# Resource Allocation Computing Algorithm for UAV Dynamical Statements based on AI Technology

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## Abstract

An unmanned aerial vehicle (UAV) is one of the complex and relevant communication networks of 5G and 2030 networks. Development of technologies for virtualization (NFV), containerization and orchestration of data systems. NFV technology can be implemented not only in the data center but also on the switch or router. Thus, by analogy with the above-described trend, flying network segments can also use computing power to solve any problems. For example, deployment on virtual distributed capacities of a flying station controller, an internal network controller. Within the framework of this direction, there are a number of interrelated tasks that need to be resolved by the trends and capabilities of Artificial Intelligence technologies. This paper proposes an algorithm for searching for computing resources in real time. The article defined the criteria for choosing the head node and the cluster with the highest total resources, considered the possibility of implementing the function of the SDN controller in the UAV cluster, the main possible functions and tasks of the UAV, proposed a three-level architecture based on the separation of the functions performed by the UAV. In this work, simulation was carried out in the Matlab program to detect areas of increased load, form UAV clusters, select a head node in clusters and select one UAV cluster with the highest total resources for its subsequent migration to the area of increased load.

## Keywords

Unmanned Aerial Vehicle, SDN, NFV, 6G Network.

## Introduction

It is expected that new generation networks will allow deliver ten gigabit per second and 1 ms latency, also will have an ultra-high density of user devices that is 106 devices per km$^2$ (3GPP TR 38.913, 2017).

With increasing density of device placement, the volume of incoming traffic also increases, which in turn can lead to the emergence of high-load zones in various network zones. This problem is also complicated by the fact that due to the constant movement of users throughout every day, the load in the same zone at different intervals of time will differ. For example, in the morning, a high load will be observed on the outskirts of the city, in the middle of the day - in the center and industrial areas.

One of the mean technologies that will allow in the future to reduce the load on the core network is the unmanned aerial vehicles (UAVs) technology (Kovalenko et. al., 2020).

Originally, only single UAVs were used to perform certain user tasks. But in the context of a constant increase in the number of devices with access network, groups of UAVs are becoming more and more popular for performing tasks. One of the ways to organize UAV groups based on interaction with the ground segment is the cluster architecture (Ateya, et. al. 2019a) (Ateya, et. al. 2019b).

Single UAVs and their groups can be used for a wide variety of tasks, such as (Aldabbas, et. al. 2016) (Ateya, et. al. 2019 a) (Ateya, et. al. 2019 b):

1. Reducing the load on the ground Base Station or restoring communication in conditions of partial or complete destruction of the existing ground infrastructure (in this case, UAVs act as additional Base Stations to provide communication between users or to gain access to the Internet).
2. Implementation of data collection from various types of sensors. In this method of application, the following actions are performed:

   a) Organization of sensor fields for collecting environmental readings by installing sensors on the ground using UAVs;
   b) Implementation of UAV data collection from sensor fields;
   c) Transfer of data to «end user».

3. For data transmission not demanding (tolerant) to delays from one user to another in conditions when data transmission over existing networks is not possible.

In this case, there is a risk of the communication infrastructure failure between two «end users» due to the peculiarities of the terrain. The most striking example of such a method of application can be considered the implementation of data transfer from one device to another using a UAV through a mountain range.

4. Use of UAVs (their computing and storage resources) to process user requests.

## Problem Statement and Related Works

### UAV Clusters for Offloading Traffic in High Load Areas

To provide a more efficient way to traffic offloading at a high-load zone, it is proposed to move one of several UAV clusters located in the network. The sequence of actions to complete this task will be as follows:

1. Determination of high load areas from service consumers.
2. Selecting a UAV cluster for offloading traffic in a certain area of increased load.
3. Ensuring the movement of the selected UAV cluster to the increased load area.

### Formation of UAV Clusters

One of the main tasks in organizing UAV networks with a cluster architecture can be considered the problem of UAV distribution among clusters.

The UAVs distributions into clusters can be done two ways:

When the UAV belongs to a specific cluster is set by the network administrator. For example, the network administrator can independently distribute the UAVs into clusters in accordance with the tasks assigned to the UAV (the network administrator can use other criteria to distribute the UAV) (Menouar et. al., 2017).

When one of the clustering algorithms is used to distribute the UAV. For example, the spatial coordinates of the UAV (x, y, z in meters or kilometers, as well as latitude, longitude, altitude in degrees) and the relative position (distance) between them can be used as criteria for the formation of clusters.

## User Processing Requirements at the UAV Cluster Level

User requests can be processed at the UAV cluster level in two ways:

1. Devices with the largest available resources in the UAV cluster will be selected.
2. At the level of UAV clusters, it is proposed to use the technology of Fog computing. Thus, Fog sub-clusters will be formed in the UAV cluster to fulfill the user's requirements based on the available resources. It is assumed that the head node of each UAV cluster will be responsible for the formation of each UAV clusters.

## Main Functions Performed in the UAV Cluster

To interact with UAVs outside a specific cluster (interaction with other clusters) or with devices of the ground (ground base stations, mobile users) and flying segment (balloons or devices above the levels of the flying segment, for example, satellites) in the cluster, one of the UAVs is assigned as the head cluster node.

To additional reduce the load on the core network and optimize load balancing in the UAV cluster can be used software-defined networks (SDN) technology (Shakhatreh et. al., 2017) (Naqvi et. al., 2018).

The application of this technology depends on how the SDN controller is implemented. The SDN controller functions can be implemented at the head node, on all nodes of the UAV cluster, or on a balloon or ground base station i.e., outside the UAV cluster (Aldabbas, et. al. 2016).

In the previous work (Kovalenko et. al., 2020), the possibility of using SDN and NFV in a UAV cluster is considered, as well as the advantages they provide for systems with

UAVs. The article also proposed an algorithm for the formation of UAV clusters for collecting data from sensor fields, including the process of forming a cluster, choosing a head node and determining the path for optimal data collection from sensor fields.

In another article (Muthanna et. al., 2019), the possibility of implementing a multi-tier cloud MEC system is considered in fifth generation networks to reduce the load on the core network and round-trip delays.

## Proposed Architecture

### UAV Clustering Architecture

In UAV clusters, one device is selected as the head node that performs the functions of organizing interaction with a multi-level cloud system or other clusters, as well as the functions of managing data transfer flows between UAVs within one cluster, thereby implementing the SDN controller functions. All UAVs in a cluster must support one of the possible flow control protocols in SDN networks (for example, OpenFlow protocol) and act as SDN switches. UAVs will interact with each other within the same cluster using Device-to-device (D2D) communications technology.

When the head node battery drops below a certain level, the new head node will be selected. The functions of the SDN controller, functions for interaction with Base Stations and other network segments, as well as the choice of UAVs (one or more when forming a Fog cluster) to process user requests will be transferred to the new head node.

Since the UAVs in the proposed system (Fig. 1) process user requests and can be used to collect data from sensor devices wirelessly, the cluster nodes will have to support, besides the functions of the switch and controller (for the head node) SDN, the functions of the Base station and the base station controller, which in turn, resulted in an increase in the costs of UAV resources to maintain the work of internal processes. To solve this problem, it is proposed to organize the structure of the cluster in the form of a hierarchical multi-level system:

Level 1 - UAVs that implement the functions of Base Stations. They receive user requests and collect data from sensor devices. The received data is transmitted to the 2 level of the UAV. We proposed to transfer data to the nearest UAV of level 2.

Level 2 - UAVs performing the functions of a base station controller and an SDN switch. Nodes of this level receive requests and data from controlled UAVs and transmit them to a specific (selected for processing) UAV within the cluster or to the head node for subsequent transmission to computing devices outside the cluster.

Level 3 - UAVs that perform the functions of the head node and SDN controller. They transfer requests and data from sensor devices to the multi-layer cloud Mobile Edge Computing (MEC) system.

Layer 2 UAVs must support one of the possible flow control protocols in SDN networks (for example, OpenFlow).

The interaction of UAVs with each other in the same cluster will be carried out using D2D communications technology (the possibility of interaction using D2D technology should be implemented on all clusters).

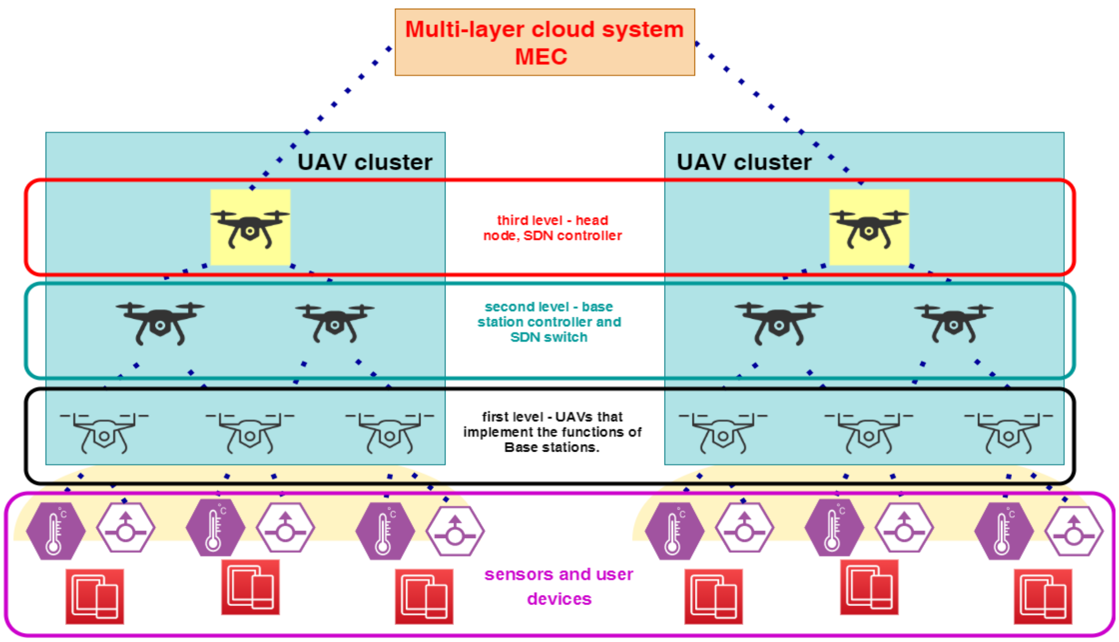


**Fig. 1 UAV clustering architecture**

## Implementation of Additional Functions in the Proposed Architecture

The UAV cluster with the proposed architecture can be used not only for the tasks of reducing the load on the basic network and fulfilling user requests, but also for the tasks of relaying data, organizing a communication channel or collecting data from sensor fields.

Therefore, in the UAV cluster, it is necessary to consider the implementation of functions associated with each of the four possible ways to use the UAV cluster:

1. Data collected from the sensors should be realized on a level 1 UAV (data will be saved on the UAV, where they had been received). At the same time, data storage for the task of collecting readings from sensor fields should have a higher priority than the task of storing delay-tolerant data.
2. The data storage functions with delay tolerant and fulfilling user requests can be implemented on any UAV, regardless of the system level.
3. We proposed to provide UAVs performing user requests with different set of implemented services. Implementation of all services on each UAV leads to unnecessary use of UAV resources.
4. All UAVs of the cluster can participate in the organization of the communication channel between users.
5. Determination of the data transmission route, the choice of UAVs for processing user requests, for storing data, as well as determining the UAVs participating in the process of organizing a communication channel in the proposed architecture will be carried out by the head node (Muthanna et al., 2019) (Muthanna et. al., 2021).

## Criteria of Cluster Head Node Selection

It is proposed, to consider the Central Processing Unit (CPU), operational (RAM) and permanent (ROM) memory of the device, capacity, and battery charge, as the main criteria for choosing a head node and calculating the total available resources of one UAV. For computing available resources, the amount of resources that are at that moment available will be considered and can be used to process the user's request. Since the functions performed by the head node, in comparison with the task of processing user requests, are much important for maintaining the normal operation of the network segment as a whole, the available UAV resources should be spent primarily on these functions, and only after that on processing user requests. In this case, the values of CPU, RAM, ROM and the capacity of the head node of the UAV cluster will be close to the values of the maximum indicators of an individual UAV in terms of these parameters.

Note: the resources provided for the performance of the functions of the head node cannot be equal to the maximum value of the UAV parameters, since part of the UAV resources will be spent on maintaining the operation of internal processes.

## Simulation of the UAV Cluster with the Proposed Architecture

In this work, in the Matlab software package, we simulated the operation of the algorithm (sequence of actions) for determining the UAV cluster for unloading traffic in areas of increased load.

The sequence of actions to be performed to determine the UAV cluster for unloading traffic in areas of high load:

1. Detection of high load areas.
2. Formation of UAV clusters.
3. Determination of the Head nodes of the cluster (since these nodes will be used to interact with other clusters or computing nodes of a multi-tier cloud system).
4. Determination of the UAV cluster for processing in a certain area of increased load.
5. Moving the selected UAV cluster to a certain area of increased load.

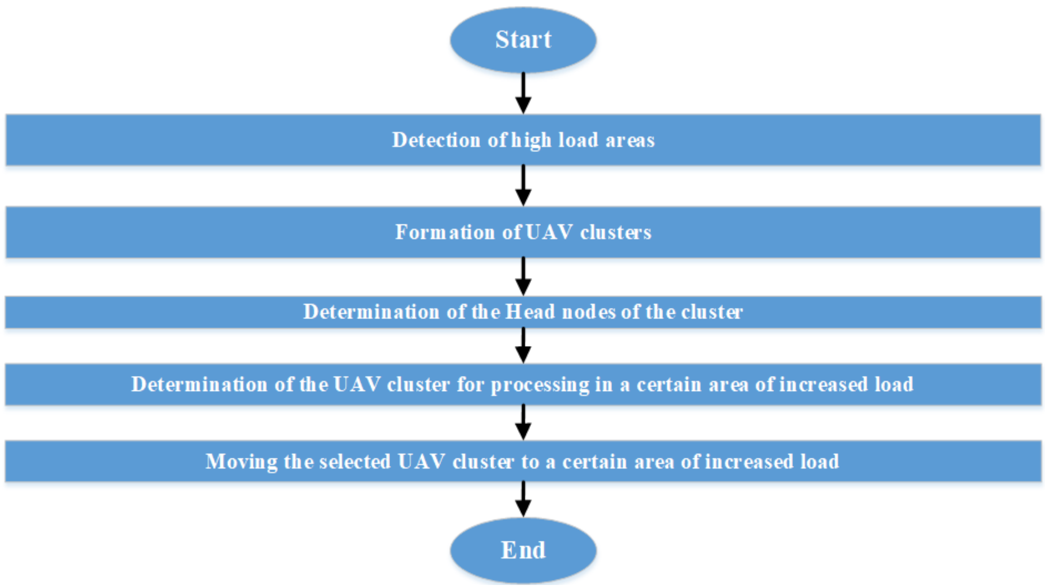


**Fig. 2 Proposed algorithm for using UAV clusters for unloading traffic in areas of increased load**

The k-means clustering algorithm was used to identify areas of increased load. As the initial parameters for this algorithm, the spatial coordinates of the UAV along the x, y, z axes, measured in meters, the number of zones with increased load, and the coordinates of the assumed centers of the clusters were taken. The k-means algorithm allows the formation of clusters of various sizes, which will contribute to a more efficient distribution of consumers among clusters, since in real conditions the zones of increased load can differ in their size and density.

It is proposed, to use the FOREL algorithm for the process of forming UAV clusters (Oubbati et. al., 2017). As the initial parameters for the FOREL algorithm, we took the spatial coordinates of the UAV along the x, y, z axes, measured in meters, the radius of the formed clusters, and the coordinates of the assumed centers of the clusters. All clusters formed by the algorithm will have the same size.

As noted earlier, it is proposed to consider the CPU, random access (RAM) and read-only (ROM) memory of the device, capacity, and battery charge as the main criteria for choosing a head node and calculating the total available resources of one UAV. The formula for calculating the total resources for the head node selection task will be as follows: Sum1 = 0.30 × battery + 0.19 × CPU + 0.19 × RAM + 0.13 × ROM + 0.19 × Capacity, where Sum1 is the total resources of a certain UAVs (in calculating of total resources of this type, all five parameters presented above are used). The total resources of the UAV for the task of choosing the head node should be calculated as a percentage. It is suggested to use random access memory (RAM) measured in MB and CPU measured in flops as criteria for choosing a UAV cluster for processing in a certain area of increased load. It is proposed to calculate the total resources of the UAV (calculated by RAM and CPU) according to the following formula: Sum2 = 0.6 × Flops + 0.4 × RAM, where Sum2 is the total resources of the UAV, calculated only by the RAM and Flops parameters.

To find the peak performance of the CPU, measured in flops, we have to multiply the clock frequency *F* (MHz) by the total number of device cores *N* and multiply by the number of floating point instructions per clock cycle *T*.

$$CPU=F\times N\times T \quad (1)$$

$$N=N_{cpu}\times N_{core} \quad (2)$$

$$R=F\times N_{cpu}\times N_{core}\times T \quad (3)$$

$N_{cpu}$ in the presented formula is the number of processors, and $N_{core}$ is the number of cores per processor.

The total resources of the cluster were found by summing the total resources (calculated only by the parameters of RAM and CPU) of all UAVs in the cluster.

In the presented model, 5 groups of users with different sizes and different numbers of mobile devices were generated, as well as three groups of UAV clusters. UAVs in this simulation were generated within a certain distance (radius) relative to the assumed centers of clusters: the first group was generated within 5 m, the second - 2.5 m, the third 1.25. In order for all UAVs to be distributed into clusters, the estimated cluster radius was taken as 10 meters (the diameter of the largest UAV group).

The first group of UAVs consisted of 8 devices, the second - from 6, the third - from 4.

The UAV CPU and Capacity parameters were generated in percentages from 25% to 75%. RAM parameter - from 1024 to 4096 MB, ROM - from 8192 to 16384 MB, the number of cores was either 1, or 2, or 4, and processors - 1 or 2 (just one UAV could have 1, 2, 4 or 8 cores). The frequency of the UAV processors was set in the range from 700 to 3500 MHz. The RAM, ROM and Floating-point Operations Per Second (FLOPS) parameters for each UAV were converted into a percentage relative to the UAV with the highest value for a certain parameter from all the UAVs presented in the simulation.

The figure obtained from the simulation showed the shortest path for moving the UAV cluster with the largest total resources to the centers of user groups (to the centers of clusters of user devices).

## Simulation Results

The results of determining the centers of high-load areas from user devices (centers of clusters of user devices are presented in Table 1.

**Table 1 The results of applying the k-means clustering algorithm to find high-load areas**

| Cluster number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Proposed (Intended) center (x, y, z) | (13.76, 13.88, 13.49) | (13.91, 74.28, 75.00) | (50.24, 50.02, 49.66) | (75.84, 12.73, 75.34) | (75.09, 74.92, 12.65) |
| Found Center (x, y, z) | (14.25, 16.90, 14.49) | (12.07, 75.18, 75.78) | (50.96, 48.75, 50.35) | (75.35, 12.28, 75.10) | (75.16, 75.62, 12.98) |

The results of determining the head node for each UAV cluster, cluster centers, as well as total resources are presented in Table 2.

**Table 2 Total resources, head nodes and cluster centers determined for each of the three groups of UAVs**

| Group number | 1 | 2 | 3 |
|---|---|---|---|
| Intended center (x, y, z) | (20.28, 45.17, 109.66) | (49.94, 14.81, 110.06) | (79.88, 50.16, 110.20) |
| Found center (x, y, z) | (20.70, 44.32, 109.91) | (50.27, 14.59, 110.67) | (79.76, 50.14, 110.49) |
| UAV number selected as the head unit | 3 | 9 | 16 |
| The coordinates of the UAV selected as the head node (x, y, z) | (24.21, 44.51, 106.50) | (48.95, 16.38, 110.18) | (79.57, 49.69, 111.17) |
| Head node total resources | 57.7817 | 63.7110 | 51.4580 |
| Total resources of UAV clusters, Gigaflop | 265.202 | 849.1084 | 225.3552 |

Fig. 3 shows the centers of clusters of high-load areas and UAV groups before applying the proposed algorithm.

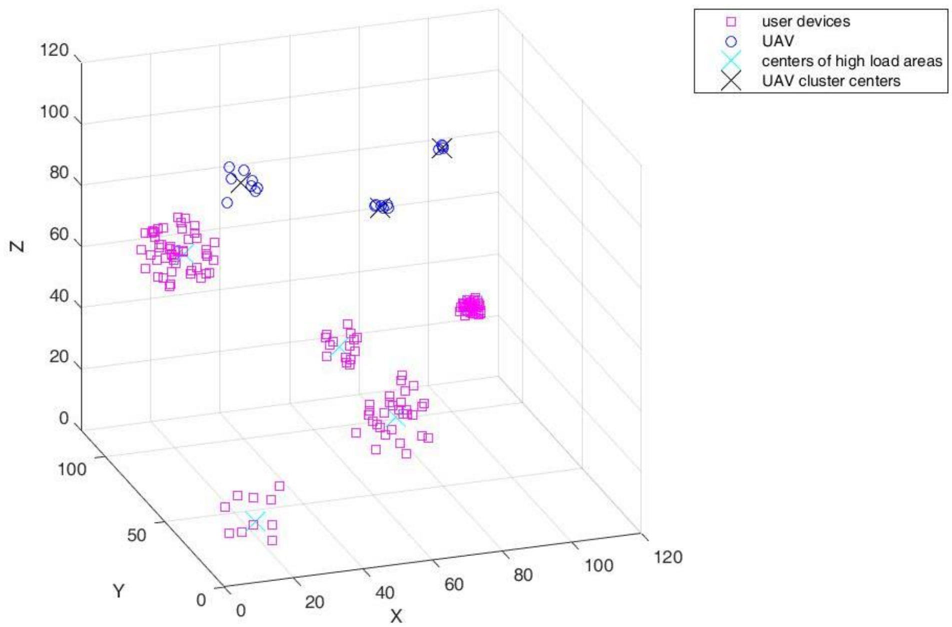


**Fig. 3 Cluster distribution centers prior to implementation of the proposed algorithm**

The results of the proposed algorithm are presented in Fig. 4.

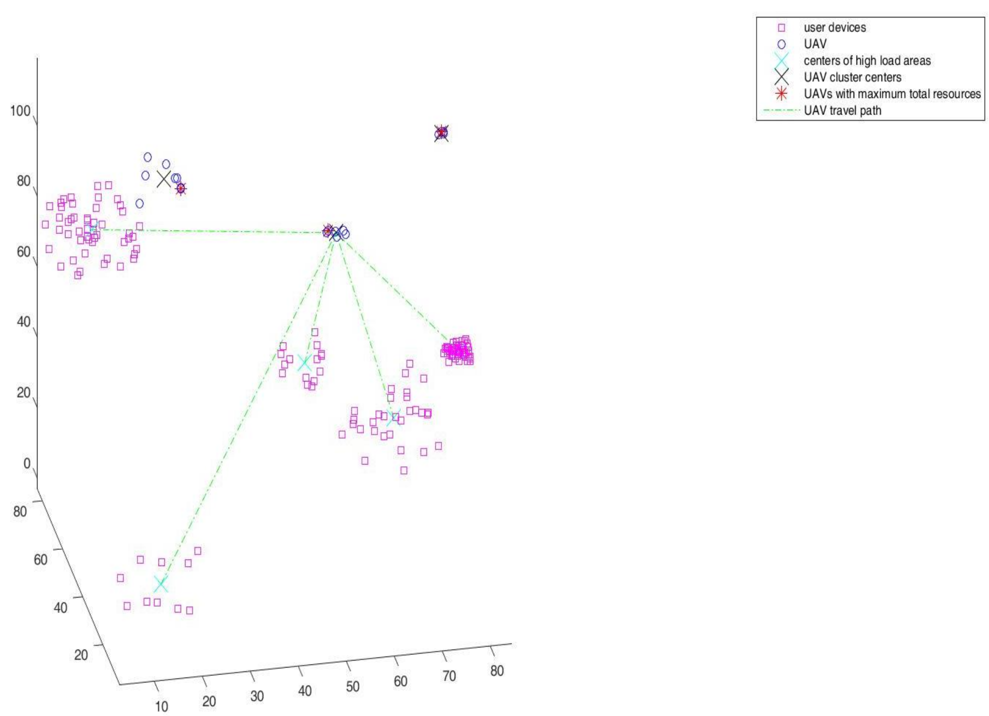


**Fig. 4 Graphical display of the results of the proposed algorithm.**

## Conclusions

This paper was proposed an approach for selecting a UAV cluster to reduce the load on network zones with an increased number of mobile devices. The choice of the UAV cluster to reduce the load and the choice of the head node was carried out according to certain criteria: CPU, random access (RAM) and permanent (ROM) memory of the device, Capacity and battery charge for the task of choosing the head node, CPU and RAM - to select a UAV cluster. Simulation of this algorithm was carried out in the Matlab software package. The paper proposed a three-tier architecture for organizing a UAV cluster, which makes it possible to distribute the cluster's functions among several UAVs. The paper also examined four ways to use the UAV cluster. It was considered the possibility of processing user requests both with the help of a single UAV and with the use of Fog Computing technology as a further development of the direction.

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