In-depth Analysis of Video Streaming Performance over varying network bandwidth conditions

Shantanu Mallik, Kajol Dwivedi, Harshit Raj, Shaswat Kaushik

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Abstract

This report delves into an empirical analysis of video streaming performance, emphasizing buffer health as influenced by network speed across various video resolutions. Data was meticulously gathered via a Python scraper for YouTube's 'Stats for Nerds' under a spectrum of network conditions from 2G to WiFi 802.11ac. The goal is to discern the streaming quality, specifically buffer health, that can be expected by users under different network constraints.

1 Introduction

The proliferation of video streaming has made understanding its performance under different network conditions a subject of utmost importance. Buffer health, representing the duration of video pre-loaded and ready to play, stands as a critical measure of a seamless viewing experience. This study presents a detailed analysis based on data captured from YouTube's built-in diagnostic tool, 'Stats for Nerds.'

2 Methodology

Using a Python scraper, key streaming metrics were logged from YouTube's 'Stats for Nerds' under artificially constrained network environments created using the Network Link Conditioner on macOS. The simulations encompassed network speeds from low-end 2G to high-end WiFi 802.11ac, covering a broad spectrum of typical user scenarios.

3 Analysis of Streaming at High Resolutions

3.1 2K Streaming Analysis

For 2K resolution, buffer health varied significantly with network speed. At speeds over 25 Mbps, buffer health was consistently above 15 seconds, suggesting a comfortable viewing experience with minimal risk of interruption. However, as speeds dipped below this mark, a corresponding drop in buffer health was observed, indicating potential for frequent buffering pauses. This variability highlights the challenge of delivering high-resolution content over slower connections and the importance of adaptive streaming techniques.

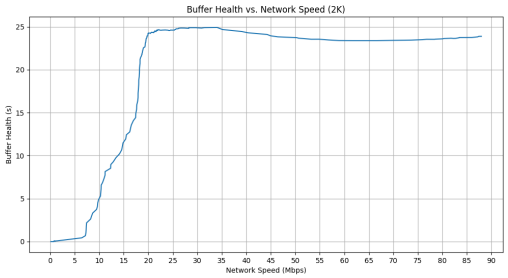

Figure 1: 2K Video Streaming buffer health across network bandwidths

3.2 4K Streaming Analysis

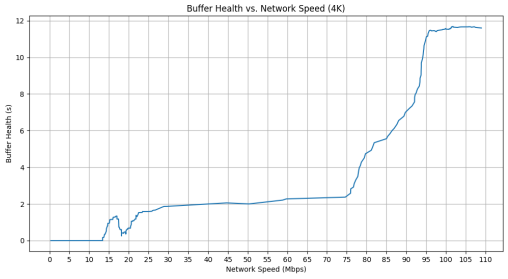

Figure 2: 4K Video Streaming buffer health across network bandwidths

The demands of 4K streaming are even more stringent, as reflected in the data. Network speeds above 40 Mbps were required to achieve a buffer health exceeding 10 seconds, a threshold below which viewers

may experience interruption. The steep decline in buffer health below this speed points to the necessity of not only high-speed internet but also a consistent and stable connection to ensure a satisfactory 4K streaming experience. Any fluctuation in speed can lead to immediate and noticeable degradation in buffer health, underscoring the need for reliable high-bandwidth networks for streaming ultra-high-definition content.

4 Performance Analysis at Full HD and Lower Resolutions

4.1 1080p Streaming Performance

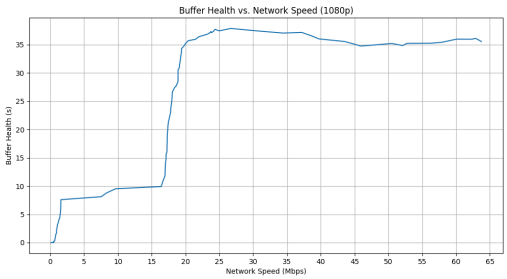

Figure 3: 1080p Video Streaming buffer health across network bandwidths

At the full HD resolution of 1080p, the streaming performance was notably better across a wide range of network speeds. Even at speeds as low as 5 Mbps, buffer health remained above 20 seconds, suggesting that 1080p is a more accessible quality option for users with varying internet speeds. This resilience is beneficial for streaming services aiming to reach a broader audience without compromising on video quality.

4.2 720p and 480p Streaming Performance

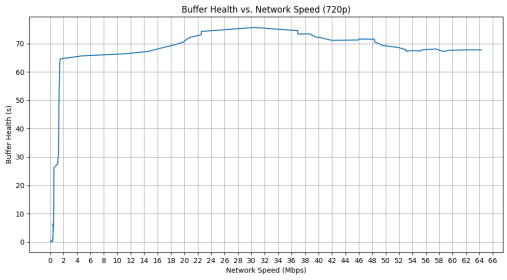

Figure 4: 720p Video Streaming buffer health across network bandwidths

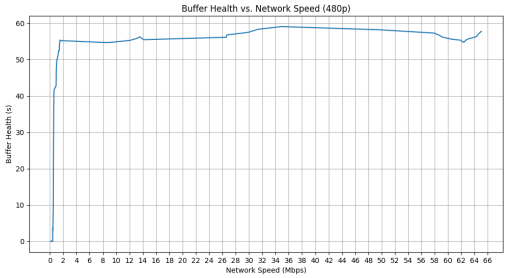

Figure 5: 480p Video Streaming buffer health across network bandwidths

The 720p and 480p resolutions showed excellent buffer health across all network speeds, rarely dropping below the 20-second threshold. This robust performance makes these resolutions suitable for users with less reliable internet connections, such as mobile data users or those in areas without access to high-speed broadband. The data also suggests that these resolutions can be confidently used for streaming content without significant risk of playback interruption, making them ideal for content providers targeting a wide array of devices and network conditions.

4.3 360p Streaming Performance

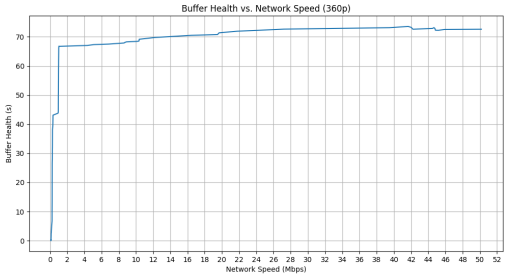

Figure 6: 360p Video Streaming buffer health across network bandwidths

The 360p resolution offered the highest degree of reliability, with buffer health consistently high across the spectrum of network speeds tested. This resolution's low data requirement ensures that viewers can enjoy uninterrupted streaming even under the most constrained network conditions. It represents the most inclusive streaming option, ensuring accessibility in regions with limited internet infrastructure.

5 Discussion

Across all resolutions, a clear correlation is evident between network speed and buffer health, with higher resolutions exhibiting a greater sensitivity to speed

variations. While lower resolutions like 360p offer excellent buffer stability across network speeds, the higher resolutions demand a more robust and faster network to maintain a similar level of buffer health. The data suggests a trade-off that content providers and streaming services must navigate: balancing the desire for high-resolution content with the practical limitations of viewers' network speeds.

6 Conclusion and Recommendations

This analysis underscores the necessity for streaming services to implement adaptive streaming protocols that dynamically adjust video quality based on real-time network speed. For end-users, choosing a resolution that aligns with their network capabilities is crucial for avoiding interruptions. As streaming technology evolves, developing more efficient codecs and streaming algorithms will be pivotal in enhancing the viewer experience across diverse network environments.