

Optimizing Statistical Multiplex Systems

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Introduction

The purpose of this application note is to guide Scientific Atlanta field service representatives who are installing encoding systems for various distribution applications, or for our customers. In both cases there is a need for tuning the encoders for the given targeted transmission channel.

The guidelines are valid for both MPEG-2 or MPEG-4/AVC encoders. Primary focus is SD encoders, but most is relevant for HD encoders as well. The application note includes statistical multiplex applications variable bit rate (VBR) and constant bit rate (CBR).

All recommendations are given in general terms, but it is anticipated that there is either a PowerVu® Network Centre (PNC) or ROSA® control system to configure the encoders.

It is assumed that the system is correctly installed and all services are running through the encoders via a multiplexer (if needed) and feeds the distribution channels, being a satellite, cable plant, IP network or other terrestrial distribution system.

Sources

Before starting to change any encoder settings, the first thing to do is to carefully characterize the sources. The video sources are coming in as digital (component) or analog (NTSC or PAL). They need to be viewed on a good monitor, and preferably on the same monitor that will be used to evaluate the encoded output. If possible, use a high-grade professional monitor, as this will give the most reliable result. See the section on monitors below.

Create a table to capture the notes on the sources as they are reviewed one by one. If we are talking about a large system (multiple multiplexes) it is beneficial to work on one multiplex at a time. An example of a table is listed below.

Index	Source Name	Encoder IP Address	Analog/Digital Origin	General Quality	Level of Noise	Observations
1	CNN	185.10.25.10	Analog	Soft	Medium analogue noise	
2	History channel	185.10.25.11	MPEG-2	Sharp	Little MPEG artifacts	

On the sources, it is important to detect whether this is a direct studio feed (high quality), an analog off air (terrestrial or satellite), or a previously digitally compressed source (typically MPEG-2 from satellite or terrestrial). If this is previously compressed, it is valuable to know the horizontal resolution, and possible bit rate range. If this is previously encoded, it may be an option to use the Auto-concatenation option on the Scientific Atlanta Model D9032™ or D9040™ encoders. When re-encoding, for best results, use the same horizontal resolution as used with the source video at the starting point. Depending on the target bit rates on the output, the horizontal resolution could be reduced.

As part of the source review it is important to estimate the level of noise in the source. Note that some noise may be content dependent, such as old film with impulse noise, a high level of camera noise in the footage or excessive MPEG-2 blocking in low bit rate DSNM material. Content-dependent noise will change over time, so it needs to be considered separately. The distribution path from the studio to the headend is likely to add some form of noise as well. Analog terrestrial or satellite distribution typically adds Gaussian noise, and if you encounter digital compressed source, there will be some level of MPEG-2 encoding artifacts.

Each source needs to be evaluated for sharpness, analog noise or MPEG-2 artifacts. Observations are noted in the table, and any content related noise, needs to be noted.

Monitors

There are a lot of different monitors: plasma flat panels, LCDs, rear projection TVs and CRTs. CRTs are generally preferred, as many flat panels rely on internal conversion circuits to fit the display resolution. The appearance of the video depends on the quality of the monitor and how it is configured. Many consumer TVs have some form of contrast or sharpness enhancement that tend to amplify compression artifacts. The monitor chosen for the evaluation should be set to a configuration where it presents the video in a neutral fashion, all digital noise reduction turned off. The most important aspect of picture quality is sharpness, hence it is important to use a monitor with a high resolution. The room where the evaluation is done should also be shielded from sharp light sources, preferably with an option to turn off the light.

Statistical multiplex systems

Optimizing a statistical multiplex system is more difficult than a constant bit rate system. First of all, the different encoders influence each other. The perceived quality of a given sequence does depend on what content is being encoded by the rest of the encoders in the system, so if a given video sequence is repeated on a test channel the quality will change from run to run depending on the other channels. Additionally, if measures to ease the encoding of a given channel are applied, e.g. noise reduction, the fact that the content has become easier to encode will cause the statistical multiplex system to allocate fewer bits to that particular channel, hence the benefits from the noise reduction is shared across all encoders. The particular channel will have less noise, but it will also be allocated less bits in the system, which tends to reduce the quality. In other words, changes need to be applied across all encoders, not just one at a time. Alternatively, if there is a need to focus on one channel at a time, the statistical multiplex system needs to be disabled.

For best possible quality, the encoders should be set to the extended delay mode. If a smaller end-to-end delay is needed, normal could be selected. Low delay is generally not recommended and should only be used for targeting set-tops with limited VBV buffer sizes.

Bandwidth Optimization

It is very important to optimize the bandwidth in your transmission channel. Every null packet represents a wasted opportunity for improved picture quality. By adjusting the default bit rates up, the amount of null packets can and should be minimized. For a ROSA-controlled system it is recommended to use the Statmux Pool Manager (SPM) to minimize null packets. For a PNC-controlled system, this is done in PNC's multiplex group manager. It is always very beneficial to measure the resulting stream with a stream analyzer. Lacking that, use the bit rate measuring capabilities in the multiplexers. For a MPEG-2-based synchronous statistical multiplex system, the amount of null packets can be reduced below 1 percent. For an asynchronous system the target is less than 2.5 percent. To ensure safe operation in an asynchronous system, switch off the REGULUS™ statmux controller, or the Scientific Atlanta Digital Content Manager (DCM) statmux controller. That causes all encoders to operate at a CBR rate with minimum overall null packets, hence it serves as a worst case from a bandwidth perspective.

Minimum Video Rate

Once the overall bandwidth has been adjusted, the focus can be targeted to the individual encoders. The minimum video rate sets the minimum rate the encoder will drop to when encoding. For an MPEG-2 SD encoder, the lowest rate is 0.5 Mbps. Setting the minimum rate very low is beneficial if some of the content is still pictures or only black. Using a very low minimum rate may cause slight problems if the content is switching from simple still pictures to high detail and motion. Here the first couple of frames may be distorted. If this is a concern, set the minimum video rate to 700-800kbps. It is not recommended to force a high minimum rate as a way to give priority to a given channel. Use the priority settings instead. As the minimum bit rates are raised, the benefits from the statistical multiplexing system are reduced, which again limits overall picture quality for the system.

Maximum Video Rate

The maximum video rate sets the maximum bit rate an encoder is allowed to peak its video rate. Typically the maximum rate should be in the range of 2-3 times the default bit rate. However, if the incoming video is very noisy, from strong MPEG-2 artifacts or a lot of analog noise, it is recommend to limit the maximum bit rate. A noise channel acts as a thief in the system and can use a lot of bits just to encode noise. Prefiltering should be used to address a noise channel, but the maximum bit rate should also be reduced. If some channels are given a high priority, their maximum rate should also be increased. This is especially the case for action-rich sports channels.

Priority and Quality Target

For each channel a priority and quality target can be set. Use the default setting of eight as a starting point. If a channel is considered more important than others, priority should be increased. Start by increasing it with three or four to 11 or 12, and watch the impact. Likewise a less important channel can be reduced.

Normally the quality target should be set for best possible quality (15), in which case an encoder always will try to get as high a bit rate as possible. By reducing the number of the target picture quality, the encoder will not take more bits than needed to achieve the given target. Other channels will benefit from that. If all channels are configured for a reduced quality target, there may be bits left over in the aggregated transport stream, which could be used for opportunistic data insertion. Reducing quality targets to 10-12 still provides decent quality, while lowering it further, significantly degrades the quality.

Horizontal Resolution

The horizontal resolution is the number of pixels per line in the video signal. In general, at any given bit rate a higher horizontal resolution gives the sharpest pictures, but also more MPEG-2 artifacts. As the horizontal resolution is decreased, the picture gets softer, but with less artifacts. The trick is to find the proper balance between resolutions and artifacts.

For previously compressed content it is recommended to use the same horizontal resolution as the source content, if known. If the target bit rates are very small, a reduced horizontal resolution can be considered.

For other types of content the horizontal resolution generally depends on the average bit rate across the multiplex. See table below:

HR	720,704	640	544,528	480	352
Mbps	>2.6	2.2 – 2.7	1.9-2.3	1.7-2.0	< 1.7

As horizontal resolution can be set individually on each encoder within the multiplex, it can be used as a way to give priority for a given channel. Everything else equal, a service with higher resolution will on average get more transmission capacity than a channel with lower resolution.

Prefiltering

Prefiltering is used for two different reasons. First, to remove unwanted noise in incoming video and second to ease the video encoder's job, reducing the general compression level and minimizing artifacts. The challenge in prefiltering is to avoid softening the image.

SD encoders offers two types of filters. A configurable low pass filter, which is standard on all encoders, and the Scientific Atlanta *PreSightPlus*[™] noise reduction filter, which is optional on some encoders.

The type of filtering selected should depend on the level and type of noise. The low pass filters are fixed but the *PreSightPlus* filters are adaptive. For analog sources with typical Gaussian noise, use only limited low pass filtering and more temporal filtering. For source with MPEG-2 artifacts, depending on the level of artifacts, use more horizontal filtering and less temporal filtering.

Low Pass Filters

A low pass filter is fairly simple and it filters all content independent of detail or noise level. If the encoder is configured for reduced horizontal resolution (less than 704), the low pass filters should be engaged to avoid anti-aliasing (see table below). Note that in the Model D9120™, the filter configuration uses different terms than for D9032™/D9022™.

The figures below should be read as minimum filter values, and if a slightly softer picture is preferred, they could be increased.

Resolution	704/720	640	544/528	480	352
D9032/34 Luminance	0%	11%	21%	27%	43%
D9032/34 Chrominance	0%	21%	32%	37%	39%
D9120 Luminance	100%	89%	79%	73%	57%
D9120 Chrominance	100%	79%	68%	63%	41%

Please note that the chrominance bandwidth can be further reduced with limited loss in quality, as the human eye is less sensitive to loss in chrominance bandwidth.

PreSightPlus Noisefilters

For more advanced and efficient filtering the *PreSightPlus* noise reduction filters are recommended. First of all, they are adaptive, which means that they avoid filtering edges and fine detail. Subjective picture quality is heavily dependent on that, hence efficient filtering needs to protect the content from extensive blurring.

By default the encoder is set for adaptive filtering, which means that it uses a fairly mild form for filtering based on spatial filters. Tailoring the filters to the content is recommended for better picture quality. So, the encoder should be set to custom filtering, in which case there exist various tuning options.

Spatial Filters

Spatial filters use a two dimensional filter that works within the same picture to reduce noise. They limit noise and preserve details, but as they only work in one picture, the effect is limited. The degree of filtering is configurable, as more noise can be removed by increasing the level of filtering. The filters are adaptive, but as the filters work more aggressively, more noise is removed, but also more sharpness is lost.

In general, temporal filters work more efficiently and are recommended as compared to spatial filters.

Temporal Filters

Temporal filters use filtering across multiple pictures (frames) to provide better noise suppression. Since the pictures change from frame to frame, you must compensate for motion and adaptively apply the filters depending on changes in the content. Again, excessive filtering of edges and fine detail, have a severe impact on the subjective quality.

Two types of temporal filters are available. A simple two frame temporal filter, and a multi-frame temporal filter. The latter is most efficient for noise removal, and the first offers backwards compatibility support. For any new installation the multi-tap filters are recommended for noise reduction.

The multi-tap filters are excellent for reducing Gaussian (typical analog) noise, but also for removing some mosquito (MPEG-2) noise. The filters can be adjusted in six levels, from minimum to very aggressive. For content with limited noise, level two is recommended; for medium noise, level three; and for significant noise level four. (The corresponding terminology for the D9120™ is, Multitap_less_than_normal, Multitap_Normal, Multitap_Strong). At the end of the day, filtering is subjective, and the final performance needs to be evaluated on the reference monitors. For extensive noise, the maximum noise reduction levels can be opted, but it starts to impact the video content significantly

Summary

Optimizing picture quality on any compression system is subjective at the end of the day. There is no absolutely correct answer. There are a few measuring solutions on the market that “claim” to measure subjective quality, but they all have limitations. Either they are single channel in nature, which makes them very expensive to use across multiple channels, or they only measure a very short period of time (non real time). In any case, experience says that you should only use measurement equipment for reference. In other words, trust your eyes or get some experienced people to help you.

Based on the recommendations above, you should be able to optimize your system and as you get more familiar with the technology, it becomes easier. Note that the characterization of your sources may change over time as the content providers change their equipment and you would possibly have to make minor adjustments. Likewise, the channel lineup may change and the priority between channels changes because of shift in views preferences, which mean that you should plan on reviewing your setup regularly.



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