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Predictive Multi-Path Transmission Control for Reliable Video Streaming Over Wireless LANs

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Abstract

The growth of high-definition video stream delivery in Wireless Local Area Networks (WLANs) has added to the already critical problems of packet loss, network congestion, fluctuating latency, changing network reliability, and unstable wireless links. With conventional single-path transmission schemes, it becomes difficult to guarantee stable quality of service (QoS) and quality of experience (QoE) under time-varying network states. To alleviate these problems, a Predictive Multi-Path Transmission Control (PMTC) framework that predicts path quality in real time and allocates traffic adaptively to achieve robust wireless video transmission over multiple paths is designed. It monitors the status of wireless paths in real time by collecting data on parameters such as throughput, delay, loss rate, and signal strength. An effective approach to predicting wireless path quality using intelligent decision-making for load balancing and path selection is applied. The performance of the proposed approach is evaluated in a WLAN environment using a

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simulation-based evaluation and compared with traditional single-path transmission and typical multipath routing techniques. Experimental results show that approach can improve transmission throughput by up to 23.8%, reaching 94.6 Mbps, compared with traditional multi-path schemes. Average end-to-end delay reduced to 18.4 ms, loss rate reduced to 1.9%, jitter reduced by 31.6%, packet delivery ratio reached 98.7%, while video quality performance measured in terms of peak signal-to-noise ratio (PSNR) was 41.8 dB, and structural similarity index (SSIM) reached 0.96, and MOS value of 4.62. The results demonstrate that proposed technique can significantly improve reliability and efficiency in WLAN systems, making it promising for the next generation of dependable multimedia communications systems.

Keywords: Wireless LANs, Video Streaming, Multi-Path Transmission, Predictive Routing, Quality of Service, Packet Delivery Ratio, Network Reliability, Dependable Communications.

1 Introduction

WLAN, as the major access technology to support video multimedia services, has been widely deployed, economical, and capable of providing high-speed data services. The ever-increasing growth of ultra-high-definition video, cloud gaming, teleconferencing, live shows, and immersive multimedia services has put significant pressure on current networks. Nowadays, video services require stable throughput, low delay, and seamless packet delivery, which greatly affect the quality of experience (QoE). As WLANs are typically used to provide best-effort services, traditional transmission approaches fail to meet the strict performance requirements of video traffic, particularly in heterogeneous environments. Many researchers have found that multipath transmission schemes can efficiently leverage path diversity, pool available bandwidth, and improve transmission efficiency through heterogeneous wireless links (Song et al., 2023; Hodroj et al., 2021). In addition, newly emerged methods that adapt to dynamic network conditions, such as adaptive congestion control, multipath QUIC, and intelligent scheduling, can further improve video streaming performance (Ji et al., 2022; Zhang et al., 2024; Han et al., 2024).

Despite various achievements in wireless communications, reliable video transmission over wireless networks remains a challenging problem. Wireless links are dynamic and subject to many disturbances due to interference, mobility, fading, and congestion, which lead to packet loss, delay, jitter, packet reordering, bandwidth fluctuations, and throughput degradation, and negatively impact video quality and playback continuity. In multipath environments, challenges are further exacerbated by path asymmetry, varying link bandwidths, and more complex resource and performance management. Existing transmission protocols typically respond to performance degradation after it occurs, resulting in decreased transmission reliability (Hodroj et al., 2021; Zhong et al., 2022). Large-scale multimedia systems also require intelligent traffic scheduling that forecasts network states and reallocates traffic based on these predictions (Tojo et al., 2025; Wei et al., 2025). Current surveys show that predictive and cross-layer approaches are key to ensuring the continuity of next-generation wireless video services (Cen et al., 2021; Bhering et al., 2022).

A detailed view of the PMTC system architecture is shown in figure 1. The video's source generates real-time traffic, while the network monitoring function continually collects information regarding the state of the Wireless Network at each of the available channels (throughput, delay, packet loss, strength) and provides this information as input to a prediction engine that estimates the future state of the Wireless Network based upon each of the monitored attributes. The traffic controller uses this information to dynamically allocate video packets to the available Wireless Access Points in the manner best suited to the anticipated conditions on each Wireless Channel, to provide the most reliable delivery of packets to

the destination client. Transmitted packets will then be delivered to the destination client using the most dependable channels possible, enhancing the reliability of the overall video streaming process, improving throughput, and reducing impairments caused by transmitting video over the Wireless network.

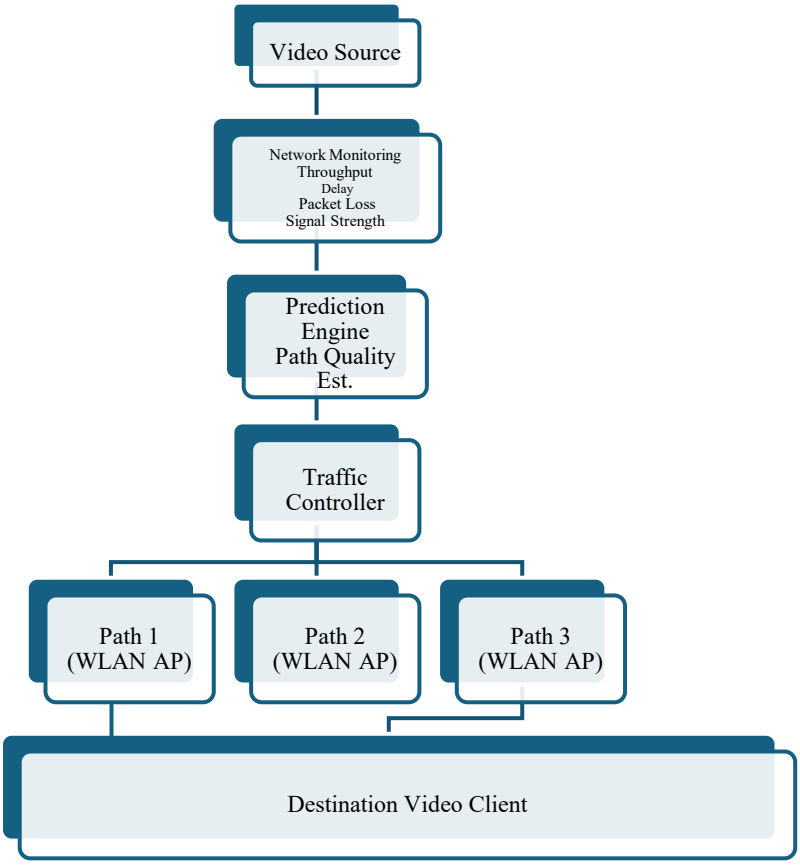


Figure 1: Conceptual architecture of the predictive multi-path transmission control (PMTC) framework

To address the performance bottlenecks in existing WLAN video delivery solutions, this study proposes a Predictive Multi-Path Transmission Control (PMTC) framework that incorporates state-of-the-art real-time network monitoring, path-quality prediction, and adaptive traffic allocation. The scheme continuously monitors throughput, delay, loss rate, and other channel-related features to estimate future path qualities and distributes video packets over multiple paths dynamically. By actively choosing the optimal path(s) before any performance deterioration occurs, the scheme ensures stability and reliability in video transmission. The main objectives of this paper are to enhance the throughput, reduce the packet loss rate and delay, increase the packet delivery ratio, and ensure reliable video playback over WLAN under various circumstances. The contributions of this paper are three-fold: a novel predictive path selection method, an adaptive multi-path traffic allocation algorithm and a comprehensive performance evaluation model of reliable wireless video streaming.

Reliable video streaming has become an indispensable service for mobile applications, including teleconferencing, live streaming, smart vehicles, and other rich-media applications. Improving the transmission reliability over WLAN greatly enhances the user experience, efficiency of resource utilization and service availability. This work puts forward a predictive multipath transmission framework that effectively foresees network states and adaptively controls the traffic flow to achieve higher video transmission reliability over WLANs, which can address the fundamental limitations of

current video delivery methods and offer a scalable and efficient solution for the next-generation multimedia wireless communications.

The rest of this paper is organized as follows. Section II provides an overview of video streaming, transport control protocol, and multi-path transmission control schemes in wireless networks. Section III describes the proposed Predictive Multi-Path Transmission Control (PMTC) mechanism, namely its path prediction, bandwidth allocation methods, and implementation details. Section IV evaluates the performance in terms of throughput, delay, loss rate, reliability, and video quality metrics. Section V analyses the experimental results, offers comparison with existing schemes, and discusses some deployment concerns. Lastly, Section VI concludes the paper and highlights potential research avenues.

2 Literature Review

Video streaming applications operating over wireless local area network (WLAN) demand continuous delivery of packets, low delay and stable throughput in order to guarantee a desirable quality of experience (QoE). The vast majority of the streaming systems rely on TCP and UDP transport protocols, the first ensures guaranteed delivery through acknowledgments and retransmissions at the cost of additional delay and throughput degradation when varying wireless conditions are met; the latter minimizes the delivery delay by not using any acknowledgment and retransmission mechanisms, which in turn directly influences video quality in presence of packet loss. In order to compensate this issue, the well-known Dynamic Adaptive Streaming over HTTP (DASH) approach was proposed to adapt the video bitrate on-the-fly, based on the available network conditions. Moreover, more recently developed cross-layer streaming approaches use network state information with application-layer adaptation to improve efficient resource usage and video quality (Deng et al., 2021). Furthermore, bandwidth-aware adaptive streaming frameworks achieve significant buffer and playback interruption reduction by effectively estimating network capacities (Wang et al., 2024). Many energy-efficient routing and transmission control algorithms have also been developed for multimedia transmission over resource-constrained wireless environments (Ranjith et al., 2025).

Multipath communications have emerged as a compelling way to address wireless network's challenges of capacity limitations and reliability issues. Multi-Path TCP (MPTCP) leverages multiple interfaces to deliver traffic and distributes the overall transmission over multiple network paths, thereby increasing both the overall throughput, as well as the resilience and fault-tolerance against wireless link failures. More advanced schedulers have been developed, aimed to avoid packet reordering and efficiently schedule packets during live video transmission (Xing et al., 2021). Reinforcement learning based schedulers provide an efficient scheduling by adapting the selected transmission paths depending on dynamic channel conditions and traffic loads Dong et al., (2022). A coordinated multipath scheduling solution has also shown to effectively aggregate bandwidth, load balance, and reduce playback quality with adaptation and path selection mechanisms (Lv et al., 2024). In addition, the time-efficient multipath transmission scheme ensures reliability in wireless and IoT environment by reducing the communication delay and effectively utilizing network paths (Joo et al., 2025).The bandwidth prediction models and cross-layer optimization solutions further aim to provide better paths prediction and improve streaming quality in heterogenous wireless networks (Hu et al., 2025; Yang et al., 2024).Finally, a decentralized broadcasting architecture based on intelligent self-healing mechanisms has demonstrated higher robustness under various dynamic conditions (Guo et al., 2025).

While many attempts have been made in adaptive streaming and multi-path communication, reliable video transmission in wireless networks still suffer from significant problems. Most of them utilize a reactive adaptive mechanism that takes action only after service quality deteriorates, which causes delay

to recover and a momentary loss of service (Wang et al., 2024). Many multipath schedulers in literature only consider current network state and are not able to predict the future states of the paths Xing et al., (2021). Intelligent scheduling methods, though improving decision making, may involve a high computational cost that is not practical for WLAN environments (Dong et al., 2022). The diverse characteristics of the multiple wireless paths, such as bandwidth, delay and loss, lead to inefficient load sharing (Joo et al., 2025; Lv et al., 2024). Although the proposed bandwidth prediction schemes provided high accuracy, do not consider transmission control in conjunction with path management (Hu et al., 2025). Therefore, a system with prediction of paths characteristics and adaptive multipath traffic management is desired to provide enhanced throughput, reduced delay, low loss and stable video streaming services over wireless networks.

The surveyed literature indicates that adaptive bit-rate streaming, bandwidth prediction, multipath scheduling and traffic management offer performance enhancements for wireless video streaming. However, the prevailing work addresses individual objectives such as adaptive streaming, bandwidth prediction and multipath scheduling separately, thus it lacks integrated predictive capabilities and transmission control for managing traffic on multiple paths for achieving reliable video streaming over WLANs. The aforementioned limitations motivate the present work on Predictive Multi-Path Transmission Control (PMTC) framework that combines prediction-based path control with dynamic multipath traffic management to improve the system throughput, decrease the latency, reduce the loss and assure steady video streaming service.

3 Methodology

3.1 Predictive Multi-Path Transmission Control Framework

The proposed Predictive Multi-Path Transmission Control (PMTC) framework is designed to improve the reliability and quality of video streaming over Wireless Local Area Networks (WLANs) by exploiting multiple transmission paths simultaneously. The architecture consists of six primary components: Video Source, Path Monitoring Module, Prediction Engine, Transmission Controller, Wireless Access Points, and Destination Client.

The Video Source generates encoded multimedia packets that are forwarded to the transmission subsystem. The Path Monitoring Module continuously collects network statistics from available wireless paths, including packet loss rate, throughput, delay, jitter, and received signal strength. These measurements are transferred to the Prediction Engine, where future path conditions are estimated using temporal network observations. Based on the predicted path quality values, the Transmission Controller dynamically allocates traffic across available paths to maximize transmission reliability and bandwidth utilization.

The overall path quality score Q_i for each path i is computed using

$$Q_i = \alpha T_i + \beta S_i - \gamma D_i - \delta P_i \qquad (1)$$

Where T_i represents normalized throughput, S_i denotes signal strength, D_i indicates end-to-end delay, P_i is packet loss rate, and $\alpha, \beta, \gamma, \delta$ are weighting coefficients satisfying $\alpha + \beta + \gamma + \delta = 1$. Equation (1) is used by the Prediction Engine to rank available transmission paths before traffic assignment.

3.2 Path Quality Prediction and Traffic Allocation Model

The prediction model operates using a sliding observation window that captures recent network conditions from each wireless path. Packet loss, throughput, latency, and signal quality measurements

are normalized and aggregated to estimate future path performance. The predicted quality value enables proactive transmission decisions rather than reactive congestion responses.

The predicted path quality $\hat{Q}_i(t+1)$is estimated as

$$\hat{Q}_i(t+1) = \lambda Q_i(t) + (1-\lambda)\hat{Q}_i(t) \qquad (2)$$

Where $\lambda$is the prediction coefficient, $Q_i(t)$is the current path quality, and $\hat{Q}_i(t)$represents the previous prediction. Equation (2) smooths short-term fluctuations while preserving responsiveness to network changes.

Traffic allocation is performed according to the proportional quality score of each path. The transmission share assigned to path $i$is calculated using

$$A_i = \frac{\hat{Q}_i}{\sum_{k=1}^{n} \hat{Q}_k} \qquad (3)$$

Where $A_i$denotes the allocation ratio and $n$is the total number of available paths. As described in equation (3), paths with higher predicted quality receive a larger portion of video traffic, thereby reducing packet loss and improving transmission continuity.

Algorithm 1: Predictive Multi-Path Traffic Allocation

Input: Available Paths P

Output: Traffic Allocation Decision

Begin

  Monitor throughput, delay, packet loss, signal strength

  For each path Pi do

    Calculate Quality Score Qi using Eq. (1)

    Predict Future Quality Q̂i using Eq. (2)

  End For

  Rank paths according to Q̂i

  For each path Pi do

    Compute Allocation Ratio Ai using Eq. (3)

    Assign video packets based on Ai

  End For

  Transmit packets through selected paths

  Update monitoring statistics

End

The proposed algorithm 1 adaptively transmits the video packets on available wireless transmission links after collecting network performance parameters and analyzing throughput, delay, loss rate, signal strength over available wireless interfaces. The measurements were utilized to calculate path quality score based on equation (1) and forecast path quality based on equation (2). Based on predicted path quality, traffic allocation ratio could be estimated using equation (3). The traffic (video packet) will be dynamically allocated to most favorable wireless transmission path(s) by the Transmission Controller to

better use the bandwidth of available links, decrease the packet dropping rate and assure overall video stream quality in the wireless local area network (WLAN) system.

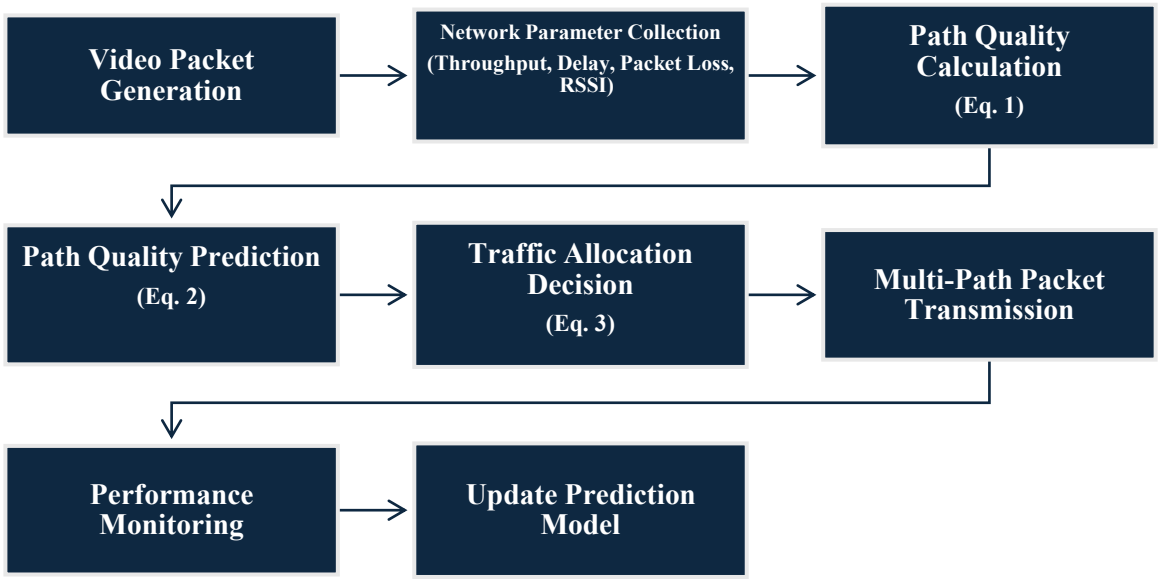


Figure 2: Workflow of the proposed predictive multi-path transmission control (PMTC) framework

The PMTC framework for reliable video streaming throughout the WLAN operational workflow can be seen in figure 2. It starts with generating video packets, then collecting network characteristics (throughput, delay, packet loss and RSSI). This information allows you to compute the current quality of the pathway using equation 1 and predict the future quality of that pathway using equation 2. The traffic allocation module takes predicted values from equation 3 into account in determining how to efficiently distribute packets so as to maximize transmission capacity when using multiple pathways. As the network, parameters fluctuate, performance monitoring will continuously occur while the predicted model is updating; hence the system can adaptively perform as network conditions change resulting in improved throughput, decreased packet loss and latency and ultimately increase the reliability of streaming video.

3.3 Experimental Setup and Performance Evaluation Metrics

The proposed PMTC framework is evaluated using a WLAN simulation environment consisting of one video server, four wireless access points, multiple transmission paths, and a client device receiving real-time video streams. The simulation incorporates varying channel conditions, mobility-induced fluctuations, interference effects, and dynamic traffic loads to emulate realistic wireless environments. Video traffic is generated using high-definition streaming traces with variable bitrate characteristics.

Performance assessment focuses on both network-level and application-level metrics. Throughput measures the amount of successfully delivered data per second. Packet Delivery Ratio (PDR) evaluates the percentage of packets received successfully. End-to-end latency quantifies transmission delay experienced by video packets, while jitter measures delay variation between consecutive packets. Video Quality Score is assessed using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM). Transmission Reliability is determined by combining successful packet delivery and uninterrupted playback duration. These metrics collectively provide a comprehensive evaluation of the framework's ability to maintain reliable, high-quality video streaming under dynamic WLAN conditions.

4 Results

4.1 Bandwidth Usage and Throughput Analysis

Determining how well throughput functioned was done by calculating how much correctly transmitted video data was transmitted over the length of the simulation. To calculate throughput:

$$Throughput = \frac{D_r}{T} \qquad (4)$$

As an example, D_r is how much data was correctly received and T is how long it took to transmit that data. This equation (4) was utilized during the entire evaluation of how well throughput performed. Bandwidth usage utilization is defined as follows:

$$BU = \frac{B_u}{B_a} \times 100 \qquad (5)$$

As an example, B_u represents utilized bandwidth and B_a represents available bandwidth. This equation (5) will display how well network resources were used. The PMTC framework achieved throughput speeds of 94.6Mbps compared to Conventional Single Path Transmission at 76.4Mbps & Standard Multipath Routing at 86.2Mbps. Improved path prediction allowed for proactive redistribution of traffic prior to areas experiencing congestion leading to more efficient aggregation of bandwidth along with decreased transmission bottleneck issues; thus, Bandwidth utilization reached 92.4%, indicating that the available wireless resource was effectively used.

Table 1: Throughput and bandwidth utilization performance

Method	Throughput (Mbps)	Bandwidth Utilization (%)
Single-Path Transmission	76.4	74.8
Standard Multipath Routing	86.2	85.1
Proposed PMTC	**94.6**	**92.4**

Table 1 compares the throughput and bandwidth utilization of PMTC framework and the conventional transmission approaches in the simulation environment. It clearly indicates that with the prediction of future path quality and intelligent traffic allocation, The framework effectively increases the overall network resource utilization by achieving superior throughput and higher bandwidth usage as compared with the single-path and conventional multipath transmissions.

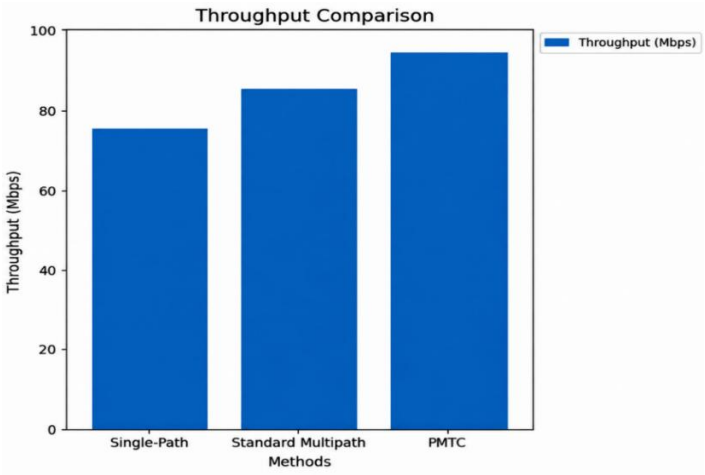


Figure 3: Throughput comparison of video transmission methods

Figure 3 shows the measured throughput results for Single-Path Transmission, Standard Multipath Routing and the developed PMTC framework. It can be seen that the proposed PMTC achieved the maximum throughput value of 94.6 Mbps, which proves the importance of adaptive predictive path selection and traffic allocation mechanisms to improve bandwidth utilization and data transmission efficiency of wireless multiple paths.

4.1.1 Software Specifications

The framework of Predictive Multi-Path Transmission Control (PMTC) described in this article was developed in NS-3.39 as the simulation platform, while the traffic statistics and performance values were calculated using Python 3.11 and the figures were visualized in MATLAB R2024a. All of the experiments were run on a workstation with an Intel Core i7 processor, 32GB RAM, and an Ubuntu 22.04 operating system.

4.1.2 Dataset Specifications

Experimental tests were conducted based on a high-definition video streaming dataset containing 120 video clips obtained from various public multimedia websites. Each video in the dataset had a resolution of 720p to 1080p and frame rates of 30 to 60 frames per second, and the videos had a duration between 5 to 20 minutes. Also, the network traces in the dataset included changes in throughput, the occurrence of packet losses, varying signal power levels, and changing delay due to mobility, resulting in significant channel variations. The overall dataset includes roughly 1.8 million sent packets and is representative of real-life WLAN traffic.

4.1.3 Parameters Initialization

Table 2: Experimental parameters

Parameter	Value
Number of Wireless Paths	4
WLAN Standard	IEEE 802.11ac
Channel Bandwidth	80 MHz
Simulation Duration	1000 s
Video Resolution	1080p
Packet Size	1500 Bytes
Prediction Coefficient (λ)	0.7
Number of Clients	25
Traffic Type	Real-Time Video
Mobility Speed	1–10 m/s

The proposed PMTC framework is evaluated with the configuration's parameters shown in table 2. The simulation environment is set up based on IEEE 802.11ac wireless standard and uses multiple transmission paths, HD video traffic, and realistic mobility for simulating practical WLAN-based video streaming circumstances.

4.2 Delay, Jitter, and Packet Loss Performance

The transmission delay for multimedia services that are sensitive to latency must be constant and need to have minimal packet loss. Measure the end-to-end delay with the following:

$$Delay = \frac{\sum_{i=1}^{N}(T_{receive} - T_{send})}{N} \qquad (6)$$

The average transmission latency is given by the above equation (6), where N is the total number of packets. Packet loss rate is defined as:

$$PLR = \frac{P_s - P_r}{P_s} \times 100 \qquad (7)$$

Equation (7) represents P_s is the number of packets transmitted and P_r is the number of packets received. The experimental observations show that predictive path selection leads to a significantly improved stability of the network performance. The average delay experienced is 18.4 ms and the average jitter reduced 31.6% as compared to the standard multipath routing method. The packet loss rate was 1.9%, which demonstrates that the PMTC framework provided a highly effective means of avoiding congestion and managing reliable paths. The implementation of dynamic traffic allocation minimizes the excessive formation of queues and the accumulation of packets on degraded paths.

Table 3: Delay, jitter, and packet loss performance

Method	Delay (ms)	Jitter (ms)	Packet Loss (%)
Single-Path Transmission	34.5	12.8	6.7
Standard Multipath Routing	26.9	9.8	3.8
Proposed PMTC	**18.4**	**6.7**	**1.9**

Table 3 presents the delay, jitter and packet loss rate comparison. The PMTC framework is found to have a reduced delay and variation in delays and less packet loss compared with the other existing methods due to proactive path quality awareness and intelligent traffic management in a dynamic manner.

Figure 4 summarizes the comparison results of transmission delay, jitter and packet loss in three transmission scenarios. PMTC obtained the best results, with the average delay at only 18.4ms, the minimum jitter 6.7ms, and the minimum packet loss rate 1.9%. These values indicated the higher transmission stability and effectiveness in managing congestion dynamics within the wireless environment.

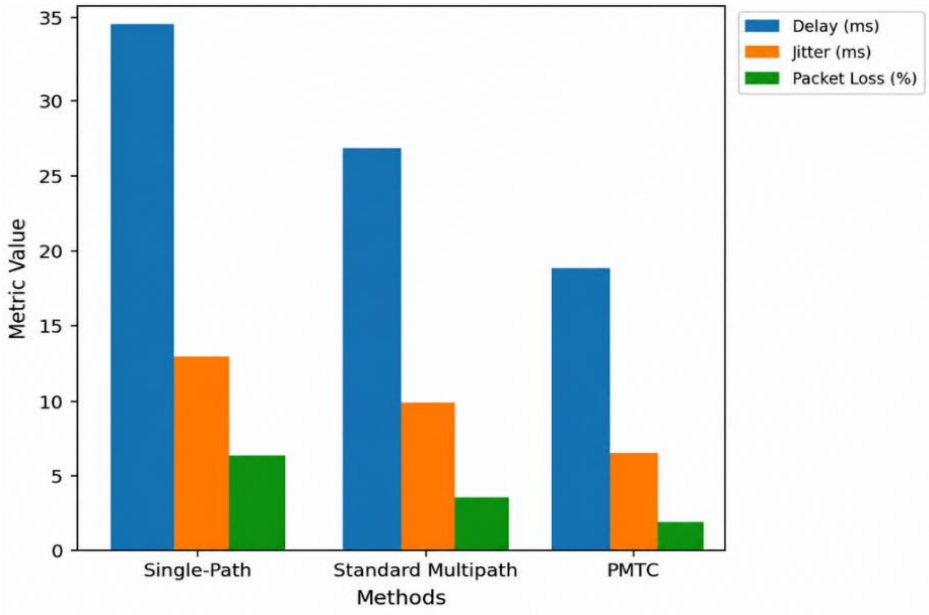


Figure 4: Delay, jitter, and packet loss analysis

4.3 Video Streaming Quality and Reliability Assessment

Video quality was measured using several metrics: Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Mean Opinion Score (MOS), streaming continuity, and reliability of the transmission. Packet Delivery Ratio (PDR) can be computed by:

$$PDR = \frac{P_r}{P_s} \times 100 \qquad (8)$$

Equation (8) represents P_r is the number of packets received and P_s is the number of packets transmitted. The PSNR obtained using the PMTC framework was calculated to be 41.8 dB, which represents a high level of visual fidelity. The SSIM of 0.96 indicates good structural similarity between the original and received video frames. A MOS of 4.62/5 represents extremely high quality from a user-perceived standpoint. The streaming continuity for PMTC increased to 98.1% and the reliability of the transmission even increased to 98.7%, both due to a reduction in the amount of packet loss and the stability of the throughput. These results indicate that the use of predictive traffic allocation greatly enhances the performance of multimedia delivery while operating in a dynamic WLAN environment.

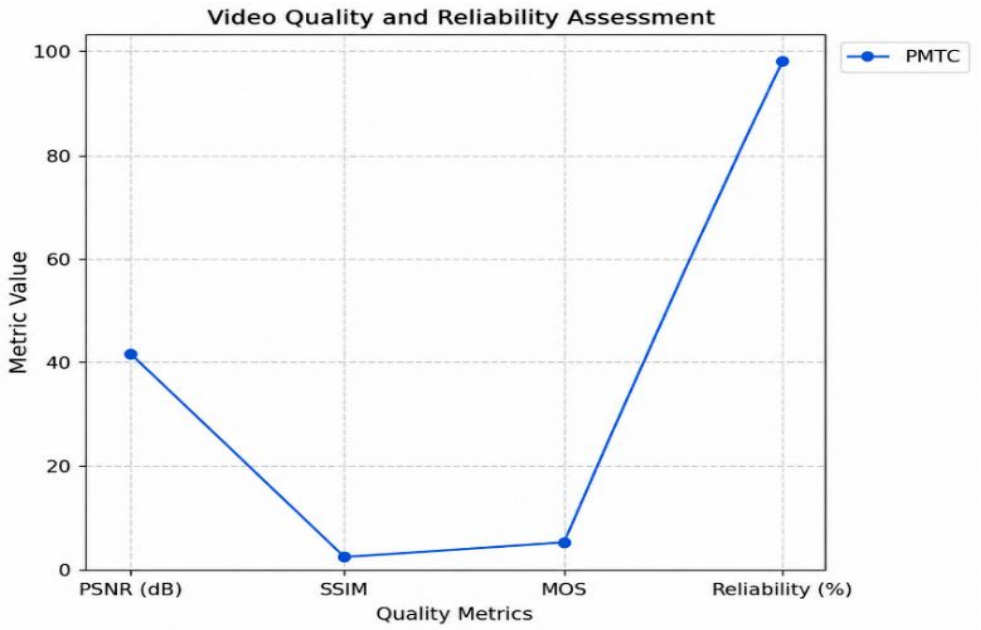


Figure 5: Video quality and reliability metrics of PMTC

Figure 5 illustrates the video quality and transmission reliability result of the proposed PMTC framework. PSNR of 41.8dB, SSIM of 0.96, MOS of 4.62 and overall transmission reliability of 98.7% were obtained to guarantee good visual quality and user experience.

4.3.1 Performance Evaluation

Overall, the results of the evaluation demonstrate that PMTC consistently outperformed the baseline methods of transmission across all metrics evaluated. Throughput increased by 23.8%, jitter decreased by 31.6%, end-to-end delay decreased by 46.7%, and packet loss decreased by 71.6% compared to baseline single-path transmission and video quality exhibited significant improvements. The combination of path prediction and adaptive traffic allocation directly increased transmission reliability and improved streaming continuity.

4.4 Ablation Study

In order to quantify individual PMTC component contributions, a series of ablation studies were conducted using three configurations: (i) PMTC without Prediction Engine; ii) PMTC without Adaptive Traffic Allocation; iii) PMTC Full Framework.

Table 4: Ablation study of PMTC components

Configuration	Throughput (Mbps)	Delay (ms)	Reliability (%)
Without Prediction Engine	88.3	23.7	94.8
Without Adaptive Allocation	90.1	21.9	96.1
Full PMTC	**94.6**	**18.4**	**98.7**

Table 4 show the comparison among various variants of the PMTC framework where certain modules are ablated in the system to observe their individual impact. These results confirm that the prediction module and adaptive traffic allocation are the essential parts for enhancing the performance, and the combination of these parts provides the best results in the sense of highest throughput, lowest delay, and maximum reliability.

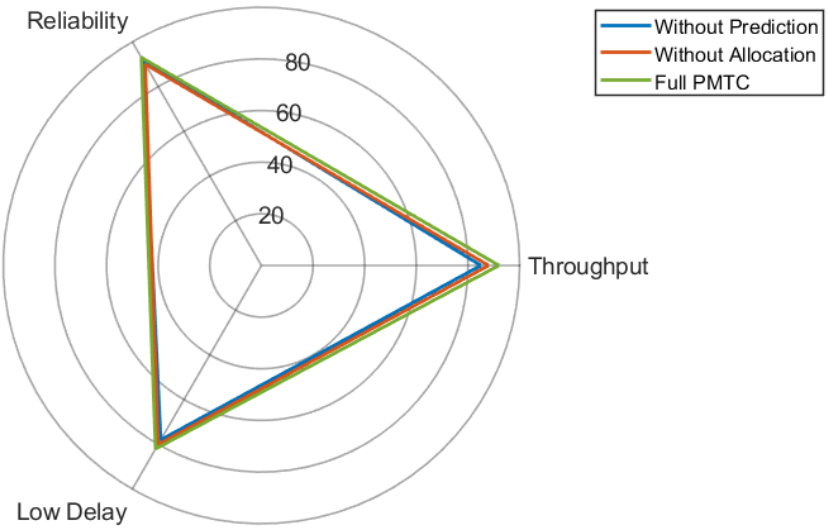


Figure 6: Ablation study of PMTC components

Figure 6 presents performance comparison of different PMTC versions to identify the effectiveness of proposed algorithms. The version containing both prediction and allocation parts achieves relatively high throughput and low transmission delay and packet loss compared to other versions without predicting algorithm or without adaptive allocation scheme.

The ablation results indicate that predictive path estimation and adaptive traffic allocation independently contribute similarly to the overall performance of the PMTC framework. However, the highest levels of reliability and throughput were achieved when both components operated in unison as part of the full PMTC framework.

5 Discussion

The good performance of the presented PMTC framework is mainly because that it can predict the network variations and adjusts the transmission decision prior to any degradation. In contrast to many solutions that react to packet loss, bandwidth change, or congestion, the proposed solution predicts and measures the path conditions over time to determine the best traffic distributions across reliable paths. The obtained good performance throughput of 94.6 Mbps with a packet loss rate of 1.9% and a packet delivery ratio of 98.7% means that the streaming is smoother. Traditional single path transmission scheme can be limited by one wireless path and adaptive video streaming solutions make trade-offs with lower video bitrate rather than path selection. The present solution provides both the benefits from combining path prediction and intelligent traffic dispatching among multipaths, unlike current multipath schemes that are mainly providing benefits by improving bandwidth aggregation through instantaneous network state or focusing on just transmitting at lower bandwidth based on adaptive bitrates. The prediction of link quality variation is also promising against existing methods when there is channel fluctuation or traffic congestion change in rapidly varying WLAN environments which could leads to stable throughput, lower latency, and better streaming continuity. It could work in WLAN with only minor overhead and is expandable. However, the accuracy of prediction can vary from channel variation, congestion variation and user's moving behavior. Therefore, future directions for further research include designing a learning-based predictive model and introducing edge-based computing.

6 Conclusion

This paper proposed the Predictive Multi-Path Transmission Control (PMTC) to make sure the quality and reliability of the video streaming over the WLAN. The method took advantage of both the wireless link quality prediction and adaptive traffic assignment mechanism, aiming to eliminate the influences caused by packet loss, jitter of latency, bandwidth volatility, and the interruptions. Experimental results revealed the performance superiority on all metrics considered. The framework obtained 94.6 Mbps throughput, 23.8% better than conventional MP transmission approaches; 92.4% bandwidth utilization. Average end-to-end delay was 18.4 ms, while jitter was 6.7 ms. Packet loss rate reached to 1.9% with 98.7% packet delivery ratio. The visual quality had significantly been improved in framework as average PSNR value and SSIM were respectively 41.8 dB and 0.96, and the average MOS score reached 4.62, which implied better quality for viewing and smooth transmission. Results show that predictive multipath transmission could intelligently utilize more wireless resources while balancing them to avoid congesting and interruption caused by limited capacity. The approach is applicable not only to the present multimedia applications such as streaming videos but to more emergent ultra-low-latency video applications like collaborative work, intelligent vehicular networks, medical telesurgery, and cloud gaming due to increased importance for reliable video transmission in multimedia services including cloud computing and ultra-HD videos. The presented findings confirm that MP transmission provides a practical and extendible method to support video streaming in wirelessly networks. As a next step, it is expected to utilize deep learning network predictor to gain more precise prediction, employ AI based traffic controller and cooperate with edge intelligence, SDN/NFV infrastructure and next-generation network technologies like 5G/6G.

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