Design Cloud-Fog Systems Using Heuristic Solutions on the Energy of IoT Devices

Nguyen Thanh Tung(✉)

International School, Vietnam National University, Hanoi, Vietnam
tungnt@isvnu.vn

Abstract. In the Cloud-Fog system paradigm, the IoT services take an important role. It is a service layer upper from the shared physical infrastructure layer. The actual implementation of service functions is a key aspect of increasing service operation. Deployment decisions need to address the resource requirements of the services, ensure that the services meet its QoS constraints while reducing the overall operating cost. Allocating resources in an inefficient operation will lead to less efficient of services and increase the number of physical servers to use while some of these having very low utilization rates.

In this paper, we investigate the problem of IoT devices deployment in Cloud-Fog system to provide the maximum operation time under the battery constraint of IoT devices. Although we can use Linear Programming (LP) to calculate the solution, we cannot run the LP in small IoT device, therefore heuristic algorithms are needed. Our trial shows that the approximate solution is far better than the random solution.

Keywords: IoT · Cloud-Fog system · Battery constraint · Operation time · Linear programming

1 Introduction

The Cloud-Fog system is very efficient for IoT services to guarantee QoS. However, IoT devices are too small to handle jobs for computation due to its limitations on power source [1, 2, 7] (Fig. 1).

The optimal implementation of IoT networks on Cloud-Fog system faces many challenges even though the core of the system have been deployed in many places. The IoT device operations are located near fog nodes but not cloud for low latency and location tracking. However, the fog nodes can only have low capability of operation. Contrary to fog nodes, cloud is a powerful and unlimited capacity of operation. As a result, developers must optimize resource usage while meeting strict latency constraints of IoT system.

When more resources are allocated than required, virtualizing services will be expensive, but under-allocation of resources will result in service inefficiencies. Cloud-Fog system is a multi-layer design in which each device has its own functions, the deployment implementation determines the cost of services. Our designs must research the capacity and energy efficiency of computing and transmission sources to lower the power cost.

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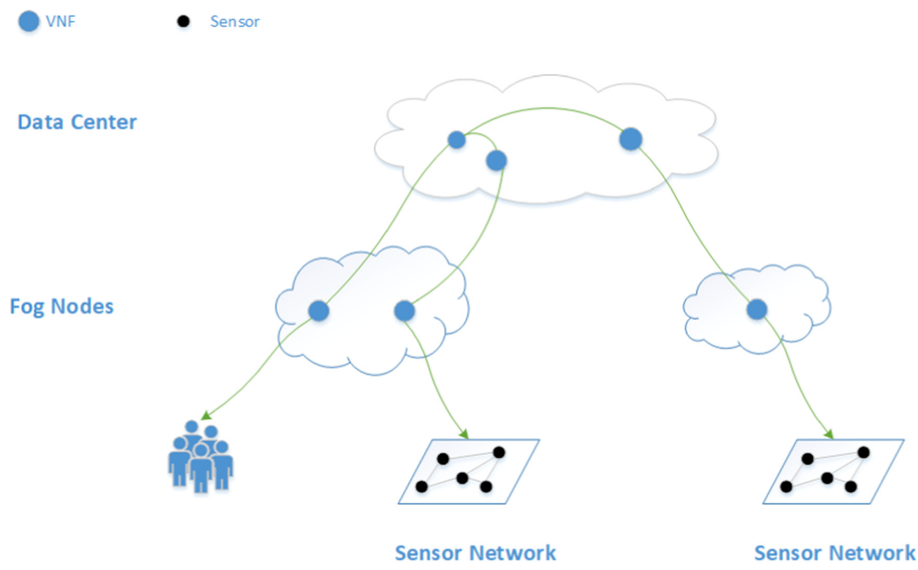

Fig. 1. Three-layer Cloud-Fog system paradigm.

2 Related Work

In [5], based on CISCO's IoT model proposes a cloud-fog architecture to provide IoT data efficiently and reliably for corresponding IoT applications while guaranteeing time delay. They use the LEACH-Centralized protocol, a modified version of LEACH, for sensor networks and estimating the power consumption of m-proxy servers and other IoT nodes. These devices are normal for the first time and keep the remaining power level for the next rounds to remove unnecessary communications power from the LEACH-C. The test results show that the total network delay and utilization are lowered.

In [6] also proposes an IoT-based fog computing model to efficiently allocate tasks to fog nodes (FNs) in a way that preserves total energy consumption. The model is called IoT-FCM (Fog Computing Model), which is made up of two components: the cloud-fog layer part and the terminating layer part. In the cloud-fog layer part, they use three criteria: latency, energy, and distance. They show that IoT-FCM is more energy efficient than some other algorithms. For the terminal layer part, IoT-FCM modified LIBP (Least Noise Signaling Protocol) by adding more sink nodes. Simulation results also show that IoT-FCM saves more energy than original LIBP and the device can operate longer.

3 Proposed Heuristic Algorithm

Linear Programming is not suitable for sensor-IoT networks because if a network changes the topology then we have to design again. Each time there is a change in the network, the solution needs to be recalculated. Also, IoT devices are too small to handle jobs for computation due to its limitations on power source [3, 4].

The energy needs to be balanced among sensor nodes and the FNs roles are also rotated to maximize the remaining energy of sensor nodes.

Therefore, the FNs position needs to be reallocated among the IoT nodes so that the remaining energy of all IoT nodes is maximized. The heuristic method is called RA-LEACH (Random LEACH) and can be stated as below.

RA-LEACH (Random LEACH):

In every round, We chose k_ Fog Node from N_ Fog Nodes

Input:

*N_*: The number of FNs indexed from 1 to *N_*

s _: The present FN solution

For every round of operation

we chose k_ different Fog Node randomly from N_ FNs.

Result: the set *s _*becomes the FNs solution for the round obtained from the algorithm.

Repeat until the first IoT device has none of energy.

(End of code)

RE-LEACH (Remaining Energy):

In every round, We chose k_ Fog Node from N_ Fog Nodes

Input:

*N_*: The number of FNs indexed from 1 to *N_*

s _: The current CH solution

For every round of operation

we chose k_ different Fog Node randomly from N_ FNs.

$$\sum_{i=1..k} \frac{1}{E_i} = min$$

Result: the set *s _*becomes the FNs solution for the round obtained from the algorithm.

Repeat until the first IoT device has run none of energy.

(End of code)

Ave-LEACH (Average Energy):

In every round, We chose k_ Fog Node from N_ Fog Nodes

Input:

*N*_: The number of FNs indexed from 1 to *N*_

s _: The current CH solution

For every round of data transmission

we chose k_ different Fog Node randomly from N_ FNs.

$$E_i \geq \frac{\sum_{k=1..N} E_k}{N}$$

Result: the set *s* _becomes the FNs solution for the round obtained from the algorithm.

Repeat until the first IoT device has run none of energy.

(End of code)

4 Simulation Results

We test performances of RA- LEACH, RE-LEACH and Ave-LEACH. We create hundreds of 100-node IoT networks in simulation, starting with 10,000,000 battery units at each device. The algorithm RA-LEACH, RE-LEACH and Ave-LEACH are test over the networks while the number of Fog Nodes is set to 3 and the total nodes is set to 5. The location of the cloud center is at (50, 1000). IoT device location and FN location are determined as shown in Fig. 2 and Fig. 3.

Figure 4 shows that RE-LEACH and Ave-LEACH performs nearly the same and far better than RA-LEACH. Figure 5 shows that RE-LEACH and Ave-LEACH spend much more energy than RA-LEACH. Therefore, RE-LEACH and Ave-LEACH balance the energy of nodes better than RA-LEACH.

Network size (100 *m* × 100 *m*)

Fog Nodes (0.0,120.0); (50.0,120.0);(100.0,120.0);(120.0,50.0);(120.0,0.0)

Cloud location (50.0,1000.0)

Number of devices one hundred devices

Position of devices: Uniformly distributed

Power consumption: square model

Fig. 2. IoT devices and Fog Nodes

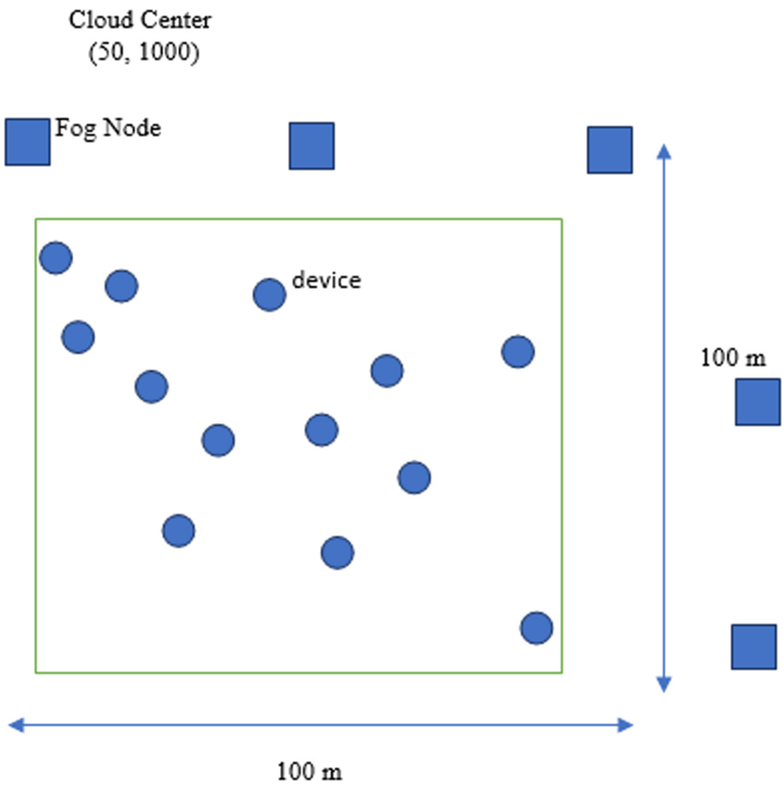

Fig. 3. Network topologies with Cloud center

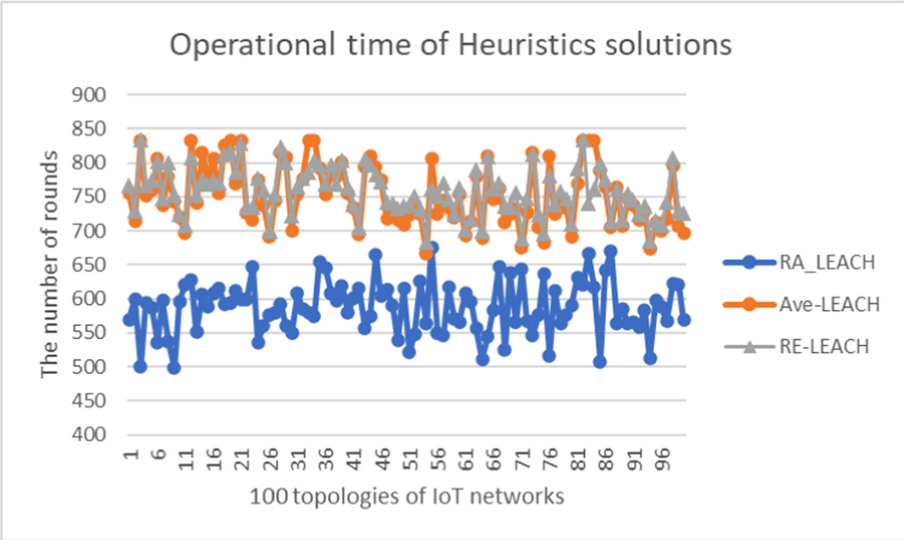

Fig. 4. The lifetime of RA-LEACH, RE-LEACH and Ave-LEACH

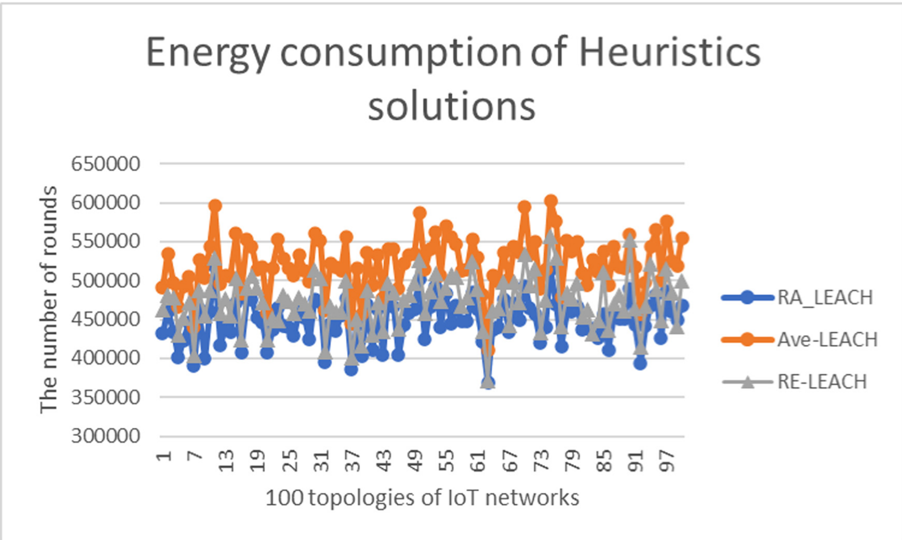

Fig. 5. The energy consumption of RA-LEACH, RE-LEACH and Ave-LEACH

5 Conclusion

Although we can use Linear Programming (LP) to calculate the solution, we cannot run the LP in small IoT device, therefore heuristic algorithms are needed. Our trial shows that the approximate solution is far better than the random solution. Simulation shows that RE-LEACH and Ave-LEACH performs nearly the same and far better than RA-LEACH and RE-LEACH and Ave-LEACH spend much more energy than RA-LEACH.

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