QoE-Aware Switch Architecture for MPEG-2 Transport Stream Digital TV Broadcast

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SUMMARY

Digital terrestrial television (DTTV) uses MPEG-2 transport stream (MPEG-2 TS) as the standard input format for radio modulators that transmit television signals in single frequency networks (SFNs). A common approach adopted by terrestrial TV stations is to employ redundant video sources, multiplex them with local content, and retransmit the resulting stream over a local coverage area. In Brazil, this scenario is widely used in the context of Regional TV, where a nationwide stream carries the national programming of a given TV channel and is later multiplexed with local content (e.g., regional news and advertisements). The resulting stream is retransmitted through DTTV, enabling regional content segregation in broadcast television.

The stream source inputs for such retransmission stations may vary across different electrical interfaces and physical or network layers; however, the transport layer is consistently based on MPEG-2 TS. Examples of interfaces used as stream sources include the European Committee for Electrotechnical Standardization (CENELEC) Asynchronous Serial Interface (ASI), IP-based networks employing Hypertext Transfer Protocol (HTTP) Live Streaming (HLS) or User Datagram Protocol (UDP) over Ethernet, and parallel data outputs from Digital Video Broadcasting (DVB) satellite demodulators. These redundant systems are deployed to maintain DTTV operation under adverse conditions. However, switching between inputs only when a failure occurs does not fully exploit the benefits of redundancy and does not necessarily ensure the best Quality of Experience (QoE) for the viewer.

In this work, the authors propose a digital architecture for a QoE-aware switch targeting DTV broadcast applications. The architecture detects available sources, processes transport stream packets, and analyzes discontinuities to automatically select the stream source that provides the best QoE. In this context, the best source is defined as the one exhibiting the lowest packet loss among redundant streams.

The proposed QoE-aware switch architecture supports four transport stream sources connected to an input FIFO group composed of asynchronous FIFOs, one for each source. The incoming streams pass through the Sync Recovery Unit (SRU), responsible for generating the synchronization flag used to identify packet boundaries and coordinate the Packet Processing Unit (PPU). The PPU monitors the incoming data flow, detecting and counting discontinuity events through independent counters associated with each input interface. These counters are evaluated by the Main Control (MC) module, which determines the multiplexer selection according to parameters configured through a memory-mapped interface. A clock divider generates the output stream clock independently of the system operating frequency, defined in this implementation as 27 MHz for the transport stream and 108 MHz for the system clock. The selected stream is then written to the output FIFO to perform clock domain crossing (CDC), ensuring safe synchronization between clock domains and preventing metastability or glitches.

The design was implemented and synthesized on an Intel Cyclone V FPGA, demonstrating low hardware resource utilization and low power consumption while achieving a maximum operating frequency of 145 MHz. Considering that transport streams typically operate at lower frequencies, such as 27 MHz, this margin indicates that timing constraints can be relaxed to further improve logic resource utilization (or silicon area in a potential ASIC implementation). Functional verification using real MPEG-2 TS video streams confirmed that the proposed architecture successfully detects discontinuities and dynamically selects the best available source. Experimental results showed noticeable improvements in playback continuity, reducing visual artifacts such as freezing and pixelation when compared to fixed-source transmission.

These results indicate that the proposed architecture is an efficient and lightweight solution for improving Quality of Experience in redundant DTV broadcast retransmission infrastructures. Future work includes extending the selection criteria to incorporate additional QoE-related metrics and supporting multiple PID tables with independent counters for each program multiplexed within an MPEG-2 TS.