QEBA: 5세대 가상화 이동 네트워크에서의 게이트웨이 배치를 위한 QoE와 에너지 밸런싱 알고리즘

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QEBA: A QoE-Energy-Balancing Algorithm for Gateway Placement in 5G Virtualized Mobile Networks

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Abstract

This paper proposes an algorithm that deploys virtual gateways in 5G mobile network systems to balance the Quality of Experience (QoE) of user equipment and the energy efficiency. This algorithm is called QoE-Energy-Balancing Algorithm (QEBA), and is evaluated in terms of round-trip time and energy usage, which is compared with an RTT-based algorithm and an energy saving algorithm.

1 Introduction

The development of Network Functions Virtualization (NFV) enabled the appearance of Virtualized Network Functions (VNFs) for various network services. In 5G mobile networks, VNFs can replace physical network devices used in the previous Long-Term Evolution (LTE) networks of the 3rd Generation Partnership Project (3GPP). VNFs of the user plane, including virtual gateways such as User Plane Function (UPF) [1], can be deployed to distributed edge clouds. Fig. 1 shows the structure of 3GPP 5G mobile networks to use virtual UPF (vUPF). A vUPF can be dynamically constructed and destroyed to adapt system performance. An algorithm that selects whether or not to deploy a virtual gateway for 5G mobile network systems can be applied to gain better efficiency. Previously, we proposed a random selection algorithm and a Voronoi-based selection algorithm for gateway selection in our previous research and evaluated these algorithms in terms of energy usage through simulation [2]. In this paper, we propose a new algorithm which considers both the Quality of Experience (QoE) of User Equipment (UE) and the energy usage of 5G mobile network systems, and evaluate it through intensive simulation.

2 Algorithms

Two algorithms for gateway selection are used as baselines for the comparison with the proposed algorithm. They are RTT-based algorithm and Energy saving algorithm.

2.1 RTT-based Algorithm

RTT-based algorithm is similar to the Voronoi-based selection algorithm in our previous work [2], but this RTT-based algorithm uses RTT from a Next Generation NodeB (gNB) to an edge cloud of the 5G mobile network systems. Once a packet is sent from a UE device to a gNB, the Euclidean distance between the UE and an edge cloud of the 5G mobile network systems may be insignificant in the End-

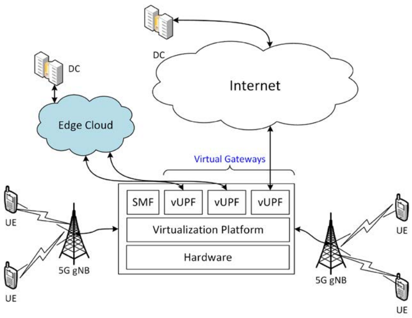


Figure 1: 5G Mobile Network Structure.

to-End (E2E) delay between the UE and the edge cloud. Instead, the delay between the gNB and the edge cloud of the 5G mobile network systems influences significantly the QoE of the UE. Thus, it is noted that the RTT from a gNB to an edge cloud of the 5G mobile network systems determines the QoE during the selection of a vUPF instance. RTT is measured by ping packets which are sent from a gNB and travel between the gNB and an edge cloud of the 5G mobile network systems. When a gNB serves a new UE, RTT-based algorithm selects an edge cloud of the 5G mobile network systems which has the shortest RTT from the gNB and establishes a GTP Tunnel from the UE to a gateway instance in the selected 5G mobile network systems.

2.2 Energy Saving Algorithm

An Energy Saving Algorithm (ESA) selects an edge cloud of the 5G mobile network systems whose energy usage would increase least when it accommodates another UE. After finding the edge cloud, ESA searches for the gateway instance in the 5G mobile network systems that will minimize the energy usage.

2.3 QoE-Energy-Balancing Algorithm (QEBA)

Our proposed algorithm is called QoE-Energy-Balancing Algorithm (QEBA), and has a threshold of the RTT between the gNB and an edge cloud of the 5G mobile network systems. Among edge clouds that have a shorter RTT than the

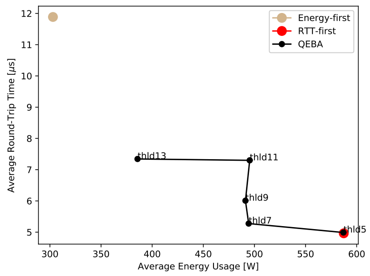


Figure 2: The Average RTT and Energy Usage of Algorithms.

threshold, QEBA selects the one with the least energy usage. If there is no edge cloud in 5G mobile network systems that satisfy the condition, QEBA increases the threshold by $0.5\mu s$ and tries to find a satisfying edge cloud. When it finds an edge cloud that satisfies the condition, it selects a gateway instance that increases the least energy usage from the 5G mobile network systems.

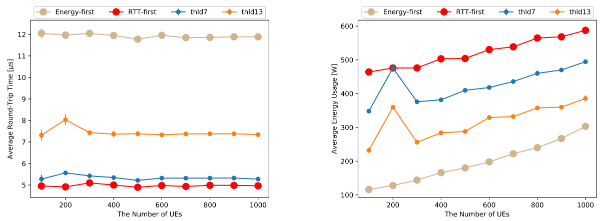
3 Performance Evaluation

3.1 Environment and Assumptions

Our simulation focuses on edge clouds and the placement of virtual gateway instances in the user plane. A vUPF represents a virtual gateways in the simulation. The specific amount of energy usage is based on an existing work [3]. OMNeT++ 5.5.1 [4] is used for the simulation in Ubuntu 18.04.3, where some of the tools are modified for the virtual network environment. In the simulation, there exist nine gNBs, six 5G mobile network systems that can create at most ten vUPF instances and serve a thousand UEs. For more reality, 30% of the UEs stay around the center of the map used in the simulation, and others (i.e., 70%) are scattered around the whole area. Among scattered UEs, 40% of them move with a speed pattern of a vehicle (i.e., a uniform random speed between 10m/s and 25m/s), and the other 30% move with the speed pattern of walking or running (i.e., a uniform random speed between 0m/s and 2m/s). The width and height of the area are 1000m, respectively, which make the area 1km^2.

3.2 Analysis on Simulation Results

There are several versions of the proposed algorithm according to the RTT threshold. The algorithm named *thld7* has the threshold of 7μs, and *thld9* has the threshold of 9μs, and so on. Fig. 2 shows the performance of the proposed algorithms when the number of UEs is one thousand. The proposed algorithms have a much shorter RTT than the ESA and have less energy usage than RTT-based algorithm. QEBA tends to have less RTT and more energy usage when the threshold becomes lower. Figs. 3(a) and 3(b) show the performance of thld7 and thld13 as the number of UEs increases. In Fig. 3(b), when the number of UEs is 200, the proposed algorithms show sudden increase in average energy usage. As shown in Fig. 3(a), this algorithm guarantees lower RTT than the threshold for every UE number. However, as shown in Fig. 3(b), it does not guarantee linear increase in energy usage. QEBA selects a vUPF that will have lowest increase in energy usage whenever a connection request from a new UE arrives, but it cannot optimize the energy usage thoroughly. It is observed that RTTs of QEBA are lower than that of the threshold and its energy usage is better than the RTT-based algorithm's.



(a) (b)

Figure 3: Impact of the Number of UEs. (a) The Number of UEs vs. Average RTT, (b) The Number of UEs vs. Average Energy Usage.

4 Conclusion

This paper proposes a QoE-Energy-Balancing Algorithm (QEBA) to select gateway instances for UEs in 5G environments regarding the balance between the energy usage of the service provider and the QoE of the UEs. It is shown that the proposed algorithm outperforms two baselines through simulation. By using a threshold for the RTT and considering the corresponding energy usage, the tradeoff between the QoE and the energy usage could be adjusted. As future work, we will try to make an algorithm which can minimize the total energy usage while considering the QoE of the UEs.

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