Video Distribution Networks Using Remote Statistical Multiplexing

By Ian Trow

Statistical techniques have been used to aggregate video content at broadcast head-ends for some time now. Direct-to-Home systems based on MPEG-2 video encoding are now commonplace thus there is considerable pressure on content providers to make programming available on multiple platforms, with voice and data traffic. Achieving significant reductions in operator costs, to maintain competitive position, is the final consideration facing broadcasters and internet service providers. These demands have led to statistically multiplexed video systems utilizing the IP infrastructure, in addition to dedicated broadcast links, to adopt a distributed topology allowing source encoders to reside at remote broadcaster sites, rather than a centralized headend.

The broadcast industry has used expensive and proprietary hardware to provide statistical multiplexing features in networks since the widespread use of MPEG-2 based systems. With the advent of IP-based networks, the notion of multiplexing compressed sources that are co-located at a broadcast headend is becoming less important, while the requirement to fit multiple channels in a bandwidth-constrained network allowing for encoders to be remotely located is increasingly important.

Centralized architectures have had the disadvantage of requiring high bandwidth links feeding the headend before statistical aggregation of the content. This has resulted in expensive duplication of compression stages, both at source origination and headend aggregation points. Although the cost of bandwidth has reduced significantly, video is still bandwidth hungry, especially when factoring additional quality during the initial compression stage to counteract the subsequent encoder/decoder loss between contribution and distribution compression stages.

Remote statistical multiplexing fundamentally changes the topology, shown in **Fig. 1**, in terms of the encoder/decoder provisioning, bandwidth utilized, number of links required, and potential quality of service.

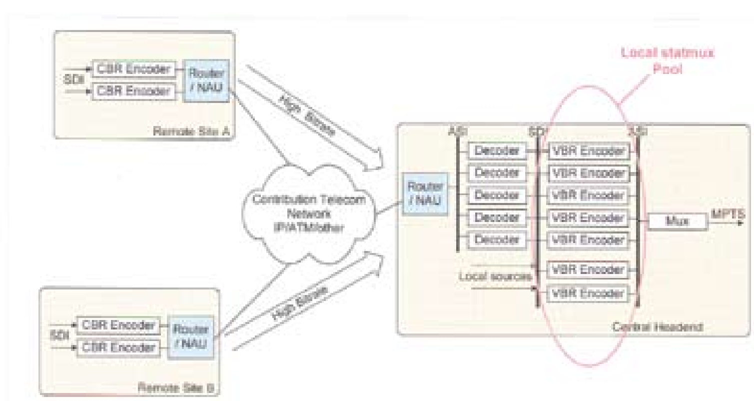


Figure 1. Traditional centralized statistical multiplex architecture.

As shown in **Fig. 2**, the encoders can be located at either remote sites or a central headend. There is no longer a need to operate contribution encoders at constant high bit rates, requiring professional decoders at the headend.

The key to being able to decentralize statistical multiplexing systems lies in the synchronization of control and signal sources across multiple sites. Before describing the mechanisms behind remote statistical multiplexing, the fundamental encoder bit rates modes will be explained, as well as the common system topologies.

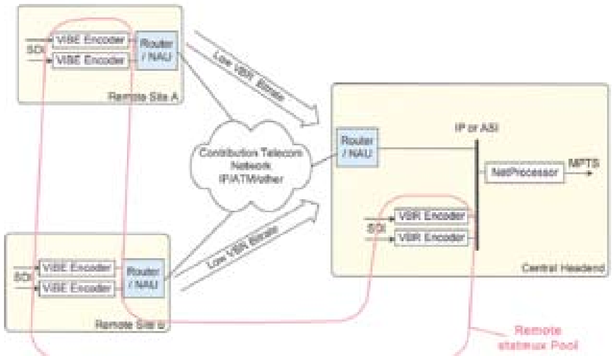


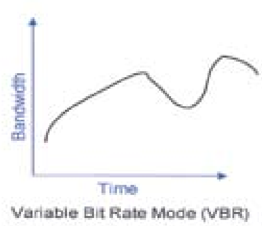
Figure 2. Remote distributed statistical multiplex architecture.

Encoder Bit Rate Modes

Fundamental to the way compression encoders operate is the way bit rate is allocated. There are four bit rate allocation methods available to encode content:

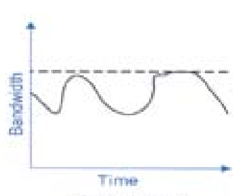
Variable Bit Rate Mode (VBR)

The encoder optimizes for a specified picture quality. Typically, the encoder will operate around an average bit rate.



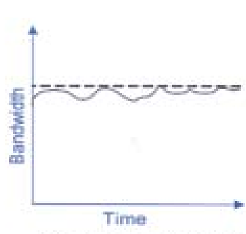
Capped Variable Bit Rate Mode

Encoder optimizes for a specified picture quality within an externally determined capping level. Typically the encoder will operate around an average bit rate, but never exceeds the cap.



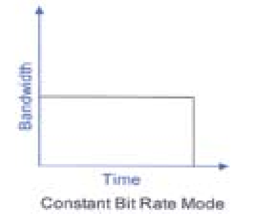
Available Bit Rate Mode (ABR)

Encoder utilizes as much of the bit rate as available within the channel.



Constant Bit Rate Mode (CBR)

The encoder utilizes as much of the bit rate as available, and uses null packet stuffing to fully utilize the available channel.



Closed Loop Statistical Systems

In closed loop statistical systems all encoders directly communicate complexity information to a central management system that allocates individual encoder bit rates. This configuration is often used in video headends where the encoders are located on the same premises. Closed systems offer the most efficient use of bandwidth, allowing the minimum bit rate to be used to encode all the channels at the desired picture quality.

Open Loop Statistical Systems

In open loop statistical systems no complexity information is exchanged between the encoders and the management system. This configuration is sometimes known as rate-shaping. Bit rate savings are made by:

1. Manipulating the compression feeds to avoid simultaneous demand peaks. Peaks occur when the most bit rate-intensive encode modes are presented to the multiplexer (i.e., I reference frames). Buffers are used to shift individual compression feeds to achieve the minimum bit rate output for all the channels.
2. Within compression feeds up to 10% of the available bit rate on CBR-encoded material consists of null packets. These can be removed, allowing the bit rate to be reallocated for conveying compressed channel data at a downstream multiplexer.
3. It is possible to reduce the bit rate of a particular compression feed by re-optimizing the quantizing applied to the compression feeds. This is done when feeds need to fit into a narrower channel bandwidth, which frequently happens with DTH material before distribution over an IPTV network. This process is sometimes known as trans-rating.

Open systems are very common in cable and IPTV headends, where distant broadcast feeds are combined for re-distribution and it is not possible to establish a feedback path for closed system operation.

Remote Closed Loop Systems

With the increasing availability of infrastructure that allows the establishment of reliable, low latency management links, it is now possible to operate closed statistical systems where all the encoders are not co-located. Operating in this mode requires

VIDEO DISTRIBUTION NETWORKS USING REMOTE STATISTICAL MULTIPLEXING close synchronization between the various encoder sites and the central signal aggregator. Two methods can be used:

1. Time-stamping on both the signal and management links, to allow the use of buffers to adjust for network variations.
2. Using signal and management networks that can guarantee operation within tight latency tolerances and high network availability limits.

The increasingly diverse makeup of delivery, playout, and content origination means there is often a strong desire to have remote encoder topologies.

Matching the Correct System Approach to a Network

Closed systems have been a dominant statistical style, particularly for legacy MPEG-2 DTH systems, where the encoders are co-located or linked through a reliable LAN. However, there are plenty of applications in which close coupling of encoders is not possible. This is where the feedback provision is prohibitively expensive or cannot offer the reliability and availability to allow tight synchronization between the encoders and management system. It is becoming increasingly popular for content owners to manage the compression of their own material, thereby creating a need for a remote statistical system. The main pre-requisite for the remote systems is a reliable, low-latency, and high-availability WAN link to link the various sites.

Although technically demanding, this is a viable option for many applications, particularly if only one compression stage is needed at the origination site. Many advanced distributed systems are using WAN linked encoders to IP multiplexers, where previously two stages of encoding had to be deployed—a contribution encoder at the content source site, and one at the transmission site along with a multiplexer.

Statistical Feed Synchronization

Although operating statistical systems consisting of remote encoders is ideal from a broadcasters perspective, the technical aspects of remotely synchronizing sources has forced implemented systems to adopt an open topology in legacy systems, where complexity information is not used and therefore the savings in bit rate are moderate compared to closed systems.

To make remote statistical multiplexing systems work, it is an absolute requirement that the encoders accurately synchronize their bit rate changes. This involves the management system not only being aware of the individual source encoder's bit rate requirement but also taking account of the path delays associated with the network connection for each encoder (**Fig. 3**).

Failure to accurately synchronize sources will result in the multiplexer incorrectly calculating the output bit rate, resulting in a potential overshoot (**Fig. 4**).

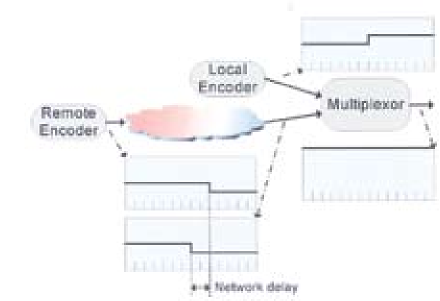


Figure 3. Encoder feeds synchronized.

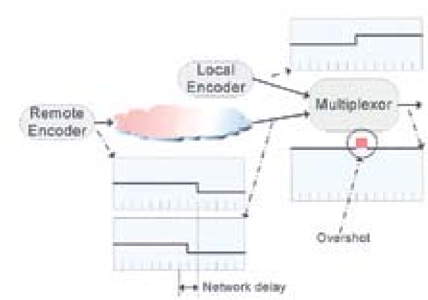


Figure 4. Encoder feeds not synchronized.

Two commonly used systems are available for synchronization, Network Time Protocol (NTP) and Global Positioning System (GPS). However, both NTP and GPS have serious drawbacks, poor accuracy for NTP, additional equipment for GPS, and, above all, they require network delays to be known with very high accuracy, which on most networks will be impossible. A network delay is typically of the order of a few tens of milliseconds where an MPEG multiplexer deals with transport stream packets of a few tens of microseconds.

Complexity and Bit Rate Exchange Mechanism

Statistical multiplexing algorithms rely on exchanging information between encoders and a bit rate allocator. The encoder sends information toward the bit rate allocator, a value representing the complexity of the video to encode and receive a bit rate to apply, from the allocator.

With remote statistical multiplexing, complexity and allocated bit rate are exchanged over IP. This makes remote statistical multiplexing very easy to deploy in the field and at the same time, introduces network latency and jitter in the transmission of complexities and bit rate messages.

As shown in **Fig. 5**, each statmux pool is assigned a pair of multicast group addresses, which serve as mailboxes to exchange bit rates and complexities. Every video frame, picture complexity is estimated by encoders and transmitted to the NetProcessor through a complexity multicast group address. Simultaneously, bit rates are calculated by NetProcessor and transmitted to all encoders through a bit rate multicast group address.

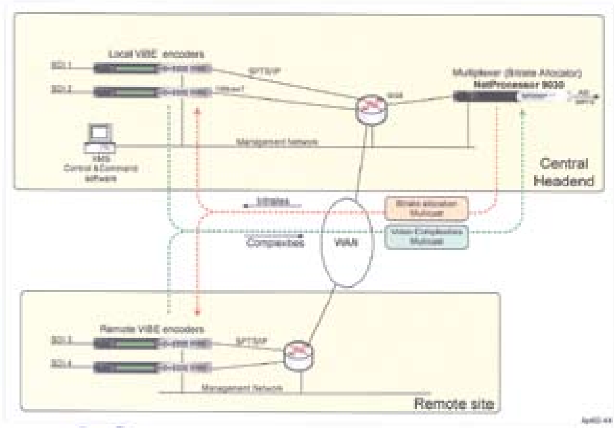


Figure 5. Remote statmux pool multicast addressing.

The main reason for using multicast is to support equipment automatic switchover at the remote encoding site and at the central headend.

Dealing with Network Delay on Control Messaging

The transmission of bit rates and complexities uses UDP/IP on WAN networks; thus it is always possible that a message may not reach its destination from time to time. It is important to evaluate the different failure scenarios to make sure the system will tolerate these failures and that no service interruption will be observed.

- *Loss of one single bit rate message:* Inherent within the remote statmux control mechanism, it is necessary to protect the protocol itself by including some level of information redundancy. This failure scenario has no impact on service.
- *Loss of several consecutive bit rate messages:* This should be a rare event, but should it happen, the encoder will switch to a minimum bit rate first and then to a default bit rate, which will guarantee a minimum level of video quality until bit rate messages are received again. This failure scenario will cause a small degradation of video quality, but will not cause any bit rate overshoot at the multiplexer.
- *Loss of single complexity messages:* The remote statmux control mechanism will simply extrapolate the complexity from a previous message. This failure scenario has no impact on service.
- *Loss of several consecutive complexity messages:* The remote statmux control mechanism will allocate the default bit rate to the encoder in order to guarantee a minimum video quality for this channel until complexity messages are received again. This failure scenario will cause a small degradation of video quality, but will not cause any bit rate overshoot at the multiplexer.

Remote Statistical Multiplexing Applied to a VSAT Network

Very Small Aperture Terminal (VSAT) systems allow a remote site to connect to an IP network via satellite. This is particularly useful in the case of remote area, temporary access, mobile application, or whenever the cost for a terrestrial IP circuit is prohibitive. At first glance, the very high latency of VSAT links does not fit well with the statistical multiplexing response time requirements. However, many MPEG-based systems are now designed to support very long latency networks and can support remote statistical multiplexing over VSAT networks.

Figure 6 is an example of deployment of statmux over VSAT, where N remote sites (OB-Van) are equipped with a redundant MPEG-4 encoder and two satellite links: one DVB S or DVBS2 link to transmit a VBR video into a CBR transport stream (e.g., 2 Mbits/sec average video into a 5 Mbit/sec CBR transport stream) and one VSAT link to the central location for data communication. It is assumed here that two different satellites carry the VSAT link and MPEG transmission. In this example, a

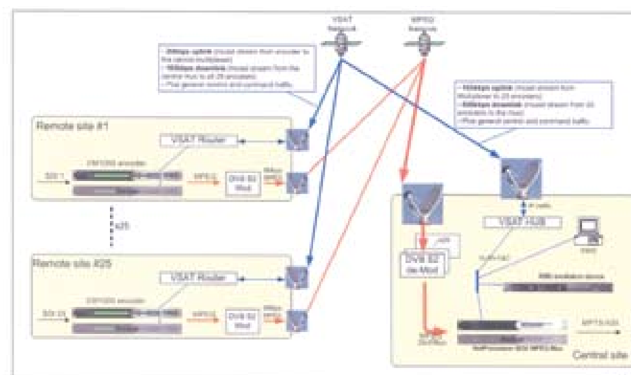


Figure 6. Example of remote statmux over a VSAT network.

central teleport is equipped with a redundant remote statistical multiplexer, which multiplexes all 25 programs into a single transport stream and controls the remote statmux algorithm.

VSAT Bandwidth

The bandwidth necessary to run remote statistical multiplexing depends on the number of encoders and multiplexers in the system. So the numbers given here apply only to the example described in **Fig. 6** (one transponder carrying 25 programs). The implementation relies on two multicast streams: one multicast stream carries video complexity messages from each encoder to be used to calculate the bit rate to be allocated to each encoder. The second multicast carries the bit rates assigned by the multiplexer to each encoder. Each encoder must receive this “bit rate” multicast to retrieve its own bit rate assignment.

Each remote site requires an uplink capacity of 20 Kbits/sec per encoder to send complexity messages to the central multiplexer. The central site must have a downlink capacity of 500 Kbits/sec to receive the 2 x 20 Kbits/sec from the 25 remote encoders.

On the return path, the Central Site must uplink 165 Kbits/sec total, to muticast bit rate allocation messages to all 25 encoders. Each remote site must therefore downlink the full multicast of 165 Kbits/sec to retrieve its own messages.

VSAT Latency

The latency of a VSAT link depends on a number of factors: technology used for transmission, VSAT router/Hub vendor, and location of uplink on earth. In order to simplify the discussion, it is assumed here that the latency of the VSAT network between the encoder ethernet port and the multiplexer ethernet port is 350 ms maximum each way (source: iDirect website).

Video Network Delay Range

The remote statistical multiplex algorithm is sensitive to video delay variation between encoders. In our example, the difference of delays for video transmission between two encoders and the central multiplexer can come from different geographic location and therefore different propagation time over the satellite. This delay is typically 20 ms.

Multiprofile, Resolution, and Bit Rate Applications

The topology shown in **Fig. 7**, is the combination of national and regional headends, offering multiple statistical groups. MPEG encoders are now being introduced with the ability to output multiple profiles simultaneously from the same input. Each of these profiles can obey different statistical rate control parameters. For example, a unit can output three DVB-H profiles, each belonging to a different statistical rate control group.

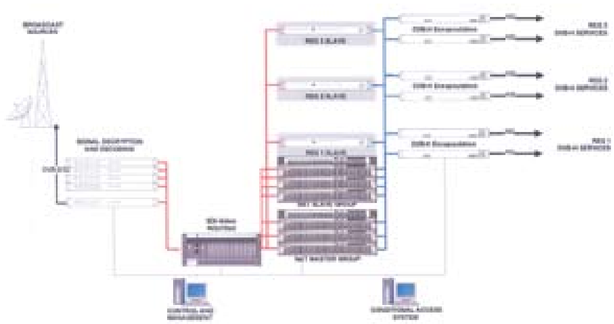


Figure 7. Multiprofile, resolution, and bit rate statmux applications.

This flexibility can have great cost advantages when it is necessary to compose various statistically rate-controlled DVB-H groupings, or "bouquets," sharing common channels. This is the case in many national broadcast networks that wish to include regional content or advertising. Instead of using dedicated encoders for each bouquet, the same encoder can be reused to output the same channel to various bouquets under different rate controls. Thus, this can significantly decrease the headend cost compared to encoders tightly linked to a DVB-IPE (IP encapsulator) where equipment needs to be replicated for each bouquet.

Conclusion

With the development of statistical multiplexing techniques, encoder design and network capability, broadcasters and internet service providers can now deploy systems with optimum multiplexing performance, minimal network bandwidth, and significantly reduced equipment inventory, compared to previous legacy systems.

Remote statistical multiplexing allows encoders within the same statistical multiplex pool to be sited in remote locations. Previously, encoders had to be co-located at a central head-end. Remote statistical multiplexing also overcomes the expense and complexity associated with closed loop statistical systems at a central headend, which require both contribution and distribution compression stages; in remote.

Overall, compression performance is optimized because cascaded compression stages are not required. Previous systems utilized encoders initially operating in constant bit rate mode for the contribution stage and variable bit rate mode for the subsequent distribution stage.

Remote statistical systems are well suited to re-use existing IP network infrastructure already deployed for voice and data. In addition, standard network protocols and open standards can be used for redundancy and error correction strategies in remote statistical multiplexing systems.

Acknowledgments

The author would like to thank Pascal Gravoille, Alain Pellen, and Are Olafsen for their help in putting this paper together.

Presented at the SMPTE 2007 Australia Conference in Sydney, Australia, July 17-20, 2007.

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