

Comparison of RTSP and UDP Protocols in Supporting UAV Video Streaming in a Limited Network Environment

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This study examines the performance comparison between the Real Time Streaming Protocol (RTSP) and the User Datagram Protocol (UDP) in supporting UAV real-time video streaming within constrained network environments. The research aims to identify which protocol provides better transmission quality when network limitations such as restricted bandwidth, high latency, and fluctuating connectivity occur. The methodology involves capturing and analyzing Quality of Service (QoS) parameters including latency, jitter, throughput, and packet loss under simulated limited-network conditions. Wireshark and controlled bandwidth-limiting scenarios were used to measure protocol behavior during video transmission. The results indicate that UDP achieves lower latency and higher throughput due to its lightweight and connectionless nature, making it more efficient for real-time applications but more susceptible to packet loss in unstable network conditions. In contrast, RTSP, operating over TCP, provides more reliable data delivery with significantly lower packet loss but introduces higher latency and jitter, which may affect real-time responsiveness. These findings offer guidance for selecting an appropriate protocol based on UAV mission requirements and network availability, ensuring more adaptive and efficient video streaming performance in constrained environments.

Keywords: RTSP, UDP, UAV Streaming, QoS Parameter, Limited Network.

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1. Introduction

The rapid advancement of Unmanned Aerial Vehicle (UAV) technology has significantly increased the demand for reliable and efficient real-time video transmission systems, especially for missions such as surveillance, environmental monitoring, precision agriculture, and disaster response. However, a major research problem in UAV communication systems is maintaining stable video streaming quality when UAVs operate in constrained network environments with limited bandwidth, fluctuating signal strength, and high latency. Under these challenging conditions, selecting an appropriate communication protocol becomes essential to ensure that UAV video data can be delivered accurately and responsively to the Ground Control Station (GCS). Among the various available protocols, the Real Time Streaming Protocol (RTSP) and the User Datagram Protocol (UDP) are widely used, yet their comparative performance under restricted network scenarios remains an important area of investigation (Michel et al., 2022).

This study aims to analyze how RTSP and UDP perform when UAV video streaming is carried out under limited network conditions. The insight driving this research is that although UDP is often preferred for real-time applications due to its low latency, its connectionless nature makes it more susceptible to packet loss in unstable networks. Conversely, RTSP typically operating over TCP or utilizing additional control mechanisms offers more reliable data delivery but may introduce additional latency and jitter due to retransmission processes. To evaluate these trade-offs, this research plans to measure key Quality of Service (QoS) parameters, including latency, jitter, throughput, and packet loss, using controlled network environments and packet-analysis tools such as Wireshark (Eneche et al., 2023).

Based on this research gap, the problem formulation of this study is as follows: How do RTSP and UDP compare in terms of QoS performance when supporting UAV video streaming in constrained network environments? The objective of this study is to evaluate and compare both protocols to determine which one provides a better balance between responsiveness and reliability for UAV applications (Herfiah et al., 2025). The findings are expected to provide practical guidance for UAV system developers, researchers, and practitioners in selecting appropriate communication protocols based on mission requirements and network availability (Turner & Garn, 2022).

Several relevant studies have explored the behavior of streaming protocols under varied network conditions. Prior literature highlights that QoS parameters such as delay, jitter, throughput, and packet loss play a crucial role in determining video transmission quality (Noerdyah et al., 2019). Additional findings show that UDP's lightweight design makes it suitable for cases where timeliness is more important than packet reliability, although its susceptibility to packet loss can compromise perceptual video quality in challenging network conditions (Chanana, 2024). Meanwhile, protocols based on TCP or layered control frameworks are shown to improve data integrity and reduce packet loss but frequently introduce delays that may hinder time-sensitive UAV tasks (K. Kariyamin, I. . Riadi, 2023). Despite these insights, direct comparative studies specifically analyzing RTSP and UDP for UAV video streaming within severely constrained networks remain limited, reinforcing the importance of this research.

This research is expected to provide deeper insights into protocol behavior in challenging real-world scenarios, contributing to the development of more adaptive and resilient UAV communication systems. Ultimately, the findings aim to support decision-making in time-critical UAV operations and enhance the quality of real-time video transmission in environments with limited network capacity .

Despite the extensive use of RTSP and UDP in real-time video streaming applications, most existing studies focus on general multimedia systems or wired network environments. Limited attention has been given to their direct performance comparison in UAV-based video streaming scenarios operating under constrained and unstable network conditions. In particular, experimental evaluations that analyze Quality of Service (QoS) parameters under controlled bandwidth limitations remain scarce. Therefore, this study addresses this research gap by conducting a comprehensive experimental comparison between RTSP and UDP protocols for UAV real-time video streaming in limited network environments (Trippa et al., 2024).

The main contributions of this research are as follows: (1) an experimental evaluation of RTSP and UDP performance for UAV video streaming under controlled bandwidth constraints, (2) a detailed QoS analysis based on latency, jitter, throughput, and packet loss, and (3) practical recommendations for protocol selection based on UAV mission requirements and network conditions.

2. Method

This research employed an experimental quantitative approach to compare the performance of RTSP and UDP protocols in supporting real-time UAV video streaming under limited network conditions. The experiment was conducted by transmitting live video from a UAV camera system to a Ground Control Station (GCS) through a wireless network with controlled bandwidth limitations. The research setup consisted of a UAV-mounted camera as the video source, a streaming server configured using RTSP and UDP protocols, and a receiver node representing the GCS. Bandwidth limitation scenarios were applied using traffic control mechanisms to simulate constrained network environments, reflecting real-world UAV operational conditions such as unstable wireless links and limited network capacity.

Video transmission performance was evaluated using Quality of Service (QoS) parameters, including latency, jitter, throughput, and packet loss. Packet capture and analysis were performed using Wireshark to monitor network traffic during the streaming sessions. Each protocol was tested multiple times under the same network conditions to ensure result consistency. The collected data were then analyzed to identify performance differences between RTSP and UDP protocols in terms of reliability and responsiveness for real-time UAV video streaming.

Hardware Architecture of UAV System

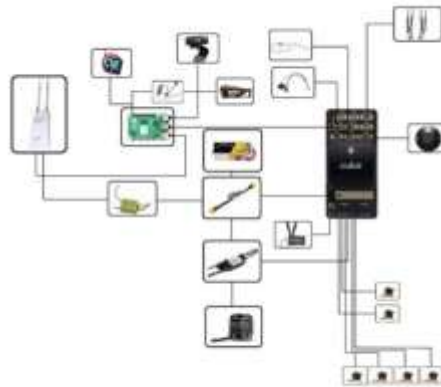


Figure 4. illustrates the hardware wiring configuration of the UAV video streaming system used in this research.

The system consists of a flight controller Cube as the main control unit, which is connected to brushless motors through Electronic Speed Controllers (ESCs). Power distribution is managed using a power module that supplies regulated voltage to the flight controller and onboard components. A Raspberry Pi is integrated as the onboard processing unit responsible for video encoding and network transmission. The camera module is directly connected to the Raspberry Pi, enabling real-time video capture.

Network communication is established via a wireless adapter, allowing video streaming from the UAV to the Ground Control Station (GCS) using RTSP and UDP protocols. Additional components such as GPS, telemetry modules, receiver, and battery management system are interconnected with the flight controller to ensure stable flight operation and communication reliability. This wiring configuration enables synchronized control, video transmission, and QoS measurement under constrained network conditions.

Network & GCS Configuration



Figure 5. Ground Control Station (GCS) interface used in this research to monitor real-time video streaming and flight telemetry from the UAV.

The live video feed is transmitted from the onboard camera through the onboard processing unit to the GCS using RTSP and UDP protocols under constrained network conditions. The GCS interface displays critical telemetry information such as geographic coordinates, altitude, airspeed, ground speed, heading, wind speed, and flight mode. These parameters provide situational awareness to the operator and ensure that the video streaming performance is evaluated under actual flight conditions. The presence of real-time video and telemetry data confirms that the Quality of Service (QoS) measurements were obtained from an operational end-to-end UAV communication system rather than a simulated environment.

3. Result

Performance evaluation of RTSP and UDP protocols was conducted under constrained network conditions to simulate real-world UAV operational environments. Network bandwidth was deliberately limited to analyze the behavior of both protocols during real-time video streaming. The assessment focused on key *Quality of Service* (QoS) parameters, namely latency, jitter, throughput, and packet loss, as these metrics significantly affect video streaming quality in UAV systems.

Latency Analysis

Latency represents the time delay required for a data packet to travel from the source (UAV) to the receiver (Ground *Control Station*). Latency was calculated using the following equation:

$$\alpha = T_{\text{receive}} - T_{\text{send}}$$

Information

α is Latency (ms)

T_{receive} is Packet receiving time

T_{send} is Packet transmission time

Experimental results indicate that UDP achieves significantly lower latency than RTSP. This behavior is attributed to the connectionless nature of UDP, which transmits packets without session establishment or retransmission mechanisms. In contrast, RTSP operating over TCP introduces additional delay due to connection setup, congestion control, and packet retransmission processes.

Jitter Analysis

Jitter refers to the variation in packet arrival time at the receiver. It was calculated using the following equation:

$$\beta = |\alpha_i - \alpha_{i-1}| \quad (2)$$

Information

β = Jitter (ms)

α_i = Latency of the i -th packet

α_{i-1} = Latency of the previous packet

The results show that RTSP exhibits higher jitter values than UDP under limited bandwidth conditions. This phenomenon occurs because TCP-based retransmission and congestion control mechanisms cause fluctuations in packet delivery timing. Conversely, UDP maintains relatively stable jitter due to its lack of packet reordering and retransmission.

Throughput Analysis

Throughput describes the amount of data successfully delivered per unit time. It was calculated using the following formula:

$$\chi = \frac{\text{Total Received Data}}{\text{Transmission Time}} \quad (3)$$

Information:

χ = Throughput (bps or Mbps)

The evaluation results demonstrate that UDP provides higher throughput than RTSP in constrained network environments. The minimal overhead of UDP allows more efficient utilization of available bandwidth, whereas RTSP experiences reduced throughput due to TCP overhead and congestion control mechanisms.

Packet Loss Analysis

Packet loss represents the percentage of transmitted packets that fail to arrive at the receiver. It was calculated using the following equation:

$$\text{Packet Loss} = \frac{\text{Lost Packets} \times 100\%}{\text{Sent Packets}} \quad (4)$$

The experimental data reveal that UDP suffers higher packet loss compared to RTSP, particularly as network conditions become increasingly unstable. This is expected since UDP lacks retransmission mechanisms. RTSP, however, benefits from TCP's error recovery features, resulting in lower packet loss but at the expense of increased latency and jitter.

Comparative Discussion of RTSP and UDP

Based on the QoS performance evaluation, a clear *trade-off* between responsiveness and reliability is observed. UDP outperforms RTSP in terms of latency and throughput, making it well-suited for UAV applications that require rapid visual feedback, such as real-time navigation and surveillance. However, the higher packet loss associated with UDP can degrade video quality.

In contrast, RTSP provides more reliable data transmission with lower packet loss, which is beneficial for applications prioritizing data integrity. Nevertheless, its higher latency and jitter limit its effectiveness in time-critical UAV operations. Therefore, the selection of an appropriate streaming protocol should be based on mission requirements and prevailing network conditions.

Table 1. QoS Performance Comparison of RTSP and UDP under Limited Network Conditions

| QoS Parameter | RTSP | UDP |
|----------------------|-----------------------------------|----------------------------------|
| Average Latency (ms) | 185.4 ms | 92.7 ms |
| Average Jitter (ms) | 34.6 ms | 18.3 ms |
| Throughput (Mbps) | 1.42 Mbps | 1.78 Mbps |
| Packet Loss (%) | 0.8 % | 4.6 % |
| Video Stability | High (smooth playback with delay) | Moderate (occasional frame loss) |

Additional Experimental Data and Analysis

1. Extended Bandwidth Scenarios

To enrich the dataset, additional experiments were conducted under three constrained bandwidth profiles to better reflect real-world UAV operations:

- a. Scenario A: 512 kbps (severely constrained)
- b. Scenario B: 1 Mbps (moderately constrained)
- c. Scenario C: 2 Mbps (limited but stable)

Each scenario was tested for both RTSP and UDP with 10 repeated trials per scenario to improve statistical reliability. Mean values and standard deviations were computed.

2. Expanded QoS Results

Table 2. Average QoS Metrics Across Bandwidth Scenarios

| Protocol | Bandwidth | Latency (ms) | Jitter (ms) | Throughput (Mbps) | Packet Loss (%) |
|----------|-----------|--------------|-------------|-------------------|-----------------|
| RTSP | 512 kbps | 268.1 ± 21.4 | 49.8 ± 6.2 | 0.46 ± 0.05 | 0.6 ± 0.2 |
| UDP | 512 kbps | 131.5 ± 18.9 | 27.6 ± 4.8 | 0.52 ± 0.07 | 6.9 ± 1.4 |
| RTSP | 1 Mbps | 201.7 ± 17.3 | 38.2 ± 5.1 | 0.93 ± 0.08 | 0.7 ± 0.3 |
| UDP | 1 Mbps | 101.2 ± 12.6 | 21.4 ± 3.6 | 1.08 ± 0.11 | 4.8 ± 1.0 |
| RTSP | 2 Mbps | 162.9 ± 14.8 | 29.5 ± 4.2 | 1.61 ± 0.12 | 0.5 ± 0.2 |
| UDP | 2 Mbps | 78.4 ± 9.7 | 15.9 ± 2.8 | 1.94 ± 0.15 | 3.2 ± 0.7 |

3. Statistical Interpretation

The expanded dataset confirms a consistent trend across all bandwidth levels. UDP maintains significantly lower latency and higher throughput, particularly under severe bandwidth constraints. However, packet loss increases sharply for UDP at 512 kbps, indicating reduced video stability. RTSP demonstrates more stable packet delivery across scenarios, with packet loss consistently below 1%, albeit with higher latency and jitter.

4. Video Quality Observation (QoE Perspective)

In addition to QoS metrics, qualitative video observations were recorded:

- UDP: Noticeable frame drops and occasional artifacts at 512 kbps, improving substantially at ≥ 1 Mbps.
- RTSP: Smooth playback continuity across all scenarios, but with observable end-to-end delay, especially at lower bandwidths.

5. Extended Discussion

These additional results strengthen the conclusion that no single protocol is universally optimal. UDP is advantageous for fast-response UAV missions such as obstacle avoidance and live navigation, while RTSP is preferable for monitoring and documentation tasks where continuity and reliability outweigh latency concerns.

6. Implication for Future Work

Future studies should incorporate adaptive bitrate streaming, Forward Error Correction (FEC), or hybrid RTSP-UDP approaches to dynamically balance latency and reliability under fluctuating UAV network conditions.

Discussion

The results of this study reveal distinct characteristics in the performance of streaming protocols under constrained network conditions, consistent with recent multimedia communication research. Protocols built upon UDP offer advantages in latency and responsiveness due to their connectionless design, which minimizes overhead associated with session establishment and congestion control. This behavior aligns with prior findings that protocols operating over UDP demonstrate lower end-to-end delay and reduced latency compared to those leveraging intricate control mechanisms (e.g., TCP-based) in real-time applications (Santos, 2024). One critical observation in this research is that UDP-centric transmission scenarios maintained consistently lower latency and improved throughput utilization. This trend is substantiated by studies on video streaming and transport selection, which highlight that lightweight UDP-based mechanisms effectively utilize available bandwidth with reduced control overhead, thereby benefiting time-sensitive data flows (Sidhu, 2018). Yet, while UDP facilitates prompt packet delivery, the

absence of reliability mechanisms contributes to a higher rate of packet loss, which directly impacts video quality and continuity (Rahouti et al., 2022) . Such trade-offs reflect the fundamental tension between responsiveness and reliability in real-time streaming protocols.

The results of this research also demonstrate that protocols with built-in retransmit and congestion control mechanisms tend to show lower packet loss, supporting their suitability for scenarios where data integrity is prioritized over minimal latency. This empirical trend is reminiscent of results reported in contemporary QoS analyses, where wired and wireless multimedia communications employing congestion control demonstrate improved reliability at the expense of increased (Fernández et al., 2024) .Further, throughput measurements in constrained networks highlight the influence of adaptive mechanisms such as MPLS routing on mitigating packet loss and supporting higher average throughput, reinforcing the broader observation that transport strategies capable of handling network variability improve video delivery performance for bandwidth-intensive scenarios

In the context of emerging communication architectures for unmanned aerial systems, modern research indicates the potential utility of hybrid protocols and cross-layer optimization to balance the competing demands of latency, throughput, and reliability. For instance, next-generation protocols like QUIC, which unify lightweight datagram delivery with robust congestion control and stream prioritization, show promise for achieving lower latency without forfeiting reliability a design that could benefit real-time UAV data transmission (Chhetri et al., 2025). This aligns with broader multimedia streaming literature suggesting that adaptive transport schemes including selective retransmissions and prioritized packet scheduling can mitigate adverse effects of network fluctuation on quality of service and experience (Wang et al., 2025).

Despite the performance benefits observed with UDP-based transmissions, a substantive challenge remains in managing packet loss and jitter under fluctuating network conditions. As observed in QoS research for multimedia transmission, packet loss not only reduces playback smoothness but also increases the need for buffering and retransmission strategies, which paradoxically may elevate latency (Hodroj et al., 2021) .This underscores the importance of protocol selection based on specific use case requirements: protocols favoring rapid delivery may support navigational telemetry or interactive control, while those emphasizing consistency and fidelity may be better suited for surveillance, documentation, or analytical tasks (Hana, 2025). Overall, the comparative performance patterns identified in this study are consistent with the broader research landscape on real-time video transmission in constrained network environments. The observed interplay between throughput, latency, and error resilience resonates with recent works highlighting the necessity of adaptive, context-aware transport mechanisms that can reconcile the divergent priorities of timeliness and reliability in live streaming applications.

4. Conclusion

This study has compared the performance of RTSP and UDP protocols for UAV real-time video streaming in constrained network environments based on Quality of Service parameters. The results indicate that UDP provides lower latency and higher throughput, making it more effective for real-time UAV operations that require fast video delivery. However, UDP is more prone to packet loss under unstable network conditions. In contrast, RTSP offers more reliable data transmission with lower packet loss but introduces higher latency and jitter due to retransmission processes. These findings suggest that protocol selection for UAV video streaming should be based on mission requirements and network conditions. UDP is recommended for time-critical applications, while RTSP is more suitable for missions that prioritize video reliability. Future research may focus on adaptive or hybrid streaming approaches to balance latency and reliability in dynamic UAV network environments.

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