

Opening the Floodgates for Digital Information Services

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The delivery on the digital promise of high quality video may not be the lever that opens the floodgates for widespread implementation of digital services by broadcasters. Rather, it may be the ability to deliver digital information services along with high-quality video and audio that pulls the lever and produces the widespread acceptance we all desire.

But what about the bandwidth to carry these digital information services? How do we carry them without jeopardizing the video quality that helps to fulfill the promise of digital television? The answer lies in Variable Bit Rate (VBR) encoding and a companion concept called Zero Bit Allocation (ZBA).

Variable Bit Rated Encoding

With the emphasis increasing on improving the information throughput of digital networks, the migration of digital coding technology from constant bit rate (CBR) to variable bit rate (VBR) encoding has enabled the achievement of substantial bit saving without sacrificing video coding quality.

Using CBR, the number of bits for encoding each segment of a video program is the same. For many video broadcasting or transmission applications, a fixed, higher bit rate is usually used to guarantee the acceptable video quality for the most complex video content segments. But, because the bit rate is fixed, bits are wasted for simple video content segments.

By comparison, VBR coding encodes the video content as much as possible to a constant quality. The number of bits used for coding each frame is a function of frame content complexity. This results in a variable bit rate bit stream. The bit saving from the VBR encoder along with the multiplexing

efficiency improvement from an intelligent multiplexer can be used to increase the number of video programs per transmission bandwidth.

Zero Bit Allocation Datacasting

The conventional configuration for video, audio, and data services is to allocate different bit rates for different services based on content needs. For a fixed bit rate channel, whether it is over terrestrial, satellite or cable media, this means a fixed bit rate has to be allocated for data, immediately reducing the bit rate available for video and audio services.

Because the combination of VBR and intelligent statistical multiplexing produces a bit “surplus” of up to 40 percent, we can capitalize on a technique called Zero Bit Allocation (ZBA) for datacasting. By allocating zero bits for datacasting, we free up the entire bandwidth to ensure video quality or to deliver a prescribed number of video services. Then, when bits become available through VBR encoding and the statistical multiplexer, those are allocated for opportunistic data transmissions with no impact on the video quality or the number of services delivered. With this 40% bit saving capability, together with the implementation of new SMPTE 325M standard on opportunistic data flow control protocol, one can implement data broadcasting with ZBA. This means that broadcasters could maintain their video service channel numbers and preserve the same video service quality. At the mean time, they could potentially have up to 40% of bits “free” for data broadcasting.

One could argue that commercial digital television broadcasting has been available for at least five years, so that it may not be a technical challenge anymore. However, the effective and efficient implementation of data broadcast services is a real technical challenge. There are multiple levels and efforts of standardization activities happening around the world such as ATSC, SMPTE, DVB, MPEG-2 DSM-CC, DAVIC, AVTEF and MPEG-7, etc.

Conventional Bit Allocation Models

Figure 1 is a very simple representation of the conventional bit allocation process for video and audio services. In this example, the audio services (including standalone radio and audio channels for video content) and video services are delivered using constant bit rates. SI/PSI tables occupy the third

constant bit rate allocation. In this case, in order to increase the number of video channels or to increase video quality, statistical multiplexing technology could be used.

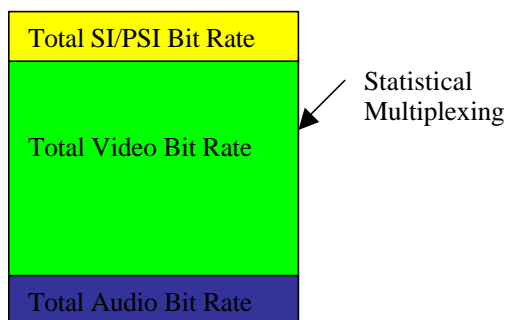


Figure 1 Bit Allocation Model Without Datacasting

Adding Data Broadcast Services

Adding a payload of data services to the broadcast channel multiplex requires a bit rate allocation. If we use the conventional bit allocation model for video, audio, and data services, we allocate bit rates for each service based on its content complexity. For a fixed bit rate channel, whether it is over terrestrial, satellite, or cable media, this means a fixed amount of bit rate has to be allocated for data, as illustrated in Figure 2.

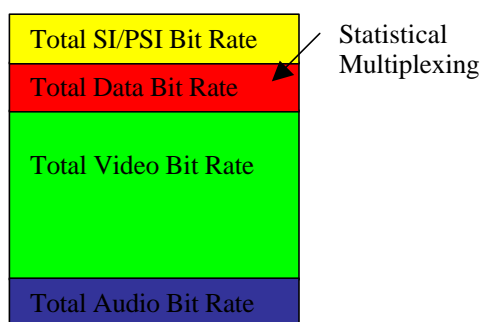


Figure 2 Bit Allocation Model With Datacasting

A comparison of the bit allocation models of Figure 1 and Figure 2 reveals the immediate impact of the insertion of data services on the availability of bit rate for video and audio services. Even if statistical multiplexing technology is used to improve bit efficiency for digital video delivery, the

reduced total bit rate for video will result in either lower video quality or reduced number of video services.

The ZBA Solution

The detailed performance comparison of VBR and CBR coding based on the coding quality test using Tektronix's PQA200 analyzer is shown in Table 1. In the table, five typical ITU video sequences named Flower Garden, Cheer Leader, Mobile and Calendar, Suzie, and Table Tennis are used as samples with different video content complexity. A real-time MPEG-2 encoder and decoder pair were used to test the picture impairment measured by PQR.

Three significant observations about VBR can be extracted from the data in the table:

- **VBR yields a smaller quality variance resulting in more constant quality**

The CBR coding bit rate was set to 3 Mbps at 704x480 resolution. The resulting PQR measures are listed in the 4th row of the table with a PQR range of 3.0 – 12.0 for the five test sequences. Using VBR coding, the peak rate was set to 3 Mbps at 704x480 resolution for comparison. The resulting PQR measures are listed in the 8th row of the table with a PQR range of 5.8 – 8.0 for the same five test sequences. This PQR range effective shows that the VBR coding achieves a more “constant” quality performance with respect to the variation of content complexity.

- **VBR yields a higher quality for certain complex video content**

Upon examining the PQR measures of both CBR and VBR coding for the Cheer Leader sequence, we see the PQR from VBR coding is actually about 3.5 better (smaller) than that from CBR coding. The explanation of this quality improvement is dependent on the VBR rate control algorithm. A good VBR rate control algorithm would actually spend fewer bits for simple content and spend more bits for complex content resulting in higher overall quality. The standard CBR coding rate control algorithm has to balance the bit spending over a short time period, say one GOP so there is no dynamic bit allocation between GOP time splices.

- **VBR yields greater bit saving on simple video content**

The third feature that can be observed from the table is the greater bit saving capability of VBR coding when content is simple such as Table Tennis and Suzie sequences, which have 53.3% and 66.7% bit savings respectively compared to CBR coding. However this bit saving

capability is realized by trade-off of PQR measure, which is reduced by 2.5 and 2.8 respectively for the two sequences. The justification to allow the PQR measures to be lower for simple content video is based on the theory of constant quality video coding. Since the coding quality could not be maintained at 3 anyway when the video content complexity is high and the PQR of 5 is good enough for final viewing consumption, why couldn't we save some bits here for other application, e.g., data broadcast services?

Table 1 VBR and CBR Coding Comparison

| | | | | | | |
|-------------------------|------|------|------|-------|-------|------------|
| <i>CBR Encoding</i> | | | | | | |
| Bit Rate (Mbps) | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | |
| PQR | 7.0 | 11.5 | 9.0 | 3.0 | 5.5 | 3.0 / 12.0 |
| <i>VBR Encoding</i> | | | | | | |
| Peak Bit Rate (Mbps) | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | |
| Average Bit Rate (Mbps) | 3.0 | 3.0 | 3.0 | 1.0 | 1.4 | 2.3 |
| PQR | 7.0 | 8.0 | 8.0 | 5.8 | 8.0 | 5.8 / 8.0 |
| <i>Results</i> | | | | | | |
| Bandwidth Saving | 0.0% | 0.0% | 0.0% | 66.7% | 53.3% | 24.0% |
| PQR Improvement | 0.0 | 3.5 | 1.0 | -2.8 | -2.5 | -0.2 |

Smaller Quality variance giving near "Constant" Quality

Higher Video Quality on complex scenes with same bit spending

Simple video allows Greater Bit Savings

Assuming the five test sequences were cascaded to represent a long test sequence with content complexity variation, Figure 3 shows the greater bit saving capability of VBR coding. Many other real video content tests showed that a bit saving of 20% to 40% is usually achievable. This is the precondition of ZBA technology.

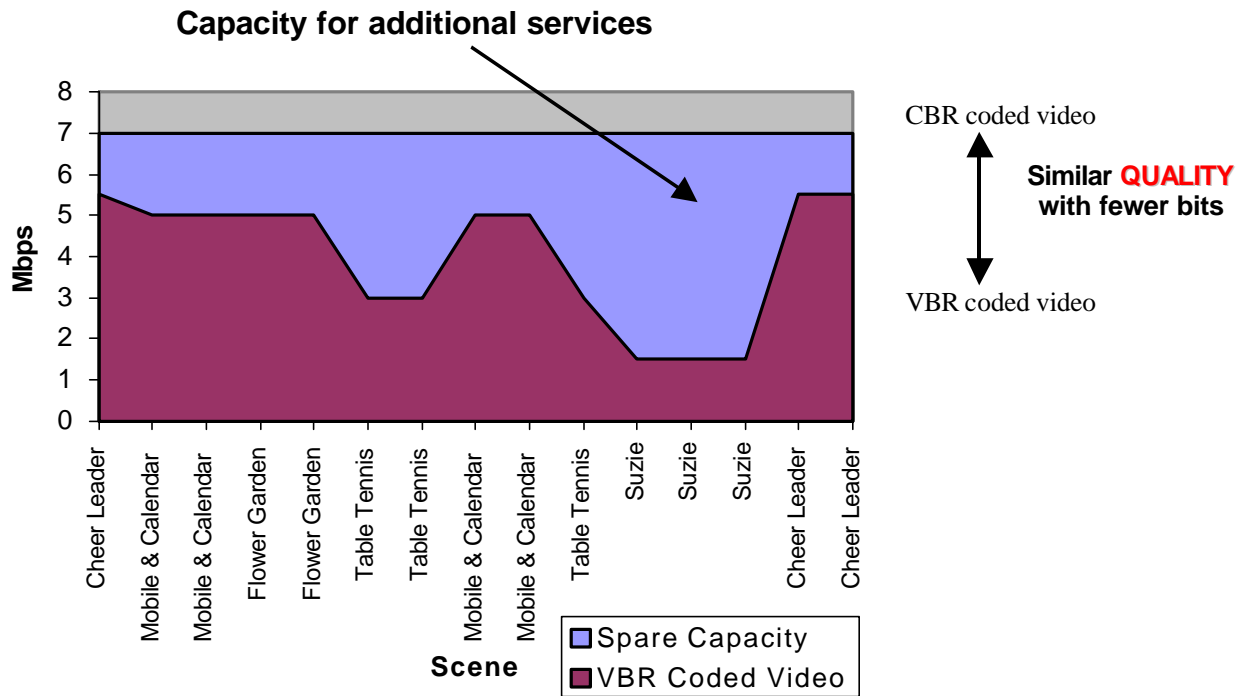


Figure 3 VBR Bit Saving Capability w.r.t. Video Content Variation

ZBA Data Broadcast Service

When data services are not synchronized or synchronous content does not have a tight time delivery requirement, such services could be provided without the need of dedicated bit allocation from the emission multiplexer. The equivalent bit rate of data services could be calculated or estimated as 20% to 40% of total video bit rate, depending on system implementation and video content. As an example, for DTV video bit rate of 19.4Mbps, a “free” data service bit rate of about 4 Mbps to 8 Mbps is obtainable.

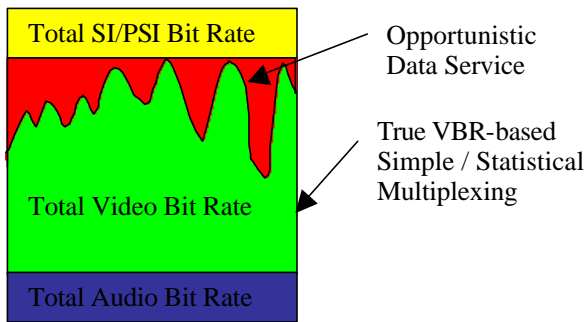


Figure 4 ZBA Bit Allocation Model With Opportunistic Data Service

Configuring a System for Implementing ZBA

Before ZBA is implemented for data broadcast services, three factors need to be weighed:

- Device capability
- System configuration
- Application requirement

The following application scenarios depict the general principle for implementation consideration.

The three configurations shown in the figures below are logic functional block diagrams. One or more such logic functional blocks may be implemented in one physical device.

Single Channel SD/HD Broadcast With ZBA Datacasting

For single channel encoder applications (either HD or SD), implementation of ZBA technology relies on the availability of a true VBR encoder that could produce “constant” coded video quality and save bits for data broadcast service. If the encoder can supply this capability, an intelligent statistical multiplexer is needed that has data buffering capability and statistical data packet injection mechanism (Figure 5). The statistical multiplexer also needs to have a feedback flow control mechanism to communicate with a data server. For ATSC datacasting application, the flow control protocol is defined by SMPTE 325M via either ASI interface or Ethernet interface, depending on implementation. The opportunistic data server receives data via Internet or Intranet and sends an MPEG-2 transport packet stream via ASI interface to statistical multiplexer.

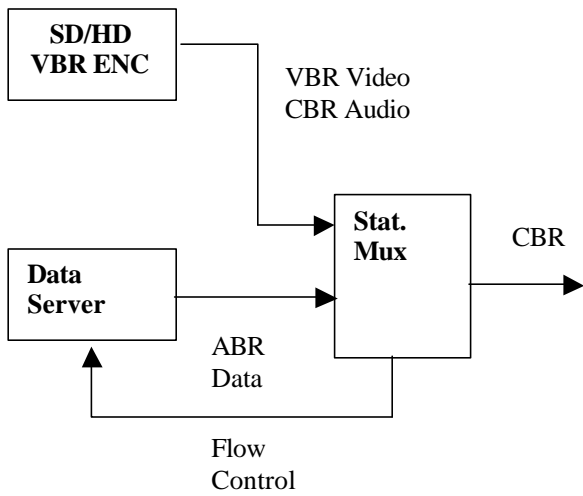


Figure 5. Single Encoder and ZBA Datacasting Configuration

One HD and One SD Simulcast With ZBA Datacasting

The superior compression efficiency provided by VBR coding technology makes it possible to simulcast one HD and one SD program together in a single DTV channel of 19.4 Mbps. On top of this simulcast benefit, one can further use ZBA technology to add data broadcast service too. Figure 6 shows a possible configuration for this application.

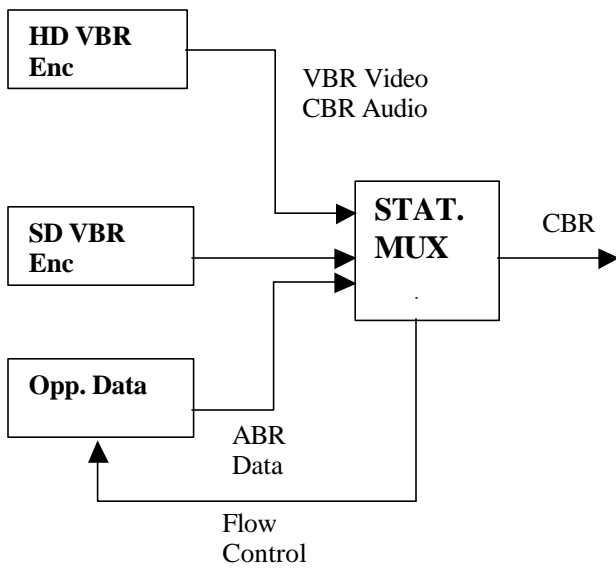


Figure 6 HD and SD Simulcast and ZBA Datacasting Configuration

Multi-channel SD Broadcast With ZBA Datacasting

When multiple SD programs need to be multiplexed in a channel, a statistical multiplexer could be used to increase the number of programs and also add ZBA data broadcast service. Figure 7 shows a possible configuration of this application.

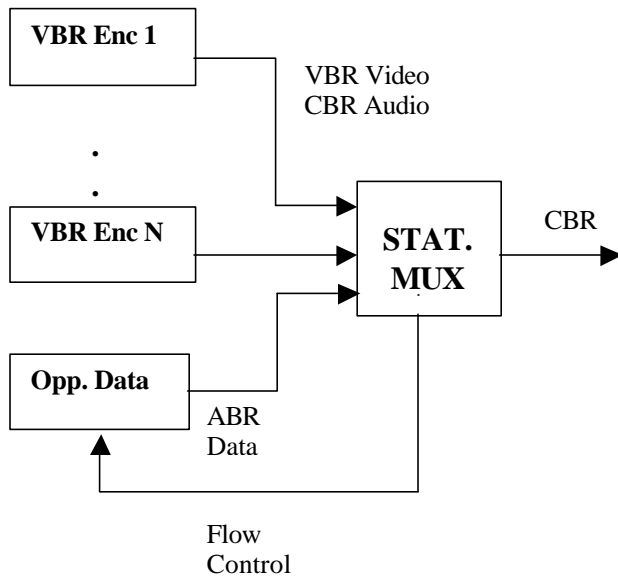


Figure 7 Multiple SD Statistical Multiplexing and ZBA Datacasting Configuration

Applications for ZBA Datacasting

Due to the opportunistic bandwidth availability nature of ZBA technology, only those applications that do not have a tight delivery time requirement should be transmitted as a variable and opportunistic data flow. Typical applications that could be provided using ZBA include:

- Receiver software upgrades and applications download
- Time-shifted program delivery
- Non time-critical meta-data delivery
- E-mail
- File downloada
- Stock ticker

- Text-based news flashes
- Non real-time on-line video rental service

ZBA's Benefits

ZBA technology will enable broadcasters to provide various data services to enhance the look, feel, and service quality of their DTV programs without the need of extra spectrum or sacrifice of video quality. The ever-growing data transmission market will be eager consumers of the “new” bandwidth that service providers can make available. And, these new bits will produce new revenue generation possibilities for the service providers. Content service providers can greatly reduce the cost of content delivery due to the virtual capacity extension of up to 40% for any transmission media without the need of heavy investment in a network capacity upgrade. Finally, for consumers, ZBA technology can speed up the vast availability of data services from more network service providers such as terrestrial, cable, satellite, and telephone networks. This will result in higher service quality and lower service cost via competition.

The Final ZBA Considerations

Remember, there are some defined “must haves” for the ZBA benefits to occur. First, you need to have a true VBR video encoder to produce “constant” quality video while saving greater bits. You need to have a third generation statistical multiplexer that supports true VBR coded bit streams and SMPTE 325M flow control for opportunistic data multiplexing. And finally, you must use a data server that supports SMPTE 325M flow control and interface with a statistical multiplexer via the DVB-ASI interface.

What To Do Next

If you're in the market for digital video encoders, look now for units that offer high quality, true VBR capable, even if you don't have an immediate need of datacasting services. The capability will be vital in the future. Again, if you are considering the addition of statistical multiplexers in your system, look for a third generation-type open loop-based statistical multiplexer that can statistically multiplex

coded bit streams from local and/or remote encoders, from real-time encoders, and/or servers with pre-compressed content. Your statistical multiplexer should also support statistical multiplexing of both SD and HD as well as 4:2:0 and 4:2:2 bit streams. Of course, your statistical multiplexer should support ZBA technology for data broadcast service. Remember, your data server needs to support SMPTE 325M flow control protocol, data packetization and DVB-ASI interface.

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Dr. Si Jun Huang joined Scientific-Atlanta in 1995 and has been an integral member of the team that developed the PowerVu *Plus*[™] products, Scientific-Atlanta's fourth-generation digital video compression system. As a Principal Engineer, he developed the Variable Bit Rate encoding technology used in the company's Statistical Multiplexer and is a leading proponent of Zero Bit Allocation Datacasting, another technological advancement which improves the efficient use of bandwidth. He participated as an active member in the MPEG-2 video standard development and was one of the editors of the video working draft.