International Journal of Mobile Computing and Multimedia Communications
Volume 17 • Issue 1 • January-December 2026

Backpressure-Aware Collaborative Learning Empowered Data Flow Backhaul for Aerial-Ground Integrated Networks

Liwei Ren
http://orcid.org/0009-0002-7770-9520
State Grid Zhejiang Electric Power Company, Ltd. Lishui Power Supply Company, Lishui, China

Yan Song
http://orcid.org/0009-0000-4347-8926
State Grid Zhejiang Electric Power Company, Ltd. Lishui Power Supply Company, Lishui, China

Shuhan Shi
http://orcid.org/0009-0002-7770-9520
State Grid Zhejiang Electric Power Company, Ltd. Lishui Power Supply Company, Lishui, China

Chang Jiang
http://orcid.org/0009-0002-7770-9520
State Grid Zhejiang Electric Power Company, Ltd. Lishui Power Supply Company, Lishui, China

Binjie Ying
http://orcid.org/0009-0002-7770-9520
State Grid Zhejiang Electric Power Company, Ltd. Lishui Power Supply Company, Lishui, China

Jinchao Fan
North China Electric Power University, China

Ziyi Zhou
North China Electric Power University, China

Yiming Chen
North China Electric Power University, China

Bin Liao
North China Electric Power University, China

Received: July 19th, 2025 | **Accepted:** March 24th, 2026

ABSTRACT

To address the critical challenge of ensuring reliable disaster data backhaul under frequent natural disasters and fragile ground communication infrastructures, a backpressure-aware collaborative learning empowered data flow backhaul framework for aerial-ground integrated networks (AGIN) is proposed. First, a data flow backhaul architecture is established by leveraging cooperative networking between unmanned aerial vehicles (UAVs) and ground facilities. Second, a QoS guarantee mechanism based on queue priorities dynamically coordinates resources to ensure low-latency backhaul for high-priority services. Thirdly, a data flow backhaul optimization approach based on backpressure-aware collaborative learning incorporates queue backlog differences into the reward function to prevent accumulation and adds a global conflict penalty to facilitate multi-UAV coordination and mitigate next-hop selection conflicts. Simulation results indicate that the proposed approach enables low-latency, energy-efficient, and high-throughput data flow backhaul under dynamic networks.

KEYWORDS

Aerial-Ground Integrated Networks, Data Backhaul, Backpressure Awareness, Collaborative Learning, Electric Emergency Communication

DOI: 10.4018/IJMCMC.406090

INTRODUCTION

With the increasing frequency of natural disasters worldwide, data backhaul has become significantly important in disaster-affected areas for achieving situational awareness, risk mitigation, and disaster loss reduction (Liu et al., 2018). For instance, by backhauling data of damage scope, casualties, and power infrastructure states to the command center, grid companies can make scientific rescue plans for rapid power supply restoration. However, ground communication infrastructures are highly vulnerable to damage and failure during disasters, severely hampering the effectiveness of critical data delivery (Xie et al., 2025). This issue is particularly acute in mountainous and remote areas, where disasters and ground infrastructure damage further exacerbate communication coverage shortage (An et al., 2024; Cosgrove, 2023). Therefore, how to establish robust and adaptive communication networks in harsh natural environments with limited connectivity to ensure low-latency, energy-efficient, and high-throughput backhaul of critical service data remains a critical challenge.

Aerial-ground integrated networks (AGIN) refer to a multi-layered, three-dimensional cooperative communication system formed by deeply integrating the flexible networking capabilities of unmanned aerial vehicles (UAVs; aircraft operated without a human pilot, including drones) with the stable coverage of ground infrastructure (He et al., 2024). AGIN enables wide-area coverage, flexible deployment, and efficient resource allocation, making it particularly suitable for emergency communication and coverage in remote areas (Qin et al., 2023; Qin et al., 2024).

Combining AGIN with data backhaul optimization enables timely critical information delivery in disaster zones, promoting situational awareness, power supply restoration, and risk mitigation. In such a framework, UAVs with core advantages of rapid deployment, three-dimensional mobility, and low-cost, high-efficiency operation, play an irreplaceable role (Seong et al., 2024). Acting as dynamic relay nodes, UAVs can be swiftly deployed to signal blind spots or hotspot areas to provide precise ground coverage enhancement and act as data relay (Li et al., 2022). They receive data from the ground personnel and relay them in multiple hops back to the command center, thereby forming air-ground integrated data backhaul.

Zeng et al. (2022) proposed a predictive decision-making approach for UAV communications in AGIN, leveraging aerial control information, prediction algorithms, and switching strategies to achieve reliable connections with multiple access points and enhance data backhaul efficiency. Wu et al. (2022) introduced a trajectory optimization method utilizing a federated multi-agent deep deterministic policy gradient, establishing an air-ground cooperative emergency network that uses federated averaging to eliminate information separation and maximizes average spectral efficiency. Hu et al. (2023) proposed a heterogeneous multi-UAV-supported collaborative air-ground framework, employing a two-layer alternative optimization algorithm. The external layer optimizes user association and resource allocation, while the inner layer focuses on UAV trajectory scheduling, achieving efficient data backhaul.

Multi-hop data relay optimization is the most critical technology of air-ground integrated data backhaul. Karar and Das Barman (2018) proposed a two-stage rate allocation method for wireless access networks based on passive optical network backhaul. By enabling global information exchange and coordination through a multi-hop network, the approach achieves efficient cross-layer resource allocation. Shu et al. (2016) introduced an improved algorithm based on multi-agent particle swarm optimization. By leveraging the evolutionary mechanism of particle swarm, the method obtains globally optimal shared information among agents, thereby enabling efficient data backhaul. However, due to the dynamic nature of UAV positions, network topologies, and communication link qualities, traditional centralized approaches struggle to acquire real-time link and location information. Additionally, the frequently changing network conditions significantly increase the complexity of the optimization problem, leading to poor scalability and making such methods difficult to be applied directly in data backhual under highly dynamic scenarios.

18 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/article/backpressure-aware-collaborative-learning-empowered-data-flow-backhaul-for-aerial-ground-integrated-networks/406090

Related Content

Accessing Learning Content in a Mobile System: Does Mobile Mean Always Connected?

Anna Trifonova (2009). *Mobile Computing: Concepts, Methodologies, Tools, and Applications (pp. 1367-1380).*

www.irma-international.org/chapter/accessing-learning-content-mobile-system/26595

Node Placement Strategy in Wireless Sensor Network

Puteri Azwa Ahmad, M. Mahmuddinand Mohd Hasbullah Omar (2013). *International Journal of Mobile Computing and Multimedia Communications (pp. 18-31).*

www.irma-international.org/article/node-placement-strategy-wireless-sensor/78383

Online Shopping in the United Arab Emirates: User Web Experience

Salam Abdallahand Bushra Jaleel (2018). *Mobile Commerce: Concepts, Methodologies, Tools, and Applications (pp. 668-690).*

www.irma-international.org/chapter/online-shopping-in-the-united-arab-emirates/183311

A Computer Vision-Driven Framework for Interactive Visual Communication in Mobile Environments

Xiudong Tu (2026). *International Journal of Mobile Human Computer Interaction (pp. 1-15).*

www.irma-international.org/article/a-computer-vision-driven-framework-for-interactive-visual-communication-in-mobile-environments/402020

A New Framework for Accessible Tourism Mobile Application Development

Fernando Reinaldo Ribeiro, Arlindo Silva, José C. Metrôlho, Ana Paula Silvaand Fernando Sérgio Barbosa (2018). *International Journal of Mobile Computing and Multimedia Communications (pp. 31-46).*

www.irma-international.org/article/a-new-framework-for-accessible-tourism-mobile-application-development/205678