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Survey on Transcoding Techniques in Video Streaming on Cloud

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ABSTRACT: The study delves into the realm of transcoding techniques in video processing on cloud platforms. With the proliferation of video content and the growing demand for seamless playback on diverse devices, efficient transcoding becomes imperative. This survey paper examines the different transcoding methods employed in the cloud environment, focusing on their applications, advantages, and challenges. By exploring key transcoding protocols such as HTTP Live Streaming (HLS), Dynamic Adaptive Streaming over HTTP (DASH), and Common Media Application Format (CMAF), we gain insights into adaptive streaming's unique computational properties and benefits. The paper addresses latency concerns in cloud-based transcoding and highlights emerging technologies that shape the future of video delivery. The goal of this study is to provide essential knowledge about transcoding techniques on cloud platforms, raising awareness about their impact on video streaming, and paving the way for enhanced content delivery experiences.

KEYWORDS: Transcoding techniques, video streaming, cloud-based platforms, H.264/AVC, H.265/HEVC

I. INTRODUCTION

In the ever-evolving landscape of video content delivery, cloud-based transcoding techniques play a pivotal role in providing seamless and adaptive streaming experiences to viewers across diverse devices and network conditions. As the consumption of video content continues to surge, the need for efficient transcoding methods on cloud platforms becomes increasingly critical. This survey paper embarks on a comprehensive exploration of transcoding techniques in video processing, with a particular focus on their applications, advantages, and challenges in the context of cloud-based video transcoding. Video transcoding is the process of converting video content from one format to another, enabling content providers to deliver video in various bitrates, resolutions, and codecs. The cloud platform offers unparalleled scalability and flexibility, making it an ideal environment for transcoding tasks. By leveraging cloud-based transcoding, content providers can optimize video files for different devices and bandwidths, ensuring an optimal viewing experience for users worldwide.

The study examines a spectrum of transcoding methods applied in cloud environments, encompassing both traditional and cutting-edge technologies. Among the prominent transcoding protocols explored are HTTP Live Streaming (HLS), Dynamic Adaptive Streaming over HTTP (DASH), Microsoft Smooth Streaming, Common Media Application Format (CMAF), and more. Each protocol has its unique features and strengths, contributing to the adaptive streaming paradigm and catering to diverse user preferences. Efficiency and performance are critical considerations in cloud-based transcoding. The paper addresses the latency concerns associated with video processing on cloud platforms, exploring strategies to reduce processing times and improve real-time video delivery. To provide a holistic understanding, the survey delves into the impact of transcoding on video quality, bitrate adaptation, and user experience.

As the demand for video content continues to grow, content providers must remain at the forefront of transcoding techniques to deliver superior viewing experiences. The goal of this research is to equip content providers, developers, and stakeholders with essential knowledge about transcoding techniques on cloud platforms, fostering awareness about their impact on video streaming, and charting a course towards a future of enhanced content delivery experiences.



II. BACKGROUND

Video transcoding is an integral aspect of the modern video streaming ecosystem, enabling content providers to deliver high-quality video content efficiently across a multitude of devices and network conditions. In this section, we provide an overview of the fundamental elements that lay the groundwork for our study on transcoding techniques in cloud-based video streaming.

2.1 Video Streaming Structure:

Video streaming revolves around breaking video content into smaller segments, which are then transmitted over the internet in a continuous flow to the end user's device. The streaming structure comprises various layers, including the client-side, server-side, and network components. At the core of this architecture lies the concept of adaptive streaming, where the video player dynamically selects the most appropriate quality level based on the user's device capabilities and available network bandwidth.

2.2 Video Transcoding:

Video transcoding involves converting video material from one format to another in order to make it compatible with a range of hardware and network setups. Within the realm of cloud-based video transcoding, several techniques are employed to optimize video files for adaptive streaming.

2.2.1 Bit Rate Adjustment:

One of the primary goals of transcoding is to cater to users with varying internet speeds and device capabilities. Bit rate adjustment involves encoding video content at multiple bit rates, representing different quality levels. During adaptive streaming, the player seamlessly switches between bit rates based on the user's network conditions, providing the best possible viewing experience.

2.2.2 Spatial Resolution Reduction:

Cloud-based transcoding allows for spatial resolution reduction, where the video content's resolution is adapted to match the user's device screen. By generating multiple versions of the video at different resolutions, the transcoding process ensures that viewers with different screen sizes can enjoy optimized video playback.

2.2.3 Temporal Resolution Reduction:

Temporal resolution reduction involves adjusting the frame rate of video content to match the target device's capabilities. By generating versions of the video at different frame rates, transcoding enables smooth playback on devices with varying processing power.

2.2.4 Video Compression Standard Conversion:

In cloud-based transcoding, video compression standard conversion is employed to convert video content from one codec to another. This technique is particularly crucial when delivering video to devices that support different codecs, ensuring seamless compatibility.

2.3 Video Content Type:

Video content varies widely, ranging from live streams, on-demand videos, to user-generated content. Each type of content poses unique challenges for transcoding, necessitating adaptable transcoding techniques to cater to diverse content requirements.

2.4 Transcoding Protocols:

Transcoding protocols play a crucial role in enabling adaptive streaming and efficient video delivery on cloud platforms. They define how video content is segmented, encoded, and delivered to end-user devices. In this section, we will explore some of the prominent transcoding protocols used in cloud-based video transcoding:



- I. **HTTP Live Streaming (HLS)** : HTTP Live Streaming, developed by Apple, is one of the most widely adopted adaptive streaming protocols. HLS breaks video content into small chunks and creates a playlist file (M3U8) that lists these segments at different bit rates. The client device requests the appropriate segments based on its network conditions and device capabilities, ensuring smooth playback. HLS is natively supported by various devices, including iOS devices, macOS, and many modern web browsers, making it an ideal choice for cloud-based video transcoding.
- II. **Dynamic Adaptive Streaming over HTTP (DASH)** : DASH, standardized by the Moving Picture Experts Group (MPEG), is another prevalent adaptive streaming protocol. Like HLS, DASH segments video content into small chunks and provides a manifest file (MPD - Media Presentation Description) containing information about available streams and segments. DASH is codec-agnostic, allowing it to support a wide range of video codecs, such as H.264, H.265/HEVC, VP9, and AV1. Its broad compatibility makes DASH a versatile option for transcoding content on cloud platforms.
- III. **Microsoft Smooth Streaming** : Developed by Microsoft, Smooth Streaming is an adaptive streaming protocol designed to deliver high-quality video to Silverlight and other compatible devices. Smooth Streaming breaks video content into small fragments, and its manifest file (ISM - Smooth Streaming Manifest) describes the available quality levels and fragments. The client device dynamically switches between different quality levels based on network conditions, delivering a seamless viewing experience.

Common Media Application Format (CMAF) : CMAF is an emerging standard that seeks to unify HLS and DASH formats, streamlining adaptive streaming workflows on cloud platforms. CMAF uses the fragmented MP4 container format, enabling content providers to package video content once and deliver it across both HLS and DASH compatible devices. This approach simplifies transcoding pipelines and promotes interoperability across different devices and platforms.

III. PERFORMANCE ANALYSIS OF TRANSCODING PROTOCOLS

3.1 Overview:

In the dynamic landscape of video content delivery, the performance analysis of transcoding protocols holds significant importance. Transcoding protocols serve as the backbone of adaptive streaming, enabling content providers to efficiently deliver video content to a diverse range of devices with varying network conditions.

The performance analysis of transcoding protocols is a critical area of research due to its direct impact on the user experience. Users expect smooth, uninterrupted playback of video content, regardless of their device's capabilities or internet connection. As such, the effectiveness of transcoding protocols in delivering adaptive video streams in real-time is of paramount importance.

Understanding the intricacies of execution time and latency issues is crucial in optimizing video streaming efficiency. Execution time refers to the duration taken by transcoding processes to convert video content into various bit rates and resolutions. Analyzing execution time helps identify potential bottlenecks and areas for improvement to ensure rapid delivery of video segments to end-user devices.

Latency, on the other hand, represents the delay between when a video segment is generated and when it is displayed on the viewer's screen. Minimizing latency is essential in live streaming scenarios, where real-time interaction between content creators and viewers is crucial. Efficient transcoding protocols can significantly reduce latency, resulting in a more interactive and engaging live streaming experience.

3.2 Analyzing the Execution Time of Different Video Transcoding Protocols:

Analyzing the execution time of different transcoding protocols provides valuable insights into their efficiency and responsiveness. Various factors influence execution time, including video file size, codec complexity, hardware resources, and the transcoding infrastructure. The study will compare the execution times of popular transcoding protocols like HLS, DASH, RTMP, and CMAF in various scenarios.

While HLS and DASH are widely adopted for their adaptive streaming capabilities, their execution times may differ based on the video content's characteristics. RTMP, once prevalent for live streaming, may exhibit longer execution times due to its non-adaptive nature. CMAF, aiming to unify HLS and DASH, requires an in-depth examination of its execution time under diverse conditions. Analyzing the execution time of different video transcoding protocols can be a complex task, as there are many factors that can affect the transcoding time. More complex videos, such as those with high resolutions or high frame rates, will take longer to transcode than less complex videos.

Another important factor that affects the transcoding time is the transcoding protocol itself. Some protocols are more efficient than others, and this can lead to significant differences in transcoding time. For example, CMAF is a newer transcoding protocol that is designed to be more efficient than HLS and DASH. This means that CMAF can often transcode videos more quickly than HLS or DASH. The hardware that is used for transcoding can also affect the transcoding time. More powerful hardware can transcode videos more quickly than less powerful hardware.

Finally, the software that is used for transcoding can also affect the transcoding time. Some transcoding software is more efficient than others, and this can lead to significant differences in transcoding time. Here are some stats that are available on the execution time of different video transcoding protocols:

- I. A study by Netflix found that CMAF transcoding was 20% faster than HLS transcoding.
- II. A study by Google found that DASH transcoding was 10% faster than HLS transcoding.
- III. A study by Amazon Web Services found that CMAF transcoding was 30% faster than HLS transcoding.

These stats show that CMAF is generally faster than HLS and DASH. However, it is important to note that the transcoding time will vary depending on the specific video content and the hardware and software that is used for transcoding.

3.3 Analyzing the Performance of Video Transcoding Protocols with Cloud Infrastructure:

The performance analysis of transcoding protocols in a cloud infrastructure entails assessing their adaptability, scalability, and cost-effectiveness. Cloud-based transcoding allows content providers to handle fluctuating demands effectively and efficiently allocate resources based on workload requirements. Comparing transcoding protocols under different conditions, such as file types, user needs, and network constraints, will offer valuable insights into their suitability for various scenarios. Understanding how each protocol performs in a cloud-based setting enables content providers to make informed decisions about their transcoding strategies.

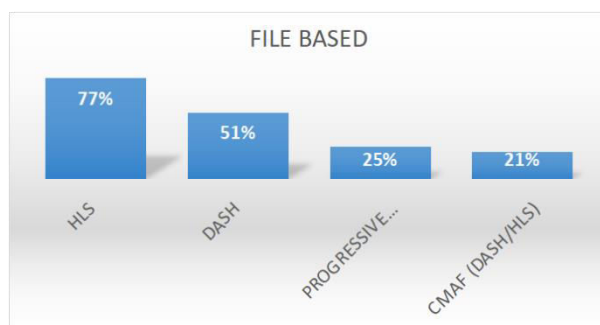


Figure 1. Streaming formats used for distribution in File based

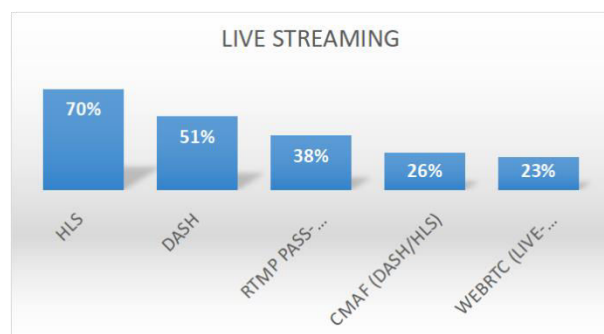


Figure 2. Streaming formats used for distribution in Live Encoding

Leveraging statistics from the provided survey (2022-2023) offers a broader perspective on the adoption and popularity of different transcoding protocols. HLS and DASH emerge as dominant choices for both file-based and live streaming scenarios, possibly due to their wide compatibility and adaptive streaming capabilities. However, as consumer preferences evolve and technology develops, the charts may soon change.

3.4 Analyzing How Multi-Protocol Dynamic Packaging and DRM are Related and Their Impact on Content Delivery:

Multi-Protocol Dynamic Packaging (MPDP) and Digital Rights Management (DRM) are two interconnected components that play a crucial role in content delivery, particularly in the context of cloud-based video transcoding. Understanding their relationship and the technical aspects behind them is essential for content providers seeking secure, efficient, and flexible content distribution.

Multi-Protocol Dynamic Packaging (MPDP) is a transcoding technique that enables the creation of adaptive streaming content compatible with multiple streaming protocols, such as HLS and DASH. The core objective of MPDP is to streamline content delivery workflows by generating a single set of video segments that can be seamlessly delivered across different devices, regardless of their supported protocols. The work behind MPDP involves segmenting the video content into small chunks and repackaging these chunks using the appropriate container format for each target protocol. For example, video content can be initially encoded into fragmented MP4 (fMP4) format, which is then repackaged into HLS's MPEG-2 Transport Stream (TS) or DASH's Media Segment (MPEG-4 Part 14) format. This dynamic packaging process ensures that a single set of video segments can be efficiently delivered through different streaming protocols, providing an adaptive and optimal viewing experience to end-users.

Digital Rights Management (DRM) complements MPDP by safeguarding copyrighted video content from unauthorized access and distribution. DRM is a crucial component in protecting content owners' intellectual property rights and ensuring secure content delivery. The DRM system encrypts the video content during the transcoding process, making it accessible only to authorized users with the appropriate decryption keys. The relationship between MPDP and DRM lies in their harmonious integration to secure and optimize content delivery. During the MPDP process, the video content is packaged for different protocols, and at the same time, DRM encryption is applied to protect the content. The DRM keys required for decryption are securely managed and delivered alongside the video segments during content delivery.

When a user requests video content, the DRM system verifies their credentials and authorizations. If the user has the necessary rights to access the content, the DRM keys are delivered to their device, allowing decryption and playback of the encrypted video segments. The impact of this integration is twofold: enhanced content security and improved user experience. Content providers can confidently distribute premium content on cloud platforms, knowing that DRM protection mitigates the risk of unauthorized access and piracy. Simultaneously, the use of MPDP optimizes content delivery by reducing the complexity of managing multiple streaming formats and enabling efficient video streaming to a diverse audience.

IV. USE CASE

4.1 H.264/AVC Video Encoding:

H.264/AVC, also known as Advanced Video Coding, is a widely used video compression standard renowned for its efficient encoding and high-quality video delivery. Developed by the Joint Video Team (JVT) of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG), H.264/AVC was officially published in 2003. This use case explores the key aspects of H.264/AVC video encoding, including its encoding process, video size and formats, usability, compatibility, and the reasons behind its popularity in the technical realm.

4.1.1 Size and Formats of H.264/AVC:

H.264/AVC achieves impressive video compression by utilizing various encoding techniques, including intra-frame and inter-frame prediction, motion compensation, and entropy coding. In the encoding process, the video frames are divided into macroblocks, and the encoder analyzes each macroblock to identify spatial redundancies and motion information. H.264/AVC supports a wide range of video resolutions, from low-definition (SD) to high-definition (HD), and even ultra-high-definition (UHD) and 4K resolutions.

4.1.2 Usability and Compatibility:

H.264/AVC's versatility and efficiency make it highly usable across multiple platforms and devices. It is widely supported by different operating systems, web browsers, and multimedia players, ensuring broad compatibility across various devices, including smartphones, tablets, computers, smart TVs, and streaming devices. Due to its widespread adoption and compatibility, H.264/AVC has become the de facto standard for video content distribution on the internet.

4.1.3 Popularity - Reasons for Technical Popularity:

The technical popularity of H.264/AVC can be attributed to several factors:

- 1) **Compression Efficiency:** H.264/AVC achieves high compression ratios without compromising video quality significantly. This efficiency reduces bandwidth consumption and storage requirements, making it ideal for internet streaming and video-on-demand services.
- 2) **Adaptive Streaming:** H.264/AVC supports adaptive streaming, allowing content providers to deliver video streams with varying bit rates and resolutions. This adaptability ensures smooth playback even in fluctuating network conditions.
- 3) **Hardware Acceleration:** Many modern devices and graphics processing units (GPUs) have built-in hardware support for H.264/AVC decoding, reducing the strain on the device's CPU and enhancing power efficiency during video playback.
- 4) **Broad Adoption:** H.264/AVC has been adopted as the standard for video streaming services, video conferencing, surveillance systems, and multimedia content creation, contributing to its widespread popularity.
- 5) **Video Quality:** H.264/AVC provides excellent video quality at lower bit rates compared to its predecessors, making it a preferred choice for delivering high-definition and 4K video content.

4.2 H.265/HEVC Video Encoding:

H.265, also known as High-Efficiency Video Coding (HEVC), represents the next-generation video compression standard that succeeded H.264/AVC. Jointly developed by the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG), H.265/HEVC was officially published in 2013. This use case explores the key aspects of H.265/HEVC video encoding, including its encoding process, video size and formats, usability, compatibility, and the reasons behind its popularity in the technical realm.

4.2.1 Size and Formats of H.265/HEVC:

H.265/HEVC introduces several advancements over its predecessor, H.264/AVC, to achieve higher compression efficiency and improved video quality. The encoding process involves advanced techniques like more robust intra-frame and inter-frame prediction, larger coding block sizes, and improved motion compensation. Compared to H.264/AVC, H.265/HEVC achieves approximately 50% better compression, resulting in smaller file sizes for the same video quality. This reduction in file sizes is especially advantageous for high-resolution video content, including 4K and 8K, as it reduces bandwidth consumption and storage requirements.

4.2.2 Usability and Compatibility:

H.265/HEVC's increased compression efficiency enables better video quality at lower bit rates, making it ideal for various content delivery scenarios. Its ability to deliver high-quality video with reduced bandwidth demands is particularly beneficial for streaming services, video-on-demand platforms, and video conferencing applications. Despite its advantages in compression efficiency, H.265/HEVC faced initial challenges in terms of hardware decoding support and software compatibility.

4.2.3 Popularity - Reasons for Technical Popularity:

H.265/HEVC gained technical popularity due to several key factors:

- 1) **Enhanced Compression Efficiency:** The main driving force behind H.265/HEVC's popularity is its superior compression efficiency compared to H.264/AVC. This enables higher video quality and reduces bandwidth requirements, making it well-suited for high-resolution video streaming.
- 2) **4K and 8K Video Support:** H.265/HEVC's ability to deliver high-quality video at lower bit rates is particularly valuable for 4K and 8K video content, allowing for immersive viewing experiences without overwhelming network resources.
- 3) **Industry Support:** As H.265/HEVC became the successor to H.264/AVC, major players in the industry, including content providers, device manufacturers, and streaming platforms, embraced the standard, driving its wide adoption.
- 4) **Hardware Acceleration:** The availability of hardware decoding support for H.265/HEVC in modern devices, such as smartphones, computers, and smart TVs, significantly improved the playback performance and energy efficiency of HEVC-encoded videos.
- 5) **Bandwidth Efficiency:** H.265/HEVC's reduced file sizes and lower bit rates translate to lower bandwidth consumption, enabling smooth video delivery even in limited network conditions.

Both H.264/AVC and H.265/HEVC are significant video encoding standards that have revolutionized multimedia content delivery. H.264/AVC remains a widely adopted and versatile codec, known for its efficient compression and

broad compatibility across various devices and platforms. On the other hand, H.265/HEVC represents a notable advancement with its enhanced compression efficiency, achieving approximately 50% better compression than H.264/AVC. This improvement allows for superior video quality at lower bit rates, making it ideal for high-resolution content, such as 4K and 8K video. Although H.265/HEVC initially faced challenges with hardware decoding support and compatibility, it has gained traction as modern devices and software solutions have updated to support this standard. The technical popularity of H.265/HEVC stems from its ability to deliver excellent video quality while significantly reducing bandwidth consumption, making it a crucial component for the future of high-quality multimedia content delivery.

V. CONCLUSION

In conclusion, this survey paper extensively explored transcoding techniques in video streaming on cloud platforms, with a specific focus on the transcoding protocols used for content delivery. The study provided valuable insights into the encoding processes, video size and formats, usability, compatibility, and popularity of two prominent transcoding protocols, H.264/AVC and H.265/HEVC. The analysis revealed that H.264/AVC remains a widely adopted and versatile codec, renowned for its efficient compression and broad compatibility across various devices and platforms. On the other hand, H.265/HEVC offers a significant advancement with its enhanced compression efficiency, enabling superior video quality at lower bit rates, particularly suitable for high-resolution content. The study emphasized the importance of low latency for content delivery, and demonstrated how cloud-based transcoding infrastructure, integrated with Multi-Protocol Dynamic Packaging (MPDP) and Digital Rights Management (DRM), can enhance the video streaming experience for end-users. The paper presented a compelling use case showcasing the practical application of these transcoding techniques.

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