PATH 1

PERFECT VIDEO OVER IP NETWORKS

Forward Error Correction

Challenges of Moving Video over IP networks

Traditional IP networks operate in a best-effort mode: they do not guarantee the delivery of every packet and even if the packets are successfully delivered, there is no guarantee that they will be delivered in the right order or in a timely fashion. For computer data communication, the best-effort mode of operation has provided scalability and reduced operator overhead. But for transmitting live, broadcast-quality video, there are a number of technical and operational issues associated with IP networks which must be properly addressed.

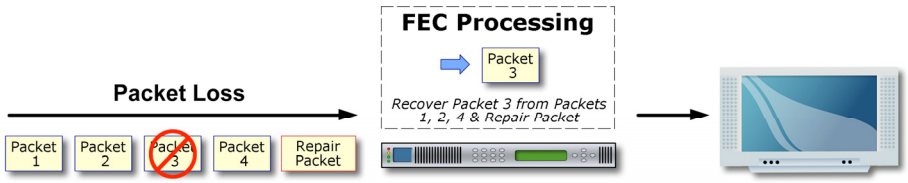
IP Network Characteristics

- **Packet Loss:** Because video is latency-sensitive, any loss or reordering of data packets over an IP network greatly impacts the quality of video and can cause video errors and link resets. A packet retransmission request cannot be processed quickly enough.
- **Packet Reordering:** Packet reordering occurs when the order of the packets at the destination is different than the order of the same packets at the source, which may result in significant picture quality degradation.
- **Packet Jitter:** IP packet jitter is the variation in arrival time of the IP packet compared to its ideal arrival time. Jitter can often cause video motion to appear jerky and cause audio synchronization problems.

Broadcast-quality, real-time video transmission requires an error-free, jitter-free, stable communication channel. While QoS-enabled IP networks can achieve almost loss-free transmission, they may still suffer from variable network delay due to dynamic queuing in the routers and switches. In addition, these networks may experience occasional packet loss and reordering due to link failures which result in temporary interruption of service and re-routing of packets.

The Solution: Forward Error Correction

Forward Error Correction (FEC) is a method of protecting data streams across networks where packet loss and delay are known to exist. Prior to transmission, the data is put through a pre-defined algorithm that adds extra FEC packets specifically for error correction at the receiving end. If a video packet is received in error, the FEC packets are used to check and repair the video so that the exact original packets can be passed on to the decoder. In this way, FEC acts as a shield that protects the video signal from the impairments imposed by an IP network, such as packet loss, packet delay and packet jitter.



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Pro-MPEG COP #3 FEC

The Pro-MPEG Forum has approved an open standard, Code of Practice #3 (COP #3), to address the issues of transporting video over IP networks. One problematic IP network characteristic, burst packet loss, is caused by buffer and re-route issues. COP #3 FEC can protect a video stream from a burst packet loss of up to 255 packets, which is suitable for most private, managed IP networks using QoS techniques such as MPLS, RSVP, and DiffServ.

The generation of FEC packets in the COP #3 standard is based upon a matrix defined by the parameters L and D. L represents the number of columns in the matrix, while D represents the number of rows. The standard defines the generation of two types of FEC packet: Column FEC and Row FEC. A FEC packet is generated by XOR of the media packets in a column or a row. Once generated, the Column FEC packets and Row FEC packets are transmitted along with the original media packets on 3 separate UDP ports to a Pro-MPEG COP #3 compliant receiving device.

Pro-MPEG COP #3 FEC is offered in Path 1's Vx8000 IP video gateway.

ClearPath Pro FEC

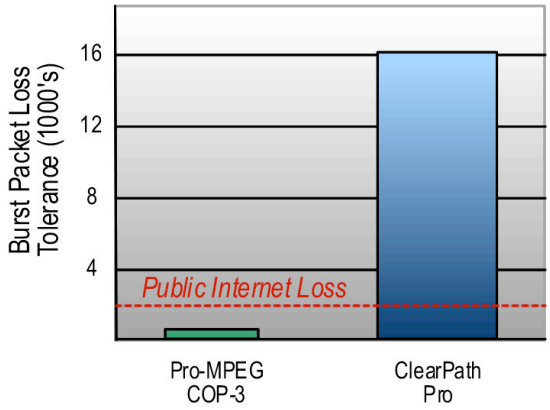
While Pro-MPEG COP #3 FEC is adequate for most private IP links, it is not robust enough to handle the challenges associated with moving video over highly lossy IP networks such as the Public Internet. Path 1's ClearPath Pro is a set of Path 1 extensions to the Pro-MPEG COP #3 standard that dramatically improves the percentage of lost packets that can be recovered by FEC operations. With a burst packet loss correction capability 60 times greater than the Pro-MPEG COP #3 standard, ClearPath Pro can reliably protect live, broadcast-quality video signals from otherwise catastrophic packet losses which often occur when transporting video over the Public Internet. In addition, ClearPath Pro offers the option of single-source UDP transmission, which greatly simplifies firewall penetration of the integrated data stream.

ClearPath Pro's advanced video protection capabilities have been designed for broadcasters, satellite service providers and other TV operators who want to take full advantage of the flexibility and cost benefits realized by leveraging the Public Internet for broadcast-quality video transport.

Both ClearPath Pro and Pro-MPEG COP #3 FEC schemes are both supported in the Vx8000 version 2.0 and greater.

The ClearPath Pro Advantage

- **Enhanced Burst Packet Loss Protection**
  Protected video bit rate increased by a factor of 4
- **Simplified Firewall Penetration**
  Single-source UDP vs. 3 UDP streams in COP #3
- **Smart Packet Interleaving**
  Improves packet recovery capabilities



ClearPath FEC

ClearPath FEC is a proprietary Path 1 FEC scheme which, like its cousin ClearPath Pro, offers enhanced burst packet loss protection capabilities. With the ability to protect video from a burst loss of up to 4096 packets, ClearPath FEC is robust enough to handle losses typical of the Public Internet.

ClearPath FEC is available in Path 1's Cx1020 and Ax120 IP video gateways.

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