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An AI-Based Dynamical Resource Allocation Calculation Algorithm for Unmanned Aerial Vehicle

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***Abstract*—**As the scale of the network becomes larger and more complex than before, the density of user devices is also increasing. The development of Unmanned Aerial Vehicle (UAV) networks is able to collect and transform data in an efficient way by using software-defined networks (SDN) technology. This paper proposed a three-layer distributed and dynamic cluster architecture to manage UAVs by using an AI-based resource allocation calculation algorithm to address the overloading network problem. Through separating services of each UAV, the UAV hierarchical cluster system performs the main function of reducing the network load and transferring user requests, with three sub-tasks including data collection, communication channel organization, and data relaying. In this cluster, a head node and a vice head node UAV are selected considering the CPU, RAM, and ROM memory of devices, battery charge, and capacity. The vice head node acts as a backup that stores all the data in the head node. The k-means clustering algorithm is used in order to detect high load regions and form the UAV layered clusters. The whole process of detecting high load areas, forming and selecting UAV clusters, and moving the selected UAV cluster to that area is proposed as offloading traffic algorithm.

***Keywords*—**k-means, resource allocation, SDN, UAV network, unmanned aerial vehicles.

I. Introduction

IN the future, networks will be improved to allow high speed and much more user devices. Specifically, network will deliver 10 GB per second, 0.001 s latency, with a very high density of up to 106 user devices per km^2 [1]. With the rapid increase of device amounts, the network traffic entering is also increasing significantly, which leads to high load areas in each region. Also, since users move constantly, the zone with high load may appear in the suburb in the evening while it is observed in the city center during the daytime. Thus, UAV technology is proposed to reduce the high load of core network in the future [2]. The technology originally uses single UAVs to carry out some user tasks. However, with the increase of devices accessing the network, single UAVs is not able to support the requirements and distributed and dynamic UAV clusters are used to perform tasks. Also, cluster architecture is proposed to organize UAV groups with the help of the interaction with ground segment [3], [4].

A. Offloading Traffic Algorithms for UAVs

For UAV clusters, a method is proposed in [5], which is to move one of the UAV clusters located in the network. Firstly, high load areas are identified and located in a specific region. Secondly, we select one of the UAV clusters to carry out offloading task in an increasing load area. Finally, we move the chosen UAV cluster to the region with increased load.

B. Distribution of UAVs in Different Clusters

There are two main ways to distribute UAVs into clusters: The first method is to distribute UAV manually. In [6], it is proposed that the network administrator can distribute a UAV based on the tasks assigned to it. Another method is to use clustering algorithms to distribute UAVs. For example, [5] uses the k-means algorithm to form UAV clusters. The number of clusters formed, the coordinates of the assumed cluster centers and the coordinates of the UAV are the initial inputs for the k-means algorithm.

C. Main Functions of the UAV Clusters

1) Head Node

In the clustering architecture, a UAV is chosen as the head node and it is used to interact with all other UAVs within the cluster. Also, it is used for the interaction of UAV cluster with the ground base station [5].

2) Vice Head Node

A vice head node is selected as a backup of the head node. If the head node's battery is low, the vice head will take place of it. This will save the time needed for choosing a new head node and the overall resource allocation will not be affected due to running out of battery.

3) SDN Technology

SDN can be used to further reduce the load on the network and improve load balancing in the UAV cluster [7]. The employment of SDN is affected by how the SDN controller is implemented. The head node, all nodes of the UAV cluster, or a balloon or ground base station outside the UAV cluster can use the SDN controller functions [8].

Problem

The UAV is one of the most promising use cases of 5G/IMT2020 [3], [4]. Due to the development of the new generation of networks, the density of user devices rises, and the traffic entering the network increases, resulting in high-load zones in many different network zones. More seriously, even the same network zone has different network load because users are constantly on the move throughout the day [5]. For instance, in the early morning, the high-load network zone is at suburb

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when people are at their home, but a high load is observed at the city center in the afternoon.

How to solve the problem of reducing the load on the network zone catches more attention. One of the main technologies to reduce the load on the core network is the UAV technology [3]. As a result, groups of UAVs organizing by the cluster architecture are more and more popular with this context [3]. However, many users request through UAVs concurrently, and the cluster nodes will have to support the functions of the base station, base station controller, SDN switch and head node SDN controller, which leads to an increasing costs of UAV resources.

Objectives

In order to solve the increasing network traffic, which leads to heavy load in various network zones, the main goal of this paper is to propose a specific UAV Clustering Architecture with deep learning algorithm k-means for searching for real time computing resources. The objectives of the research include:

1) To study UAV clusters used in high load zones in order to offload traffic;
2) To determine the formation of UAV clusters;
3) To process user requirements at the UAV cluster level;
4) To propose the functions performed in the UAV cluster.

Research Questions

The research questions are listed below:

1) How to solve the problem of UAV distribution among clusters?
2) What is the proposed UAV clustering architecture that can efficiently solve problems?
3) What are the actions to be taken in sequence to complete the task of processing user requests and offloading traffic?
4) What are the functions to be performed in the UAV cluster and which AI-based algorithm is proposed?

II. Framework

To address the problem, this research proposed a hierarchical three-layer system (Fig. 1) to structure the cluster.

- Layer 1: UAVs in this layer act as base stations to receive user requests through user devices and sensors. The received information is transmitted to the nearest UAV in the 2nd layer.
- Layer 2: In this layer some UAVs act as base station controller, while other UAVs function as SDN switch. Data from the 1st layer are received by the base station controller UAVs, and then transmitted to the SDN switch UAVs. The UAVs SDN switch will forward the information to UAVs acting as SDN controller in the 3rd layer.

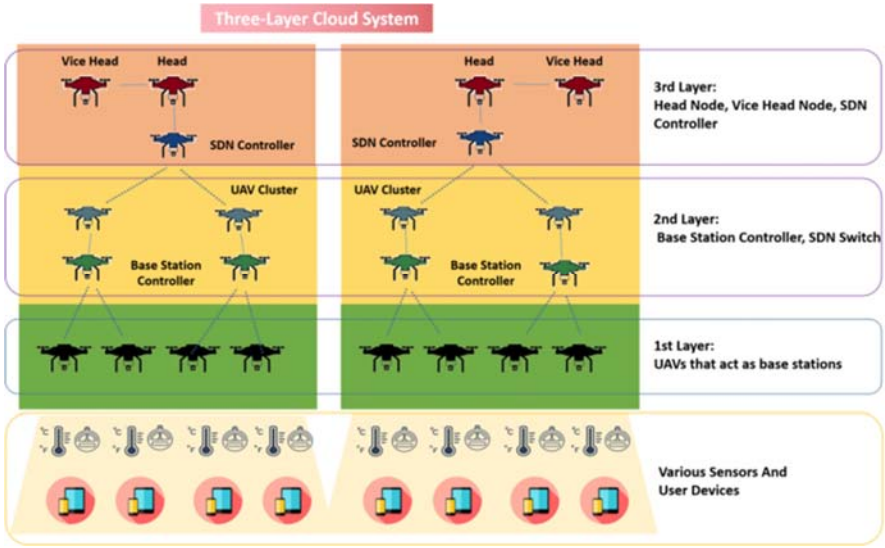

Fig. 1 Three-layer Cloud System

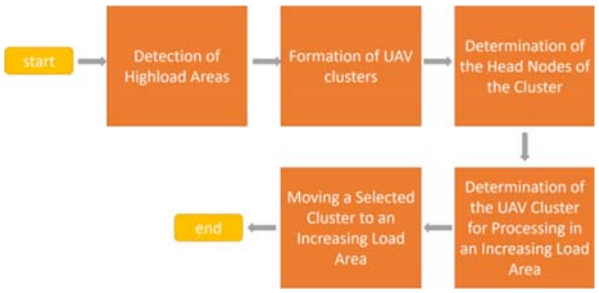

Fig. 2 Offloading Traffic Algorithm

- Layer 3: After the SDN controller UAVs received data of user requests, they transfer it to the head node UAV. Then the head node NAV can transmit it to the multi-layer cloud Mobile Edge Computing (MEC) system. When the head node UAV is lack of battery, the vice head UAV will become the new head to receive and transfer information immediately.

The progress of offloading traffic algorithm is shown in Fig. 2. The k-means algorithm was proposed to both determine increasing load fields and to form the UAV clusters. In this algorithm, the number of grew load regions, the cluster hypothesis center coordinates and the UAV spatial coordinates

on X, Y and Z axes (in meters) are taken as initial parameters. The formation of different sizes clusters is allowed using k-means algorithm, which will help to allocate users more efficiently, as the areas that increase the load can vary in their size and density in real situations. Besides, in order to distribute all UAVs into clusters, the length of cluster radius is important to be considered an appropriate value.

III. Findings and Discussion

To reduce the high load of core network, methods based on single UAV are firstly proposed. However, when the devices accessing the network increase, single UAV cannot support the requirements. Thus, methods based on UAV clusters are proposed. A method based on SDN and NFV is proposed in [2]. The research presented the steps of cluster forming, head node selecting and optimal path determining for collecting data from various sensor devices. Nevertheless, the cluster nodes need to support SDN controller, SDN switch, base station and base station controller, which causes a rise of UAV resources usage. Thus, to allocate resources more efficiently, a hierarchical UAV cluster-based method is proposed in this research. In this framework, different functions are separated in different layers and UAVs in the cluster are assigned with different tasks. Fig. 3 shows the process of user information flow in a UAV cluster, which is proposed in this research. Also, there are two ways for UAV distribution. The first method is that the UAV clusters are set by the network administrator [6]. The network administrator is able to allocate the UAVs into clusters according to the tasks distributed to the UAV. However, this method is lack of efficiency since it is done manually. The other method is based on AI-based cluster distribution algorithms. In this research, k-means algorithm is adopted for UAV cluster formation. By using k-means algorithm, the formation of different sizes clusters is allowed. This improves the efficiency of allocating users as the areas with increasing load can vary their size and density in real world cases. Also, by using AI-based algorithms, the time and human resources needed for the work are reduced significantly, which improves the efficiency of the distribution.

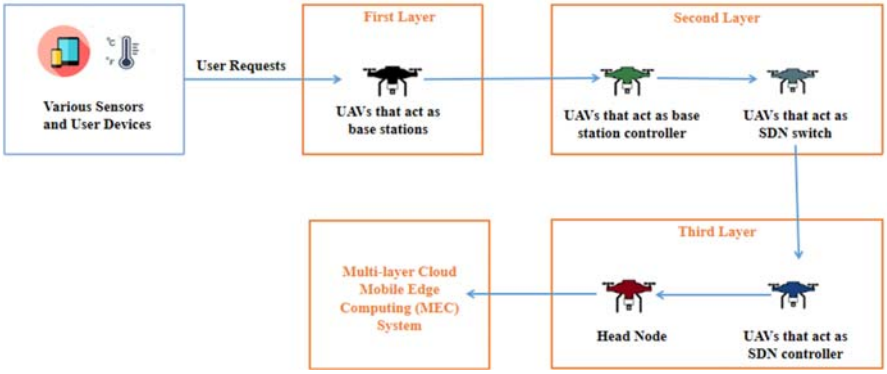

Fig. 3 Process of User Information Flow in a UAV Cluster

IV. Recommendation

The main functions of the proposed three-layer UAVs are transmitting user requests and reducing the network load. Other functions such as data collection from sensors, communication channel organization and data relaying should also be considered. Therefore, several implementation details in the proposed UAV structure are listed to fulfill these additional functionalities.

Firstly, the 1st layer UAVs should save data from sensors instead of only receiving them. Besides, no matter the UAV is in which layer, they should perform the function of storing data including the delay-tolerant data from the last layer and user requests.

Secondly, the different kinds of UAVs will perform different types of services in order to fulfill user requests. Thus, unnecessary waste of resources can be avoided in this way instead of each UAV implementing all services.

Thirdly, the head node UAV plays a role in selecting UAVs to process user requests, choosing UAVs to participate in organizing a communication channel and determining the route when transmit data. The vice head node UAV does not make a decision and plan the route but it records all the scenarios happened with all the choices made by the head node UAV. As a result, when the battery of head node is below a certain level, the vice UAV can take place of it without delay because a new head is not selected.

In addition to k-means algorithm stated in Framework section, it is necessary to use the FOREL algorithm in the future to process the forming UAV clusters [9] by planning UAV groups' moving path. Some centers of certain clusters are going to be the point where the UAV cluster optimally collects data from sensors. Therefore, this algorithm can form clusters with a given radius. In the execution process, the center of the cluster will set the movement point of the UAV group. Furthermore, a specific UAV flight path, an effective user offloading strategy as well as a reasonable real time scheduling strategy also need to be designed and developed in order to give full play to the advantages of UAV layered structure, solve the larger scale network complexity and achieve the real time requirements [10].

V. Conclusion

In the future, the amounts of devices will increase rapidly

which causes network traffic to be heavy and leads to high load areas in different places. Also, because of the movement of users, the high load zones change constantly. Thus, UAVs are adopted to reduce the high load of the network. Since the single UAV is not able to cope with the high load zones, distributed and dynamic UAV clusters are adopted in this research to carry out the resource allocation tasks. There are five steps in the UAV cluster-based resource allocation method. Firstly, high load areas are detected and UAV clusters are formed by using k-means algorithm. Then, we determine the cluster's head node. After that, we identify the UAV cluster for processing in an increasing load area. Finally, we move the chosen cluster to the increasing load zone.

What is more, a three-layer cloud system framework for data transmission within a UAV cluster is proposed in this research. UAVs in a cluster act different roles and provide different functions. In the first layer, UAVs act as base stations to receive user requests and send them to base station controller UAVs in the second layer. The base station controllers then send the information to SDN switch UAVs in this layer. After receiving information, SDN switch sends it to SDN controller in the third layer. Next, the information will be sent to the head node and the MEC system. The hierarchical framework improves the efficiency of data transmission within a UAV cluster by dividing functions appropriately.

For future work, the proposed framework can be used not only for network offloading, but also for offering wireless network coverage to infrastructure-less or spectrum-scared areas [11]. What is more, it is planned to use a single UAV to realize the same functions as those of a UAV cluster to help reduce the use of UAV resources. Also, Fog Computing technology and Network Function Virtualization (NFV) technology can be adopted to improve efficiency and security in further development.

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