Design and Implementation of an IP-based Data Stream Switching System for Beijing Television Station (Postprint)

Authors: Zhu Jiang

Date: 2023-10-08T00:00:00+00:00

Abstract

This paper, set against the backdrop of Beijing Television's IP-based data stream exchange system construction, describes how the station has preliminarily achieved unified IP-based aggregation capabilities for diverse signal types—including SDI, IP, and externally provided signals across the entire station—through the adoption of IP stream content aggregation and scheduling technology, real-time stream transcoding technology, and IP signal monitoring and distribution technology. Simultaneously, by integrating the stream scheduling system with the real-time online transcoding system, the station has accomplished unified scheduling and distribution of all IP-based signals aggregated within the station, unified monitoring of all IP signals, and, following real-time online packaging of the signals, the dissemination of IP stream content both internally and externally via various IP live broadcasting methods.

Full Text

Design and Implementation of Beijing TV Station's IP-based Data Stream Exchange System

Abstract: This paper presents the design and implementation of Beijing TV Station's IP-based data stream exchange system. By employing IP stream content aggregation and scheduling technology, real-time stream transcoding technology, and IP signal monitoring and distribution technology, the station has established unified IP-based aggregation capabilities for diverse signal types—including SDI, IP, and externally sourced signals. Integration of the stream scheduling system with real-time online transcoding enables unified scheduling and distribution of aggregated IP signals, comprehensive monitoring of all IP signals, and real-time online packaging for IP stream content delivery to both internal and external platforms through various IP broadcasting methods.

Keywords: IP-based data stream; IPTV; SDI Over IP; Ultra-high-definition

Classification: TN948.1
Document Code: A
Article ID: 1671-0134(2019)12-122-05
DOI: 10.19483/j.cnki.11-4653/n.2019.12.037

Citation Format: Zhu Jiang. Design and Implementation of Beijing TV Station's IP-based Data Stream Exchange System[J]. China Media Technology, 2019(12):122-126.

Author: Zhu Jiang

In recent years, traditional television stations have been undergoing IP-based transformation, leveraging internet and mobile communication network technologies to extend their media attributes and develop new media platform products such as IPTV, websites, and mobile applications. Our station has actively pursued development and research in this domain. Consequently, establishing a unified IP-based interactive platform has become essential. This system aggregates our station's proprietary IP streams, external live streams, and other resources, utilizing IP switching matrices and real-time transcoding to enable flexible scheduling and multi-platform distribution, thereby meeting diverse content requirements and supporting future all-IP transformation.

2. Solution

Based on Beijing TV's current network infrastructure, we have designed a comprehensive IP streaming architecture comprising three core components: content aggregation and scheduling, multi-screen transcoding, and publishing node monitoring. The overall framework is illustrated in Figure 1 [Figure 1: see original paper].

From a business function perspective, the platform aggregates various SDI/IP signals from internal and external sources, processes them through IP scheduling management to provide standard IP signals to the transcoding cluster, which then transcodes them into formats suitable for multi-screen distribution to downstream publishing platforms.

From a technical design perspective, this platform is deployed in the Smart Media Network Domain of Beijing TV Station, directly interconnected with the Smart Media Core Switch. Through the station's internet gateway, it facilitates input and output interaction with external signals, creating a mixed unicast and multicast transmission environment within the station network to support IP signal distribution both internally and externally while managing system signaling. The system comprises three primary subsystems: "Content Aggregation and Scheduling Management," "Multi-screen Transcoding Cluster," and "Publishing Node Monitoring and Surveillance." The following sections elaborate on these subsystems (as shown in Figure 2 [Figure 2: see original paper]).

1. Requirements Analysis

The system's construction purpose and design intention is to support IP-based real-time stream transcoding architecture, utilizing our station's self-owned local signal sources, live streams, and other audio-visual content, supplemented by external streaming resources. Through IP-based switching matrices, the system achieves real-time stream scheduling and distribution, performs distributed real-time transcoding as required, overlays station logos, subtitles, and other elements to satisfy diverse live content requirements for IPTV, websites, and third-party platforms.

1.1 Building a Unified IP Real-time Stream Aggregation Platform

This involves unifying the aggregation of IP live content currently present in Beijing TV Station, the IPTV centralized control platform, and the news production platform, as well as future IP live signals requiring access, providing a standardized IP real-time stream access method.

1.2 Building a Unified IP Real-time Stream Scheduling Platform

This platform uniformly schedules and distributes all aggregated IP stream signals across the station to facilitate live content access for the television station, IPTV centralized control platform, and related new media studios. The existing network architecture is preserved, with signal interfacing only at the IPTV output end. The design emphasizes IP operation mechanisms, pushing multi-format, multi-bitrate signals from the IP scheduling platform to various business applications (including internet media, content production outsourcing providers, IP source analysis, OTT platforms, etc.). Multiple external field signal interfaces enable direct signal injection into the matrix, allowing real-time signals to be pushed to the station's broadcast control platform after scheduling.

1.3 Building a Unified IP Real-time Stream Publishing Platform

Through the IP stream centralized scheduling system, the platform implements polling monitoring of all IP live signals across the station. Coupled with the live real-time transcoding system, it enables on-demand transcoding and publishing of IP signals, providing flexible broadcast control management that supports both automatic and manual playlist compilation to execute broadcast tasks according to scheduled timelines. The system adopts separate management modes for IP matrix scheduling and transcoding clusters, both utilizing B/S architecture that can be flexibly configured according to the station's actual network conditions. Publishing nodes after IP matrix scheduling are monitored using multi-screen content surveillance alarms and IP stream analysis alarms.

2.1 Content Aggregation and Scheduling System

The system adapts to various IP and SDI signal aggregations, converting them into designated IP stream formats. Through a graphical interface, it enables signal scheduling and switching management, achieving real-time IP stream switching and IP address/port redirection to designated multi-screen transcoding clusters. The distributed scheduling node service approach imposes no strict requirements on underlying network switches, theoretically adapting to all mainstream switching equipment currently deployed within the station and commercially available. The scheduling management service can unlimitedly adjust the number of scheduling nodes to accommodate business expansion and seamlessly adapt to additional business scheduling formats that may be introduced.

The system supports SDI and IP signal aggregation, with IP signals accommodating diverse formats including HD/SD-SDI, IP signals, encapsulation formats (HTTP/RTP/UDP), and encoding formats (TS compression, H.264/Mpeg2 video, Mp3/AAC/Mpga audio).

2.1.1 Multi-format Adaptation

The system supports multi-signal adaptation and FEC transmission guarantee: FEC redundant error correction technology ensures transmission quality during minor network packet loss.

2.1.2 Switching Modes

The system comprises five servers—one central controller and four node schedulers. A single node scheduler supports up to four seamless switches or twenty non-seamless switches. Currently, the system supports eighty non-seamless switches and sixteen seamless switches, with the flexibility to adjust the ratio between these modes according to business requirements (as shown in Figure 3 [Figure 3: see original paper]).

The two switching modes are "seamless switching" and "non-seamless switching." Seamless switching represents zero-frame switching in traditional broadcasting. Since stream encoding occurs during aggregation, this mode achieves I-frame-based switching equivalent to conventional broadcast switching. Non-seamless switching does not perform stream encoding during aggregation, resulting in approximately one-second switching duration. Each scheduling node can be configured for either mode according to business needs, with the ability to convert between modes at any time.

Due to the substantial resource requirements of seamless switching, non-seamless switching is employed for non-online live channels. The two modes are managed separately: four channels of free signals utilize seamless switching, while sixty IPTV channels employ non-seamless switching. Both modes feature automatic padding using video or image materials. Table 2 provides a detailed comparison.

2.1.3 Scheduling Management

The scheduling management module enables manual or automatic scheduling of aggregated IP signals, providing playlist compilation functionality and external interfaces to support program list upload and export, satisfying business requirements for program scheduling and automated processing.

2.1.3.1 Custom Broadcast Time Control This feature supports custom timeline adjustment of input and output broadcast control, automatically generating schedules for custom-time broadcasting. It is primarily applied to emergency scenarios such as external field signal access and sudden signal source insertion, offering flexible operation and high emergency responsiveness for direct distribution to IPTV, mobile web, studios, and other platforms.

2.1.3.2 Program List Broadcast Control The system supports playlist-based automatic switching and scheduling, featuring a B/S Web management interface. It provides manual playlist management and automatic program list import functionality, capable of interfacing with the station's broadcast control system.

2.1.3.3 Open Interface Open APIs support customized management processes (timeline-based scheduling) and integration with third-party management systems, enabling playlist systems, automatic switching, and channel program replacement (as shown in Figure 4 [Figure 4: see original paper]).

2.1.4 Process Display

The scheduling operation interface employs a "checkerboard" visualization style, connecting input and output sources with lines to represent scheduling paths while displaying real-time video frames for operators to monitor signal status. A single scheduling node provides a 20×20 schedulable range, with each node capable of opening an independent browser window for simple mouse operation (as shown in Figure 5 [Figure 5: see original paper]). Multiple scheduling nodes integrate into a larger matrix, providing expanded scheduling status display and operation capabilities (as shown in Figure 6 [Figure 6: see original paper]).

2.2 Multi-screen Transcoding System

The multi-screen transcoding system receives IP streams from the content aggregation and scheduling platform, real-time transcoding them into multi-screen, multi-terminal formats specified by operators for delivery to backend publishing platforms. Utilizing four encoders, the system completes transcoding tasks for fifteen HD programs and forty-five SD programs in a 1-input-3-output configuration. It receives scheduled program streams from the IP scheduling system, transcodes them into multi-format streams required by downstream platforms, and pushes them to downstream switches. A cluster management server receives external transcoding commands and manages task allocation across online transcoding servers (as shown in Figure 7 [Figure 7: see original paper]).

2.2.1 "CPU+GPU" Hardware-Software Combined Transcoding

The unique "CPU+GPU" hardware-software combined transcoding solution achieves high-speed, high-quality processing by leveraging the GPU's thousand-core parallel computing capability and proprietary hardware (CUDA) algorithms, significantly improving transcoding efficiency and quality. This approach substantially increases concurrent stream capacity per server compared to CPU-only software solutions, while offering superior encoding quality and greater flexibility than hardware encoding cards.

2.2.2 Rich Input and Output Stream Format Support

The system supports extensive input protocols—including TS Over UDP, TS Over HTTP, FLV Over HTTP, Apple HLS, RTSP, RTMP, SDI/HD-SDI, and ASI—greatly expanding business possibilities for live program aggregation. Output protocols are equally comprehensive: TS Over UDP, Apple HLS, MS Smooth Streaming, Adobe RTMP, and Adobe HDS. The system supports streaming media quality monitoring across UDP, RTP, HTTP, RTMP, RTSP, HLS protocols and FLV, MP4, 3GP, TS, MP2T, MP2T+RTP encapsulation formats. It automatically detects streaming media transmissions within network nodes, accurately identifying protocol types and extracting key information such as media URLs, response times, and duration. The system supports MDI (RFC4445) and TR101 290 metric analysis, with deep stream analysis capabilities including bandwidth, PID, and PSI/SI information.

The system enables station logo insertion, occlusion, black edge addition/removal at any screen position, with remote real-time preview of modified playback effects via Web console. Real-time preview plug-ins provide intuitive visualization of image processing effects and signal sources. The configured input format is fifteen HD channels (H.264, 1920×1080) and forty-five SD channels (H.264, 720×576). Output formats include: fifteen HD channels at 1920×1080 (8Mbps), 1024×576 (1.2Mbps), and 640×360 (800Kbps); forty-five SD channels at 720×576 (2.5Mbps), 640×360 (800Kbps), and 640×360 (500Kbps).

2.3 Publishing Node Monitoring System

The publishing node monitoring system implements IP multi-screen monitoring and stream analysis alarms for IP signals scheduled by the content aggregation and scheduling platform.

2.3.1 Multi-screen Display Monitoring and Alarm

The system performs real-time monitoring and alarm functions on decoded video/audio content, multi-screen composition, and stream monitoring information display. It supports color format display and anomaly alarms, black screen detection, silence detection, audio static frame detection, high/low volume detection, multi-screen composition, stream information display, continuous recording and fault-triggered recording, with the ability to arbitrarily select TS over IP multicast streams and programs for combined monitoring, listening, and surveillance. The system supports forty SD or eight HD H.264 multi-screen monitoring (HDMI, DVI output).

2.3.2 Stream Monitoring Probe System

The system supports streaming media quality monitoring across multiple transmission protocols and encapsulation formats, with automatic detection and discovery of streaming media transmissions within network nodes. It accurately identifies protocol types and extracts key information including media URLs, response times, and duration. The system supports MDI (RFC4445) and TR101 290 metric analysis, with deep stream analysis capabilities for bandwidth, PID, and PSI/SI information.

3. System Features and Main Contributions

Based on operational experience, the system demonstrates several key characteristics:

Traditional SDI over IP solutions continue to face challenges in television production and broadcasting. Deploying uncompressed IP transmission systems is non-trivial, with IP streams exhibiting lower switching precision than SDI and involving more complex network management and protocol handling. However, this system focuses on internet-side applications, avoiding high-bitrate traditional television requirements while leveraging IP advantages. It reuses existing network infrastructure, provides flexible and scalable signal aggregation and scheduling, and achieves effective integration with external internet resources.

Integration with our IPTV platform yields significant advantages. As the primary input source for the IP stream system, IPTV signals can be flexibly allocated and delivered to target platforms and partners both inside and outside the station through aggregation, scheduling, and transcoding, while meeting traditional SDI requirements for ultra-high-definition (4K/8K) transmission. The IP architecture resolves bandwidth constraints for HD and UHD signal delivery.

The IP-based data system facilitates convenient interfacing with other platforms, enabling rapid and flexible adjustments that reduce construction costs—essentially requiring only network-level configuration before deployment. Access to external third-party internet resources as upstream inputs feeds back into critical platforms such as the station's main facilities and IPTV, creating an effective fusion of traditional broadcasting and internet distribution that integrates traditional television resources, IPTV, and internet video resources into a virtuous cycle.

This IP-based data exchange system inherits the high-reliability characteristics of traditional broadcasting while embracing the fast, flexible, and dynamic nature of internet and new media. The current design provides excellent scalability for business expansion; as operational scale grows, the platform can be flexibly upgraded. Integration with external third parties and internet companies not only explores an IP-centric development path for our station but also establishes groundwork for implementing IP-based operational models.

4. Summary and Outlook

Amidst the broader IP transformation of broadcasting and television production systems and the drive toward ultra-high-definition infrastructure, this system's implementation represents a successful and effective exploration for the industry—addressing whether to continue with SDI or transition to all-IP technology. It provides valuable insights for navigating the challenges of IP transformation. We remain committed to applying emerging technologies to television station system upgrades, serving operational stability and sustainable development through technological innovation.

References: [1] Shi Feng. Preliminary Exploration of SDI/IP Hybrid Architecture in Ultra-high-definition Production and Broadcasting Systems[J]. Cable Television Technology, 2017(2):102-108.
[2] Wu Zhi. All-media Studio in the IP Era[J]. Modern Television Technology, 2015(7):46-49,54.
[3] Chen Zhenghui. Discussion on IP-based Transformation of All-media Studios[J]. Radio & TV Journal, 2018(8):215-216.

(Author's Affiliation: Beijing TV Station Information Network Management Department)

Note: Figure translations are in progress. See original paper for figures.