Live video over IP based networks

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Abstract

Since the inception of Television, the movement of video signals across distance is the most important facet of the television industry. When TV first started a single line of coaxial cable could carry 1 black and white picture from point A to point B. Today however, with modern advances in technology, these signals can be sent to the moon and back. The biggest advance in this industry is the digitization, compression and transport over a standard IEEE 802.3 ethernet network. There are many ways to complete this both with advantages and disadvantages. High latency compressed video streams will be explored, followed by low latency network transport streams. Finally, High bandwidth, low latency video transport protocols will be explored.

Introduction

Getting video over an IP network has proved to be a very challenging and costly endeavor, both in time, and performance. Overall, digital video has existed since 1989, where SMPTE 259M was enacted. This standard allowed standard definition video to be transmitted digitally over a 75 ohm coaxial cable at a rate of 270 mbps. It also replaced analog baseband (composite) video as the main transport for professional broadcast equipment. Although this standard is obsolete, SMPTE has SDI standards up to 4320p60 fps. (SMPTE ST-2083) However uncompressed, this standard uses 24 gbps. How can these monstrous video streams be sent over a standard IP network?

High Latency internet based video transport

The first method of transporting live video over an IP connection would be a high latency (+1 sec), low bandwidth transport solution. Examples of these include protocols such as HLS, and MPEG-Dash. These are most often found on video streaming websites such as Twitch, and

Youtube. These protocols work fundamentally different from other protocols listed below in the fact that they send separate video files of varying lengths to the client device. Because of this, on slower connections, larger video files are transported over the link to minimize the amount of buffering a user experiences should a connection fail to maintain data integrity. These video files are stored on the client's RAM for seamless rewinding of clip and smooth playback once the file has completed transferring. In general, this is referred to a progressive download video stream The main drawback of this is the latency is the length of the clip stored on the device. This makes it challenging to gain audience interaction as the viewer will be watching a delayed version of the program. In addition to that, because delay can be more than 1 minute, makes it unsuitable for live Television as program scheduling often requires frame accurate timing when scheduling programming.

Low Latency Transport Stream over IP

The next form of video over IP would be Low latency compressed video. The main use case for this would be for IP-based Studio Transmitter links. (STLs) Because the ATSC Television Standard in use in North America specifies a 19.3mbps transport stream for terrestrial television across the continent. SDI video signals are then sent into an encoder which utilizes MPEG 2 (H.262) compression to lower the data rate from 1.5gbps (in the case of HD video) to 19.3mbps. In addition to that, multiple streams can even be muxed further decreasing the amount of bandwidth per video stream. However, adding more video streams per TS lowers the bitrate per each stream causing compression artifacts in the form of blocky picture grain to occur as well as worse viewer experience as a result. Traditionally TV stations would use a microwave link between a studio and a transmitter as the transmitter is often located in a separate geographical location from the studio. Currently a multitude of stations are converting to an IP based system

where the TS is sent over an IP network (TSoIP). This allows multiple paths to be taken both over a LAN, (utilizing dark fiber) and a WAN. It also supports both TCP and UDP based transport. This allows both varying levels of forward error correction to be applied, as well as multicast streams to be created. Overall this greatly increases the versatility of the protocol compared to a point-to-point based system. Because of its low data rate 1-2 frame latency can be achieved. (30 millisecond) This is often increased to create a small buffer should packet loss occur, however, TSoIP is a very low latency protocol for sending multiple compressed video streams over an IP network that ranges from the same building to a different state.

Ultra low latency synchronized broadcast networks

Finally, in a lot of live, multi-camera events, such as sporting tournaments and concerts, a full, uncompressed video signal must be sent over an IP network. This is often due to cabling restrictions where more than one stream has to be sent over a single fiber-optic cable. In addition to that, multiple video devices connected to the ip network can receive every stream present in a software based dashboard, as opposed to installing a coax based distribution amplifier. Currently the leading format for this kind of transport is SMPTE ST2110. It utilizes JPEG XS, a low latency (>1ms) lossless codec to send uncompressed video over an IP network. This codec is very lightweight and offers no image degradation between devices. Because of the low latency it is imperative that packets arrive on time and in the correct order. As such, a GPS based grandmaster clock is used to send a precision timing protocol (PTP) either by unicast, or multicast to every device drawing a video signal. This not only allows an extremely low latency to be sent over the network, but it also synchronizes every device in the signal chain. This is very important in both instant replay for athletic events, but also musical performances cameras across a performance venue out of sync with other angles, as well as audio make for an extremely

unpleasant viewing experience. The main drawback to ST2110 is that a 1080P60 stream is 3gbps of constant throughput through network devices, and 4k60 streams increase that to 12gbps per stream. Because of this, 25gbps SFP28 is the current standard for interfacing devices and 100gbps QSFP28 must be high-bandwidth trunk cables between multi layered switches and core pieces of video equipment such as replay servers, production switchers etc. Cisco recommends "the use of Nexus 9300 switches in a spine-leaf topology due to the extremely high data rates and low latency" (Cisco) that is getting passed through the network. Because of this, initial investments are massive and are often an entry barrier for smaller production entities. Currently ST2110 is a new standard and manufacturers are only beginning to adopt the standard, however with the price of high speed networking gear decreasing this standard will allow better high quality programs to be produced all over one cable.

Conclusion

In conclusion, there are 3 main types of video transport that exist, high latency low bandwidth, low latency low bandwidth compressed signals, and ultra low latency, very high bandwidth synchronized video networks. With new advances in local and widespread area networks, the barriers for entry into the IP based video world are decreasing and, soon video over coaxial cable will be a thing of the past.

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