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Heuristic-based IoT Application Modules Placement in the Fog-Cloud Computing Environment

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***Abstract*—Nowadays many Smart City applications make use of Internet of Things (IoT) devices for monitoring the environment. The increase in use of IoT for smart city applications causes exponential increase in the volume of data. Using centralised cloud for time sensitive IoT applications is not feasible due to more delay because of the network congestion. Hence, fog computing is used for processing the data near to the edge of the network, where processing is done by distributed network nodes. But, there is a challenge to select the fog nodes which can host and process the application modules. The placement of application module on these fog devices is known as NP-hard problem. Hence, we need better placement strategies to decide placement of application modules in fog infrastructure to minimize the application latency. In this paper, we design a First-Fit Decreasing (FFD) heuristic based approach for placing IoT application modules on Fog-Cloud and carried out the experiment using iFogsim simulator. The simulation results demonstrate that the proposed method shows significant decrease in both the application latency and energy consumption of Fog-Cloud as compared to the benchmark method.**

***Keywords*-Internet of Things, Cloud Computing, Fog Computing, Latency, Energy Consumption, and Network usage.**

I. Introduction

Fog computing is defined for bringing the cloud services very close to the edge of the network. Fog computing makes use of the geographically distributed network nodes as the computing resources to process the data and takes the decision very quickly. The different devices such as router, gateways (smart gateways), edge servers, access points are used as the fog nodes to process the data at the edge [1]. But, the key challenging issue in fog computing is to find the eligible device which can host the application module and process the data. The placement of these IoT application modules on computationally limited resources is known as the NP-hard problem. This motivated us to design the better placement strategy for solving the IoT application module placement problem using the heuristic approach. Our main contribution in this paper is to formulate the placement problem as an optimization problem so that we can reduce the service delay for IoT application by placing some of the application modules in fog-cloud environment and thus utilizing the network resources efficiently with minimum energy consumption. We carried out simulation for fog-cloud environment using ifogsim simulator [2].

II. Proposed Methodology

The placement of the application modules or services is the key challenge in the fog environment because of the geographical distribution and also due to the limited computing capabilities of the fog devices. The node which can host the IoT application module should satisfy the QoS of applications and also the resource requirement of applications. Hence better placement strategies are required for placing these applications in fog nodes such that the latency for the application is minimized while reducing the total energy consumption. Fog nodes and cloud resources are considered for placement of application such that smaller application modules are hosted by fog nodes and larger modules are forwarded to the cloud.

Each application module is given with a request for resource requirement and the deadline for the completion. The application resource constraints which are defined by the equations 1 - 3.

$$\sum_{i=1}^{m} A_i^{RAM} * x_{ij} <= R_f^{RAM} \tag{1}$$

$$\sum_{i=1}^{m} A_i^{MIPS} * x_{ij} <= R_f^{MIPS} \tag{2}$$

$$\sum_{i=1}^{m} A_i^{Storage} * x_{ij} <= R_f^{Storage} \tag{3}$$

The placement of each application should satisfy the application deadline, the service execution time is calculated as given by following equations.

$$L_t = L_f + L_c \tag{4}$$

Where, L_t is the total latency incurred from the application running in the cloud and fog nodes.

$$L_f = \sum_{i=1}^{m}\sum_{j=1}^{n}((\delta_f + M_{if} + A_{tf}) * x_{ij}) \tag{5}$$

Where, M_{if} is the makespan for the application deployed in the fog node and A_{tf} is the communication time over link between the fog nodes and the edge devices and δ_f is the average deployment time for application modules. L_f is the sum of the deployment time, makespan time for the application deployed on fog nodes and as well as the communication time between edge and fog nodes defined by Eq. (5).

$$L_c = \sum_{i=1}^{m}\sum_{k=1}^{p}((\delta_c + M_{ic} + A_{tc}) * x_{ik}) \tag{6}$$

Where, L_c is the sum of deployment time, makespan time and communication time in the cloud environment defined by Eq. (6). A_t is the transfer time taken over the

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communication link connected to the cloud for transferring all data to the cloud. The Eq. (8) is used to minimize the application latency.

Our main task here is to reduce the total latency for the IoT applications which are deployed over fog and cloud.

$$L_T = \sum_{i=1}^{n} L_t \tag{7}$$

$$Minimize(L_T) \tag{8}$$

A. Placement of Application Modules

The placement of application modules in the fog-cloud environment is referred to as the bin packing problem. We propose a First-Fit Decreasing based heuristic approach for placing the application modules on the fog nodes while considering the available resources. Algorithm 1 shows the details of the placement of application modules.

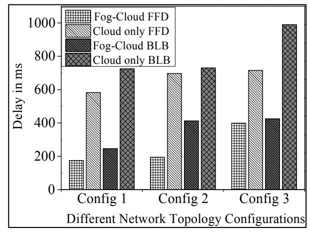
Algorithm 1 First-Fit Decreasing based Module Placement

Input: Application Modules A_i={A_1,A_2,.....A_m}
Fog Nodes F_i={F_1,F_2,............F_n}
Output: Placement_List [ ].

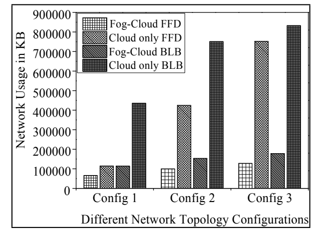
```
Sort List of applications based on resource request
for each applications A_i do
    for each Fog Nodes F_j do
        check for the Resource availability in fog nodes
        CheckRequirementAvailability(A_i, F_j)
        if resource requests satisfied then
            place application module A_i on fog node f_j
            Update the placement list
            Placement_ List.insert (A_i, F_j)
            Update the resource remaining in Fog node
        else
            Place A_i in Cloud
            Update the resource availability
        end if
    end for
end for
return Placement_ List
```

III. Experimental Results and analysis

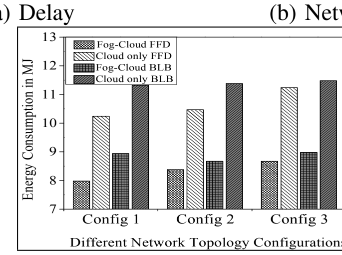
We carried out the simulation for the different network topology configurations, namely: Config 1, Config 2, and Config 3 are used with 4, 6 and 8 fog gateway devices. In Fog-cloud environment, application modules are distributed on both fog and cloud based on the resources availability. In cloud only approach all application modules are placed only onto the centralized cloud. We used these two computing approaches for comparing the application latency, network usage and energy consumption for the considered network topologies, and also proposed FFD is compared with the benchmark lower-bound (BLB) method [3] used for application module placement in fog-cloud environment. Figure. 1 shows the performance of the algorithms for applications deployed in Fog-Cloud and Cloud only computing environments. It is observed from Figure. 1a 1b 1c that proposed FFD method performs better than BLB in terms of Application delay, Network usage and Energy consumption respectively.



(a) Delay



(b) Network usage



(c) Energy Consumption

Figure 1: Performance Evaluation

IV. Conclusion

Using fog computing architecture for processing the data close to the edge of the network is better approach for reducing the network congestion and thus reducing the application latency. Hence, IoT application modules are placed on fog nodes for processing the data for real-time smart city applications such as Health monitoring and Industrial monitoring. But the key challenge in fog computing is to select the suitable node which can host the IoT applications. In this paper, we solved the placement problem using the First-Fit Decreasing based heuristic approach to reduce the application latency and thus utilizing the network resources efficiently with minimum energy consumption. In future we would like to consider the dynamic workloads for estimating the cost of the service while scheduling the tasks in the fog computing environment.

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