Mathematical method manage resource pool in VFC

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***Abstract*—Vehicular Fog Computing(VFC) which utilizes the potential resources between the cloud and the edge of Vehicular Networks to improve the ability to compute for the edge in fog is a significant development of intelligent transportation. VFC has characteristics: low latency, high dynamic, a large number of nodes, heterogeneity and so on. Due to decentralization and high mobility, the resource is hard to manage. It has more challenges to manage, compared to cloud computing. This report proposes a resource pool model to manage vehicular resources and RSU fixed resources in VFC.**

I. INTRODUCTION

Over the last two decades, mobile communication changed our lifestyle, which transmits more information quickly between more things. Meanwhile, the automotive industry is also developed by the technological innovations [4]. Vehicles have more sensors and stronger computing ability. Vehicular Cloud Computing which is controlled by the cloud is using vehicles as servers to provide computation resources and data. Vehicular networks are recognized as a significant component of intelligent transportation systems [8] and they support various mobile services. With the development of more advanced technologies and equipment, more applications and services come out(such as self-driving) that increase the demand for more computing and data with low latency.

Fog is a new layer between the cloud and the edge of the network. Vehicular Fog Computing (VFC) extends Vehicular Cloud Computing (VCC) paradigm to the edge of the vehicular network. VFC using vehicles as nodes has closer computing resources which do not need to communicate with the cloud bringing out low latency. Due to the dispersed of vehicles, aggregating idle computing resources of the individual vehicles and the computing resource of Road Sides Units(RSU) can enhance the Quality Of Services(Qos) greatly [1].

Although VFC has a huge opportunity for computing resources, its heterogeneity and mobility of vehicular nodes are challenges. The challenges stem from the heterogeneity of VFC and the high mobility of vehicular nodes. As vehicles move at high speeds and frequently change location, ensuring continuity and quality of service becomes a significant challenge. Furthermore, the diversity in computation and storage resources among vehicles raises the question of how to efficiently manage and schedule these resources to meet the needs of different applications.

In this report, a resource pool model is proposed, which has fixed computation resources from RSU and idle resources from the vehicles. The vehicular resources will be put into a resource pool and provided the resource in a specific order by the distance of vehicles and the matching degree of resources.

II. BACKGROUND

A. Vehicular Network

The vehicular network is an emerging network. In vehicular networks, the nodes are usually vehicles and equipment on roads, which have high mobility. VANETs also called Vehicular Ad Hoc Networks are a subclass of the MANETs also called Mobile Ad Hoc Networks. VANETs provide wireless connection in vehicles to vehicles (V2V); vehicles to infrastructure (V2I); mix V2I and V2V. In VANETs, they communicate by a variety of wireless communication technologies, such as short-range radio, cellular and WiMax.

B. Vehicular Cloud Computing

Vehicular cloud computing (VCC) is a distributed computing paradigm which has the advantage of cloud computing and vehicular networks. In VCC, vehicles are mobile nodes which can provide computation resources and process data to the others vehicle, as well as centralized to the cloud.

C. Vehicular Edge Computing

Vehicular edge computing (VEC) uses edge devices, such as on-board units (OBU) in vehicles, or RSU, and other forms of edge infrastructure to process and store data, rather than relying on centralized remote cloud infrastructure. VEC extends cloud capabilities and services to the edge of the network for a wide range of applications.

D. Vehicular Fog Computing

Fog computing architecture (the fog) distributes the tasks from the distant central management system in the cloud to the intermediate nodes which contain computational resources, to reduce the latency caused by transmitting messages between the front-end IoT devices and the back-end cloud [13].

VFC emerged as a way to combine the benefits of fog computing and vehicular networks to provide services and applications. Vehicles covered the vehicular network as fog nodes while providing decentralized local resources. The main characteristics of the Fog are Low latency, Wide-spread geographical distribution, a large number of nodes and heterogeneity [9]. Compared with VCC, the computation resource is typically at the edge of the network such as OBU or RSU rather than the remote cloud, so VFC has shorter transport distances, which come with less latency. Besides, fog computing has lower costs on deployment compared with cloud computing [10].

III. Related Works

Similar to the collaboration of the fog nodes concept, there are some offloading techniques [11] [12]. They introduce models that partition the fog landscape into distinct fog clusters, each one encompassing a centralized fog control node along with other distributed fog units. Furthermore, every individual fog unit embodies a visualized fog node that's equipped with computational, networking, and storage capabilities which are essential for coordinating an assortment of terminal IoT devices. [11]Using Maximal Resource Utilization-Based Allocation and Task Priority-Based Resource Allocation based on the task process time,but did not consider the mobility of the fog node.

In [1], they consider vehicles as infrastructures for communication and computation and propose a novel system of VFC. Four scenarios about utilizing moving and parked vehicles were provided. Two of them is using moving vehicle as infrastructures and the others are using parking vehicles. Each type of vehicle can be used to communicate and compute.

Moving vehicles transmit information by moving and communicating with different vehicles by using VANETs. Slow-moving vehicles work with RSU as local cloudlets and RSU connect to remote clouds. This hybrid cloud can provide computation capability to vehicles.

Parked vehicles can serve as static backbones and service infrastructures to improve connectivity. Besides, parked vehicles are able to service large computation demands.

Chaogang Tang, Shixiong Xia, Qing Li, Wei Chen, and Weidong Fang [2] propose pooling the vehicles together to share their computing resources in a community. Meanwhile, with the development of VFC, vehicles have more choices to join communities at the same time, they provide a genetic algorithm based strategy to optimize that process depending on how much benefit they can earn by joining the community.

Compared to other wireless networks, vehicular networks is a highly dynamic topology, short transmission time and so on. Pereira et al. [4] propose an allocation and management resource policy for vehicular cloud(NANCY) to decide if allocate the available resource to the request, which is based on the mathematical method Multiple Attribute Decision.

Lee and Lee [5] suggest utilizing parked vehicles to minimize service latency and present a heuristic algorithm which combines with reinforcement learning to solve the solutions the formulation set from the problem of allocating the limited fog resources.

IV. Problem Statement

Despite the rapid development and inherent advantages of Vehicular Fog Computing (VFC), several significant issues remain unaddressed, which hamper its full-fledged implementation and use in the field of intelligent transportation systems.

Firstly, the dynamic nature of VFC, characterized by the high mobility of vehicular nodes, poses a significant challenge in managing resources. Vehicles continuously change locations, and ensuring the consistent and high-quality provision of services becomes increasingly difficult. The effective management of such a dynamic system necessitates efficient strategies to predict, schedule, and allocate resources.

Secondly, the heterogeneity of computing resources in VFC is another issue. Vehicular nodes can greatly vary in their computational and storage capabilities. This disparity raises the question of how to efficiently distribute, manage, and utilize these diverse resources to meet the demands of different applications.

Finally, given the distributed nature of resources in VFC and the high cost of communication with the remote cloud, there's a pressing need to devise strategies that could minimize latency and maximize the usage of local resources, improving overall system performance.

This report proposes a novel resource pool model as a solution to these challenges, aiming to optimize the management and allocation of vehicular and Road Side Units (RSU) resources in VFC. Through this model, we attempt to address the current issues faced by VFC and pave the way for its broader implementation in intelligent transportation systems.

V. System Model

The controller(such as RSU) of the resource pool will collect the resource that the vehicles agree to share. The controller will send broadcast messages periodically to update if vehicles coming and willing to share resources and if vehicles leaving. When the vehicles are no longer in the range of The controller, they will be deleted from the resource pool. When the vehicle sends a request to the controller, if the fixed computation resources in the controller are not enough for the request, the controller will evaluate the resource pool and then provide the resource in a specific order.

The evaluation method uses the quantity of the resource and the distance between the request and the vehicle which provide the idle resource to produce two parts. Then sort and combine them and the lowers score will be used to serve the request first.

The first part is sorting by resource. Algorithm 1 describes the process. The quantity of the requested (Qr)resources and the quantity of each available(Qa) resource will be compared. The exact same one will have the lowest scores. The smaller differences will have lower scores. Qr bigger than Qa will have higher scores than Qr smaller than Qa. This part aims to use as less as possible vehicles to serve the requests. Algorithm 1 describes the process. Fig1 shows the relation of Qa and the score it will get after evaluation. The purpose of this section is to satisfy the request with as few resource vehicles as possible.

The second part calculates the distance using the distance formula. The smaller value of distance will have a lower score. Vehicles can communicate with vehicles around them by using VANETs. The smaller distance can reduce the latency. Fig2 shows the relation of the distance between the request and the resource vehicle and the score it will get after evaluation. The evaluation result of the first part and the second part will be sorted from low to high. The lowest score of them will have

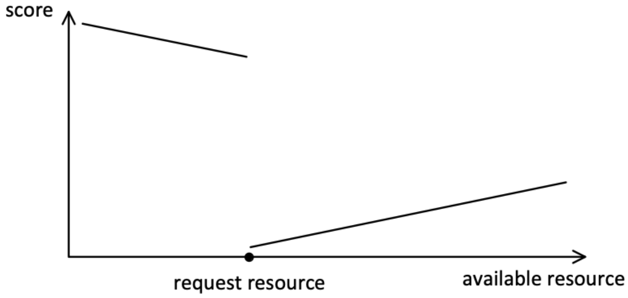

Fig. 1. Example of a figure caption.

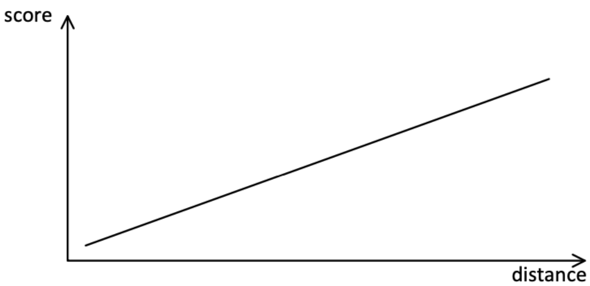

Fig. 2. Example of a figure caption.

one score and the second lowest score will have two scores and so on. Summing the score with the same vehicle ID and sorting the combined score. The lowers score will be used to serve the request first. If there are no more available resources in the pool, but still need more resources. The remaining requested resource will be served by the resource pool nearby.

Algorithm 1 getResourceScore

total=Qr - Qa;
if (total<0) **then**
  score=|total|+100000;
else
  score=total;
end if
return score;

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