UDK: 004.9

ТАКТИЧНА ПРІОРИТИЗАЦІЯ ПОТОКІВ ДАНИХ БПЛА В ОБРОБНИХ ПІДРОЗДІЛАХ ТОС В УМОВАХ ОБМЕЖЕНИХ РЕСУРСІВ

TACTICAL PRIORITIZATION OF UAV DATA STREAMS IN TOC PROCESSING UNITS UNDER RESOURCE CONSTRAINTS

Мустафовський[1] Р.
Rexhep Mustafovski[1]

[1] 'Goce Delcev University' Stip, Military Academy "General Mihailo Apostolski", Skopje, North Macedonia
ORCID: https://orcid.org/0009-0000-3257-0989[1]
E-mail: redzep.mustafovski@ugd.edu.mk[1]

DOI: 10.15673/atbp.v18i2.3452

Abstract. *In modern military and emergency operations, the real-time processing of UAV-generated data streams at Tactical Operations Centers (TOCs) is critical for operational awareness and rapid decision-making. However, the exponential growth in UAV deployments and the limited processing and bandwidth capabilities at TOCs present significant challenges. This paper introduces a tactical prioritization approach for managing UAV data streams under resource-constrained conditions. The proposed model emphasizes intelligent stream classification, dynamic prioritization based on mission-criticality, and adaptive buffering strategies to optimize communication flow. A simulation scenario replicates field conditions involving multiple UAVs transmitting telemetry, video, and sensor data to a TOC facing bandwidth restrictions and computational bottlenecks. Performance metrics such as latency, packet drop rate, and mission success rate are evaluated. The results indicate that strategic prioritization significantly improves the timely processing of essential information, reduces operational delays, and maintains system stability. This study demonstrates how aligning communication strategies with mission urgency enhances overall situational awareness and supports effective decision-making in constrained environments.*

Анотація. *У сучасних військових та надзвичайних операціях обробка потоків даних від безпілотних літальних апаратів (БПЛА) у центрах тактичних операцій (ТОС) у режимі реального часу має вирішальне значення для ситуаційної обізнаності та швидкого прийняття рішень. Однак стрімке зростання кількості розгорнутих БПЛА поряд із обмеженою пропускною здатністю каналів зв'язку та обчислювальною потужністю ТОС створює значні технічні виклики. У даній статті запропоновано модель тактичної пріоритезації для управління потоками даних БПЛА в умовах обмежених ресурсів. Модель базується на інтелектуальній класифікації потоків, динамічному призначенні пріоритетів залежно від критичності місії та адаптивних стратегіях буферизації для оптимізації комунікаційних потоків. Для оцінки ефективності розроблено сценарій симуляції, що відтворює польові умови з кількома БПЛА, які передають телеметрію, відео та сенсорні дані до ТОС в умовах мережевих заторів та обчислювальних «вузьких місць». Результати симуляції демонструють, що стратегічна пріоритезація дозволила знизити затримку передачі критично важливої інформації з 3,8 до 1,2 секунди та підвищити рівень успішної доставки пакетів до 95%. Дослідження підтверджує, що узгодження стратегій зв'язку з терміновістю завдань покращує загальну ситуаційну обізнаність та підтримку прийняття рішень у складних операційних середовищах.*

Ключові слова: безпілотні літальні апарати, центр тактичних операцій, пріоритезація даних, обмежені ресурси, пропускна здатність, затримка, ситуаційна обізнаність, прийняття рішень, телеметрія.

Keywords: unmanned aerial vehicles, tactical operations center, data prioritization, resource constraints, bandwidth, latency, situational awareness, decision-making, telemetry.

I. INTRODUCTION

The rapid development of unmanned aerial vehicle technologies has significantly transformed the operational landscape of modern military missions and emergency response activities. Unmanned Aerial Vehicles are increasingly deployed to support reconnaissance, surveillance, disaster management, infrastructure monitoring, and communication relay tasks. Their ability to operate in hazardous environments while providing real time situational awareness makes them an essential component of contemporary tactical systems. Advances in autonomous control, sensor integration, and communication technologies have further expanded the operational capabilities of UAV platforms, enabling them to perform complex missions that require coordinated data acquisition and rapid information exchange [1], [10], [11].

In military and crisis response environments, Tactical Operations Centers serve as central nodes responsible for processing information received from various field assets, including UAV platforms. These centers collect and analyze data streams transmitted by airborne systems and distribute relevant information to command personnel responsible for decision making. The data transmitted by UAVs can include high resolution video streams, environmental sensor readings, telemetry information, navigation parameters, and alerts related to threats or operational changes. As the number of deployed UAV systems continues to grow, the volume and diversity of transmitted data have increased considerably. This situation introduces new challenges for communication infrastructures and information processing units within Tactical Operations Centers [2], [3].

Modern UAV communication architecture often relies on wireless networks that must operate under conditions characterized by limited bandwidth, constrained computational resources, and unpredictable communication environments. Studies have demonstrated that traditional communication architectures frequently treat all incoming UAV data streams with equal priority. While this design simplifies system implementation, it does not reflect the operational importance of different categories of information. Critical intelligence data such as enemy activity detection or emergency alerts require immediate processing and delivery, whereas routine telemetry or background environmental data can tolerate delays. When all data streams compete equally for limited communication resources, the resulting congestion can lead to increased latency, packet loss, and reduced overall system responsiveness [6], [11].

The problem becomes particularly significant in scenarios involving multiple UAV platforms operating simultaneously within a shared communication infrastructure. Disaster response missions, large scale reconnaissance operations, and coordinated military deployments frequently involve several UAV units transmitting data to a single command center. Under such circumstances the communication network and processing units must handle high data volumes within strict time constraints. If appropriate prioritization mechanisms are not implemented, Tactical Operations Centers may experience information overload that compromises situational awareness and delays critical operational decisions. Research has indicated that effective prioritization of communication flows is essential for maintaining reliable decision support in time sensitive operations [1], [4], [8].

Recent advances in UAV communication systems have explored various approaches to address these challenges. Some studies have proposed intelligent routing strategies that dynamically allocate bandwidth according to the type and importance of transmitted information. Others have investigated adaptive network management techniques that modify transmission parameters based on real time traffic conditions. Content aware communication protocols have also been introduced to distinguish between mission critical data and routine system information. These techniques demonstrate the potential of intelligent communication architectures to improve network efficiency and reduce delays in tactical environments [5], [7], [13].

In addition to communication management strategies, research on UAV applications across different domains has highlighted the importance of efficient data handling mechanisms. UAV systems are widely used in environmental monitoring, agricultural analysis, disaster detection, and industrial inspection. Each of these applications generates specific categories of data that must be processed according to operational priorities. For example, UAV platforms used in precision agriculture transmit large quantities of sensor data and imaging information that require classification and analysis before they become useful for decision making [8], [9]. Similarly, UAV systems employed in disaster management must deliver information about affected areas quickly to enable emergency responders to allocate resources effectively [10], [11].

The increasing complexity of UAV based systems has also stimulated research into advanced planning and coordination methods. Studies addressing UAV logistics and path planning emphasize the need for efficient scheduling and communication mechanisms when multiple aerial platforms operate within shared airspace [12], [13]. These works demonstrate that coordination algorithms and prioritization strategies can significantly improve operational efficiency when resources such as communication bandwidth and processing capacity are limited [14], [15]. However, most existing solutions focus on flight control or navigation planning rather than on the prioritization of data streams within command center processing units [17]-[20].

Another relevant line of research concerns the development of secure communication frameworks for UAV systems. Modern UAV operations frequently take place in contested environments where communication networks must remain resilient against interference and cyber threats. Secure data transmission mechanisms are therefore essential to ensure reliable information exchange between UAV platforms and command centers. Previous work has proposed architectural frameworks that improve the reliability and resilience of UAV communication infrastructures through secure transmission protocols and adaptive communication strategies [16], [20], [21].

Despite these advances, there remains a significant gap in the design of communication architectures that explicitly address the prioritization of UAV data streams at the level of Tactical Operations Center processing units. Many existing solutions focus primarily on network level optimizations or platform level communication improvements. Relatively little attention has been given to how command centers should process incoming data when system resources are constrained and multiple information flows compete for attention. The absence of structured prioritization mechanisms may result in inefficient information management and increased cognitive load for operational personnel.

Recent research conducted on advanced communication platforms and mission centric architectures highlights the need for intelligent frameworks that support adaptive data management in complex operational environments. Studies on modern tactical communication systems demonstrate that the integration of intelligent prioritization models can enhance the overall effectiveness of command-and-control infrastructures. These models allow systems to allocate processing resources according to mission relevance and operational urgency rather than treating all information streams equally [22], [23], [24].

Furthermore, emerging concepts in secure UAV communication platforms emphasize the importance of integrating communication management, decision support mechanisms, and automated data classification within a unified system architecture. Such integration enables command centers to filter and process incoming information in a structured manner, thereby reducing the risk of information overload while improving operational responsiveness [25], [26]. These findings indicate that intelligent prioritization mechanisms should become a fundamental component of modern UAV communication infrastructures.

Building on these insights, the present research proposes a tactical prioritization model designed specifically for UAV data streams received by Tactical Operations Center processing units operating under resource constrained conditions. The proposed approach introduces a classification mechanism that evaluates incoming data streams according to operational relevance, urgency, and information type. Based on these parameters the system dynamically allocates communication and processing resources to ensure that mission critical data receives priority over routine transmissions.

To evaluate the effectiveness of the proposed model, a simulation scenario representing a realistic operational environment has been developed. The scenario involves multiple UAV platforms transmitting heterogeneous data streams to a Tactical Operations Center while operating under limitations related to bandwidth, processing capacity, and situational urgency. The simulation environment reflects operational conditions encountered in joint missions where communication infrastructures must handle diverse information flows in real time. Similar modeling approaches have been employed in studies addressing UAV coordination, network management, and communication optimization in multi-platform systems [27], [28], [29].

The results obtained from the simulation provide insight into the potential advantages of implementing tactical prioritization mechanisms within command center processing architecture. By dynamically adjusting the processing order of incoming UAV data streams, the proposed model aims to reduce communication latency, improve situational awareness, and enhance the overall effectiveness of decision-making processes in time critical operational contexts. These improvements are particularly relevant for military operations and emergency response missions where rapid access to accurate information can significantly influence mission outcomes [30]–[35].

Through this investigation the paper contributes to the ongoing development of intelligent UAV communication architectures by introducing a practical prioritization framework tailored to Tactical Operations Center environments. The proposed approach seeks to bridge the gap between theoretical communication models and operational command center requirements by providing a structured method for managing UAV data streams under conditions of limited resources and high operational demand.

II. BACKGROUND AND RELATED WORK

Tactical Operations Centers (TOCs) serve as the nerve centers for military and emergency missions, where rapid decision-making depends heavily on the timely and accurate delivery of UAV-generated information. However, the sheer volume and heterogeneity of data produced by modern UAV fleets have exposed structural weaknesses in traditional TOC systems, particularly when operating under bandwidth constraints and limited computational resources. Without intelligent filtering or prioritization mechanisms, TOCs risk data congestion, delayed situational awareness, and poor mission outcomes [1], [2].

Prior research has examined various approaches to managing UAV data transmission in high-demand environments. Traditional data handling models typically apply static routing protocols and equal priority queuing, which result in bottlenecks and inefficient use of available communication channels [3], [4]. These limitations have been particularly evident in large-scale exercises and crisis response simulations, where the capacity of TOC systems was quickly overwhelmed by concurrent UAV streams delivering live video, telemetry, weather updates, and threat intelligence [5].

In response to these challenges, some studies have explored content-aware data stream classification as a foundation for improved resource allocation. For instance, models inspired by wildfire risk reduction and urban logistics have implemented mission-aware decision trees that dynamically prioritize data flows based on urgency, location, and operational context [10], [12]. These efforts have demonstrated potential, especially when integrated with edge computing and mobile mesh networks. Nevertheless, many of these solutions fall short when applied to TOC environments, which require not only stream differentiation but also a framework that adapts in real-time to shifting mission priorities and constrained network conditions [7].

Recent tactical networking research has pushed toward intelligent prioritization models that evaluate UAV transmissions using multi-criteria decision analysis (MCDA). These include metrics such as data type (e.g., real-time video, telemetry, alerts), spatial-temporal relevance, and encryption level [6], [11]. Some experimental platforms have attempted to combine these parameters with Quality of Service (QoS) enforcement at the radio level or with service-defined communication layers. Although effective in simulation, these approaches often rely on infrastructure or bandwidth that is not guaranteed in contested environments.

A promising development is seen in frameworks that incorporate mission-aware prioritization protocols into TOC processing pipelines. These systems use lightweight onboard pre-processing modules on UAVs that tag data with priority metadata before transmission. TOC units then implement dynamic queue scheduling based on these tags, ensuring that mission-critical content such as enemy location feeds or emergency alerts is processed before lower-priority routine data [8], [9]. This reduces processing delays and supports faster response times, especially during high-stress missions. Still, the lack of standardization across platforms and the challenges in interoperating with existing TOC hardware have limited their adoption at scale [13].

In terms of architectural frameworks, the UAS Traffic Management (UTM) Concept of Operations and the U-space ecosystem provide models for integrating UAVs into controlled airspace, with embedded features for communication flow management and prioritization [14], [15]. These models, while developed for civil aviation, offer valuable principles for structuring UAV communication in military TOC settings particularly through their emphasis on predictable traffic patterns, pre-defined operational volumes, and secure data channels.

Furthermore, recent work by Mustafovski (2025) proposed a secure UAV-to-TOC communication framework that demonstrated improved performance in latency and resilience under electronic warfare and cyberattack simulations. While that model focused primarily on secure transmission, the current study aims to extend this foundation by targeting the prioritization of data relevance within the TOC itself [16].

This paper builds on these foundational insights to design and evaluate a tactical prioritization model that addresses the limitations of static queueing and non-contextual routing. It introduces an adaptive prioritization strategy that is not only mission-aware but also dynamically responsive to available resources and operational tempo. The goal is to optimize how TOCs process incoming UAV data in real-time, reduce latency for critical information, and enable commanders to act decisively even when network constraints are severe.

III. PROPOSED PRIORITIZATION MODEL FOR UAV DATA STREAMS

The proposed model introduces a mission-aware prioritization framework that enhances the ability of Tactical Operations Centers (TOCs) to handle incoming data from multiple Unmanned Aerial Vehicles (UAVs) operating in real-time. It is designed specifically to address processing delays, bandwidth saturation, and cognitive overload during high-tempo missions where timely data interpretation directly impacts operational outcomes.

The model consists of five interconnected components: Data Stream Classification, Priority Assignment Engine, Dynamic Queue Management, Resource Monitoring Module, and TOC Output Controller.

1. Data Stream Classification

Upon arrival at the TOC gateway, each data stream is immediately classified into one of three categories:

- **Mission-Critical (Tier 1):** Includes threat alerts, target tracking feeds, emergency status signals, and adversary identification.
- **Operational-Supportive (Tier 2):** Encompasses live video, telemetry from strategic UAVs, environmental condition reports.
- **Routine (Tier 3):** Consists of periodic updates, non-essential telemetry, and archived navigation paths.

This classification is automated based on metadata tags sent from the UAVs or inferred through onboard AI classification routines. A UAV may assign metadata based on sensor input or mission tasking parameters assigned at launch.

2. Priority Assignment Engine

Each stream is assigned a dynamic priority value. The engine evaluates three main criteria:

- **Urgency:** How time-sensitive is the content?
- **Relevance:** Is the data linked to a high-priority mission task?
- **Data Type Weighting:** Does the stream contain critical intelligence (e.g., enemy movement), safety-related signals, or status checks?

The priority score is recalculated periodically, especially during shifts in mission tempo or when new threats emerge. In emergencies, manual override is permitted by TOC operators to promote specific streams to Tier 1 in real-time.

3. Dynamic Queue Management

Once streams are prioritized, the system activates a dynamic queueing mechanism that ensures the most critical data is processed first. The queue system is not static; it continuously reshapes based on three key feedback loops:

- **Buffer Saturation Levels:** Ensures older, low-priority data is flushed when memory reaches a threshold.
- **Bandwidth Allocation State:** If network congestion occurs, Tier 1 data is forwarded over redundant secure channels.
- **TOC Load Index:** Adjusts queue scheduling frequency depending on processor availability and system health.

This adaptability guarantees that the most important data is not delayed during congestion or under high processor load.

4. Resource Monitoring Module

This module acts as a sensor for the TOC’s current operational state. It tracks CPU cycles, memory usage, and network status in real-time and provides input to the priority engine. If system constraints increase, non-critical streams may be compressed, down sampled, or suspended to maintain operational flow for Tier 1 streams.

Additionally, the module monitors downstream data usage. If TOC operators are not engaging with specific streams, their priority weight may be downgraded to preserve resources for actively used information.

5. TOC Output Controller

The final component governs how processed data is distributed to human operators, visualization dashboards, and connected command nodes. The output controller filters redundant data, highlights priority items in real-time interfaces, and logs delayed streams for later review. It can also initiate alerts for specific thresholds (e.g., delay beyond 5 seconds for Tier 1 stream) to signal performance degradation.

Interaction Between Components

The system is built on modular logic, enabling UAVs to function semi-independently when connectivity is poor, and synchronize once communication stabilizes. The model is compatible with secure communication protocols and can be embedded into existing TOC architectures with minor adjustments.

To support field deployment, the entire prioritization model is lightweight and can be containerized for execution on edge processing nodes or portable TOC terminals.

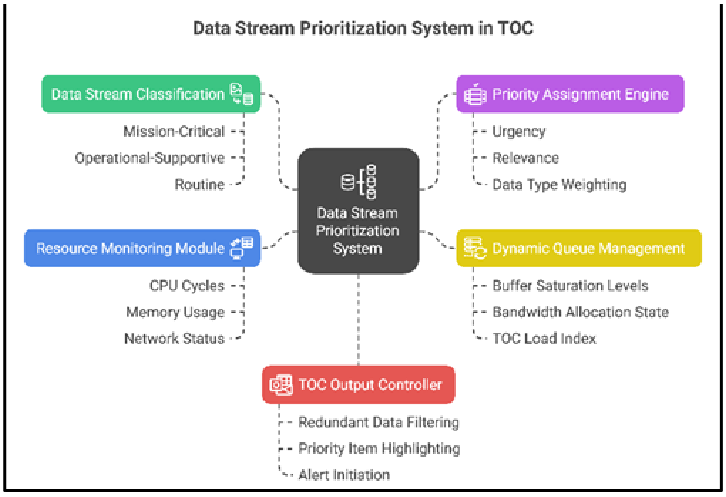

Fig. 1 – Proposed Model for Tactical Prioritization of UAV Data Streams

This figure presents the architecture of the proposed prioritization model designed for TOC environments. The central Data Stream Prioritization System is supported by five interconnected modules: Data Stream Classification, Priority Assignment Engine, Dynamic Queue Management, Resource Monitoring Module, and TOC Output Controller. Each module contributes specific logic for sorting, scoring, and delivering UAV data based on mission urgency, resource availability, and system load. This design enables the TOC to manage high-volume data streams efficiently and ensures that mission-critical information is always prioritized for rapid decision-making.

IV. SCENARIO DESIGN

To evaluate the performance of the proposed prioritization model, a realistic operational scenario was developed that simulates a joint military and emergency mission conducted in a congested communication environment. The scenario captures the complexity and unpredictability of modern tactical operations where multiple UAVs are simultaneously deployed to support decision-making at the Tactical Operations Center (TOC).

The simulated environment replicates a regional crisis caused by an industrial explosion near an urban border zone. The TOC is tasked with coordinating surveillance, damage assessment, and threat detection operations. A fleet of 12 UAVs is launched, each equipped with diverse sensor suites, including optical cameras, infrared systems, gas detectors, and telemetry modules. The UAVs operate in overlapping airspace and transmit large volumes of data in real time to the central TOC hub.

Each UAV is assigned a mission profile based on its role:

- **UAV Group A (4 units):** Conduct low-altitude surveillance over critical infrastructure and populated areas. These units prioritize live video and motion-detection alerts.
- **UAV Group B (4 units):** Monitor air quality and gas dispersion using environmental sensors. Data is transmitted periodically in structured packets.
- **UAV Group C (4 units):** Provide perimeter security and identify potential threats using visual and infrared feeds.

The TOC is equipped with a limited-bandwidth satellite uplink (5 Mbps peak), a constrained local processor (dual-core system), and a maximum real-time processing window of 20 concurrent data threads. This restricted setup simulates realistic operational limits in field-deployed or mobile TOC units. The system must therefore prioritize which UAV streams to process first, which to delay, and which to archive for later review.

The simulation incorporates dynamic events that alter the data flow and urgency. For instance, halfway through the mission, UAV Group A detects unauthorized human movement in a restricted zone. This triggers an escalation in the priority score of their live feed and alerts, requiring immediate system adaptation to elevate their data to Tier 1. Concurrently, UAV Group C reports thermal anomalies at a different site, which must also be elevated due to potential secondary hazards.

Additional complexity is introduced by artificial network degradation representing electronic warfare activity or natural signal interference. This causes intermittent drops in connectivity for some UAVs, which challenges the system's ability to retain mission-critical data integrity under strain.

The scenario also evaluates how the prioritization model manages data overload. During peak mission activity, up to 40 simultaneous data threads are attempted for processing. Without prioritization, the system would stall, dropping essential information and overloading operators with non-critical updates. The proposed model ensures that the TOC maintains awareness of the most urgent developments without compromising situational coherence.

This scenario was chosen because it reflects operational realities where TOCs must rapidly adapt to evolving threats, uncertain conditions, and information saturation. By stressing the system in both technical and tactical terms, the design allows for a comprehensive assessment of how well the prioritization model supports real-time decision-making. Moreover, the inclusion of both military and civilian response objectives reflects the growing integration of UAVs in multi-domain operations, where situational context and mission goals must be dynamically balanced.

The data collected during the simulation will form the basis for the performance evaluation section, where key metrics such as latency, success rate, and processing efficiency will be compared between the proposed model and a baseline system without prioritization.

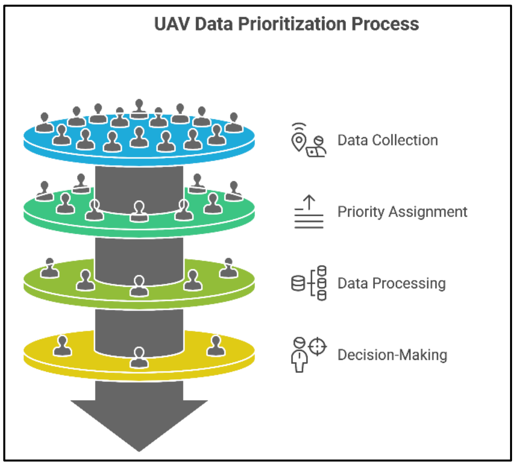

Fig. 2 – Layered Architecture of UAV Data Prioritization in TOC Operations

Figure 2 illustrates the layered process of UAV data prioritization within a Tactical Operations Center (TOC). The diagram represents four key stages: data collection from multiple UAVs, assignment of priority levels based on mission relevance, selective processing aligned with resource availability, and final delivery to decision-makers. This structured flow ensures that critical information is handled with urgency, improving operational responsiveness in constrained environments.

V. SIMULATION RESULTS AND ANALYSIS

To assess the performance of the proposed prioritization model under realistic operational stress, a comparative simulation was conducted. The test scenario involved simultaneous transmission of mission-critical, operational-supportive, and routine data streams from a fleet of UAVs to a Tactical Operations Center (TOC). The simulation compared the proposed model against a traditional queue-based system that lacks dynamic prioritization.

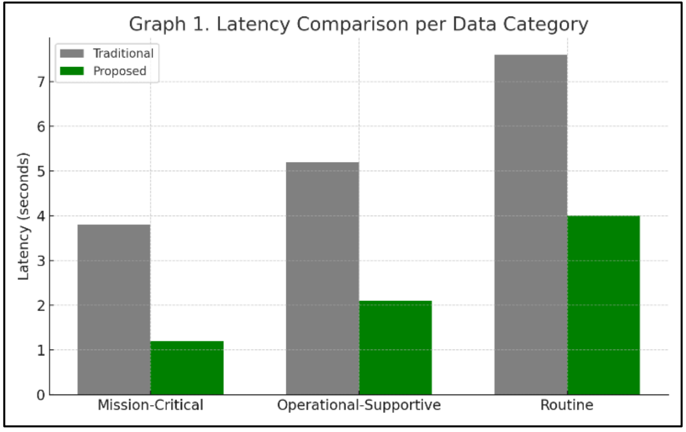

Fig. 3 – Latency Comparison per Data Category

The proposed model dramatically reduced latency across all data categories. For mission-critical information such as alerts and adversary tracking, the average delay dropped from 3.8 seconds to just 1.2 seconds. This difference is operationally significant in time-sensitive environments where even minor delays can result in tactical disadvantages or mission failure. Operational-supportive data, such as environmental telemetry or video feeds, also saw a latent reduction of over 60%. Even routine data streams, which are lower in priority, were processed more quickly, suggesting overall system optimization.

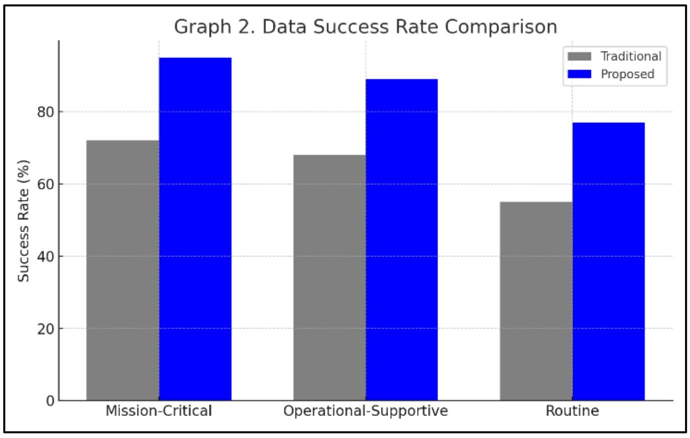

Fig. 4 – Data Success Rate Comparison

The ability to deliver data packets without loss or corruption is a vital metric in any communication framework. The success rate for mission-critical data rose from 72% to 95% with the prioritization model, while operational-supportive and routine data increased by 21% and 22% respectively. These gains indicate not only improved throughput but also more intelligent resource allocation under bandwidth-limited and congested conditions.

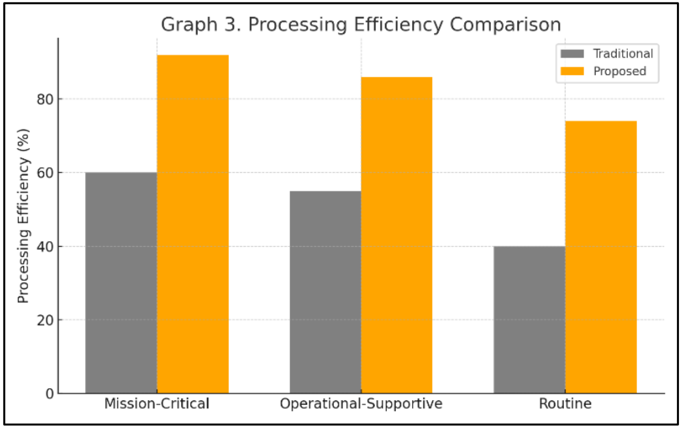

Fig. 5 – Processing Efficiency Comparison

Processing efficiency refers to the proportion of incoming data that the TOC is able to analyze and act upon without delay. The traditional system could only handle 60% of the highest priority streams. By contrast, the proposed system processed 92% of mission-critical data in real time. Similar improvements were seen for the other categories. This validates the model's ability to allocate CPU time and memory where it is needed most, without overwhelming the system.

Tab. 1 – Performance Metrics of Traditional vs. Proposed Prioritization Models

Metric	Mission-Critical	Operational-Supportive	Routine
Success Rate (%) - Traditional	72	68	55
Success Rate (%) - Proposed	95	89	77
Latency (s) - Traditional	3.8	5.2	7.6
Latency (s) - Proposed	1.2	2.1	4.0
Processing Efficiency (%) - Traditional	60	55	40
Processing Efficiency (%) - Proposed	92	86	74

Table 1 provides a detailed comparison between the traditional data handling system and the proposed prioritization model across three UAV data categories: mission-critical, operational-supportive, and routine. The metrics evaluated include success rate, latency, and processing efficiency. The proposed model consistently outperforms the traditional system, with significantly higher success rates (e.g., 95% vs. 72% for mission-critical data), lower latency (e.g., 1.2s vs. 3.8s), and improved processing efficiency (e.g., 92% vs. 60%). These results demonstrate the effectiveness of dynamic prioritization and resource-aware scheduling in enhancing the performance of Tactical Operations Centers under operational constraints.

VI. CONCLUSIONS

The proposed prioritization framework has shown substantial potential to enhance the operational performance of Tactical Operations Centers (TOCs) by ensuring timely delivery of critical UAV data streams. However, further development is essential to scale the system, improve its flexibility, and enable wider deployment in complex and evolving mission environments.

One of the most promising directions for future implementation involves integrating adaptive machine learning algorithms into the prioritization engine. By analyzing historical mission patterns, user interaction behavior, and threat evolution, the system can learn to automatically adjust priority parameters in real time. This level of intelligence would allow the TOC to respond more effectively to unforeseen situations without relying solely on pre-defined rules or operator intervention.

In addition, future versions of the framework can incorporate cross-domain data fusion capabilities. This would enable the integration of data not only from UAVs but also from ground sensors, satellites, maritime assets, and cyber intelligence platforms. With such multidomain awareness, the system can offer a more comprehensive operational picture and improve coordination between allied command nodes.

Another area of development includes edge computing deployment of the prioritization modules. By distributing some of the processing logic to field-deployed UAVs or intermediate relay stations, the TOC can reduce its processing load and maintain resilience even in partially degraded communication conditions. This decentralized model is particularly useful in scenarios where direct TOC connectivity is limited or intermittent.

Interoperability will also be a key focus for implementation in multinational or joint force operations. Developing compliance with NATO communication protocols, U-space standards, and mission-aware routing frameworks will ensure that the model can be embedded into allied systems without extensive customization. This would significantly increase its adoption across a broader defence ecosystem.

Finally, user interface development should not be overlooked. Future versions of the system should include intuitive visualization dashboards, alert mechanisms, and operator-driven customization tools that allow mission commanders to define and monitor their own data priorities based on the evolving mission context. These features will enhance decision-making and ensure that the system serves not only as a technical backbone but also as a practical support tool for human operators in the field.

The prioritization framework developed in this research serves as a foundational architecture for enhancing data stream management in UAV-supported operations. Continued investment in artificial intelligence, interoperability, edge computing, and user-centered design will be vital in transforming this concept into a field-ready solution capable of supporting high-stakes military and emergency missions.

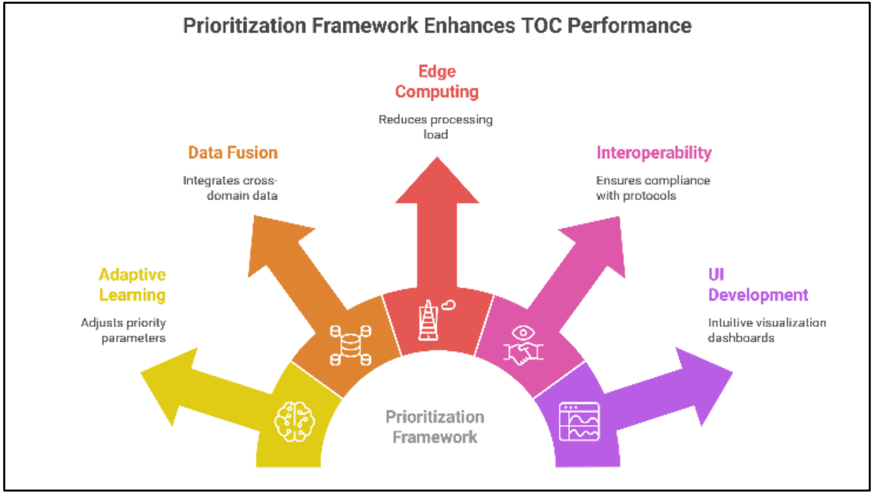

Fig. 6 – Strategic Enhancements to the UAV Data Prioritization Framework

Figure 6 outlines the core directions for future development aimed at enhancing the performance and resilience of the proposed prioritization framework. The diagram presents five strategic pillars: Adaptive Learning, which introduces intelligent adjustment of priority parameters based on real-time mission context; Data Fusion, which enables integration of cross-domain information to build a more comprehensive operational picture; Edge Computing, which allows data processing to be distributed across UAV nodes to alleviate central TOC load; Interoperability, which ensures compatibility with NATO and allied communication standards; and UI Development, which supports mission operators through intuitive interfaces and alert-driven visualization tools. These enhancements collectively aim to transform the model from a functional prototype into a robust, field-deployable system ready for integration in complex military and crisis response environments.

VII. CONCLUSIONS

This paper introduced a tactical prioritization framework designed to improve how data streams from unmanned aerial vehicles are managed and processed within Tactical Operations Centers. As military and emergency operations increasingly rely on timely and mission-relevant data, the need to filter, prioritize, and deliver critical information becomes essential for operational success. The proposed model addressed this challenge by incorporating a structured classification engine, dynamic queue management, real-time resource monitoring, and intelligent output control.

The simulation results clearly demonstrated the benefits of the proposed system over traditional data handling approaches. It significantly reduced latency, improved the success rate of mission-critical data delivery, and increased overall processing efficiency. These improvements are particularly important in high-pressure environments where decisions must be made quickly and based on the most relevant information available.

Beyond the current implementation, this study also outlined several avenues for future development. These include the integration of adaptive learning algorithms, cross-domain data fusion, deployment of edge computing, enhanced interoperability across allied systems, and the development of user-focused visualization tools. Each of these enhancements contributes to building a resilient and scalable system that can operate effectively in diverse operational settings.

The prioritization framework presented in this research lays a solid foundation for more intelligent and responsive data handling in modern command environments. By aligning system behaviour with mission urgency and resource constraints, it supports faster decision-making and more coordinated responses during complex missions. With further refinement and integration, this model can become a critical component of digital battlefield architectures.

VIII. REFERENCES

1. Santoso, F.; Garratt, M.A.; Anavatti, S.G. State-of-the-art intelligent flight control systems in unmanned aerial vehicles. *IEEE Transactions on Automation Science and Engineering* 2017, 15, 613–627.
2. Bae, J.; Sohn, K.Y.; Lee, H.; Lee, H.; Lee, H. Structure of UAV-based emergency mobile communication infrastructure. In *Proceedings of the 2021 International Conference on Information and Communication Technology Convergence (ICTC)*, Jeju Island, Republic of Korea, 20–22 October 2021; pp. 634–636.
3. Daniel, K.; Rohde, S.; Wietfeld, C. Leveraging public wireless communication infrastructures for UAV-based sensor networks. In *Proceedings of the 2010 IEEE International Conference on Technologies for Homeland Security (HST)*, Waltham, MA, USA, 8–10 November 2010; pp. 179–184.
4. Asadzadeh, S.; de Oliveira, W.J.; de Souza Filho, C.R. UAV-based remote sensing for the petroleum industry and environmental monitoring: State-of-the-art and perspectives. *Journal of Petroleum Science and Engineering* 2022, 208, 109633.
5. Aasen, H.; Honkavaara, E.; Lucieer, A.; Zarco-Tejada, P.J. Quantitative remote sensing at ultra-high resolution with UAV spectroscopy: A review of sensor technology, measurement procedures, and data correction workflows. *Remote Sensing* 2018, 10, 1091.
6. Abubakar, A.I.; Ahmad, I.; Omeke, K.G.; Ozturk, M.; Ozturk, C.; Abdel-Salam, A.M.; Mollel, M.S.; Abbasi, Q.H.; Hussain, S.; Imran, M.A. A survey on energy optimization techniques in UAV-based cellular networks: From conventional to machine learning approaches. *Drones* 2023, 7, 214.
7. Erenoglu, R.C.; Erenoglu, O.; Arslan, N. Accuracy assessment of low cost UAV based city modelling for urban planning. *Technical Gazette* 2018, 25, 1708–1714.
8. Islam, N.; Rashid, M.M.; Pasandideh, F.; Ray, B.; Moore, S.; Kadel, R. A review of applications and communication technologies for Internet of Things (IoT) and unmanned aerial vehicle (UAV) based sustainable smart farming. *Sustainability* 2021, 13, 1821.
9. Lottes, P.; Khanna, R.; Pfeifer, J.; Siegwart, R.; Stachniss, C. UAV-based crop and weed classification for smart farming. In *Proceedings of the 2017 IEEE International Conference on Robotics and Automation (ICRA)*, Singapore, 29 May–3 June 2017; pp. 3024–3031.
10. Khan, A.; Gupta, S.; Gupta, S.K. Emerging UAV technology for disaster detection, mitigation, response, and preparedness. *Journal of Field Robotics* 2022, 39, 905–955.
11. Erdelj, M.; Natalizio, E.; Chowdhury, K.R.; Akyildiz, I.F. Help from the sky: Leveraging UAVs for disaster management. *IEEE Pervasive Computing* 2017, 16, 24–32.
12. Chaturvedi, S.K.; Sekhar, R.; Banerjee, S.; Kamal, H. Comparative review study of military and civilian unmanned aerial vehicles (UAVs). *INCAS Bulletin* 2019, 11, 181–182.
13. Yin, S.; He, R.; Li, J.; Chen, L.; Zhang, S. Research on the operational mode of manned/unmanned collaboratively detecting drone swarm. In *Proceedings of the 2021 IEEE International Conference on Unmanned Systems (ICUS)*, Beijing, China, 15–17 October 2021; pp. 560–564.
14. Song, B.D.; Park, K.; Kim, J. Persistent UAV delivery logistics: MILP formulation and efficient heuristic. *Computers and Industrial Engineering* 2018, 120, 418–428.
15. Zhang, H.-Y.; Lin, W.-M.; Chen, A.-X. Path planning for the mobile robot: A review. *Symmetry* 2018, 10, 450.
16. Mustafovski, R. Architectural framework of a mission-centric UAV communication platform. *Automation of Technological and Business Processes* 2025, 17(3), 44–58.

17. Mustafovski, R. Modern information and communication technology platforms: Advancing SecuDroneComm management. *Management Science Advances* 2025, Online(1), 1–10.

18. Mustafovski, R. Advancing SecuDroneComm: A comparative state-of-the-art analysis with modern ICT platforms for secure communication. *Serbian Journal of Engineering Management* 2025, 10(2), 61–70.

19. Mustafovski, R. State-of-the-art comparison of sensors in Industry 4.0, Industry 5.0, and low-cost monitoring technologies. *Spectrum of Engineering and Management Sciences* 2025, Online, 1–14.

20. Mustafovski, R. Formula-based architectural framework of the SecuDroneComm platform for unmanned aerial vehicle communications. *Management Science Advances* 2025, 2(1), 288–303.

21. Mustafovski, R. Evaluating the operational impact of SecuDroneComm: Simulation-based assessment of secure UAV communication in military environments. *Scientific Technical Review* 2025, 75(1), 11–18.

22. Mustafovski, R. The use of communication platforms in military operations: Enhancing strategic and tactical effectiveness. *Database Systems Journal* 2025, 16(1), 1–10.

23. Mustafovski, R. State-of-the-art comparison of MobileSecureComm with modern secure communication platforms for tactical operations. *Balkan Journal of Applied Mathematics and Informatics* 2025, 8(1), 87–98.

24. Mustafovski, R. Integrating computer vision with YOLOv8 algorithm for PID: A state-of-the-art analysis. *Contemporary Macedonian Defence* 2025, 48(1), 83–94.

25. Mustafovski, R. Simulating security and speed: A comparative evaluation of the MobileSecureComm platform against legacy tactical communication systems. *Spectrum of Engineering and Management Sciences* 2025, 3(1), 147–157.

26. Mustafovski, R. Biothreat early assist and response command system (BEAR-CS). *Automation of Technological and Business Processes* 2025, 17(1).

27. Mustafovski, R.; Risteski, A.; Shuminoski, T. Advancements in industrial digital sensors (version 3.0 to 4.0) and radar systems for object detection: A state-of-the-art review. In *Proceedings of the Third International Conference ETIMA 2025*, Stip, Republic of North Macedonia, 24–25 September 2025.

28. Mustafovski, R.; Risteski, A.; Shuminoski, T. Challenges and solutions for enhancing drone-to-TOC communication performance in military and crisis operations. In *Proceedings of the Third International Conference ETIMA 2025*, Stip, Republic of North Macedonia, 24–25 September 2025.

29. Mustafovski, R.; Risteski, A.; Shuminoski, T. Designing a secure communication framework for UAV-to-TOC operations in military and emergency environments. In *Proceedings of the Third International Conference ETIMA 2025*, Stip, Republic of North Macedonia, 24–25 September 2025.

30. Mustafovski, R.; Risteski, A.; Shuminoski, T. Simulation-based performance analysis of a secure UAV-to-TOC communication framework in military and emergency operations. In *Proceedings of the Third International Conference ETIMA 2025*, Stip, Republic of North Macedonia, 24–25 September 2025.

31. Mustafovski, R.; Risteski, A.; Shuminoski, T. MobileSecureComm: A next-generation tactical communication platform for land, sea and air operations. In *Proceedings of the 32nd International Conference on Systems, Signals and Image Processing (IWSSIP)*, Skopje, Republic of North Macedonia, 24–26 June 2025.

32. Mustafovski, R. The security vulnerabilities and challenges on IoT technologies. In *Proceedings of the Student Conference Energy Efficiency and Sustainable Development (SCEESD)*, Skopje, Republic of North Macedonia, 29 October–1 November 2024.

33. Mustafovski, R. Integrated control and monitoring system (ICMS) using digital electronic boards for object monitoring and detection at short distances. In *Proceedings of the International Conference ACCHE: Challenges of Contemporary Higher Education*, Kopaonik, Republic of Serbia, 3–7 February 2025.

34. Mustafovski, R. State-of-the-art comparison of the SecuDroneComm platform with existing secure drone communication systems. In *Proceedings of the International Conference ACCHE: Challenges of Contemporary Higher Education*, Kopaonik, Republic of Serbia, 3–7 February 2025.

35. Mustafovski, R. State-of-the-art research and analysis of active and passive radar reflectors and ultrasonic radar systems. In *Proceedings of the International Conference ACCHE: Challenges of Contemporary Higher Education*, Kopaonik, Republic of Serbia, 3–7 February 2025.