Postprint: Research on Time Reference in Broadcasting Network Transformation

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Abstract

As broadcasting and television services transition to IP-based architectures in future developments, network optimization and construction remain a major challenge confronting radio stations. This paper primarily focuses on the broadcast control system at radio station centers, analyzing the technologies required for clock system construction and the issues requiring attention during its network transformation.

Full Text

Research on Time Reference in Broadcast Network Transformation

Abstract: As broadcast and television services transition to IP-based architecture, network optimization and construction remain significant challenges for broadcast stations. This paper focuses on the broadcast control systems at radio stations, analyzing the technologies required and key considerations for clock system construction during network transformation.

Keywords: broadcast business; networking; IEEE1588; clock

With technological innovation and shifting audience preferences, the integration of traditional media with modern Internet technology has become an undeniable necessity. The effective combination of traditional media content with new media technology enables resource convergence, communication integration, and shared benefits. A review of network technology’ s evolution reveals that the modern Internet has always been technology-driven, making technology leadership the inevitable path for broadcast development. However, in the transition of professional broadcast and television to IP-based architecture, a major obstacle persists: network control. Essentially, IP networks lack the predictability and Quality of Service (QoS) required by real-time broadcast environments.

Network congestion, bandwidth management, network configuration, the identification and calculation of dynamic changes in network nodes caused by device additions or removals, and the timeliness of troubleshooting with new technologies all complicate existing broadcast operations. To achieve this transition, beyond specifying transmission signal standards, establishing a time reference for signals and devices is another critical requirement.

TOP (Timing over Packet) technology embeds local clock information into data packets through algorithms and encapsulation formats for transmission, recovering the clock at the receiving end to minimize network transmission losses. Using TOP technology enables synchronization across the entire network. Its advantages include: support for network transparent transmission, no requirement for intermediate devices to support TOP, flexible application, and mature implementation technology. Its disadvantages are: clock quality depends heavily on network quality, significantly affected by network delay jitter, packet loss, and out-of-order delivery; and lack of standardized protocols prevents support for time synchronization.

Ethernet physical layer synchronization fundamentally transforms asynchronous networks, achieving synchronization at every network node. Similar to SDH methods, it directly utilizes physical layer signals to recover the clock from serial data streams, differing from TOP' s packet-based synchronization and remaining independent of service data. It employs dedicated packets for clock information transmission. Advantages include excellent clock synchronization quality, approaching that of SDH networks, and immunity to network conditions. Disadvantages include: not all Ethernet interfaces can recover clocks, and it requires full network deployment.

1. Time Reference Technology Introduction

With the AES67 standard' s introduction, signal transmission specifications now have a foundational protocol. Current AOIP solutions—including RAVENNA, Dante, and LiveWire+—all achieve interoperability based on AES67. These systems convert real-time audio and video into IP data streams, requiring a unified reference clock to align with Internet packet-based transmission principles. Time deviations can cause packetization and switching errors in IP networks, ultimately leading to packet loss and sequencing issues. While IGMP and other network protocols can ensure data transmission and reception priority, error accumulation causes increasing switching delays. When this delay exceeds 512 sample values, real-time audio and video decoding at the receiving end will be interrupted, which is fatal for broadcast' s real-time business requirements.

Therefore, in IP environments, we must provide a time reference equivalent to traditional synchronization mechanisms for broadcast applications. To carry real-time audio and video streams over IP-based packet transport networks, the industry has proposed several packet clock synchronization technologies: TOP (Timing over Packet), Ethernet physical layer synchronization, IEEE1588V1/V2, and NTP (Network Time Protocol).

IEEE1588 is a precision clock synchronization protocol standard for network measurement and control systems, employing PTP (Precision Time Protocol) with microsecond-level accuracy. IEEE1588 achieves this high precision through timestamp technology. A timestamp (TS—Time Stamp) marks the transmission time of data packets. When transmitting PTP messages via Ethernet, the 1588V2 protocol inserts the timestamp point at the first bit position after the Ethernet preamble, before the network layer packet. By moving timestamp processing below the data link layer and utilizing hardware to record packet arrival and departure times, timestamp accuracy is greatly improved [1]. The IEEE 1588 standard was approved by the IEEE Standards Committee at the end of 2002, with the V2 revision completed in 2007. Advantages include: time and frequency synchronization, high synchronization precision, and an industry-unified standard. Disadvantages include: no support for asymmetric networks and requiring software and hardware upgrades.

NTP (Network Time Protocol) synchronizes time between distributed time servers and clients, defined by RFC 1305. NTP transmits based on UDP messages using port 123. Similar to IEEE1588, NTP employs timestamp technology, but while IEEE1588 processes timestamps at the data link layer, NTP processes them at the network layer. The uncertain delays from network layer to link layer encapsulation and link layer to network layer decapsulation cause NTP errors to reach tens of milliseconds, severely affecting time recovery precision.

2. Key Technology Analysis

Although the entire AOIP network can be built as a relatively simple local area network, considering future wide area network applications, our station selected IEEE1588V2 as the unified reference clock technology for our AOIP network. The network diagram is as follows:

[FIGURE:N]

To provide stable IEEE1588 clock synchronization while calibrating with GPS, our station selected Sonifex’ s AVN-GMCS series products. This series features built-in GPS receivers, phase-locked loops, and dedicated vehicle-mounted clock equipment to ensure precise, low-jitter clock signals while synchronizing with GPS. It can provide both PTPv2 and WordClock synchronization signals, serving as both an AES67 PTP master clock and maintaining compatibility with existing equipment. Based on our station’ s actual requirements, we selected the model with a built-in chip-level cesium atomic clock, which can maintain accuracy of $±$1 second per 11.5 days worst-case scenario when GPS signals are lost.

A crucial technology in the IEEE1588 protocol is the BMC (Best Master Clock) algorithm. This algorithm ensures that every device in the clock network can serve as a master clock, significantly enhancing clock network stability and security. The BMC algorithm consists of two components: a dataset comparison algorithm and a state decision algorithm. The state decision algorithm determines local clock port states using the dataset comparison algorithm, making it essentially a collection of multiple dataset comparison operations [2]. In IEEE1588, the dataset comparison algorithm compares the device' s own clock information with the master clock' s information through three specific steps:

(1) Compare the UUID fields of the two master clocks participating in the comparison. If they reference the same master clock, proceed to step 2; if not, determine which to use as master clock by comparing clock characteristics.

(2) If the participating master clocks belong to the same system or have equivalent status, compare the path length from the local clock to the master clock. The clock with the shortest path length is selected as master clock.

(3) If the path length comparison results are identical, compare the receiving port numbers of the two clocks, selecting the smaller port number as master clock. If the receiving port numbers are also identical, compare the clock' s sequence ID value, selecting the larger value as master clock [3].

With SMPTE 2110 standard's inclusion of IEEE1588V2 clock support, it further demonstrates that IEEE1588 is a generalized standard with extensive coverage and application fields. Deploying this PTP standard system at our station facilitates seamless integration between existing audio networks and future video networks, providing a solid foundation for broader IP data stream applications.

3. Considerations for Network Transformation

According to the formula n = c/v, where the speed of light in vacuum is c = 299,792,458 m/s and n represents the fiber refractive index (typically using the recommended value of 1.458 from Agilent OTDR testers), we calculate: v = c/n = 299,792,458/1.458 = 205,618,969 m/s. The delay for 1 meter of fiber is calculated as: 1/205,618,969 = 4.86e-9 s/m = 4.86 ns/m. This means 1 meter of fiber introduces approximately 5 ns transmission delay. According to the 1588V2 time synchronization calculation formula, approximately 400 meters of fiber asymmetry introduces 1 s time synchronization error, while 1 meter of asymmetry introduces 2.5 ns error. The IEEE1588 protocol has stringent requirements for fiber asymmetry. Therefore, our station adopted two measures when deploying the AOIP network to avoid fiber asymmetry: first, minimizing fiber usage; second, using two fibers per path—one for upstream and one for downstream. In practical application, AOIP signal delay remains below 0.1 s, causing no impact on data transmission.

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