VIDEO STREAMING SERVICES OVER THE INTERNET VIA TCP

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Abstract: **TCP is widely used in commercial media streaming systems, with recent measurement studies indicating that a significant fraction of Internet streaming media is currently delivered over HTTP/TCP. These observations motivate us to develop analytic performance models to systematically investigate the performance of TCP for both live and stored media streaming. We validate our models via <i>ns</i> simulations and experiments conducted over the Internet. Our models provide guidelines indicating the circumstances under which TCP streaming leads to satisfactory performance, showing, for example, that TCP generally provides good streaming performance when the achievable TCP throughput is roughly twice the media bitrate, with only a few seconds of startup delay.**

Keywords: Streaming, Live Streaming. Buffering, Bandwidth, Data Packets, Congestion Control Algorithms.

1. INTRODUCTION

Figure 1. describes an architecture of TCP Video Streaming. Video streaming over TCP networks involves several key processes to ensure smooth delivery of video content. Here's an overview of how it's achieved:

a) Connection Establishment:

TCP begins with a three-way handshake, where the client initiates a connection by sending a SYN packet to the server.

The server responds with a SYN-ACK packet, indicating acknowledgment of the client's request and readiness to establish a connection.

Finally, the client sends an ACK packet, confirming the connection establishment. Now the TCP connection is established, and data transfer can begin

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b) Segmentation:

Video data is divided into smaller segments or packets for transmission over the network. These segments are typically of fixed size, depending on the Maximum Segment Size (MSS) negotiated during connection setup.

c) Reliable Data Transfer:

TCP ensures reliable data transfer by using sequence numbers, acknowledgments, and retransmission mechanisms. Each segment sent by the server is assigned a sequence number. The client acknowledges received segments by sending acknowledgment packets (ACKs). If a segment is lost or corrupted during transmission, TCP retransmits it based on timeout or duplicate ACKs.

d) Flow Control:

TCP employs flow control mechanisms to prevent the sender from overwhelming the receiver with data. The receiver advertises it receive window size, indicating the amount of data it can accept without overflowing its buffer. The sender adjusts its transmission rate based on the receiver's advertised window size to avoid congestion.

e) Congestion Control:

TCP dynamically adjusts its transmission rate based on network conditions to prevent congestion. Algorithms like TCP congestion avoidance and TCP Tahoe/Reno adjust the sender's congestion window size based on packet loss and round-trip time (RTT) measurements. Congestion control algorithms aim to utilize available network bandwidth efficiently while avoiding network congestion.

f) Rate Adaptation:
TCP-based video streaming often incorporates rate adaptation mechanisms to adjust the video bitrate dynamically based on network conditions. Adaptive bitrate streaming protocols like HLS (HTTP Live Streaming) or MPEG-DASH (Dynamic Adaptive Streaming over HTTP) switch between different quality levels (bitrates) of video segments according to available bandwidth and client playback capabilities.

g) Quality of Service (QoS) Management:
QoS mechanisms prioritize video traffic to ensure consistent quality and minimize interruptions. TCP-based video streaming applications may utilize QoS techniques at the network level to allocate sufficient bandwidth and minimize latency for video traffic.

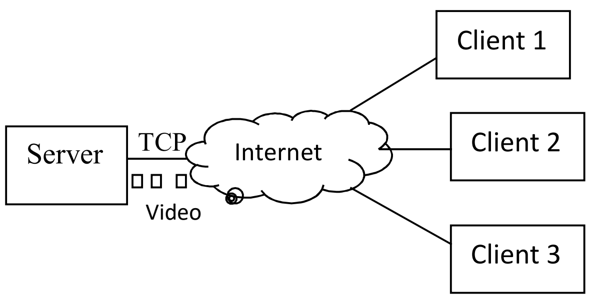

Figure 1. TCP Video Streaming Architecture

Advanced TCP mechanisms for wireless environments are designed to address the unique challenges posed by wireless networks, such as high error rates, variable latency, and bandwidth fluctuations. Here are some advanced TCP techniques tailored for wireless environments:

a) TCP Variants:

TCP Vegas: Vegas is a congestion control algorithm that uses the variation in the delay (instead of packet loss) as an indication of congestion. It works well in wireless networks where packet loss may not always accurately reflect congestion.

b) TCP Westwood: Westwood is an enhancement to TCP Tahoe/Reno that improves performance in wireless networks by using more accurate estimates of available bandwidth and less aggressive congestion control.

c) Fast Retransmit and Fast Recovery: TCP's fast retransmit and fast recovery mechanisms help to quickly recover from packet losses in wireless networks. Upon detecting duplicate acknowledgments, TCP triggers a retransmission of the missing packet without waiting for a timeout.

d) Selective Acknowledgment (SACK): SACK allows the receiver to acknowledge out-of-order packets and provides the sender with information about which packets have been received successfully. This helps in reducing unnecessary retransmissions and improving throughput, particularly in wireless networks where packet reordering is common.

e) Explicit Congestion Notification (ECN): ECN allows routers to notify endpoints of impending congestion without dropping packets. TCP can react to ECN signals by reducing its sending rate, which can be beneficial in wireless networks to avoid congestion collapse and improve fairness.

f) Buffer Management: Efficient buffer management is crucial in wireless networks to cope with variable link conditions and reduce bufferbloat. Techniques such as Adaptive Receive Window and Dynamic Buffer Sizing adjust buffer sizes dynamically based on network conditions to optimize performance.

g) Cross-Layer Optimization: Cross-layer optimization involves coordination between different layers of the network stack to improve TCP performance in wireless environments. For example, the MAC layer can provide feedback to TCP about channel conditions, allowing TCP to adapt its behavior accordingly.

h) **Mobile IP and Handover Support:** Mobile IP protocols like Mobile IPv6 or Hierarchical Mobile IPv6 (HMIPv6) handle the mobility of devices between different networks. Advanced TCP mechanisms may be designed to minimize disruption during handovers and ensure seamless connectivity.

i) **Wireless-specific Congestion Control:** Some TCP variants are specifically designed for wireless networks, such as TCP-friendly Rate Control (TFRC). TFRC adjusts its sending rate based on feedback from the receiver, taking into account the characteristics of wireless links.

j) **Cross-layer Adaptation with Rate Control:** Adaptive streaming protocols, such as MPEG-DASH or HLS, can work in conjunction with TCP to adapt video streaming quality based on network conditions, ensuring smooth playback in wireless environments.

2. CONGESTION CONTROL ALGORITHMS IN THE INTERNET:

Congestion control algorithms play a crucial role in managing network congestion and ensuring fair and efficient use of network resources in the Internet.

Quick UDP Internet Connections (QUIC) is a transport layer protocol developed by Google to address some of the limitations and performance bottlenecks of traditional TCP-based communication over the Internet. Here's more information about QUIC:

a) **Protocol Overview:** QUIC is a transport layer protocol that runs over UDP (User Datagram Protocol) instead of TCP. This allows QUIC to achieve lower latency and faster connection establishment compared to TCP. QUIC integrates features of both TCP and TLS (Transport Layer Security) into a single protocol, providing encryption, reliability, and congestion control.

b) **Key Features:** Faster Connection Establishment: QUIC eliminates the TCP handshake and TLS negotiation phases by combining them into a single handshake, resulting in reduced connection establishment latency.

c) **Multiplexing:** Like HTTP/2, QUIC supports multiplexing multiple streams over a single connection. This enables concurrent transmission of different data streams, improving overall efficiency.

d) **Connection Migration:** QUIC allows for seamless migration of connections between network interfaces or IP addresses, such as switching from Wi-Fi to cellular networks, without interrupting ongoing data transfers.

e) **Forward Error Correction (FEC):** QUIC includes built-in FEC mechanisms to recover from packet loss more efficiently, reducing the need for retransmissions and improving reliability.

f) **Congestion Control:** QUIC employs congestion control mechanisms similar to TCP, adapting its transmission rate based on network conditions to prevent congestion and ensure fair resource allocation.

g) **Security:** QUIC integrates encryption and authentication features from TLS directly into the protocol, providing confidentiality, integrity, and authenticity of data exchanged between endpoints. QUIC uses Datagram Transport Layer Security (DTLS) 1.3, which provides forward secrecy and protects against various attacks, including eavesdropping and tampering.

h) **Deployment:** Google started deploying QUIC in its products, including Google Search, YouTube, and Google Chrome, to improve performance and reliability. QUIC gained widespread attention and support from other major web browsers and platforms. It is standardized as HTTP/3 by the IETF (Internet Engineering Task Force).

i) **HTTP/3:** HTTP/3 is the latest version of the Hypertext Transfer Protocol (HTTP) that uses QUIC as its transport layer protocol. HTTP/3 offers significant performance improvements over HTTP/2 by leveraging QUIC's features such as faster connection establishment, multiplexing, and improved congestion control.

j) **Challenges:** Despite its benefits, QUIC adoption faces challenges, including compatibility with existing infrastructure, deployment in enterprise networks, and potential network congestion issues.

3. CONCLUSION

The paper has discussed about the TCP Video Streaming and the congestion control algorithms used in the internet. Though TCP has certain limitations with video streaming, the buffer management schemes and congestion control methods involved in it improves the video streaming which is still a challenging problem to be solved.

QUIC's integration of encryption and authentication features directly into the protocol enhances security, providing confidentiality, integrity, and authenticity of data exchanged between endpoints. Its support for forward error correction (FEC) and seamless connection migration further improves reliability and robustness, making it suitable for various network environments, including mobile networks and data centers.

In conclusion, this paper represents a study on various congestion control algorithms to improve video streaming services.

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