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A Survey of Optimization Algorithms for Fog Computing Service Placement

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***Abstract*— Fog computing provides Quality Of Service to latency sensitive applications in bandwidth constrained WAN networks. Fog environment consist of a set of IoT devices, fog nodes, and cloud node that gathers the sensed data, application requests from the user and decided to place the application modules in the suitable node. Fog framework uses the optimization algorithms to distribute the IoT application modules, based on functional requirements. This survey explores various optimization techniques to the application module placement, which includes Exact methods, Heuristic methods, Hybrid methods, and Hyper heuristic techniques on fog networks. The proposed work analyses and examine different optimization criteria, and outline the research challenges in the service placement.**

Keywords*— *Quality Of Service, WAN, IoT, optimization, framework

I. INTRODUCTION

The number of IoT devices will be increased day by day, and estimates huge amount of data should be generated from the IoT sensors. There is some limitations with respect to network connectivity between the cloud and IoT devices[1]. It is not suitable to deploy the latency sensitive applications in the cloud only due to the data processing speed and network bandwidth[2].

The fog computing framework took the responsibility to connect the cloud with IoT devices to better supporting the time-critical applications in bandwidth constrained networks by providing the services close to the end devices[3]. These fog devices are

geographically distributed and it supports hardware heterogeneity. The fog framework is not the replacement of cloud computing, It extends the computation, storage, and networking features of the cloud servers to the fog devices[4]. The computational devices having the capability to processing the application modules in lower fog and IoT devices[5]. This Fog framework provides low latency by shifting the processing to low computing devices near to the user.

Fog framework choose the optimal place for placing the application modules based on the different functional requirements(i.e. QoS, cost, energy, fault tolerance)[6].Since fog environment are geographically distributed and hardware heterogeneity, different application module interaction(i.e. SOA, micro services),it is challenging to fulfil all the requirements in application module placement[7].

In this review it is broadly recognized that fog environment feasible for the IoT application placement problem with optimization algorithms. Optimization is a normally encountered mathematical hassle in all engineering disciplines. It finding the great viable (or)acceptable answer. Optimization issues are extensive ranging and several, consequently techniques for fixing those issues should be, an lively research subject matter. Optimization algorithms can be both deterministic or stochastic in nature. This survey concentrate on these things with exploring various optimization algorithms for application module placement in the fog environment.

II. RESEARCH CHALLENGES

- Placement challenges in this framework when an application is at running state.
- It is the challenging task to provide the scalability in the dynamic fog infrastructure.
- It is crucial for Applying the decentralized distributed algorithms in the hierarchical fog networks
- Considering the different virtualization technology i.e. container virtualization in the cloud and fog networks.
- It is the crucial role for security aspects for application placement in lower level fog nodes.
- Placement challenges with critical control services running on energy constrained computing nodes.
- Placement challenges in device mobility(i.e. IoT, fog).
- Placement challenges in dynamic network topology, latency, bandwidth, and workload conditions is challenging in hierarchical network.
- Distributed management in the cloud and fog servers.
- It's challenging to place the applications in the real world fog test beds.
- Challenging in service placement on heterogeneity devices, and platforms.
- Providing the reliability for the mission critical applications.

III. SERVICE PLACEMENT AND ALGORITHMS

The mutual deployment of fog and cloud brings amazing advantages. In accordance with this, fog computing environment as an effective framework to improve the execution of requesting IoT applications, making ready to an ideal coordinating between capacities of hardware resources and applications requests, by using the centralized controller of the service placement[39].

If the IoT application modules required the resources, then we deploy the application modules both cloud and fog nodes. otherwise, the modules will be deployed either cloud or fog. The deployment strategy must consider application-specific demands and required resource availability at fog and cloud node. Now it is imperative to differentiate two fundamental concepts of service placement and service offloading. The service placement decides where the application services to place. In Service offloading ,first it place the services then it shifted to other nodes according to criteria[40]. Indeed, service offloading can be done beyond service placement for placement optimization. This proposed work mainly concentrates on service placement. The strategies and methodologies to characterize the proper number of layers is as yet a progressing process in fog frameworks and surely is out of the extent of this paper.

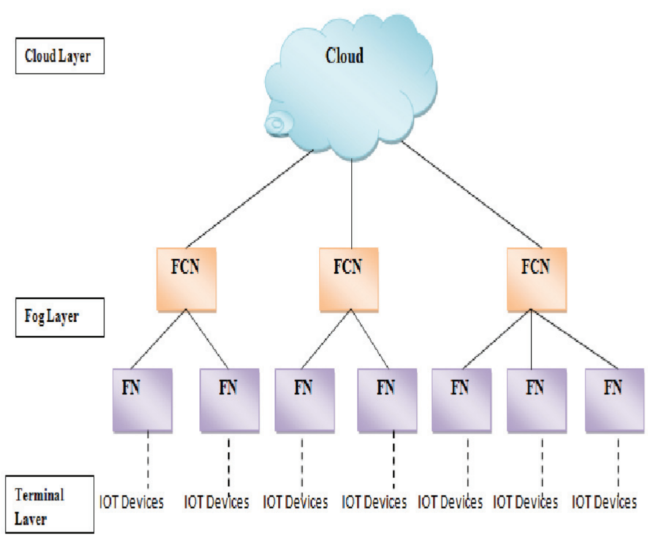

Fig. 1. Fog environment

The fog environment in Fig 1,formed with multiple layers.

A. Terminal layer

This lower level consist of IoT devices, sensors and actuators which directly communicate with the user. The data transmission is coming from these devices. These lower devices does not having the processing capability.

B. Fog layer

This layer having the different types of nodes such as switches, gateways, routers, access points and fog servers arranged in two levels in the fog layer. The lower level fog nodes having low computational capability than parent fog controller node. The fog controller node controls the entire cluster nodes.

C. Cloud layer

The nodes in this layer having rich resources, which provides the cloud services. The communication latency is very high when deploying the applications in the cloud layer. I consumes more energy for cooling system in cloud.

So as to encourage the controlling functionality of the fog environment, Figure 1 having heterogeneous distributed nodes form as a cluster. Each cluster has the controller node called FCN(fog controller node). The FCN having the responsibility of deploying the application modules either in fog node or controller node or neighbor controller node or cloud node.

The algorithms finds the optimal arrangements among service modules and computational nodes(i.e. fog, cloud), for limiting/boosting the estimations of the fitness capacities and fulfilling the predetermined constraints. The application placement problem is a NP-hard .

IV. HEURISTIC ALGORITHMS COMPARISON

The thought of heuristic techniques using these principles— selection, acceptance, and termination — for viable possibilities. In the Figure 2, the selection operator creates the solutions. The acceptance operator measures the fitness of individual solution with predefined metrics, after which the termination principle decides subsequent possibilities from the individual solution of the selection principle and the acceptance principle.

The heuristic algorithms provides better results than Exact algorithms for large size problems on fog computing systems. Moreover, as far as this paper is concerned, by the large size problems i.e. NP-Hard, needs huge solution space for checking with algorithm in a reasonable time.

The alternative for creating the placement algorithm is by integrating two or more heuristic algorithms in each iteration gives the advantage to find a better result. In Fig.2the hybridheuristic algorithm combines the one or more heuristic algorithms(H1,H2,....Hn) to perform the selection, acceptance, and termination at each iteration. The integration may overcome the weaknesses of specific heuristic algorithms. The limitation of the hybrid-heuristic is, it takes more computation time because of the convergence process. The another method of combining the two or more heuristic algorithms, called hyper-heuristic algorithm which shown in Fig.2.The Lower Level Heuristic selects one of the heuristic algorithms(H1, H2 ,....Hn) to perform, which is referred as Hi in Figure 2. selects one of the heuristic algorithms(H1, H2 ,....Hn) to perform, which is referred as Hi in Figure 2.

TABLE I. LITERATURE OF MULTIPLE OPTIMIZATION TECHNIQUES FOR APPLIACTION PLACEMENT

S.No	References	Optimization Algorithm	Control Parameters	Major Contribution
1	[8], [9], [15], [16]	Exact Algorithm	Latency, Network usage, Energy consumption	IoT application placement by using Edge-ward in fog framework
2	[10], [24], [25]	Exact Algorithm	Service Deadline	Design the hierarchical fog architecture and provide resource utilization
3	[11], [12]	Exact Algorithm	Communication Latency	Minimize the distance between user and deployed service
4	[13], [14]	Exact Algorithm	QoS requirements, Response time	Providing the QoS-assurance in Application placement
5	[17], [18], [19], [23]	Exact Algorithm	Latency, Energy consumption, Cost	Poly-time algorithm used for Application placement
6	[20], [21], [22]	Exact Algorithm	Response time	Considering both Sequntial and Parallel resource allocation for placement
7	[26]	Heuristic Algorithm	Service Deadline	Genetic algorithm based placement for guarantee the deadlines of application
8	[27]	Heuristic Algorithm	Fault tolerance	Using parallel Genetic algorithm for placement
9	[28]	Heuristic Algorithm	Reliability	Providing more replicas for faster execution
10	[29]	Hybrid Heuristic	Scalability	Improved the resource utilization by combining with nature inspired algorithm
11	[30]	Hybrid Heuristic	Latency	Reducing the maximum iterations in genetic algorithm
12	[31], [32], [33]	Hybrid Heuristic	Makespan, Energy consumption	Minimize the processing time and effective resource utilization
13	[34]	Hybrid Heuristic	Cost	Providing high success ratio
14	[35]	Hybrid Heuristic	Reliability	Providing high Availability
15	[36]	Hyper Heuristic	Makespan time	Providing the Diversity detection and Improvement detection functionality for better placement
16	[37]	Hyper Heuristic	Robustness, flexibility	Build the multi objective evolutionary framework

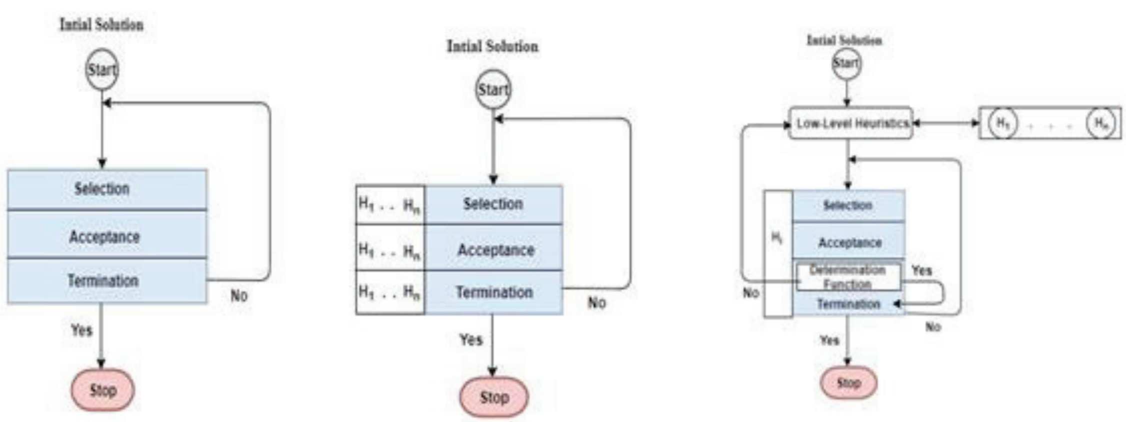

Fig. 2. Execution sequence of Heuristic, Hybrid, Hyper heuristic methods

V. CONCLUSION

This paper gives a detailed description of application module placement algorithms in the fog computing environment. The challenges and future directions of application module placement in fog environment have been discussed. This paper compared the various heuristic algorithms on Exact methods, Heuristic, Hybrid, and Hyper-heuristic optimization algorithms for multiple application service placement. These algorithms optimize the specified control parameters such as makespan time, cost, energy, service deadline, fault tolerance, scalability and network usage in application module placement. The primary promising results conclude that heuristic and hyper-heuristic algorithms provide better results for NP hard problems.

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