

A Preliminary Analysis of High-Definition Broadcasting System Construction for County-Level Television Stations (Postprint)

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Abstract

[Objective] To deliver high-definition, high-fidelity audio-visual effects to audiences and satisfy their ever-increasing viewing demands. Amidst the rapid advancement of science and technology, the high-definition transformation of television channels represents an inevitable requirement.

[Method] This article validates a feasible technical solution through the construction practice and systematic testing of a high-definition broadcasting system for county-level television stations.

[Results] The constructed high-definition broadcasting system features comprehensive hardware hot backup, online data hot backup, and program broadcasting hot backup, eliminating any single point of failure and establishing a secure and rational network architecture. The system is quantitatively evaluated across various dimensions including network, storage, hosts, and software to ensure operational convenience and high-definition quality of the final television output.

[Conclusion] The construction and deployment of the high-definition broadcasting system have further enhanced the security prevention capabilities and monitoring intensity of the broadcast control platform, significantly improved broadcasting effectiveness and quality, ensured safe and high-quality broadcasting of television programs, and continuously met the new expectations of urban and rural residents for a richer spiritual and cultural life.

Full Text

Preamble

Analysis of HD Broadcasting System Construction for County-Level Television Stations

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Abstract

[Objective] To deliver high-definition, high-fidelity audio-visual experiences that satisfy audiences' growing viewing demands. In today' s rapidly evolving technological landscape, the high-definition transformation of television channels is an inevitable requirement. **[Methods]** Through practical construction and systematic testing of an HD broadcasting system at a county-level television station, this paper validates a feasible technical solution. **[Results]** The completed HD broadcasting system features comprehensive hardware hot backup, online data hot backup, and program broadcasting hot backup, eliminating any single point of failure and ensuring secure and rational network architecture. The system is quantified across networking, storage, hosts, and software to guarantee ease of use and ultimate HD broadcast quality. **[Conclusion]** The construction and deployment of the HD broadcasting system have further strengthened the security and monitoring capabilities of the broadcast control platform, significantly improved broadcast effectiveness and quality, ensured safe and high-quality program transmission, and continuously met urban and rural residents' new expectations for enriching spiritual and cultural life.

Keywords: high-definition transformation; broadcasting system; broadcast control; system design; system testing

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Modern network technology continues to advance, prompting television stations nationwide to actively upgrade their broadcasting systems from traditional models to digital broadcasting systems, establishing high-network-information hard-disk broadcasting systems [1]. Feidong County Broadcasting Station has actively secured funding to upgrade its two-channel broadcasting system to HD, aiming to build a hard-disk broadcasting system capable of simultaneous HD/SD broadcasting for both Feidong News Comprehensive and Feidong Economic Life channels.

1. System Construction Requirements

Feidong County Broadcasting Station has comprehensively considered an overall HD solution for equipment and systems, having previously completed upgrades to program acquisition and editing systems including HD live trucks, HD studios, HD cameras, and HD editing and storage. This HD broadcasting system construction must, under the premise of ensuring security and reliability, effectively integrate and link with other systems to achieve high compatibility and scalability, improve work efficiency, and guarantee the security and uniformity

of materials and program broadcasting.

2. System Planning and Construction

According to the plan, the system construction can handle HD/SD broadcasting tasks for two channels, including broadcast server systems, broadcast content management systems, broadcast control systems, synchronization systems, clock systems, switching systems, and broadcast peripherals. The main systems consist of broadcast upload video server systems, broadcast control computer systems, broadcast management computer systems, video/audio systems, broadcast switching matrix systems, and other peripheral equipment. The primary application software includes device sharing software, broadcast software, program scheduling software, material upload software, automatic technical review software, manual review software, interface software, messaging software, and broadcast content management software.

2.1 Business Process Analysis

From a business perspective, this system construction employs advanced information, storage, and network technologies to optimize the architecture and workflow of file-based television broadcast control, meeting the requirements of various business subsystems and achieving high-quality, high-efficiency, and secure broadcasting through file-based business processes, hierarchical storage management, and online backup of the broadcasting system. The overall workflow is shown below:

[Figure 1: see original paper] Overall Business Analysis Diagram

2.2 Key Hardware Design Analysis

Video servers and broadcast peripheral equipment constitute the critical hardware determining whether an HD broadcasting system can operate safely, stably, and reliably. The selection of primary and backup video servers and peripheral equipment, following recommendations from provincial and municipal broadcasting experts and adhering to principles of both economy and security, adopts a 1+1 heterogeneous backup approach with imported primary servers and domestic backup servers. All video servers employ modular design.

The primary video server uses the well-known GV company's K2 Summit server, providing 2 HD bidirectional channels and 2 HD decoding channels, with all outputs supporting flexible broadcasting of DV/DVCPRO and MPEG-2. The backup video server uses the Beijing Zhongke Dayang VIPS-2H-4XHD server, providing 2 bidirectional channels and 2 unidirectional output channels. Each bidirectional channel can be independently configured for input/output, supporting up to 4 outputs maximum. The backup video server forms a heterogeneous backup mechanism with the primary and backup video servers, while

peripheral equipment also uses high-stability GV company devices to better ensure broadcast security.

The hardware system design also includes: application server clusters composed of core database servers, policy servers, synchronization migration servers, and automatic technical review servers; hardware boards, matrices, and subtitle machines capable of signal conversion, switching, distribution, and processing; secondary storage systems composed of disk arrays; workstation clusters for scheduling, control, upload/download, and monitoring functions; and monitoring systems composed of multi-viewers, monitors, and video walls.

2.3 Overall Software Architecture Design

The overall software system architecture is as follows:

[Figure 2: see original paper] Overall Software Architecture Diagram

2.3.1 Device Sharing Software According to the plan, the system adopts the concept and methodology of a shared device resource pool, using direct VTR broadcasting under emergency conditions. It obtains shared device usage status from the broadcast control module, utilizes a device sharing control module to update the real-time status of VTRs, and then allocates network VTRs based on media information and scheduling strategies, thereby achieving automated and intelligent shared resource scheduling, reducing equipment investment, and improving the utilization efficiency and work efficiency of existing equipment.

2.3.2 Broadcast Software The broadcast software system is built upon a high-availability system-level backup mechanism, enabling uninterrupted channel broadcasting during maintenance shutdowns of the broadcast control center's relevant systems, solving environmental problems required for system testing during business software upgrades, establishing an intelligent control mechanism for primary and backup systems, and addressing challenges in information sharing, automatic switching, and synchronization playback accuracy between primary and backup control devices, thereby improving system stability.

2.3.3 Program Scheduling Software Technicians use the scheduling module to read the master program schedule generated by the program production management system from the database, and refine it into actual channel broadcast schedules based on the "broadcast standard template," "program change notices," and "live broadcast notification forms/live process forms." The main function of broadcast scheduling is to generate initial versions of broadcast program schedules after entering the next day and to modify existing broadcast program schedules. The initial version is formed by reading and refining the locked master program schedule from the database, which after verification is sent to the broadcast control machine and updates the database and corresponding replicas. For same-day program schedules, modifications are made directly

on the broadcast program schedule, then sent to the broadcast control machine for execution, and the database and corresponding replicas are updated. When database failures occur, the local broadcast program schedule copy on the superior machine is read for editing. Since various notifications are one of the important bases for scheduling, the scheduling software features notification management functions. Broadcast program schedules manage changes in program content and length through versioning.

The broadcast editing machine manages packaging entries and generates program schedules, enabling one-to-one correspondence between packaging entries and broadcast entries based on program IDs. One broadcast program can match multiple packaging sub-entries. The broadcast editing machine sends confirmed program schedules to the broadcast control machine for use. The broadcast editing machine can provide broadcast services for clone systems, enabling synchronization between clone channel program schedules and main channel program schedules, ensuring safe broadcast control under emergency conditions.

2.3.4 Material Upload Software Video and audio files are one source of broadcast materials. Upload technicians use the upload module to read material information and utilize upload software to control upload servers, achieving the function of converting material files into recognized digital files.

2.3.5 Automatic Technical Review Software The automatic technical review software is a media processing software adopting a layered management approach of Manager+Actor+Work, where the Manager uses an active-active deployment method and Work enables distributed management. The automatic technical review employs a B/S architecture for convenient deployment; any node on the network that can connect to the server can deploy its site and log in and operate through an account. In the automatic technical review software administrator interface, multiple business processes can be arranged according to different business needs, breaking the previous problem of software being disconnected from business, making the software more applicable to business, reducing customized software development volume, and moving toward standardized general software. It also makes operation and management more user-friendly, achieving closer integration between software usage and actual business usage, maximizing alignment with local actual business processes.

The automatic technical review software enables administrators to arrange and combine modules according to actual business situations, thereby implementing complex business processes. It also provides a complete and clear task management retrieval system, process management retrieval system, and operator management authority system.

2.3.6 Manual Review Software Manual review software is an important part of the broadcast software system and a mandatory passage from secondary to tertiary preparation. It is responsible for reviewing materials and packag-

ing in the secondary preparation stage of the entire broadcast control system, such as materials transmitted from the production department and materials imported from hard disks. Manual review software ensures the normality of broadcast materials and packaging by manually reviewing materials and packaging items in secondary storage, guaranteeing broadcast security. All materials and packaging in secondary storage must undergo manual review, and only after passing manual review can the tertiary broadcast preparation process be initiated.

2.3.7 Interface Software The broadcast control system is a crucial component of broadcasting and television technology systems, responsible for program signal broadcasting and release, with security being paramount. Under the guidance of file-based workflow throughout the television station, the interconnection between the broadcast control system and other systems inevitably brings security risks. There are two forms of data connecting the broadcast control system with other systems: media data and information data. To reduce risks and improve security, these two data types need to be processed through dedicated equipment to obtain relevant update information through communication between the broadcast control system and other systems. Throughout the data processing, the broadcast control system does not communicate directly with external system equipment, ensuring the independence of the broadcast control system and guaranteeing broadcast security. The broadcast control system uses migration services and interface services to connect with other systems. These two services are the only means of data communication between the broadcast control system and external systems. Regardless of how many systems exist across the station, all interactions occur through these two services. Other services or applications within the broadcast control system do not connect with external networks, ensuring broadcast control system security.

2.3.8 Messaging Software Messaging services are the core of the broadcast control system and one of the means of service invocation between systems. By transmitting instruction information through message queues, various application subsystems within the broadcast control system receive timely and accurate message data. The display and query of various message data are important bases for system business logic and normal equipment operation, providing a solid foundation for the correct execution of various tasks in the broadcast control system. For whether tasks between system equipment are correctly received, there is a clear response. When tasks do not correctly reach target equipment, the system automatically performs re-execution, alarms, or other processing according to policies, ensuring correct task execution.

2.3.9 Broadcast Content Management Software According to the current status and working mode of the broadcast control system, the broadcast content management software aggregates status information for all channels' program broadcasting, equipment control information, and service provision mod-

ules affecting current channel broadcasting, such as message servers, shared device scheduling, and shared device control. Through information filtering mechanisms, it sets information requiring monitoring during duty shifts and provides alarm prompts. Specific applications include: timely grasping missing tape situations for all channels on the current day, sorting missing materials according to broadcast time, and setting alarm time thresholds. The duty shift client system can minimize personnel operations on the broadcast control system to the greatest extent, improving the reliability of broadcast control machines.

2.4 Broadcast Control System Design

The broadcast control system design is the heart of HD broadcasting system signal scheduling, centered on GV company's 32×32 matrix master control matrix, with each of the two channel sequ

sub-control matrices. All signal sources—including HD live truck signals, HD studio signals, primary and backup video server signals, satellite reception relay signals, cable front-end room signals, HD test patterns, filler broadcasts, and external signals—are connected to the master and sub-control matrices for comprehensive scheduling and selective switching, primarily used for program broadcasting and recording of the station's two channels. The key control panels for the master and sub-control matrices are placed in front of the primary and backup station display screens, facilitating real-time monitoring and emergency switching by duty personnel. Compared with single matrix configuration, the dual matrix configuration for each channel significantly improves safety and reliability, elevating the backup level from channel-level to system-level [2]. If either the primary or backup matrix fails or becomes paralyzed, the scheduling system can still receive and schedule all input signals, achieving 1:1 backup of signal links. Simultaneously, the principle of link independence is adopted to configure chassis deployment for the master control section, arranging equipment from the same link within the same group of chassis, with all critical equipment powered by dual power supplies on different circuits, minimizing the number of affected links during power failures or other faults. The master control monitoring system's six large screens use multi-viewers to monitor and listen to key node transmissions of various routing signal sources, enabling duty and technical personnel to intuitively and efficiently identify potential fault locations in equipment systems and effectively improve emergency response capabilities.

The broadcast control system design uses the program schedule as the main bus, focusing on program schedule editing, modification, and updating, broadcast control workstation control, emergency upload review and head/tail detection processing, mobile backup broadcast system follow-up broadcasting and control, and specific implementation methods of time synchronization and time-keeping. It achieves a complete file-based system management workflow, supporting program schedules and advertisement schedules to generate program file preparation tasks according to business needs and automatically perform file preparation. The preparation process employs dynamic, intelligent optimiza-

tion algorithms that dynamically adjust migration strategy priorities based on program broadcast times and importance levels, achieving intelligent program file preparation. Media file lifecycle management achieves global control, enabling unified scheduling and deletion in various storage levels through unified management of media files across different channels, storage media, and lifecycle stages. Under the hierarchical storage architecture, task quantity control and queue sorting processing are performed based on broadcast times and submitted migration tasks, achieving dynamic real-time adjustment of program preparation task priorities. Based on the hierarchical storage architecture, hierarchical quality control is implemented, employing different technical control methods for program files in different storage media to maximize safe broadcasting. Secondary storage holds all broadcast files, while video server storage only holds media files for current and upcoming days. This hierarchical storage approach satisfies the storage of all programs, improves video server speed, and reduces video server storage pressure [3].

According to each channel's program rundown or preset strategy conditions, the unified program preparation platform supports query and management of all broadcast files, controlling deletion, copying, and migration of broadcast files, effectively utilizing storage space, reasonably allocating transmission bandwidth, and finally completing program broadcast preparation tasks.

To ensure storage security of broadcast program files, both broadcast video server storage and secondary storage adopt primary-backup approaches. File mirroring between primary and backup storage no longer uses migration methods between primary and backup but instead employs simultaneous writing to primary and backup storage through the previous level's migration server. For example, when files migrate from secondary storage to primary and backup video servers, the migration server reads files from secondary storage and simultaneously dual-writes to primary and backup video servers. This structure ensures no connection between primary and backup storage—they are two independent entities—so a failure in either storage medium will not affect the other. MD5 verification is performed after media file migration, comparing MD5 values before and after migration to ensure file consistency. This mirroring method significantly improves file transmission efficiency and accuracy.

Broadcast workstations can monitor broadcast channel status at any time, using corresponding control plugins to control different equipment systems, such as video servers, matrices, switchers, VTRs, and keyers. Upon detecting unresponsive primary broadcast channels, they can automatically control switchers to switch broadcast signals to backup channels. If backup channels also become unresponsive while primary and backup channels remain unrestored, the broadcast control software can automatically or manually control switchers to switch to emergency filler or other backup channels [4]. To ensure absolute control safety, the system supports four-level switching (primary/backup broadcast servers, emergency VTR, emergency line). The specific implementation is: when the primary broadcast video server has problems, it immediately automatically

switches to the backup video server; if the backup video server has problems, it automatically switches to emergency VTR; if emergency VTR fails, it automatically switches to predefined emergency line signals.

In the control system, broadcast software continuously detects the status of backup control equipment. If backup control equipment shows abnormalities, such as unresponsiveness or missing materials, it immediately alarms. Alarm sounds support customization, with various fault alarms set in the software. The closer to broadcast time, the more frequent the alarms, reminding broadcast personnel to pay attention.

3. System Integration and Testing

3.1 System Integration

After project completion, the integration phase began. The client organization assembled technical personnel and engineers from relevant companies to first debug all signals and audio/video paths of the master and sub-control systems, achieving the goals of unified signal phase and correct links. Embedded audio was uniformly adjusted and each video path was individually verified, completing preliminary debugging of the two television channel broadcast audio/video systems. Simultaneously, technical personnel from both sides repeatedly tested various broadcast modes, exchanged practical requirements conforming to the station's broadcast link design and operating habits, and performed appropriate modifications and improvements. This further verified that the automatic broadcast control network possesses reliable intelligent preparation capabilities and global control capabilities when dealing with large-scale networked broadcast systems, and validated the high reliability of the automatic broadcast control network's system-level backup mechanism. This completed the overall integration of the two-channel HD broadcasting system.

3.2 System Testing

According to schedule, Feidong County Broadcasting Station commissioned relevant departments of Anhui Television Station to test the HD broadcasting system. The test group used Tektronix TG8000 to provide HD/SD digital video test signals input to production system boards, monitoring output signals through Tektronix WFM8300. The monitoring results are shown in Table 1 .

3.3 SDI Signal Eye Diagram Characteristics

Eye diagrams reflect the analog characteristics of SDI signal waveforms. In eye diagram observation and analysis, observing the closure degree of digital signal eye diagrams is the most critical aspect. Vertical eye diagram closure is caused by noise and amplitude variations, while horizontal closure is caused by timing jitter. Therefore, when eye diagrams maintain a certain standardized opening, it indicates the digital system is operating normally [5]. Eye diagram observation,

as shown in Figure 3 [Figure 3: see original paper], includes rise and fall time observation, signal amplitude observation, overshoot observation, clock period measurement, and various jitter measurements.

The construction of the two-channel HD broadcasting system at Feidong County Broadcasting Station prioritizes television program broadcast stability and reliability. Through scientific and rational equipment selection and solution design, with HD capabilities in both software and hardware, it provides guarantees for further enhancing HD production and broadcasting capabilities.

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