Responses to Reviewers' Comments for Manuscript TMC-2025-02-0445

Optimizing Joint Speed and Altitude Schedule for UAV Data Collection in Low-Altitude Airspace

Addressed Comments for Publication to

IEEE Transactions on Mobile Computing

by

Yiqian Wang, Jianping Huang, Feng Shan, Yuming Gao, Runqun Xiong and Junzhou Luo

Dear editors,

Please find enclosed the revised version of our previous submission entitled “Optimizing Joint Speed and Altitude Schedule for UAV Data Collection in Low-Altitude Airspace” with manuscript number TMC-2025-02-0445. We would like to thank you and the reviewers for the valuable comments which help improving the quality of our manuscript. In this revision, we have carefully addressed the reviewers’ comments. A summary of main modifications and a detailed point-by-point response to the comments from Reviewers 1 and 3 (following the reviewers’ order in the decision letter) are given below.

Sincerely,

Yiqian Wang, Jianping Huang, Feng Shan, Yuming Gao, Runqun Xiong and Junzhou Luo

Note: To enhance the legibility of this response letter, all the editor’s and reviewers’ comments are typeset in boxes. Rephrased or added sentences are typeset in color. The respective parts in the manuscript are highlighted to indicate changes.

Response to the Meta Review

Summary Comment 1

The reviewer(s) have suggested some minor revisions to your manuscript. Therefore, I invite you to respond to the reviewer(s)' comments and revise your manuscript.

Response S1: We appreciate your handling of the review process.

According to the reviewers' comments, we have checked our manuscript and addressed them in the following way:

1. We added content.
2. We removed our wrong statements in Section I.

Response to Reviewer 1

Comment 1.1

This paper fails to justify the selection of heuristic factors (α, β) in SSF-ACO. You should conduct grid search experiments to demonstrate parameter sensitivity or cite theoretical foundations for ACO parameter tuning.

Response 1.1:

Comment 1.2

Current experiments only cover small-scale scenarios (≤ 30 nodes), it should extend to more nodes to should the scalibility of algorithm.

Response 1.2:

Comment 1.3

The assumptions of linear GN deployment and complete GN knowledge are restrictive and not sufficiently justified. Please provide a detailed discussion of the assumptions, including their implications for real-world applicability and potential extensions.

Response 1.3:

We appreciate the reviewer's comment regarding the assumptions of linear GN deployment and complete GN knowledge. We would like to provide additional details about GN deployment and GN knowledge, as well as a discussion of these assumptions in Section 6 of our revised manuscript.

Linear GN deployment. The linear configuration of GNs represents a reasonable and commonly utilized setup in real-world systems. This deployment pattern often arises in infrastructure monitoring scenarios. For instance, in the power line [1], [2], UAVs are dispatched to autonomously collect data from sensors on the transmission tower. Similarly, in the oil and gas industry [3], UAVs are used to fly along pipelines for inspection activities. In addition, sensors can be deployed along rivers [4] and coasts [5] to capture diel and seasonal fluctuations, with the purposes of ecological monitoring, flood warning, and scientific research.

In fact, the effectiveness of such linear GN deployment has already been demonstrated in industrial applications to reduce costs, improve work efficiency, and avoid hazardous manual tasks. For instance, DJI has successfully implemented UAV-enabled solutions in scenarios such as long-distance pipelines [6], power transmission line in plateau regions [7], and river ecosystems [8], where the UAV trajectories can be regarded as linear or the combination of multiple straight-line segments.

Complete GN knowledge. Sensor (*i. e.*, GN) knowledge mainly includes information such as position, amount of data to be collected, transmission rate, and data transmission range. (1) In the online problem, each sensor has an additional control communication range, which covers a larger area than the data transmission range. When the UAV enters the sensor's control communication range, it can detect the sensor and receives a response containing information such as the amount of data and the sensor's position. (2) There is a proportional relationship between the radius of the data transmission range and the control communication range. Based on the distance between the sensor and the UAV at the moment the response is received, the radius of the data transmission range can be estimated. (3) The sensor position is fixed, and thus, it can be obtained during the initial deployment and periodic maintenance. This allows for the calibration of sensor positions.

Discussion in the manuscript. We have extended the discussion of these assumptions in Section 6 of the revised manuscript as follows.

> The UAV keeps broadcasting 'Probe' message during the flight to detect sensors. Once receiving the 'Probe' message, the sensor sends back an 'ACK' message, which includes its position, the amount of data, and transmission characteristics. Note that each sensor sends 'ACK' message only once. This partial information availability fundamentally changes the nature of our optimization problem, requiring real-time decision-making based on local information.

Comment 1.4

Could the proposed models and algorithms be adapted for 3D GN layouts?

Response 1.4:

Thanks for your comment. linear GN distribution: 2D or 1D?

Comment 1.5

Some statements have inconsistent tenses (e.g. "Our previous work [20] investigated..."). vs. ("we propose..."), need to unify the full text tense; The reference format should be checked according to IEEE standards (e.g. URL references [6] are not standardized).

Response 1.5:

Thank you for the comment. We have carefully reviewed the tense usasge throughout the manuscript and corrected the inconsistent expressions to ensure consistency. Additionally, we have standardized the website reference format according to IEEE Reference Guide.

[1] B. Mendu and N. Mbuli, "State-of-the-Art Review on the Application of Unmanned Aerial Vehicles (UAVs) in Power Line Inspections: Current Innovations, Trends, and Future Prospects," *Drones*, vol. 9, no. 4, p. 265, 2025.

[2] Y. Luo, X. Yu, D. Yang, and B. Zhou, "A survey of intelligent transmission line inspection based on unmanned aerial vehicle," *Artif. Intell. Rev.*, vol. 56, no. 1, pp. 173–201, 2023.

[3] L. C. Sousa, Y. M. R. da Silva, G. G. R. de Castro, *et al.*, "Autonomous Path Follow UAV to Assist Onshore Pipe Inspection Tasks," in *2022 7th Int. Conf. Robot. and Automat. Eng. (ICRAE)*, IEEE, 2022, pp. 112–117.

[4] S. G. Burman, J. Gao, G. B. Pasternack, *et al.*, "TempMesh - A Flexible Wireless Sensor Network for Monitoring River Temperatures," *ACM Trans. Sen. Netw.*, vol. 19, no. 1, p. 28, 2022.

[5] T. Ahmed, L. Creedon, and S. S. Gharbia, "Low-Cost Sensors for Monitoring Coastal Climate Hazards: A Systematic Review and Meta-Analysis," *Sensors*, vol. 23, no. 3, 2023.

[6] DJI, *Pipeline Inspection - Oil and Gas - Inspection - DJI Enterprise*, DJI Enterprise. Accessed Apr. 21, 2025. [Online]. Available: `https://enterprise.dji.com/inspection/pipeline-inspection`.

[7] DJI, *Powerline Inspection - Electricity - Inspection - DJI Enterprise*, DJI Enterprise. Accessed Apr. 21, 2025. [Online]. Available: `https://enterprise.dji.com/inspection/powerline-inspection`.

[8] DJI, *Unmanned Aerial Vehicles Help the Environmental Management of Rivers in the Yangtze River Basin*, DJI Enterprise. Accessed Apr. 21, 2025. [Online]. Available: `https://enterprise.dji.com/cn/news/detail/yangtze-river-river-treatment`.

Response to Reviewer 2

Comment 2.1

The computational latency of SSF-ACO-Online needs justify.

Response 2.1:

Thank you for the comment.

Comment 2.2

Alg. 4 does not specify the specific implementation of “Roulette-Wheel-Selection”, which needs to supplement pseudocode or reference standard methods.

Response 2.2:

Thanks for your suggestion. The classic Roulette wheel selection method is applied, and we have added a brief description of the Roulette-Wheel-Selection method in the revised manuscript.

Specifically, in **Roulette-Wheel-Selection**, the vertex $(\varphi+1, j')$ is selected if $\sum_{j''=0}^{j'-1} p(\varphi, j, j'') \leq \mathrm{rand}() < \sum_{j''=0}^{j'} p(\varphi, j, j'')$, where rand() generates a random number in $[0, 1)$.

Comment 2.3

The vertical energy consumption is assumed to be linear related to the altitude difference, which seems oversimplified, more justification is needed.

Response 2.3:

Thanks for the comment. Research [1] serves as the theoretical basis for this “linear assumption”. According to [1], the following equation fits well with the theoretical derivation,

$$p_V = c_{0,V} + c_{1,V}v + c_{2,V}v^2, \tag{1}$$

where p_V is the vertical power consumption, $c_{0,V}$, $c_{1,V}$ and $c_{2,V}$ are coefficients, and v is the climbing or descending speed of the UAV. In our manuscript, we assume that the UAV climbs or descends at a constant speed and flies in a stable environment. Therefore, the vertical power consumption is constant. For a certain altitude difference Δh, the vertical energy consumption is $E_V = \frac{p_V \Delta h}{v}$, which supports the “linear assumption”. Furthermore, similar assumptions have also been adopted in previous research [2].

Comment 2.4

The difference between the transmission range model of Equation (17) and literature [35] is not fully explained, and the improvement points or advantages need to be clearly defined.

Response 2.4:

Comment 2.5

What is the purpose of presenting Equation (18)?

Response 2.5:

Thans you for the comment. Equation (18) in the original manuscript was included to provide a quantitative description of the data transmission range's width. To retain a more holistic presentation, we have modified the expression.

> The width and height of the range are linearly related to the coefficients C_W and C_H, respectively. And the quantitave relationship can be found in Appendix F of the supplementary material.

Comment 2.6

There are too many curves in Figure 8 and the colors are similar, so it is difficult to distinguish them. It is suggested to optimize the color matching or add mark symbols

Response 2.6:

Thanks for your suggestion. We have revised the color scheme and marker symbols to make the curves in Figure 8 in the revised manuscript, and also adjusted the layout of it to improve clarity.

Comment 2.7

The dynamic nature of the sensor is not considered, such as movement, inaccurate position, failure and other problems.

Response 2.7:

We appreciate the reviewer's comment on the dynamics of sensors, which highlights important aspects that could influence the effectiveness the UAV scheduling. In the following, we will discuss the ground nodes (GNs) mobility, inaccurate position, failures, and unstable communication environment.

GN mobility. GN mobility is an important factor in various UAV-assisted systems. However, our current work focuses on data collection from stationary sensors. In the scenarios we consider, the sensors are fixed in the environment to monitor infrastructures or natural conditions. Admittedly, a number of existing studies [3]–[6] have investigated GN mobility. In these studies, GNs typically refer to mobile user devices with significant movement, such as user-carried devices [3], [4] or vehicles [5], [6], which are fundamentally different from the stationary GNs considered in our work.

Inaccurate position. The proposed algorithm relies on the precise sensor positions. However, the inaccurate sensor localization leads to discrepancies between the UAV scheduling and actual environment. In our future, we intend to employ more advanced relative positioning techniques to reduce localization inaccuracy and incorporate error-tolerant strategies to improve the system's robustness and reliability.

Failures. Failures may occur either before or during data transmission. Failures before transmission will result in the sensor being undetectable by the UAV. On the other hand, failures during the transmission process will lead to a disruption in the connection between the UAV and the sensor. The UAV will attemp to reconnect and, after reaching the maximum number of reconnection attempts, will abandon the connection. Regardless of whether reconnection is successful, the scheduling will be re-planned to ensure energy efficiency.

Unstable communication environment. The changes in the communication environment may lead to fluctuations in the transmission rate. When the UAV first detects the sensor, it will receive the sensor's guaranteed minimum transmission rate included the sensor's 'ACK' message. When the guaranteed transmission rate is not met, the UAV's speed and altitude scheduling will be re-planned by our algorithm to adapt to the environment changes.

Comment 2.8

Some minor suggestions:
(1) The the first sentence in subsection 2.1, "UAV" $\rightarrow$ "UAVs".
(2) Second paragraph of subsection 2.1, "maintaining" $\rightarrow$ "maintained".
(3) Second paragraph of subsection 2.2, "maintaining" $\rightarrow$ "and maintain".
(4) The "=" in table 1.
(5) Add $k \neq k'$ to equation (11), and $i \neq i'$ to equation (12).
(6) The parameter $\mathbb{S}$ of algorithm 1 and 2 is neither used nor updated.
(7) Line 2 of Algorithm 3, why set 20 to Z?

Response 2.8:

Thanks for your detailed suggestions. In response, we have made the following revisions.

For points (1) to (4), we have improved the phrasing and table in the manuscript to mamke it more consistent and easier to read.

For point (5), we would like to clarify that in Definition 1 in the manuscript, the condition $k < k'$ is defined. Additionally, in Equation (11), the condition $b_k < b_{k'}$ already implicitly ensures that $k \neq k'$. As for Equation (12), we have removed it along with its related content to improve the overall structure and clarity of the manuscript.

For point (6), $\mathbb{S}$ is defined as a data structure that encapsulates essential sensor information. To improve clarity and facilitate readers' understanding, we have revised the manuscript by relocating the description of $\mathbb{S}$ closer to Algorithm 1 and 2.

> For details, Alg. 1 takes the necessary sensor information as input and returns the optimal horizontal energy consumption. For simplicity, we denote these pieces of sensor information (such as l_i and r_i) by $\mathbb{S}$.

For point (7), we have added an explanation in the revised manuscript.

> Here, Z is set to 20 to balance solution quality and computational efficiency.

[1] K. Wu, M. Feng, C. Wu, Y. Lin, and S. Lu, "Trajectory Planning for Multi-rotor UAV Based on Energy Cost Model," in *2022 41st Chinese Control Conf. (CCC)*, IEEE, 2022, pp. 1–6.

[2] Y. Cao, A. Wang, G. Sun, and L. Liu, “Average Transmission Rate and Energy Efficiency Optimization in UAV-assisted IoT,” in *2023 IEEE Wireless Commun. and Netw. Conf. (WCNC)*, IEEE, 2023, pp. 1–6.

[3] L. He, G. Sun, Z. Sun, *et al.*, “An Online Joint Optimization Approach for QoE Maximization in UAV-Enabled Mobile Edge Computing,” in *IEEE INFOCOM 2024 - IEEE Conf. Comput. Commun.*, IEEE, 2024, pp. 101–110.

[4] Z. Sun, G. Sun, L. He, F. Mei, S. Liang, and Y. Liu, “A Two Time-Scale Joint Optimization Approach for UAV-assisted MEC,” in *IEEE INFOCOM 2024 - IEEE Conf. Comput. Commun.*, IEEE, 2024, pp. 91–100.

[5] X. Dai, Z. Xiao, H. Jiang, and J. C. S. Lui, “UAV-Assisted Task Offloading in Vehicular Edge Computing Networks,” *IEEE Trans. Mobile Comput.*, vol. 23, no. 4, pp. 2520–2534, 2024.

[6] L. Fu, Z. Zhao, G. Min, W. Miao, L. Zhao, and W. Huang, “Energy-Efficient 3-D Data Collection for Multi-UAV Assisted Mobile Crowdsensing,” *IEEE Trans. Comput.*, vol. 72, no. 7, pp. 2025–2038, 2022.

Response to Reviewer 3

Comment 3.1

Compared with previous works, the current work further considers the complex overlapping range relationship between sensors. Therefore, the authors should spend a lot of effort to emphasize this contribution in Section I.

Response 3.1:

Comment 3.2

The system model assumes an idealized scenario without incorporating real-world path loss effects (e.g., fading, shadowing). This limits the practical use of the proposed algorithm.

Response 3.2:

Comment 3.3

The claim of "near-optimal performance" for SSF-ACO-Online lacks a clear benchmark (e.g., theoretical bounds or exhaustive search). Provide a quantitative comparison to support this conclusion.

Response 3.3:

We appreciate the reviewer's insightful comment. We recognize that the term "near-optimal" was not precise. Our intention was to indicate that SSF-ACO-Online performs closely to the offline algorithm SSF-ACO. We have revised the abstract to clarify this point and removed the term "near-optimal" to avoid confusion.

> Extensive simulations demonstrate that SSF-ACO significantly outperforms baseline approaches in energy efficiency, and SSF-ACO-Online achieves comparable performance with energy consumption 1.24% higher than offline counterpart in average.

Comment 3.4

The robustness of the SSF-ACO and SSF-ACO-Online algorithms to network dynamics (e.g., node mobility) is not evaluated. Include tests under time-varying conditions to demonstrate adaptability.

Response 3.4:

We appreciate the reviewer's comment on the network dynamics. The ground nodes (GNs) mobility, failures, and the computational latency of SSF-ACO-Online are discussed in the following.

GN mobility. GN mobility is an important factor in various UAV-assisted systems. However, our current work focuses on data collection from stationary sensors. In the scenarios we consider, the sensors are fixed in the environment to monitor infrastructures or natural conditions. Admittedly, a number of existing studies [1]–[4] have investigated GN mobility. In these studies, GNs typically refer to mobile user devices with significant movement, such as user-carried devices [1], [2] or vehicles [3], [4], which are fundamentally different from the stationary GNs considered in our work.

Failures. Failures may occur either before or during data transmission. Failures before transmission will result in the sensor being undetectable by the UAV. On the other hand, failures during the transmission process will lead to a disruption in the connection between the UAV and the sensor. The UAV will attemp to reconnect and, after reaching the maximum number of reconnection attempts, will abandon the connection. Regardless of whether reconnection is successful, the scheduling will be re-planned to ensure energy efficiency.

The computational latency of SSF-ACO-Online.

Comment 3.5

The paper uses multiple important symbols, but a comprehensive table of symbols and definitions is missing. Adding such a table would enhance readability and help readers locate information more easily.

Response 3.5:

Thanks you for the suggestion. We have added more important symbols and definitions in Table 1 to make it more comprehensive. The revised Table 1 is as follows.

Comment 3.6

The discussion of related work is not sufficient. Please include recent literature on "the fusion of AI, UAV, and LAE" and provide further discussion.

Response 3.6:

[1] L. He, G. Sun, Z. Sun, *et al.*, "An Online Joint Optimization Approach for QoE Maximization in UAV-Enabled Mobile Edge Computing," in *IEEE INFOCOM 2024 - IEEE Conf. Comput. Commun.*, IEEE, 2024, pp. 101–110.

[2] Z. Sun, G. Sun, L. He, F. Mei, S. Liang, and Y. Liu, "A Two Time-Scale Joint Optimization Approach for UAV-assisted MEC," in *IEEE INFOCOM 2024 - IEEE Conf. Comput. Commun.*, IEEE, 2024, pp. 91–100.

[3] X. Dai, Z. Xiao, H. Jiang, and J. C. S. Lui, "UAV-Assisted Task Offloading in Vehicular Edge Computing Networks," *IEEE Trans. Mobile Comput.*, vol. 23, no. 4, pp. 2520–2534, 2024.

[4] L. Fu, Z. Zhao, G. Min, W. Miao, L. Zhao, and W. Huang, "Energy-Efficient 3-D Data Collection for Multi-UAV Assisted Mobile Crowdsensing," *IEEE Trans. Comput.*, vol. 72, no. 7, pp. 2025–2038, 2022.