A Task Offloading Strategy for Compute-Intensive Scenarios in UAV-Assisted IoV

Yufei Zou, Li Lin, Lei Zhang
College o f Information Science and Technology, Donghua University, 201620, Shanghai, China
Ministry of Education, 201620, Shanghai, China
lei.zhang@dhu.edu.cn

2022 IEEE 5th International Conference on Electronic Information and Communication Technology (ICEICT) | 978-1-6654-7211-1/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICEICT55736.2022.9909200

***Abstract*—With the development of the low-altitude digital economy and the further improvement of the Internet of Vehicles (IoV), the IoV assisted by Unmanned Aerial Vehicle (UAV) has been promoted in many fields. Under task-intensive scenarios, UAV-assisted Mobile Edge Computing (MEC) has been extensively studied due to its flexibility and efficiency. However, with random distribution of computing data, the deployment of UAV and offloading strategy are important issues to be solved. In this context, this paper proposes a UAV-assisted offloading strategy, considering fixed and mobile edge nodes respectively, to meet the requirements of low latency and high reliability of vehicle users. It has been experimentally verified that our system reduces the delay by 30%.**

Keywords—task offloading,edge computing, UAV, Internet of vehicle

I. INTRODUCTION

The low-altitude digital economy is a major innovation in the economic model. It is a comprehensive economic form based on low-altitude airspace such as UAV. As the leading force of the future low-altitude economy, UAV has gained rapid momentum in technological innovation and industrial development. At the same time, with the promotion of a new generation mobile communication technology, the number of devices connected to the Internet is rapidly rising [1]. Through the development of edge computing technology, edge servers cLoSer to mobile users are built to provide high-bandwidth and low-latency services. Considering the limited computing power of edge servers, offloading all tasks to edge servers may reduce the efficiency seriously. Therefore, it is meaningful to take suitable offloading methods into consideration.

The application of UAV-assisted computing has been widely used in various fields, for example, it can be used as a network for emergency in [2]. Wang establishes a Multi-UAV operative edge computing framework in [3], employing differential evolution to determine the position of UAV and proposing a algorithm for task scheduling to help decide the strategy of offloading. Similarly, Wang and Tian propose an iterative algorithm to divide the region of flight area into several parts aiming to find the shortest path in [4]. Mukherjee in [5] formulate a multi-armed bandit-based offload path selection scheme, which save the energy greatly for long operation duration compared with choosing the shortest path. Most of existing work focuses on three fronts, the first one is the path planning of UAV, next is the offloading strategy, the last one is the optimization of the energy consumption. However, there exists little work focusing on the offloading strategy for task-Intensive scenarios in UAV-Assisted IoV considering the channel condition.

In the field of task-Intensive IoV, the reliability of communication channels is extremely important. The addition of UAV causes some changes in channel conditions, the channel between mobile vehicle user and base station (BS) changes frequently between Non Line of Sight (NLoS) and Line of Sight (LoS). In the previous study, most of channel models employ ideal Gaussian channel models, which are not accurate. Only by depicting the channel in detail can we enhances the reliability of system, so as to make the entire task offloading strategy more feasible.

In this paper, by fully exploiting the channel between UAV and mobile user, we propose a task offloading model:

- We propose a three layer UAV-assisted computing network, including the vehicle user layer, the mobile edge node layer, and the fixed node layer. In a given area, the UAV hovers above the vehicle user and BS, the UAV and BS provide task offloading service for the vehicle user.
- Based on maximum clique basic algorithm, we solve the problem of UAV deployment. In order to make the offloading strategy more reliable with minimal delay, we propose an offloading strategy based on joint optimization algorithm .

II. SYSTEM MODEL AND PROBLEM FORMULATION

We consider a task-intensive scenario in UAV-assisted IoV as figure 1.The UAV is denoted as $\boldsymbol{U} = \{1, 2, . . . , M\}$, where M represents the number of UAV. The vehicle is denoted as $\boldsymbol{V} = \{1, 2, . . . , N\}$, where N represents the number of vehicle. We assume that each vehicle generates a task in each time slot, and the parameters of the task are $\{D_n, H_n, R_n\}$, where D_n represents the data size of task. $H_n = k * D_n$ represents the computing resources required to perform the task, where k is the complexity of task. R_n means the reliability requirements of task needed to be satisfied

A. Communication model

The transmission model in this paper includes two types: Vehicle to BS model and Vehicle to UAV model.

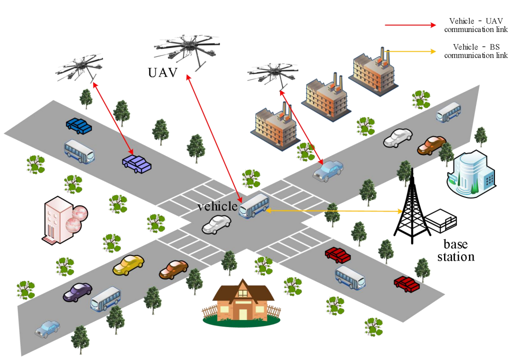

Fig.1. A Task-intensive application scenarios for the UAV-assisted IoV

a) Vehicle to BS transmission model

First, we define the coordinates of BS: ($_r$, Y_r), and then define the coordinates of the vehicle ($_{vn}$, Y_{vn}). Therefore, the transmission distance between the vehicle user and BS is given by:

$$X = \sqrt{(X_{vn} - X_r)^2 + (Y_{vn} - Y_r)^2} \quad (1)$$

And the transmission rate between the vehicle user and BS is denoted as:

$$R_n^r = B \log_2\left(1 + \frac{P_n X^{-\xi} |h_0|^2}{\sigma^2}\right) \quad (2)$$

Where B represents the transmission bandwidth between vehicle user and BS, σ^2 is the additive white Gaussian noise power, P_n represents the transmission power of the vehicle user, h_0 is the Rayleigh Channel coefficient considering the multipath effect and Doppler effect as [6]. ξ is the path LoSs index.

The local computation ratio of vehicle n is defined as B_n^0 , and B_n^r denotes the ratio of task offloading to the BS. $C_n^r = 1$ indicates that the task is offloaded to BS, otherwise it is 0. According to the current situation of the edge nodes, such as the communication quality and the burden of the edge nodes, vehicles can select an appropriate offloading strategy. Finally, the transmission time from vehicle to BS is defined as:

$$T_{n,bs}^{trans} = \frac{C_n^r B_n^r D_n}{R_n^r}, \forall n \in V \quad (3)$$

b) Vehicle to UAV transmission model

Let $\boldsymbol{C} = \{C_n^1, C_n^2, \ldots, C_n^m\}$, where $C_n^m = 1$ means vehicle n offloading task to UAV m, otherwise it is 0.We define B_n^m as the ratio of task offloading from vehicle n to UAV m, define the set of offloading ratios from vehicle user to UAV as $\boldsymbol{B}$.

We can use the two-ray model to simulate the air to ground channel [9] as figure 2 , and the average path LoSs between the UAV and the vehicle is given by [9]:

$$L_n^m = 10 \log\left(\left|\frac{\lambda}{4\pi}\left(\frac{\sqrt{G_{los}}}{d_{los}} + \frac{\Gamma(\theta)\sqrt{G_{ref}}\, e^{-j\Delta\Phi}}{d_{ref}}\right)\right|^2\right) \quad (4)$$

Where G_{los} and G_{ref} are channel gains along the LoS path and the reflected path in [9]. λ denotes the wavelength of the transmission signal, $\Gamma(\theta)$ denotes the reflection coefficient of the ground in [7]. d_{los} and d_{ref} are the distances of direct LoS path and ground-reflected path respectively in [8], where $d_{los} = d_{ref1} + d_{ref2}$. $\Delta\Phi$ is the phase difference of the two signals, and can be expressed as [8]:

$$\Delta\Phi = \frac{2\pi(d_{ref} - d_{los})}{\lambda} \quad (5)$$

Therefore, the transmission rate between the vehicle user and UAV is defined as follows:

$$R_n^m = B_0 \log_2\left(1 + \frac{P_n}{L_n^m N_0}\right) \quad (6)$$

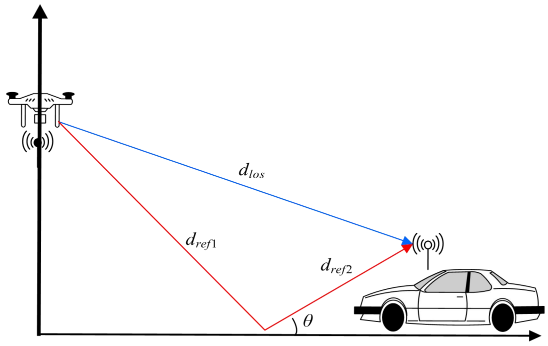

Fig.2. Two ray channel model

Where B_0 represents the channel bandwidth between the vehicle user and the UAV, P_n represents the transmission power of vehicle, and N_0 is the noise power. So the transit time from vehicle to UAV is defined as:

$$T_{n,m}^{trans} = \frac{C_n^m B_n^m D_n}{R_n^m}, \forall n \in V, \forall m \in U \quad (7)$$

B. Computing model

The computing model in this paper is divided into three parts: local computing model, fixed computing model and mobile edge computing model.

a) local computing model

First, we assume that the computing power of each vehicle is l_n . Considering the local computing ratio of vehicle n is B_n^0 , the delay for local computing is given by:

$$T_n^{Loc} = \frac{B_n^0 H_n}{l_n} \quad \forall n \in V \quad (8)$$

b) fixed computing model

The fixed computing model refers to the part that the vehicle offloads to BS for computing, and the computing delay can be given by:

$$T_{n,bs}^{Comp} = \frac{B_n^r C_n^r H_n}{f_n^r} \quad \forall n \in V \quad (9)$$

Where f_n^r denotes the computing resource allocated by the base station to the vehicle user. We define f_r as the total computing resource of BS .

c) mobile edge computing model

The mobile edge computing model are used when vehicle user offloads tasks to the UAV to assist in the computing. The computing delay of task is defined as follows:

$$T_{n,m}^{Comp} = \frac{B_n^m C_n^m H_n}{f_n^m} \quad \forall n \in V, \forall m \in U \quad (10)$$

Where f_n^m denotes the computing resource allocated by UAV m to vehicle n. We define f_m as the total computing resource of each UAV .

Considering that the vehicle task is processed in parallel on the local and edge nodes， the completion delay of the task can be expressed as:

$$T_n = \max\{T_n^{Loc}, T_{n,bs}^{Trans} + T_{n,bs}^{Comp}, T_n^{UAV}\} \quad (11)$$

Where T_n^{UAV} denotes the computing delay when tasks are offloaded to the UAV for transmission and computation, and is given by:

$$\mathrm{T}_{\mathrm{n}}^{\mathrm{UAV}} = \sum\nolimits_{m \in U} \left(T_{m,m}^{trans} + T_{n.m}^{comp} \right) \tag{12}$$

C. Reliability model

Considering the complexity of the Internet of Vehicles, the process of offloading may interrupt [10]. This paper takes a reliable evaluation method [11] which is widely accepted to estimate the failure probability of a node from a statistical point of view, the reliability probability of the task at each node is defined as:

$$\begin{aligned} R_n^{loc} &= e^{-\lambda_{\mathrm{n}}^{l}\left(\frac{B_n^0 H_n}{l_n}\right)} \\ R_n^{rsu} &= e^{-\lambda_{\mathrm{n}}^{r}\left(\frac{C_n^r B_n^r H_n}{f_n^r}\right) - K_{\mathrm{n}}^{r}\left(\frac{C_n^r B_n^r D_n}{R_n^r}\right)} \\ R_n^{m} &= e^{-\lambda_{\mathrm{n}}^{m}\left(\frac{C_n^m B_n^m H_n}{f_n^m}\right) - K_{\mathrm{n}}^{m}\left(\frac{C_n^m B_n^m D_n}{R_n^m}\right)} \end{aligned} \tag{13}$$

We assume that the rate of failure can be defined as a Poisson distribution for a given value [12]. λ_n^l , λ_n^r and λ_n^m denotes the probability of failure for the local computing, BS computing nodes and UAV computing nodes respectively. K_n^m and K_n^r represents the probability of failure of the communication link between vehicle to UAV and vehicle to BS. Considering the parallel computing mode of the system, any failure of the transmission link or nodes will lead to mission failure, so the reliability of vehicle mission execution is defined as:

$$\mathrm{R}_n^{tol} = \begin{cases} R_n^{loc} * R_n^{rsu} * \sum\nolimits_{m \in U} \left(R_n^m C_n^m \right), & \sum\nolimits_{m \in U} C_n^m = 1 \\ R_n^{loc} * R_n^{rsu}, & \sum\nolimits_{m \in U} C_n^m = 0 \end{cases} \tag{14}$$

D. problem formulation

We divide the task into sub-tasks which are computed in parallel at the edge node and locally, so that the task delay can be effectively reduced. Based on the reliability requirements of the task, the optimization problem denoted by P1 can be formulated as:

$$\begin{aligned} & P1: D_n = \min \frac{1}{N} \sum_{n=1}^{N} T_n \\ s.t.. \quad & C1: R_n^{tol} \geq R_n \qquad \forall n \in V \\ & C2: \sum_{m \in U} C_n^m + C_n^r \leq 1 \qquad \forall n \in V \\ & C3: 0 \leq B_n^r, B_n^m, B_n^0 \leq 1 \qquad \forall n \in V, \forall m \in U \\ & C4: C_n^m, C_n^r \in \{0,1\} \qquad \forall n \in V, \forall m \in V \\ & C5: B_n^m \leq C_n^m, B_n^r \leq C_n^r \qquad \forall n \in V, \forall m \in U \\ & C6: f_n^r \leq C_n^r f_r, \sum_{n=1}^{N} f_n^r \leq f_r \qquad \forall n \in V \\ & C7: f_n^m \leq C_n^m f_m, \sum_{n=1}^{N} f_n^m \leq f_m \qquad \forall n \in V, \forall m \in U \end{aligned}$$

Where $P1$ represents the optimization objective is to minimize the average time delay of the offloading strategy. $C1$ to $C7$ are the constraints. $C1$ ensures the reliability of vehicle communication. $C2$ shows that the vehicle can only select one edge node to offload task. $C3$ guarantees that the vehicle offloading rate and the local computing rate must be a decimal less than or equal to 1. $C4$ ensures that the offloading decision of the vehicle to the UAV or the base station is a binary integer. $C5$ constrains the offloading ratio. $C6$ and $C7$ restrict the resource of BS and UAV, it means that the computing resources allocated by the BS and UAV to vehicles cannot exceed its own computing capacity respectively.

III. Solution procedure

We decomposed problem $P1$ into two sub-problem: the deployment of UAV and the offloading decision. Maximum clique algorithm is used to compute the number and position of UAV, and the convex optimization method is used to determine the offloading strategy to minimize the system delay while ensuring reliability constraints and other constraints.

A. The deployment of UAV

We look for the areas where the tasks are most compressed firstly, and then determine the location and number of UAV. By employing Maximum clique algorithm, the generation principle of the edge is as follows:

$$\left\| P_i - P_j \right\| \leq R_{grd} \tag{15}$$

Where R_{grd} represents the projection of the UAV communication distance on the ground, P_i , P_j represents the coordinates of tasks i and j respectively. After Confirming the max clique, let the position of the center of clique as the coordinate position of the UAV. The specific algorithm is as follows:

Algorithm1 the maximum clique problem for UAV deployment

Input: the position of the task, the number of the task *N*
Output: the location of UAVs : *POS*
While *N* **do**
generate the graph according to Equation (15)
find the max clique of the graph: *MaxClique*
find the center of *MaxClique*: *POS*
get the number of the *MaxClique*: N_c
if $N_c \geqslant 1$ **then**
    Choose the farthest *MaxClique* from the BS
delete the chosen *MaxClique* from the graph
Update the current number of tasks: *N*
return *POS*

According to the coverage of edge nodes, system users can be divided into three categories: the vehicle users outside the range of the UAV and BS is $\boldsymbol{N}_l$, while vehicles within the coverage of UAV and BS is $\boldsymbol{N}_a$, and vehicles only within the coverage of BS is $\boldsymbol{N}_b$.

B. The decision of offloading

When the channel condition is superior, the transmission delay is low, and the reliability requirements of the task are easy to meet. Conversely, when the communication conditions are poor, the stability and speed of the transmission link are greatly affected. Therefore, we propose an algorithm based on communication quality. We define the UAV and BS as a whole as $\boldsymbol{L}$. First, in order to ensure vehicle users have better communication conditions, a channel gain threshold $Thre_n$ is set. For vehicle users within the coverage of BS and UAV, traverse all available edge nodes, and select the best node where the communication quality requirements and the load requirements are met. If the user cannot obtain edge computing nodes that meet the requirements, it choose local computing. The specific algorithm is as follows:

Algorithm2 offloading decision based on channel condition

Input: the number of the task N; the number of edge node $M+1$, Load capacity of UAV: N_{load}

Initialize channel gain matrix: $\boldsymbol{H}=\{h_n^m\}$, $\forall$n $\in \boldsymbol{V}$, $\forall$m $\in \boldsymbol{L}$

Initialize offloading decision: $C_n^m=0, \forall$n $\in \boldsymbol{V}$, $\forall$m $\in \boldsymbol{L}$

Initialize edge node task set and number of tasks: $\boldsymbol{N}_m=\varnothing$, $N_m=0, \forall$m $\in \boldsymbol{L}$

Output: Offloading decision $\boldsymbol{C}$, Service Vehicle Set $\boldsymbol{N}_m$, the number of service vehicle N_m

```
for n∈N_l do
    set the offloading decision : C_n^m =0, ∀m ∈ L
for n∈N_b do
    set the offloading decision of vehicle : C_n^{M+1} =1
for n∈N_a do
    get channel condition: H_n = { h_n^1, h_n^2..., h_n^M, h_n^{M+1} }
    if max(H_n)≤Thre_n then
        set offloading decision : C_n^m=0 , ∀m ∈ L
    else    while H_n ≠ ∅  do
            m*=arg max(H_n)
            if    N_{m*} ≤ N_load then
                set  C_n^{m*} = 1
                N_{m*}=N_{m*} ∪ n , N_{m*}=N_{m*}+1
                break
            else  set C_n^{m*}=0
                set H_n = { h_n^1,..., h_n^{m*-1}, h_n^{m*+1},..., h_n^M }
                continue
return   C, N_m , N_m
```

The offloading decision can be obtained by Algorithm 2. Therefore, it is only necessary to ensure the average delay under each edge node is the smallest, then $P1$ can be reformulated as $P2$:

$$
\begin{aligned}
P2: D_n = \min \frac{1}{N_m} \sum_{n=\in N_m} T_n \qquad \forall m \in L \\
s.t. \quad C1: R_n^{tol} \geq R_n \qquad \forall n \in N_m \\
C2: 0 \leq B_n^m, B_n^0 \leq 1 \qquad \forall n \in N_m \\
C3: B_n^m + B_n^0 = 1 \\
C4: \sum_{n=\in N_m} f_n^m \leq f_m
\end{aligned}
$$

In order to further reduce the coupling degree of the problem, a joint optimization method is given here. Given the local computing ratio b_n^0, after bringing in the local computing ratio, the resource allocation of edge nodes and the offloading ratio to the base station are obtained by Lagrange Duality Theorem.

IV. SIMULATION AND RESULTS

We assume that the base station is arranged in the center of the area of 300m × 300m, and the service radius is 150 meters. The computing capacity of the base station, UAV and vehicle is 100GHZ, 10GHZ, 1GHZ respectively [13]. The data size, complexity and reliability of task are restricted in (100KB, 900KB), (1000, 9000), (0.95, 0.98), and other main parameter settings are shown in Table 1 .

TABLE I
SUMMARY OF THE MAJOR PARAMETERS

Description	value
Bandwidth of UAV communication	B_0 = 5MHZ
Bandwidth between vehicle and BS	B = 10MHZ
The index of path LoSs	ξ = 4
The power of Gaussian white noise	σ^2 = -100dbm
The transmission power of vehicle	P_n = 20dbm

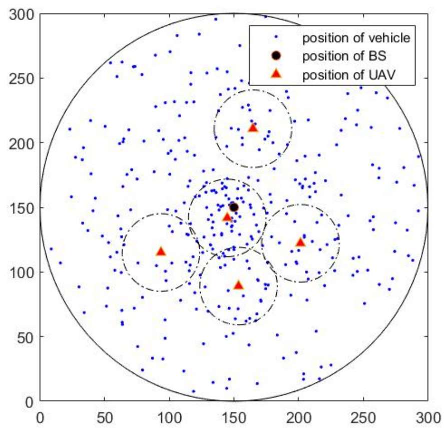

Fig.3. Results of Maximum clique algorithm

To illustrate the performance of our proposed scheme, we compare it with the following baselines

- **Local Computing**: All tasks are computed directly by the local vehicle.
- **Random offloading Strategy without UAV**: the vehicle offload the task completely to BS randomly.
- **Random partial offloading strategy without UAV**: vehicles randomly offload part of the task to BS.
- **Random partial offloading strategy with UAV**: With the deployment of UAV, vehicles randomly selected edge nodes(UAV) to offload the task partly.
- **UAV-assisted joint optimization strategy**: Using the UAV-assisted offloading model proposed in this paper to perform the task.

Figure 3 shows the deployment of UAV based on the maximum clique algorithm. The solid and dotted circles represent the coverage of BS and UAV respectively.

Figure 4 illustrates the average system delay under different task complexity. As the task complexity increases,

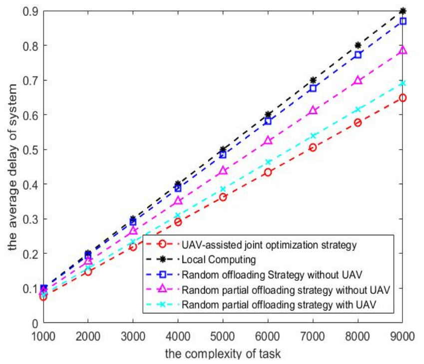

Fig.4. The delay of system under different scheme

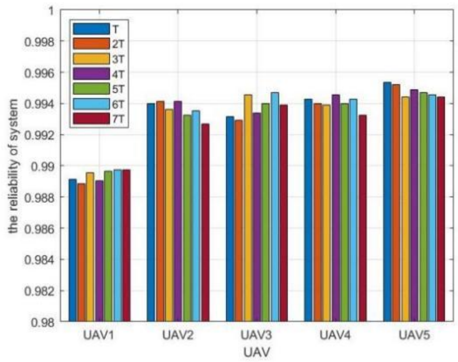

Fig.5. The reliability of system under different UAV in different time

the system average delay increases linearly. That is because as the complexity of the task increases, more computing resources are required, so the computing delay is much longer. The joint optimization strategy with the deployment of UAV proposed in this paper has the best performance among them which demonstrate our algorithm works. The second is the partial unloading strategy under UAV deployment, this is due to the deployment of UAV, which effectively relieves the load pressure of the base station. In the case of not deploying UAV, the random partial offloading strategy is better than the full offloading strategy, because the full offloading strategy not only causes a waste of local resources, but also is not conducive to the improvement of the overall system performance.

Figure 5 shows the reliability of five edge nodes in different time slots. T-7T represent seven different time slots, it can be seen that the reliability of UAV5 is relatively high, because the load of UAV5 is the smallest, and it has a good communication environment and sufficient computing resources. On the other hand, UAV1 is the opposite, it is in the area with the most busy task requests, its load is the largest in the current system, so the reliability is also the worst.

V. CONCLUSION

In this paper, we propose a UAV-assisted task offloading scheme. Combining with the channel condition and the deployment of UAV, We formulate a delay minimization problem. To solve the problem of UAV deployment, we apply the maximum clique algorithm. We use a joint optimization algorithm to solve the delay minimization problem. Comparing with four other schemes, the results illustrate that the proposed scheme can significantly reduce the system delay with high reliability .

ACKOWLEDGEMENT

This work was supported by the National Natural Science Foundation of China (NSFC) under grants No.61901104, and the Science and Technology Research Project of Shanghai Songjiang District No. 20SJKJGG4.

REFERENCES

[1] Z. Liao, Y. Ma, J. Huang, J. Wang and J. Wang, "*HOTSPOT: A UAV-Assisted Dynamic Mobility-Aware Offloading for Mobile-Edge Computing in 3-D Space*," in *IEEE Internet of Things Journal*, vol. 8, no. 13, pp. 10940-10952, 1 July1, 2021, doi: 10.1109/JIOT.2021.3051214.

[2] W.Jin, J. Yang, Y. Fang and W. Feng, "*Research on Application and Deployment of UAV in Emergency Response*," *2020 IEEE 10th International Conference on Electronics Information and Emergency Communication (ICEIEC)*, 2020, pp. 277-280, doi: 10.1109/ICEIEC49280.2020.9152338

[3] Y. Wang, H. Wang and X. Wei, "*Energy-Efficient UAV Deployment and Task Scheduling in Multi-UAV Edge Computing*," *2020 International Conference on Wireless Communications and Signal Processing (WCSP)*, 2020, pp. 1147-1152, doi: 10.1109/WCSP49889.2020.9299765.

[4] D. Wang, J. Tian, H. Zhang and D. Wu, "*Task Offloading and Trajectory Scheduling for UAV-Enabled MEC Networks: An Optimal Transport Theory Perspective*," in *IEEE Wireless Communications Letters*, vol. 11, no. 1, pp. 150-154, Jan. 2022, doi: 10.1109/LWC.2021.3122957.

[5] A. Mukherjee, S. Misra, V. S. P. Chandra and M. S. Obaidat, "*Resource-Optimized Multiarmed Bandit-Based Offload Path Selection in Edge UAV Swarms*," in *IEEE Internet of Things Journal*, vol. 6, no. 3, pp. 4889-4896, June 2019, doi: 10.1109/JIOT.2018.2879459.

[6] .D. W. Matolak and R. Sun, "*Air —Ground Channel Characterization for Unmanned Aircraft Systems —Part I: Methods, Measurements, and Models for Over-Water Settings*," in *IEEE Transactions on Vehicular Technology*, vol. 66, no. 1, pp. 26-44, Jan. 2017, doi: 10.1109/TVT.2016.2530306.

[7] M. Feuerstein, K. Blackard, T. Rappaport, S. Seidel, and H. Xia, *"Path LoSs, delay spread, and outage models as functions of antenna height for microcellular system design," IEEE Transactions on Vehicular Technology*, vol. 43, no. 3, pp. 487—498, 1994

[8] C. -C. Chiu, A. -H. Tsai, H. -P. Lin, C. -Y. Lee and L. -C. Wang, "*Channel Modeling of Air-to-Ground Signal Measurement with Two-Ray Ground-Reflection Model for UAV Communication Systems*," *2021 30th Wireless and Optical Communications Conference (WOCC)*, 2021, pp. 251-256, doi: 10.1109/WOCC53213.2021.9603250.

[9] P. Zhao and G. Dán, "*Resilient placement of virtual process control functions in mobile edge clouds*," *2017 IFIP Networking Conference (IFIP Networking) and Workshops*, 2017, pp. 1-9, doi: 10.23919/IFIPNetworking.2017.8264849.

[10] GILL P, JAIN N, NAGAPPAN N. *Understanding Network Failures in Data Centers: Measurement, Analysis, and Implications[C]//Acm Sigcomm Conference 2011.*

[11] H. R. Faragardi, R. Shojaee, M. A. Keshtkar and H. Tabani, "*Optimal task allocation for maximizing reliability in distributed real-time systems*," *2013 IEEE/ACIS 12th International Conference on Computer and Information Science (ICIS)*, 2013, pp. 513-519, doi: 10.1109/ICIS.2013.6607891.

[12] X. Hou et al., "*Reliable Computation Offloading for Edge-Computing-Enabled Software-Defined IoV*," in *IEEE Internet of Things Journal*, vol. 7, no. 8, pp. 7097-7111, Aug. 2020, doi: 10.1109/JIOT.2020.2982292.

[13] LIU Y, YU H, XIE S, et al. *Deep Reinforcement Learning for Offloading and Resource Allocation in Vehicle Edge Computing and Networks*[J]. *IEEE Transactions on Vehicular Technology*, 2019, PP(99): 1-1.