employment of resources. Similarly, in this work, when service is availed by the end-user, it will confirm its contentment regarding an application that is offered by the fog network. Two parameters are used to evaluate the contentment by end users on the acceptable delay, and the second is the price paid against the service.

5 Experimental Results

In this section, we will discuss the proposed solution's initial experiments that contain the results regarding the network, node load, and latency on fog devices compared to the cloud. Table 2 shows the variables related to the proposed solution that consists of a prime node, fog node, and cloud setup.

The following table shows the experimental results. When the subscriber devices have increased that causing to expand the network traffic, then obviously, performance will affect the proposed solution.

Table 3 shows that as the devices are increased, the network usage and latency will increase in both layers middle and top layers. The middle layer consists of fog devices, and the top layer consists of cloud devices. The main thing is that there is a notable difference in latency and network usage of both the middle and top layers. This shows that a fog network is more efficient as compared to a cloud network. As proposed solution focuses on the middle layer to improve the efficiency of the fog network based on the pay-per-use model. The graphical representation of the results is below.

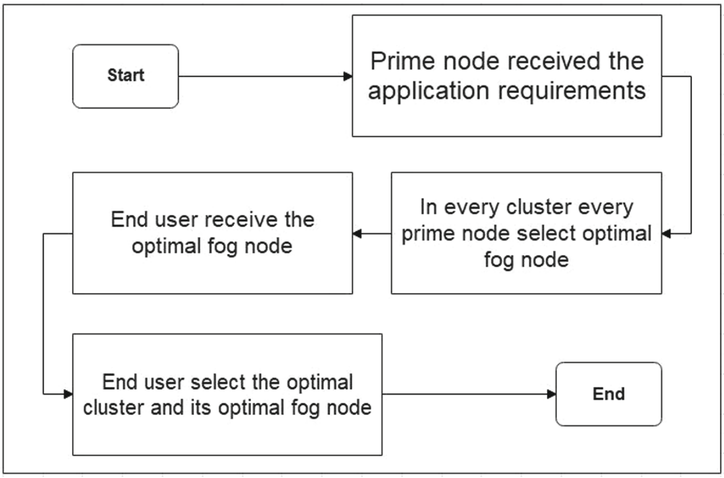

Fig. 2. Flowchart of our proposed pay-per-use model

Table 2. Simulation configuration

Parameters	Cloud	Prime fog node	Fog node
CPU Length (MIPS)	44,800	2,800	2,800
RAM(MB)	40,000	4,000	4,000
UP Link Bandwidth(MB)	100	10,000	10,000
Down Link Bandwidth (MB)	10,000	10,000	10,000
Level	0	1	2
Rate Per MIPS	0.01	0	0
Busy Power (Watt)	1,648	107.339	107.339
Idle power(Watt)	1,332	83.43	83.43

Table 3. Experimental results

Devices	16	20	24	28
Fog Latency (ms)	7.87	8.23	8.59	8.95
Cloud Latency (ms)	8.4	9.5	10.73	12.13
Fog Network Usage (kb)	3198.4	3998	4797	5597
Cloud Network Usage (kb)	27632.16	36099.48	45206	54951

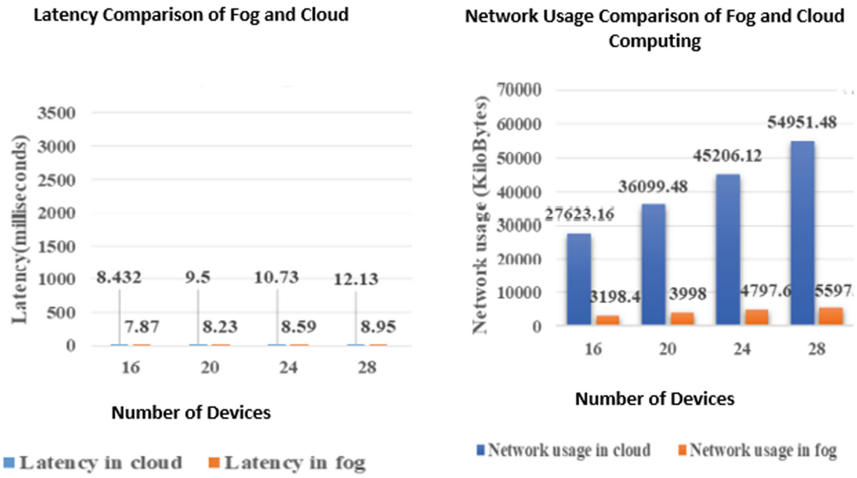

Fig. 3. Comparison of latency and network usage fog and cloud computing

6 Conclusion

In this work, we have compared the latency and network usage of fog computing and cloud computing. The results show that fog computing is more efficient in terms of low latency and less usage of network resources. Furthermore, our target is to achieve more efficiency through resource management in fog networks while combining the end-user demands for the service, and allocating individual nodes against the batch application. The purpose of the proposed solution is to avoid underutilization of the fog network resources.

In the proposed architecture, there are several clusters and several end users as well. In every cluster, there is one prime node and several fog nodes. At starting the end-user request the service to the cluster and the prime node checks by using a dynamic coalition game in which the node is capable of the services that are requested by the end-user and then offers resources against the request. The end user decides on the fog node based on service delay and the price paid against the requested service. In the future, we can extend this work to migrate the fog network services towards the cloud and testify migrated services that turn out to be distributed.

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