Postprint: MPEG-2 TS-Based Downstream Transmission System for Broadcast Radio

Authors: Zhou Chong, Wen Binhui

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

Abstract

The transmission links through which radio broadcast stations transmit audio signals to downstream units for broadcast coverage are characterized by large quantities, complex structures, and heterogeneous technologies. This article focuses on the MPEG-2 audio encoding technology, elaborates on the formation process of the Transport Stream (TS) under this encoding scheme, and introduces various downstream transmission systems adopted by radio broadcast stations based on the MPEG-2 TS stream, including ASI optical signal transmission, E1, SDH, and others.

Full Text

MPEG-2TS-Based Downstream Transmission Systems for Radio Broadcasting

Abstract: The transmission links for radio broadcasting of audio signals to downstream units for emission coverage are characterized by numerous channels, complex structures, and non-uniform technologies. This paper focuses on MPEG-2 audio coding technology, explains the formation process of the Transport Stream (TS) under this coding scheme, and introduces various downstream transmission systems employed by radio stations based on MPEG-2TS, including ASI optical signal transmission, E1, and SDH.

Keywords: MPEG-2 TS; transmission; E1; ASI; SDH
CLC Number: TN931.2
Document Code: A
Article ID: 1671-0134(2017)08-067-03
DOI: 10.19483/j.cnki.11-4653/n.2017.08.023

By Zhou Chong and Wen Binzhi

Radio broadcasting is a news dissemination tool that transmits sound via radio waves or wired channels, serving as a powerful “weapon” for public voice. Broadcast signals originate from radio studios and are delivered to downstream transmission stations through multiple transmission modes and diverse routing paths. In China, radio coverage is achieved through various methods including FM signals, satellite AM, digital microwave, and fiber-optic cable coverage.

Uninterrupted broadcasting is the lifeline of radio operations. To ensure continuous signal delivery from studios to transmission stations, we design redundant transmission paths for each station, routing the same signal through different links and diverse paths. Representative technologies include Asynchronous Serial Interface (ASI), the European-standard E1 primary-group PCM transmission system also used in China, and Synchronous Digital Hierarchy (SDH). This paper provides a brief introduction and analysis of the principles and applications of these three transmission systems in radio broadcasting.

1. MPEG-2TS Fundamentals

Radio broadcasting has now achieved full digitalization, with professional digital audio formats predominantly using AES/EBU. In each transmission cycle, AES/EBU transmits one frame consisting of two subframes representing left and right channels, with each subframe containing 32 bits. According to China’s broadcasting industry standard “Digital Audio Signal Interface for Studios” (GY/T 158-2000), digital audio uses a 48 kHz sampling frequency [1]. Consequently, the total data rate for a stereo digital signal is 48 kHz $\times$ 32 bits $\times$ 2 = 3.072 Mbit/s. This bandwidth is prohibitively large for transmission and storage, necessitating audio compression techniques to reduce the bit rate. The MPEG family of compression coding technologies emerged to address this requirement.

The MPEG audio coding system employs lossy compression based on perceptual coding, implemented according to psychoacoustic masking effects. During audio encoding, signals below the auditory threshold are either skipped or assigned fewer bits, reducing transmission bit rates without degrading subjective listening quality [2]. Building on this technology, the MPEG-1 standard addressed compression, decompression, and synchronization of audio-visual signals [3], while MPEG-2, an upgraded version, further reduced bit rates and improved audio compression quality. The MPEG-2 standard defines how Elementary Streams (ES) output from the compression layer are packetized into Program Streams (PS) for storage or Transport Streams (TS) for broadcast television transmission.

Typically, AES/EBU signals from radio studios are compressed by encoders into MPEG-2 format, forming Elementary Streams (ES). Packers then perform initial packetization on ES streams through grouping, packaging, and adding packet header information, producing Packetized Elementary Streams (PES) of variable length. PES streams subsequently enter multiplexers for secondary encapsulation, where they are repackaged and multiplexed into Program Streams (PS) of arbitrary length. Transport Stream (TS) represents a third packaging stage of PS. By this point, the Elementary Stream has undergone three encapsulation layers. TS has a fixed length of 188 bytes (though PES can also be directly packetized into TS [3]). Because PS stream length is variable, synchronization information positions within PS packets are not fixed, making them prone to information loss. In contrast, TS streams have fixed lengths, enabling detection of synchronization information at fixed positions within packets. Consequently, TS streams are most suitable for transmission over error-prone channels, while PS streams are used when channel conditions are good and cost/time savings are desired. The MPEG-2-based PS and TS formation process is illustrated in Figure 1 [Figure 1: see original paper].

2. Radio Broadcasting Transmission Methods for MPEG-2 TS

In radio broadcasting, signals from studios are encoded by encoders, sent to multiplexers for packaging into MPEG-2 TS streams, and then transmitted to downstream units through different transmission methods and multiple routing paths. The following sections introduce these transmission approaches.

2.1 ASI Optical Signal Transmission

ASI (Asynchronous Serial Interface) adapts MPEG-2 TS streams to an asynchronous serial interface, enabling MPEG-2 TS streams at different rates to be transmitted at a constant ASI bit rate between encoders, multiplexers, and modulators. It primarily uses 8B/10B encoding, generating 10-bit words from each byte of the MPEG-2 TS input stream to create a constant 270 Mbit/s rate. Additionally, 8B/10B encoding provides inherent error-checking capability and robust byte synchronization, enhancing MPEG-2 TS stream interference resistance in transmission channels [3]. Consequently, ASI offers high transmission security and reliability.

In practice, we typically use coaxial cable with BNC connectors for physical ASI stream connections, while employing fiber optics with LED light sources for transmission. This configuration enables long-distance MPEG-2 TS transmission, such as 50-70 km over fiber-optic cables or via satellite links. Therefore, radio stations predominantly transmit ASI streams as optical signals through optical transmitters to downstream units.

2.2 E1 Transmission

The E1 standard is a PCM-based transmission system used in China and European countries. It digitally multiplexes 32 equal channels through synchronous time-division multiplexing. Each channel transmits 8 bits at an 8 kHz sampling rate, yielding a per-channel rate of 8 kHz $\times$ 8 bits = 64 kbit/s, for a total aggregate rate of 64 kbit/s $\times$ 32 = 2.048 Mbit/s. However, not all 32 channels are available for data transmission. The 32 timeslots are numbered CH1-CH31, where CH1 serves as a frame synchronization marker and CH16 carries control instructions, leaving 30 channels for data transmission [4].

A typical stereo radio signal occupies approximately 256 kbit/s after encoding. We can combine four E1 channels through digital multiplexing to form a single broadcast channel for audio signal transmission. Thus, E1 technology enables effective integration of multiple radio signals for transmission through a single device, fully utilizing channel resources and improving efficiency. Most radio stations employ E1 transmission systems with encoding capabilities that enable bidirectional audio transmission to downstream units. Typically, we use fiber-optic media for E1 signal transmission.

However, most radio stations choose to further multiplex E1 signals into SDH for final transmission, as discussed below.

2.3 SDH Transmission

Broadcasting systems primarily transmit audio and video content with long durations, diverse categories, and large bandwidth requirements. The E1 system, limited to 2 Mbit/s per transmission, proves somewhat inadequate. Moreover, broadcasting programs require strict timing synchronization to enable low-latency transmission and accurate parsing.

The emergence of Synchronous Digital Hierarchy (SDH) effectively addresses these issues. SDH integrates digital multiplexing, demultiplexing, transmission, and line switching into one system. It employs Synchronous Transport Module (STM-N) with user-selectable bandwidth levels. SDH transmission rates are determined by STM-N, where N = 1, 4, 16, 64, up to a maximum of 256. With an 8 kHz sampling frequency, each frame consists of $9 \times 270 \times N$ bytes (N = 1, 4, 16, 64, 256). Therefore, STM-N transmission rates are $8000 \times 9 \times 270 \times N \times 8 = 156 \times N$ Mb/s (N = 1, 4, 16, 64, 256). This provides multiple bandwidth options: 156 Mb/s, 622 Mb/s, 2.5 Gb/s, 10 Gb/s, etc. [4]. The large bandwidth and flexible selection well satisfy broadcasting program transmission requirements. Most broadcasting departments select 2.5 Gb/s bandwidth, with some high-demand units upgrading to 10 Gb/s.

SDH's strict synchronization ensures high reliability and low bit error rates for the entire network. Additionally, SDH can form ring networks with self-healing protection capabilities and strong survivability, effectively preventing complete link failure from a single node interruption. SDH also features unified frame structures and network node interfaces, creating a globally unified transmission standard with excellent compatibility. As SDH belongs to the physical layer in the OSI model, we can implement IP network layer transmission based on SDH systems—a direction currently being adopted by some broadcasting systems. Finally, SDH is suitable not only for fiber-optic transmission but also works well in microwave and satellite communications [4], making it the primary choice for national and provincial cable television transmission in China.

In practice, we can adjust ASI signal bandwidth through appropriate adapters before sending them into SDH systems for unified transmission. SDH bandwidth consists of multiple 2 Mbit/s and 45 Mbit/s channels, as shown in Figure 2 [Figure 2: see original paper].

3. Conclusion

Radio stations employ diverse program signal transmission methods, which collectively ensure uninterrupted, high-quality broadcast signals. However, no single transmission method holds absolute advantages. For instance, while SDH offers high bandwidth, strict synchronization, and self-healing capabilities, it also has higher costs. Therefore, in practical applications, we must select appropriate transmission methods based on specific requirements, channel conditions, and cost considerations to achieve optimal transmission quality and economic efficiency.

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