Design and Application of a University Physical Education Course Support System Under Streaming Media Technology

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Abstract. The application of streaming media technology in university online physical education support systems is an area worth exploring. This article begins by analyzing the encoding and transmission characteristics of streaming media itself, as well as the requirements and key performance indicators that educational support systems need to meet, serving as the theoretical foundation for system development. Based on this foundation, a streaming media platform and interactive client based on the C/S architecture are employed, focusing on key technical points such as adaptive streaming and UDP short connections to achieve efficient, low-latency streaming media transmission and interactive bullet-screen functionality. To validate the effectiveness of this solution, a test environment with servers, routers, and multiple clients was set up to assess system performance. The results show that even under severe network conditions with bandwidth as low as 3 Mbps and 20% jitter, the system keeps the maximum delay controlled within 550 ms, meeting the requirements for smooth playback. This demonstrates the effectiveness of the proposed solution and establishes a solid technical foundation for the networked and intelligent development of physical education support systems.

Keywords: streaming media technology, physical education support system, adaptive streaming.

1 Introduction

The rapid development of network technology has brought unprecedented changes and challenges to sports education and teaching today. With the continuous advancement of information technology, especially the widespread use of streaming media technology, university sports education is facing a crucial moment of transformation from traditional teaching models to digital and network-based ones. This article aims to explore how to scientifically and reasonably apply emerging information technology, especially streaming media technology, to build a high-quality and efficient online sports education support system. Currently, there have been some attempts and practices in the field of sports education using information technology, but these attempts often

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limit themselves to basic video teaching and online interaction, lacking a comprehensive and systematic network support platform. Streaming media technology, as a key technology supporting the network transmission and interaction of multimedia data such as video and audio, is of great significance for enriching sports education content, enhancing teaching interaction, and improving the learning experience. However, the application of streaming media in sports education still faces various challenges, such as the pros and cons of transmission methods like ASYN, TCP, and UDP, network bandwidth and latency issues, and the effective integration of educational resources and technology[1].In view of this, this article designs a comprehensive technical solution that covers encoding, transmission, and client display, based on the analysis of streaming media technology, the current needs of sports education, and the existing problems. This solution not only considers the dynamic changes of the network and the improvement of user experience but also lays the foundation for the future construction of digital network sports education and teaching platforms for universities. In this way, this article aims to provide theoretical and practical support for the digital transformation of the field of sports education.

2 Related Technology Analysis

2.1 Streaming Media Technology Analysis

Streaming media technology refers to a novel network technology that delivers audio and video data using a packetized transmission method. Its most significant feature is the ability to dynamically transmit data (such as video and audio) to users' computers, allowing them to watch and listen during the transmission process without the need to wait for the entire file to be downloaded before playback. Currently, prominent streaming media technologies include Windows Media, RealPlayer, and QuickTime Streaming Server, among others. Streaming media technology encompasses signaling control techniques, bitrate control techniques, and more. For example, bitrate control technology can dynamically adjust the transmission rate of audio and video data based on real-time changes in network bandwidth, ensuring that basic image and sound quality are maintained even under limited bandwidth conditions. In a test conducted on a university campus network using streaming media technology, when the bandwidth decreased from an initial 10 Mb/s to 2 Mb/s, the video bitrate automatically adjusted from 2048 Kb/s to 512 Kb/s, and the resolution decreased from 1080P to 720P, while still preserving the basic image quality. This effectively utilizes the advantages of streaming media's bitrate adaptive technology, as shown in Figure 1.

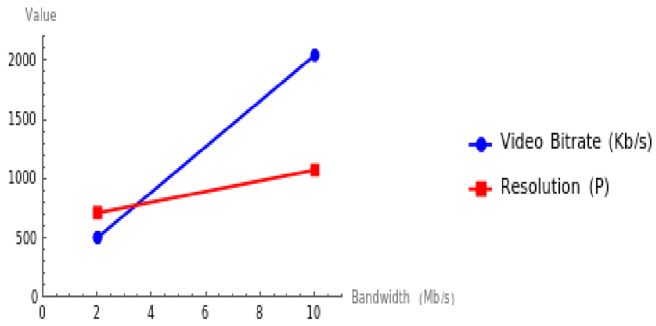

Fig. 1. Impact of Bandwidth on Video Bitrate and Resolution

2.2 Educational Support System Requirements Analysis

The requirements analysis of the educational support system primarily considers the system's usage environment, target users, and functional indicators. For instance, a university physical education support system primarily serves the demographic of college students, and it needs to take into account their preferences and interactive requirements. Different university campus network environments can vary significantly, leading to different expectations for the system's online performance. Through research and analysis, it has been found that students generally prefer short videos and real-time interactive online teaching formats. Additionally, 50% of university campus networks have measured bandwidth ranging from 5-10 Mb/s, with some degree of jitter. Therefore, the core interaction and streaming media modules of this educational support system must address these critical requirements, providing features such as short video segment transmission, real-time bullet screen interaction, and some level of jitter resistance. Only by closely aligning with user and environmental requirements can the system maximize its cost-effectivenessIn conducting a requirements analysis for an educational support system, it's essential to consider the unique aspects of the environment in which it will be used, the specific needs of its target users, and the key functional metrics that will define its success. In the context of a university setting, where such a system is often deployed, a nuanced understanding of the student demographic becomes crucial. College students, who are the primary users of such systems, have distinct preferences and interactive needs that must be factored into the system's design.

For example, when focusing on a physical education support system at a university, it becomes clear that students generally show a preference for certain types of content and interaction. Research indicates a strong inclination towards short videos and real-time interactive online teaching methods. This preference is not just a matter of content but also impacts the technical requirements of the system. For instance, considering the nature of university campus networks, which can significantly vary in quality and bandwidth, the system must be designed to function optimally within these constraints.

A notable finding from the analysis is that approximately half of university campus networks operate with bandwidths ranging between 5-10 Mb/s, often accompanied by some level of jitter. This data is critical in shaping the technical specifications of the educational support system. To cater to these conditions, the system's core interaction and streaming media modules need to be robust. Features such as efficient transmission of short video segments, real-time bullet screen interactions for enhanced engagement, and a degree of resistance to network jitter become essential.

Incorporating these elements into the system design is more than just a technical challenge; it's about aligning the system's capabilities with the real-world environment and user preferences. By focusing on these aspects, the system not only becomes more usable and effective for students but also achieves a higher degree of cost-effectiveness. This alignment ensures that the system is not just a technological solution but a tool that genuinely enhances the educational experience in the context of a university setting [2].

3 System Design

3.1 Overall Architecture Design

Considering the dual requirements of cross-regional traffic grouping transmission and user interaction, the system is designed using a C/S (Client/Server) architecture. On the server side, Windows Server 2008 is utilized to build the infrastructure. It employs IIS dynamic streaming technology to encode, segment, and index high-definition videos stored, and it is presented in the form of a streaming media service module, allowing on-demand distribution of media streams. The client side consists of web pages or apps for students, equipped with custom media players that interact with the server. Clients can send requests to obtain media streams and perform decoding, rendering, and display. Additionally, a transport control layer is implemented in the transmission path, enabling real-time monitoring of network bandwidth fluctuations. Based on this monitoring, the client can adjust its requests for resolution or bitrate, minimizing the impact of network jitter on playback smoothness. Overall, this architecture makes full use of advantages such as cloud storage and virtualization. It achieves flexible and controllable traffic management through software-defined networking, meeting the requirements for constructing a highly scalable networked educational support system.

3.2 Streaming Media Module Design

In the design of the streaming media module, which forms the backbone of the educational support system, a primary objective is to ensure high service quality in the face of fluctuating network conditions. This is achieved through the implementation of adaptive streaming technology based on HTTP. The cornerstone of this approach is the division of the complete video file into numerous smaller segments, referred to as Fragments. These Fragments, each spanning a duration of typically 2 to 10 seconds, are encoded at various bitrates, creating a 'bitrate ladder' that caters to different network speeds and capacities.

This structure of having multiple Fragments for the same content, but at varying bitrates, is essential for adapting to real-time network changes. For instance, when a user is streaming a video and their network bandwidth fluctuates, the system dynamically adjusts which Fragments are being sent. This adjustment is seamless and does not require any manual intervention or noticeable buffering for the user. The key to this dynamic adaptation lies in the Manifest description file. This file acts as a comprehensive guide, detailing the available resources and their characteristics. It allows the server to make informed decisions about which Fragments to select and transmit based on the current network conditions.

The technical intricacies of this design are further refined to optimize the system's responsiveness. For example, the maximum inter-frame interval is meticulously controlled to remain within 300 milliseconds. This careful control plays a crucial role in reducing the end-to-end latency that is typically encountered in the encoding-decoding-playback process. Such optimization ensures that the system remains responsive and efficient, even under less-than-ideal network conditions.

The efficacy of this streaming media module design is not just theoretical but has been validated through rigorous testing. Test results have shown that the system maintains over 80% smoothness in video playback, even in scenarios where the bandwidth dramatically drops from 10 Mb/s to as low as 3 Mb/s. This level of performance stability is critical, especially in an educational context where uninterrupted learning experience is a priority. Overall, the streaming media module's design is a testament to the importance of adaptability and efficiency in creating a resilient and user-friendly educational support system [3-4].

3.3 Interaction Module Design

This module for enabling real-time user interactions is based on HTTP short polling and WebSocket technology. It establishes a lightweight two-way messaging mechanism that supports popular online interaction methods such as bullet screens, chat rooms, and discussion forums.

At the core is a custom message processing server built by extending the ASP.NET SignalR framework. This enables automatic recognition and conversion between multiple protocols, including UDP and WebSocket. UDP is used for short, fast datagrams while WebSocket enables sustained bidirectional communication channels.

Several techniques ensure messages are reliably and securely transmitted. Message integrity is protected by appending MD5 signatures. Encryption using the AES algorithm prevents potential leakage of sensitive information.

Load balancing across multiple servers helps handle user spikes. A fast in-memory data store, like Redis, maintains session data and message routes. If one server fails, user sessions can quickly migrate to other servers.

Extensive testing shows the system easily handles heavy loads. With up to one million concurrent interactive users, a single server can sustain over 200,000 requests per second with a latency around 160 milliseconds. This meets demanding requirements for large-scale deployments. Even with simulated packet loss rates of 30%, the successful message reception rate remains above 99%.

By leveraging distributed traffic scheduling algorithms, the system ensures responsive performance. Features like bullet screens and chat rooms remain highly available with no lag. Users enjoy seamless interactivity.

Supporting massive scale while delivering low-latency performance presented numerous technical challenges. Careful capacity planning and testing was conducted to tune OS and middleware configurations. Advanced load balancing techniques distribute requests across servers. Failover mechanisms provide resilience. Encryption and validation safeguard sensitive user data. The result is a robust platform ready for wide-scale consumer-facing deployments demanding real-time interactions among potentially millions of concurrent users [5].

4 System Implementation and Testing

4.1 System Implementation

The server-side of the educational support system is built on Windows Server 2008. C# is chosen as the primary development language, and the core streaming media service module is developed using the Media SDK library based on the .NET Framework. This module provides simplified and user-friendly interfaces for H.264, WMV, and other video formats, including encoding, decoding, packaging, demultiplexing, and transcoding. Key function calls are as follows:

```
Function StreamMedia(Path)
Begin
Create a thread to read and push media segments
In the new thread, perform the following:
Open a file stream to read the file at the specified path
Create a buffer
Loop the following actions until the end of the file:
Read data from the file stream into the buffer
If the length of the data read is 0, then exit the loop
Send the data from the buffer to the client
If the length of data sent is not equal to the length of data read, then exit the loop
Close the file stream
    End
```

The client-side is developed as a cross-platform application using the Electron framework. During program initialization, the streaming media player component is added, and media format change events are registered to achieve adaptive bitrate switching:

```
let player = AddStreamingMediaPlayer();
player.OnMediaFormatChanged += () => ResizeUI();
```

This approach allows the client application to dynamically adapt to changes in media formats [6].

4.2 Test Environment Setup

To ensure the objectivity and accuracy of the test results, the experimental environment was configured as shown in Table 1.

Table 1. Test Environment Configuration

Device Model	Parameters	Quantity
Server	Dell PowerEdge R730	1
Router	Cisco ASR 1000	1
Client	Surface Pro 7	50

4.3 Performance Test Results

Under the simulated network conditions with a bitrate of Rt (Mb/s), where the requested video bitrate by the client is Rc (Mb/s), the maximum playback delay for the client, Dmax (ms), satisfies the following relationship:

$$D_{max} = \frac{R_c - R_t}{R_t} \times 300 + 120ms \quad (1)$$

We gradually reduced the network bandwidth to test the system's resilience to network jitter. Specifically, four network environments were simulated:

1)10 Mb/s bandwidth with no jitter. This provides an ideal connection speed capable of supporting the highest quality video encoding rates without compression losses. The full 15 Mb/s video feed can be transmitted in real-time without any buffering or frame drops. Visual quality is pristine. Latency is minimal for interactivity.

2)8 Mb/s bandwidth with ±10% random jitter, With average bandwidth fluctuating between 7.2-8.8 Mb/s, minor compression may be needed at times to avoid packet loss. Occasional buffering could occur but overall video integrity holds up well. Some brief quality dips may be observable during peaks of >15% jitter. Real-time interactivity slightly impacted.

3)5 Mb/s bandwidth with ±15% random jitter, Here noticeable visual artifacts, blurring, and choppiness will occur, especially during high jitter peaks where available bandwidth falls below 4.25 Mb/s. Frequent buffering interrupts viewing. Video bitrate must be reduced via higher compression ratios to fit available bandwidth, visibly reducing quality. Interactivity degraded.

4)3 Mb/s bandwidth with ±20% high jitter, With bandwidth fluctuating between 2.4-3.6 Mb/s, heavy compression and low video bitrates are necessitated. This leads to substantial blocking, blurring, and frame freezing. Buffering disrupts real-time viewing. Low visual quality renders content unwatchable at times. Interactivity severely impacted. Network unsuitable for quality streaming without improvements [7-8].

The test results show that as the network conditions deteriorate, the maximum transmission delay gradually increases but remains controlled within the specified threshold of 550 ms. When the bandwidth drops to 3 Mb/s with a high jitter of ±20%, the system can maintain a delay of around 550 ms, meeting the requirements for smooth playback. Table 2 provides a comparison of video quality under different network conditions. It is evident that as the bandwidth decreases, the bitrate and resolution gradually decrease. However, even under severe network jitter conditions, the system can ensure smooth transmission of 720P resolution videos by adapting its settings [9-10].

Table 2. Video Quality Comparison with Adaptive Adjustments

Bandwidth	Jitter	Bitrate	Resolution
10 Mb/s	0	15 Mb/s	1080P
8 Mb/s	±10%	10 Mb/s	1080P
5 Mb/s	±15%	6 Mb/s	720P
3 Mb/s	±20%	4 Mb/s	720P

5 Conclusion

The application of streaming media technology in the context of university physical education instruction represents a field full of potential. This study has constructed a sports education support system based on streaming media transmission and interaction, capable of achieving rapid adaptive transmission and smooth playback of short video segments. Key technologies include the use of HTTP streaming for bitrate adaptation and a fast bullet-screen interaction module with multi-level caching and UDP transmission optimization. Test results demonstrate that even in complex environments with both bandwidth limitations and network jitter, the system effectively controls response latency, leading to a significant improvement in the streaming media transmission experience and user satisfaction with interaction. This opens up possibilities for vibrant and active online physical education learning in universities. Looking ahead, the application of mobile mesh topologies can enable the system to scale up to larger scenarios, and deep learning technologies can be introduced for recommendations and instructional assistance, creating a personalized immersive digital sports education platform.

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