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Research Article

A Novel Analytical Framework Is Developed for Wireless Heterogeneous Networks for Video Streaming Applications

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Due to bandwidth and time limits, delivering high-quality video streaming facility offers real-time wireless networks, but assuring quality of experience (QoE) is rather difficult. A network host can deliver its data stream via numerous different network pathways. At the same time, using multipath data transmission, where video streaming may be supplied through Internet protocols (IPs) as well as broadband with bidirectional communication between video sources and consumers, is one way to address this difficult problem. In this work, a novel framework is developed for wireless heterogeneous networks for video streaming applications using concurrent multipath transfer (CMT). The performance of frame-level delay can be enhanced for better video quality using this proposed method. The network congestion on end-to-end path utilised in CMT is not dependent of one another, and we operate under prior assumption that receiver's announced window does not limit the sender. The analytical results show that the proposed framework outperforms existing methods in terms of performance with minimum retransmission delay.

1. Introduction

Wireless communication technologies and network infrastructures have advanced to unprecedented levels in the last few years. Multihoming is a technologically possible and more cost-effective solution for networked machinery and devices. Multipath transmission refers to a network host's capacity to deliver a single data stream through many network pathways at the same time. Today's mobile gadgets, for example, come with more than one network interface such as LTE and WiFi as shown in Figure 1. Using many network routes at the same time has two distinct advantages. To begin with, multipath transmission allows a host to completely exploit the bandwidth capacity of several network pathways, resulting in significantly increased throughput. If LTE and WiFi deliver 100 Mbps and 150 Mbps, respectively, the overall throughput employing multipath transmission can reach 250 Mbps [1]. Second, because the loss of one network path may be compensated for by sending over another network path, multipath transmission offers an extremely dependable data link. For example, a mobile device's LTE connection can be maintained even if it travels out of the WiFi range.

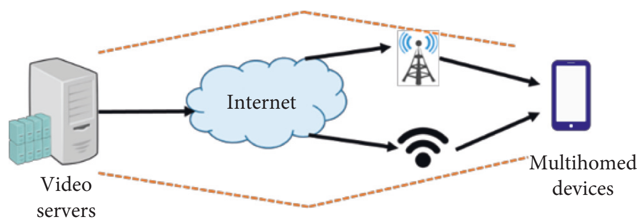

Figure 1: Multipath streaming over wireless networks.

The proliferation of wireless networks has resulted in a rapid increase in mobile video traffic. Multipath protocols at the transport layer are critical for maintaining network traffic flow management, congestion control, and fairness. When bandwidth is constrained, numerous interfaces are employed to transmit data, resulting in improved bandwidth aggregation [2]. CMT has a number of advantages in video transmission, including load balancing, throughput improvement, bandwidth aggregation, and improved dependability.

By means of asymmetric channels with varied features are vulnerable to fluctuations in heterogeneous wireless networks, "blind" round-robin technique for scheduling data paths over these networks will almost certainly produce major data delivery difficulties [3]. For reordering, the receiver side must keep a large number of out-of-order data pieces. As a result, CMT frequently experiences major receiver buffer blockage issues, which reduces transmission efficiency. Mobile devices' rising computer power and storage capacity are opening up new possibilities for multimedia applications maintenance and improvement. The capacity of IP access networks is advantageous for the dissemination of multimedia sources like as voices and videos, as compared to traditional mobile networks. The real-time nature of multimedia material dissemination, on the other hand, necessitates a high level of bandwidth, latency, and loss. These criteria have a big influence on the performance of the underlying networks and protocols [4]. The major contributions of the proposed work are as follows:

(i) The assumption that the transport layer resources at each destination address are autonomous creates a manageable framework for modelling CMT

(ii) Additionally, flawless scheduling is expected in order to overlook the consequences of receiver reordering

This paper is structured as follows. Section 2 briefly explains the existing literature associated with multipath transmissions with CMT with drawbacks. The proposed framework for efficient video transmission over wireless networks is described in Section 3 followed with simulations and results in Section 3. The concluding remarks are presented in Section 4.

2. Related Work

The IETF has standardized the multipath TCP (MPTCP) protocol as an appropriate option for multipath data delivery. MPTCP is a protocol that extends traditional TCP by establishing multiple subflows across multiple interfaces for a given application. It has been revealed to be well-suited with existing networks [5], by achieving robustness and excellent effectiveness in datacenter [6] and heterogeneous wireless networks [7]. Users may access various access points over a heterogeneous wireless network, which has become vital for 5G communication technology networks. Multipath concurrent transmission technology, according to relevant research [8, 9], may effectively increase wireless network transmission performance. One of the issues is receiver buffer blockage that is investigated by improving CMT's quality of service by implementing a suggested retransmission path selection mechanism [10].

Poor flow splitting method may increase MCT delay and significantly impair transmission throughput based on irregularity and time variation properties of heterogeneous wireless networks. As a result, choosing the best flow splitting approach is critical. Multipath flow splitting technology has been the subject of substantial research at many levels. The fundamental goal of the proposed framework is to handle this difficulty, as packet transmission scheduling plays a crucial role in the event of differences in multipath characteristics. The scheduling mechanism is in charge of sending packets from the sending buffer down the correct path. The packet reordering at the receiver is minimized, which leads to reduction in time of transmission, owing to this correct routing. Several packet transmission algorithms are bandwidth aware scheduler (BAS) [11], on-demand scheduler (ODS) [12], adaptive CMT [13], weighted round-robin (WRR) [14], ELBA [15], and EVIS [16].

Nonetheless, in heterogeneous wireless networks, significant bit error rates are unavoidable, and forward error correction (FEC) can still be used to improve video streaming quality shown in Figure 2. Tsai et al. [17] present a CMT control method which appropriately modifies length of the FEC blocks and delivers data incorporated over several routes at the same time. A delay-sensitive multipath FEC technique is considered by Chilamkurti et al. [18]. For the basis of an assessment of available bandwidth and some of the quantitative analytical models, the authors optimized FEC redundancy, length of FEC blocks, and transmission rate on each link. In [19, 20], the authors proposed an adaptive FEC encoding and distributing technique aimed at CMT video transmissions.

Go et al. [21] presented a streaming method for multihosted environment to deliver HTTP adaptive streaming ability with high quality over heterogeneous wireless networks that can utilize both TCP and UDP. Xu et al. [22] looked at network resource fairness and presented a unique "cross-layer fairness-forced concurrent multipath transfer strategy" based on SCTP to boost video transmission speed. Literature [23] developed data scheduling for MVT based on priorities to reduce bandwidth utilization while maintaining preferred broadcast qualities with delay restrictions. Wu et al. [24] presented a frame-level delay model for MVT and multipath approach for HD video transmission with delay constraints ensuring delay performance, with the goal of minimising distortion within the stringent delay. The transmission challenge of region of interest coded

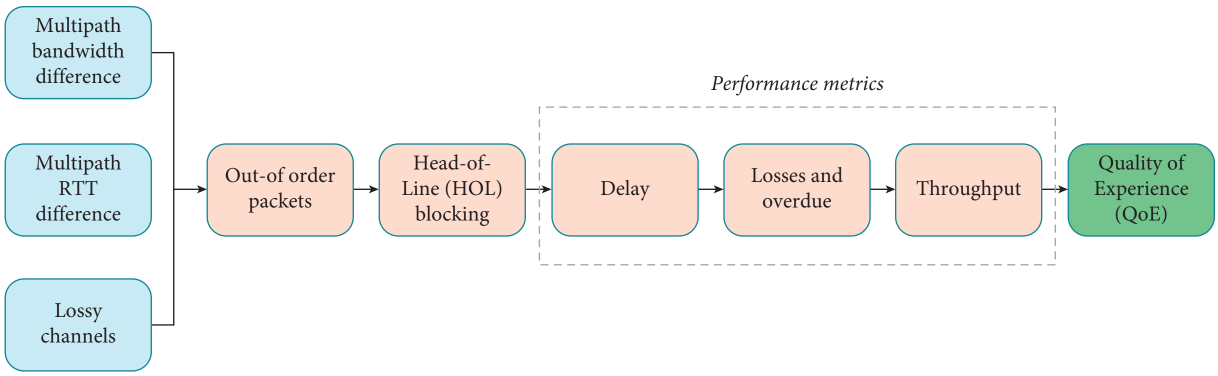

FIGURE 2: Multipath transmission challenges in wireless video streaming applications.

multihomed devices was studied by Wu et al. [25]. They created a packet-scheduling control mechanism using the ROI detector and frame splitter to provide balance between transmission latency and distortion. In order to overcome these issues, a novel framework based on CMT for heterogeneous networks is proposed. The proposed work has very less packet loss, and the performance of framework is also increased due to dynamic path selection.

3. Proposed Methodology

Multihomed data transmission over heterogeneous wireless networks is being driven by the exponential rise of mobile videos streaming over the cloud. Figure 3 depicts the suggested architecture for scheduling using concurrent multipath transmission. This framework can be divided into three sections. The "Paths Map" is the initial phase, and it collects information such as bandwidth, latency, path loads, and rate of packet losses for each path between receiving and sending terminals. The receiver allows the transmission details to the sender. The broadcast variables for every paths such as bandwidth, latency, packet loss rate, and path load are estimated in the second stage, dubbed "path score estimator," to choose the optimum path to transport future packets. The path scores are calculated based on these parameters for each terminal. In the third phase, dubbed "best path selection," the path with high path score is chosen for every packet to be sent. In order to increase packet transmission performance, a selection criterion is established.

The present CMT uses a single common sender buffer, making getting communication information for each individual route unfeasible. In the meanwhile, transmission blockage due to the sender buffer can occur. Once data packets are delivered to the receiver end, they are held in sender buffer and given the unresolved state until the sender gets acknowledgements. When there is a large variation in transport capacity across pathways, the common sender buffer can quickly fill up with data packets that are labelled on the slow paths [26]. Even if the present congestion and flow management systems permit, no additional data packets on the best path will be delivered under this case. Based on the proposed architecture, path quality can be formulated as

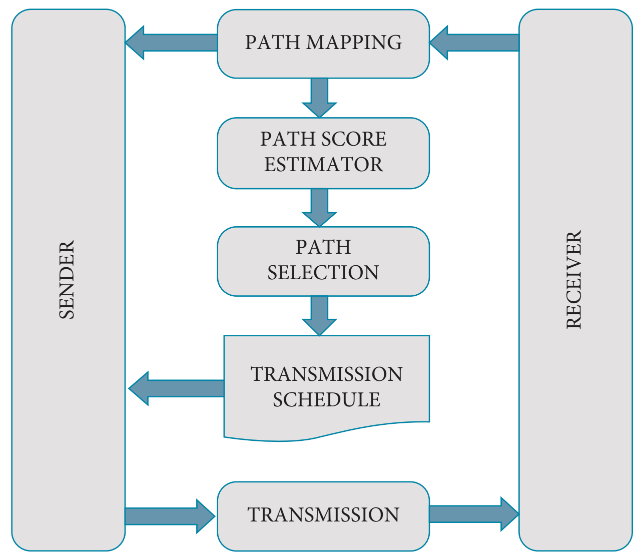

FIGURE 3: Proposed streaming architecture for best possible path selection.

$$Q_x = \frac{T_i - T_j}{\text{size of the buzzer}}, \tag{1}$$

where T_i and T_j are the time taken for sending and receiving data from buffers. Data are allocated to various pathways based on the estimated data delivery capabilities of each path. The congestion window (congestion control), announced receiver window (*rwnd*), and buffer size of the sender all confine the sender while transmitting new data is given in

$$D = \min\left(\sum_{i=1}^{m} (cwnd_i - \text{out}_{\text{data}}), rwnd\right). \tag{2}$$

When packet loss happens during concurrent multipath transfer, the loss phenomena affect the current path's transmission efficiency by dramatically lowering the *cwnd*. Meanwhile, the current technique does not distinguish between random packet losses and congestion losses in wireless networks [8]. The time it takes to identify a timeout packet in a route failure reduces transmission efficiency. Finally, there is a clear need to develop new ways for dealing with packet loss more effectively. We immediately packetize the video frame on the sender side and then send in a rush. The subsequent immediate transmitting rate will very certainly exceed the link's instantaneous capacity. As a result, packets form a backlog in the bottleneck. On the receiving end, the calculation of capacity by dividing the time taken just passed by the result of the frame size. The receiver transmits a brief feedback packet to the source, and the sender utilises the most recent feedback to forecast the available bandwidth for resulting iterations.

In this work, the real-world testbed for real-time video transmission is proposed which includes HoloWAN network simulator, front-end multihomed client (transmitter), and back-end server (receiver) shown in Figure 4. The transmitter and receiver both use the Linux operating system. The transmitter and receiver are linked to the HoloWAN network simulator's Port1 and Port2 to imitate the real-world network state [27]. We encode the test video sequences, and it is transmitted to the sending buffers; following that, the encoded video information may be transferred to the receiver simultaneously through different pathways [28, 29]. For data transfer, the user datagram protocol (UDP) is used.

The load balancing algorithm can disable a path depending on its quality without the need for a separate mechanism, and the flowchart is shown in Figure 5. When a path's scheduling weight is dropped to a very tiny number close to zero, the path is deactivated. Because of the load balancing method, if a path does not operate well, the transmit path progress pointer of that path does not move ahead, and the scheduling weight of that path continues to decrease. The path can be detected as a low-quality path and deactivated if it does not operate even with a minor load (i.e., small scheduling weight).

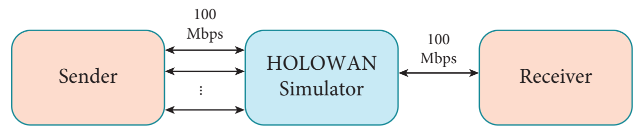

Figure 4: Workflow for testbed application.

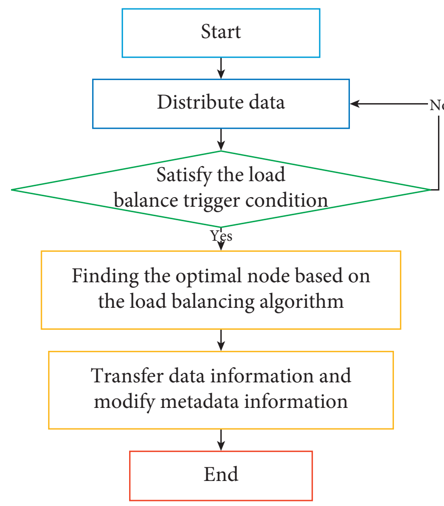

Figure 5: Flowchart of the load balancing algorithm.

4. Results and Discussion

Higher data transmission capacity cannot necessarily eliminate visual channel distortion, which is a unique aspect of video streaming. Allocating subflow to a communication link with abundant capacity and a long propagation delay, for example, increases throughput but lowers average video quality. This is owing to the fact that there will be a large number of late packets on this communication line. Figure 6 represents the average energy consumption of existing literature. But this parameter is not considered in this work since we adapt only for path selection for video streaming over heterogeneous wireless networks. The multipath transmission protocol must ensure that all active pathways are fully functional. If the communication quality of a particular way suddenly deteriorates, packets assigned to that path will be delayed or lost, lowering the overall throughput. To circumvent this, the MP layer should label the low-quality link as inactive, and no packets should be scheduled to inactive pathways. In addition, if the communication quality via that way improves, the presently inactive path should be reactivated. The load balancing algorithm can disable a path depending on its quality without the need for a separate mechanism. When a path's scheduling weight is dropped to a very tiny number close to zero, the path is deactivated. The transmit path progress pointer of a path that is not working properly does not move ahead, and the scheduling weight of that path does not change.

The experimental results show that the dynamic path selection method can increase the performance of wireless networks to handle with failures and minimize packet loss rate. The frequent path selection and scheduling will increase network delay to some extent, as calculation of path weights and frequent path detection will affect the network's overall performance. We estimated the change in the average throughput of the whole network at different number of subflows, as shown in Figures 7 and 8. It can be observed that when the scheduling time is increased, the network's average throughput begins to climb and then falls. It basically does not alter after you have reached a certain point. The time cost of proposed algorithm is represented in Figure 9.

The multipath transmission protocol must ensure that all active pathways are fully functional. If the communication quality of a particular way suddenly deteriorates, packets assigned to that path will be delayed or lost, lowering the overall throughput [30, 31]. To circumvent this, the MP layer should label the low-quality link as inactive, and no packets should be scheduled to inactive pathways. In addition, if the communication quality via that way improves, the presently inactive path should be

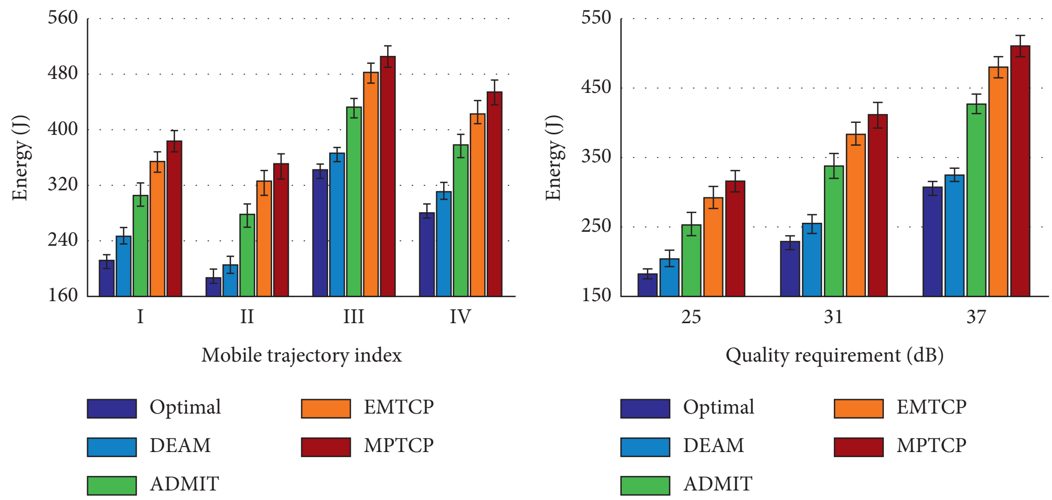

Figure 6: Comparison of energy consumption [16].

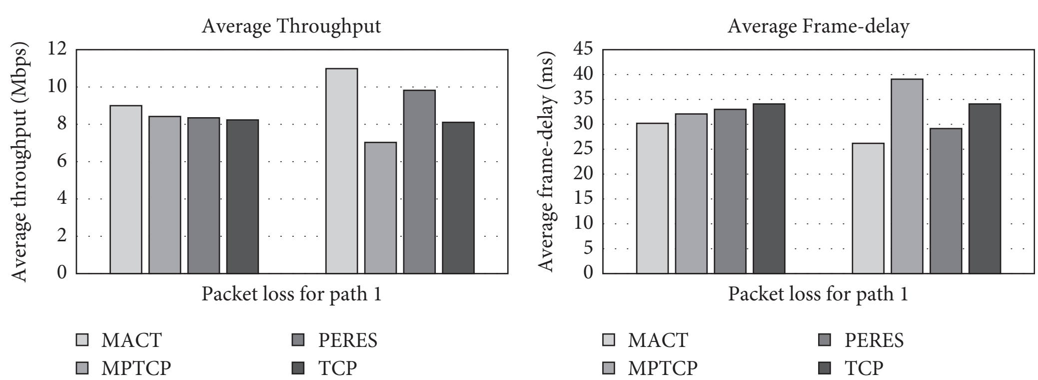

Figure 7: Average throughput and average frame delay for path 1 in the proposed architecture.

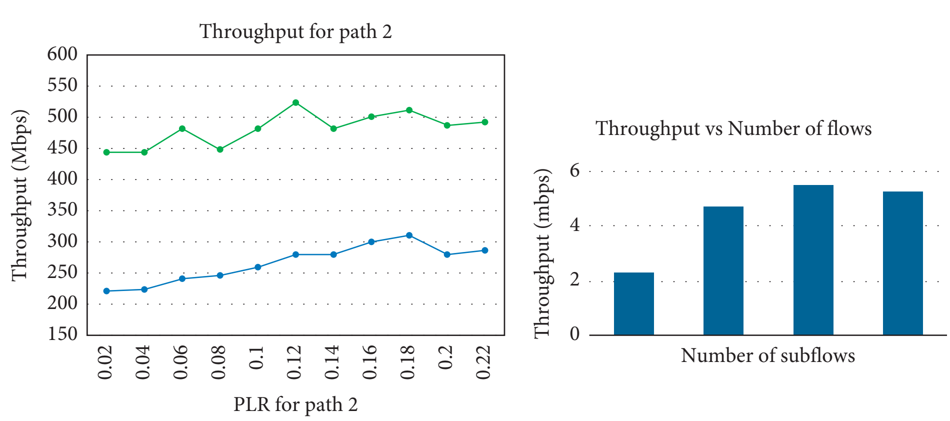

Figure 8: Average throughput for path 2 and number of subflows used in the proposed architecture.

reactivated [32, 33]. The efficiency of the proposed approach is examined in order to evaluate the proposed factor (path score). Path score is used to distribute video packets across two pathways by determining which path is the best for each packet. Then, in terms of bandwidth, a comparison is made between the proposed framework— MACT and MPTCP. Path2 has a variable packet loss rate ranging from 1% to 15%, while path1 has a

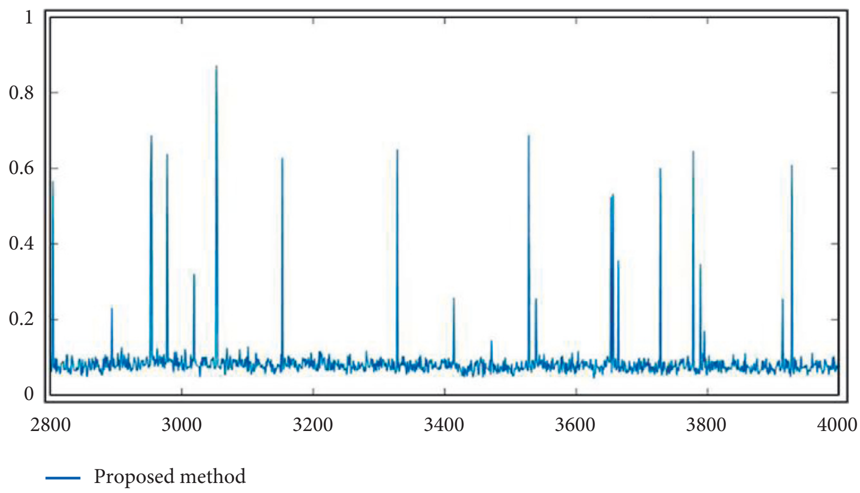

Figure 9: Average run-time of the proposed framework.

Table 1: Parameters for proposed framework simulation.

Parameter	Size
Maximum segment size	1600 bytes
Sender buffer size	64 kb
Receiver buffer size	64 kb
Queue size	50 packets
Network traffic	TCP and UDP
Bandwidth	10 mbps
Simulation time	178 sec

consistent packet loss rate of 1%, according to our simulation. The simulation experiment lasts 178 seconds shown in Table 1.

5. Conclusion

A wireless device is increasingly likely to be linked with several access networks using either heterogeneous networks such as GPRS, 3G, WiFi, WiMax, or some homogeneous technology. Because of the characteristics of multihomed devices, the possibility of frequent disconnections and bandwidth fluctuations present major challenges for researchers as well as mobile application developers. The path redundancy provided by the relevance of the multihoming protocol is obvious. When a link/path fails or a temporary loss occurs, multihoming systems, which allow a host to consider numerous IP addresses, provide significant benefits. An efficient video transmission technique is proposed in this work, which is meant to provide greater levels of throughput and SSIM performance to improve the QoE of real-time video streaming services across multipath networks with packet delivery failures. In future, the proposed technique can be implemented on real-time systems such as FPGAs or GPUs to improve the performance and flexibility.

Data Availability

There are no relevant data to be made available.

Conflicts of Interest

The authors declare no conflicts of interest.

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