DEPLOYMENT OF GROOMING WITHIN THE COMPRESSED DIGITAL DOMAIN

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Abstract

"Be careful what you wish for" could be the watchword for the cable industry with digital television. After years of advocacy for the technical superiority of digital compression and modulation, digital broadcasting, from standard definition television (SDTV) to high definition television (HDTV), should reign supreme by the middle of the next decade.

The greatest challenge for cable operators here will be to respond to the market-driven, multiple-sourced expansion of demands to deliver customized programming with ad insertion, video on demand (VOD) and even datacasting, Internet access, telephony and interactivity capabilities for the individual cable operator.

MPEG-2 multiplexes from remote and local sources must be processed through a demultiplexer, transcoded and then remultiplexed to form the outgoing multiplex. To transmit a coherent outgoing program transport stream with good picture quality, this process must include parsing, synchronized scheduling, stream transcoding and splicing, and analysis and service information editing.

To gain the increased revenue opportunities of customized programming, this process must also maximize bandwidth. Imedia's statistical re-multiplexing optimizes compression ratios without feedback, separates the encoder from the multiplexer and seamlessly switches and splices MPEG-2 programming in real time. This supports the capability to selectively groom programs to create a new statistical multiplex customized for a cable system and transmit it over the space of a single analog channel.

The reasons for using digital representations of video derive from the flexibility and power of digital compression and processing with integrated circuit technology via the reduction of video to the common denominator of the bit.

Digitally compressed video is increasingly replacing analog for capturing, representing, storing, and transmitting visual sources for selective display. Digital compression technology also permits multiple TV programs per each transmission channel.

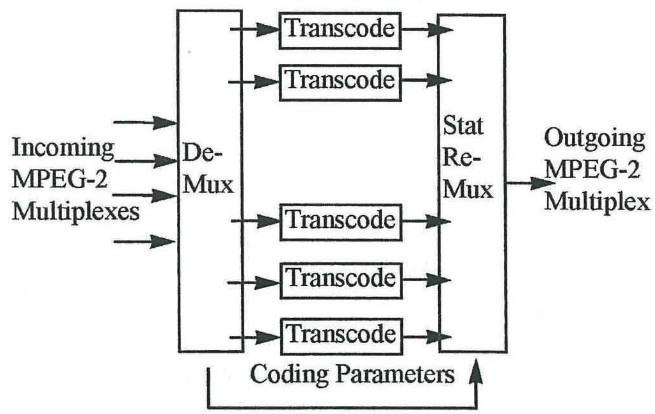

Figure 1: *Fundamental statistical re-multiplexing architecture*

Figure 1 represents the fundamental architecture to statistically re-multiplex digital television for cable. A multi-program transport stream can originate from a variety of incoming sources such as local feeds like video servers, data servers, tape and live-encoded video, and remote feeds like satellite, off-air broadcasts, and fiber networks. Transport streams are fed into a Demultiplexer that splits apart all the constituent video streams and audio streams and other services into the individual services.

Each service that is selected and passed to the output is re-multiplexed and transcoded, if necessary, to fit in the output fixed-rate band width. Coding parameters generated during the original encoding process are extracted from the incoming streams and passed over to the Statistical Re-Multiplexer when controlling the transcoding process. The input sources are then combined into a newly-formed statistical multiplex that can be transmitted over a single analog channel.

algorithm-driven package which can efficiently choreograph all of their actions to most directly address customized grooming for quality output.

The first step is to input the multi-program transport stream, represented in Figure 2 by the thick arrow. Its source could come

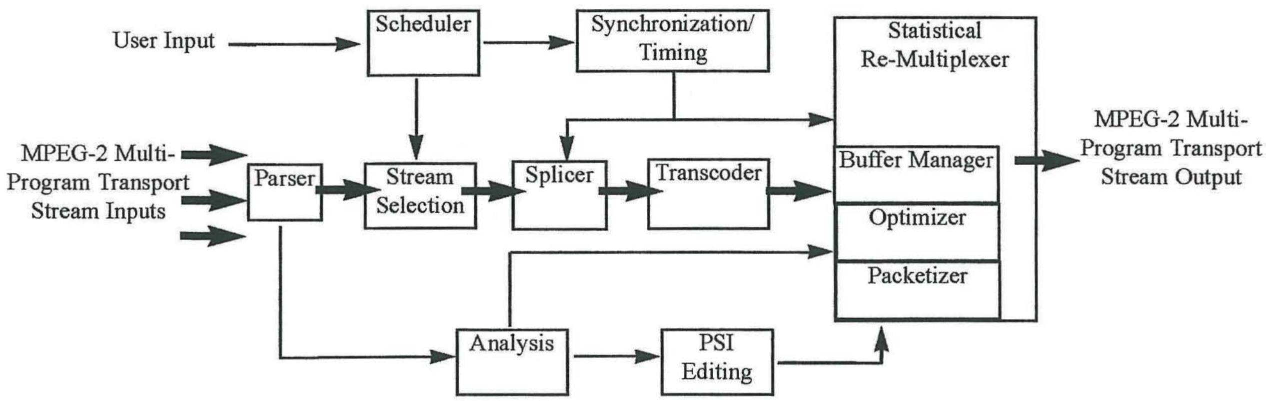

Figure 2: *The building blocks of statistical re-multiplexing for cable*

Cable operators, large or small, must aim for the highest picture quality, most flexible, bandwidth efficient, and cost-effective digital video implementations to reach their various goals, like:

- Add desirable new programs (channels) of interest to viewers,
- Use bandwidth efficiently to permit introduction of other services,
- Perform digital insertion of local advertisements and programs,
- Combine enhancement and transaction-oriented data with video streams, and
- Filter satellite-contributed program statistical-multiplexes efficiently to select only desired programs (grooming).

The key to each goal is stand-alone statistical re-multiplexing. The Imedia CherryPicker stand-alone statistical re-multiplexer technology reflects a comprehensive view of these combinant processes and integrates them into an

from one encoder, a video/ad or VOD server, or a satellite transponder such as one of the pods on HITS carrying 12 programs. A program - or service - is made up of streams which in turn can contain video, audio, and/or data.

The transport streams go directly into a Parser. A parser is a demux that looks at the program identifiers and service information in the MPEG-2 systems layer as it analyzes the composition of the streams. The next step is user input from the Scheduler through a control GUI, where the stream selection and configuration processes are performed.

Here is where decisions are made for what's going to be on the output and the point at where bit rate can also be controlled. If, say, you want one program from input #1 and three programs from input #2, this is where that selection will be confirmed.

Here also is where the user interfaces to decide which stream at this time, and what stream at that time, and also where scheduled ad insertions are triggered. If its VOD, this is where information will be entered as to when and how often a movie should be shown.

After stream selection and configuration, the Splicer is where one stream will be spliced into another stream. Splicing is where two different streams are combined together into one stream, like advertising or a traffic alert into a network feed. This Splicer will do seamless, frame-accurate MPEG-2 splicing between video streams and between audio streams, enabling the insertion of digital ads without black frames or freeze frames in between.

The next block is the Transcoder, where the bitrate adjustments occur. The Transcoder is required because bandwidth output is always fixed, so you are required to adjust the bitrates of each individual stream to be able to interlock all of the chosen streams together into the given output bandwidth. This, in combination with the intelligence of the Statistical Re-Multiplexer, optimizes bandwidth and preserves picture quality.

The Statistical Re-Multiplexer is really the heart of the CherryPicker system. Its job is to perform rate control and to monitor how the Transcoder and the Splicer operate. These three elements collaborate to ensure that relative timing is maintained, that the target decoder buffers are managed correctly, and that the Packetizer addresses all the streams.

Imedia has pioneered advanced statistical re-multiplexing techniques that manage the challenges of statistical re-multiplexing - (1) not exceeding the bit-rate capacity of the transmission channel, (2) accepting remotely encoded inputs, (3) optimizing channel bandwidth utilization, (4) maintaining high picture quality, and (5) packetizing all data forms into the output multiplex.

In a statistical multiplex, each program dominates the average bit rate capacity at one point or another, when it takes much more than its "share" of the average bit-rate available. To achieve a constant picture quality for all streams, the bitrate must vary for each stream. This creates a multiplex in which it is difficult to separate out a program and combine it with other variable-bit-rate programs from other statistical multiplexes; that's why it must be statistically re-multiplexed.

The Synchronization and Timing block serves the critical tasks of monitoring the timing and switching between the streams and assuring that all the streams are synchronized together. To guarantee proper decoding and proper presentation in time at the set-top box, timing elements within the MPEG-2 syntax such as Program Clock References (PCR), Presentation Time Stamps (PTS), and Decoding Time Stamps (DTS), need to be monitored and updated as all of the transcoding and multiplexing operations occur.

In order to make decisions about which streams are to be transcoded at what times, the statistical re-multiplexing system here needs to know information about each individual stream and it needs to know this on an instantaneous basis. The Analysis block is always monitoring the stream and deciding what to do. The information from the Analysis block goes to the Statistical Re-Multiplexer and also to the PSI Editing (Program Specific Information) block, which is a function that describes and reconciles the contents of a transport stream.

The PSI Editor also makes sure that all the information in the output stream is described correctly and that the information is constantly updated. When you go from one stream to another, program-specific information will change, and that information may be arrayed across several programs in a transport stream as you're switching between programs.

All of that needs to be reconciled and compiled together so that all the different pieces of information are brought together to describe the resultant single transport stream. That information is then fed back into the Packetizer and the Re-Multiplexer and included as part of the outgoing transport stream. These building blocks of advanced digital deployment are already enabling a wide variety of cable and satellite providers to build value and revenue opportunities, each choosing unique combinations of multiple services into one unified stream to reach and serve their customers.

Figure 3 represents a local control headend of a small MSO located in a rural community serving a subscriber base of over 100,000. Taking full advantage of the versatile flexibility of their Imedia installation, this customer wants to cherry pick programs from HITS transponders to create a new program lineup for their cable system. Here they are choosing programs from HITS1 and HITS7 and putting this new multiplex onto a single 6Mhz channel output and doing the same operation with HITS3 and HITS9. Both inputs to the CherryPicker are DHEI.

They are also experimenting with revenue-enhancing ad insertion into the HITS1 and HITS7 channels using an ad server connected to the CherryPicker via the DVB-ASI input. The CherryPicker does the insertion. The output of that CherryPicker then goes to an IRT for encryption, and through a C6U for upconversion. Encryption in this system is locally controlled by the GI DAC6000 Network Control System. Both inputs and outputs to the CherryPicker in this system are 27 Mbps.

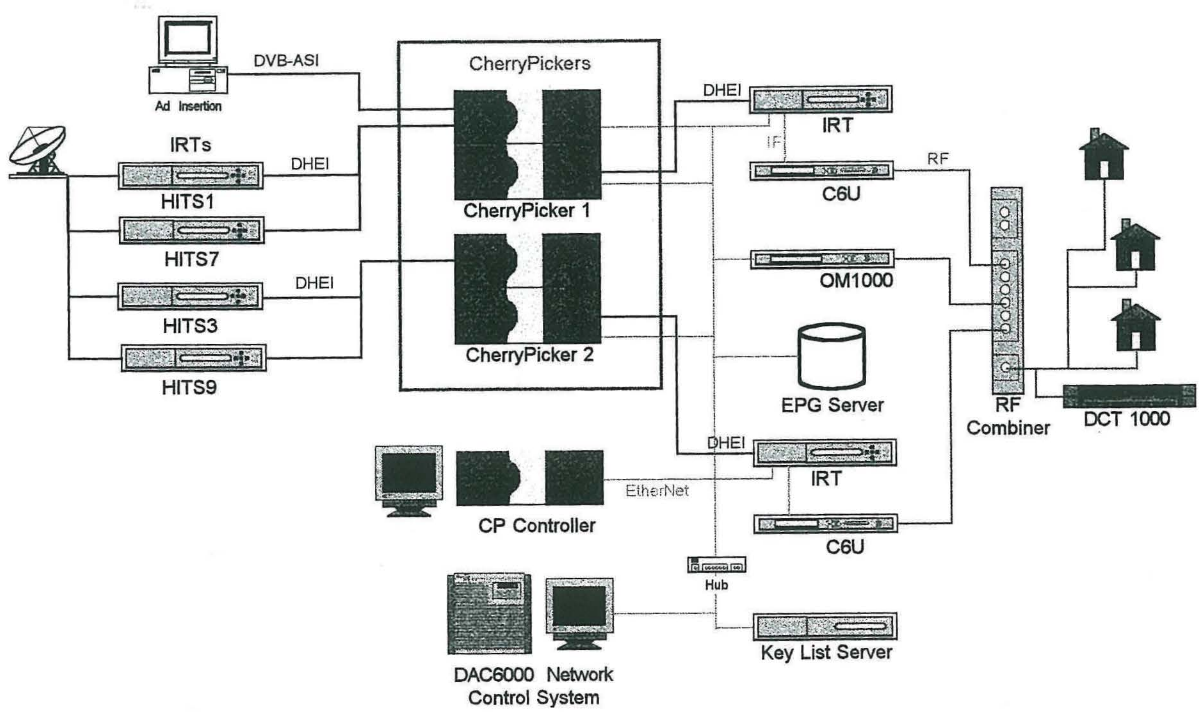

Figure 3: *Customer A: GI Local Control Headend*

After upconversion, the multiplex goes to an RF Combining Network which then transmits out onto the cable system to the subscribers' homes which are using DCT 1000 MPEG-2 Digital Consumer Terminals.

Both of these two CherryPickers are controlled by the CP Controller and all of the elements are hooked together by Ethernet including the Electronic Programming Guide Server and the Out-of-Band Modulator (OM1000.) With these aggregate gains in broadband efficiency, this provider is able to enjoy the benefits of more ad buying power.

Figure 4 represents a large MSO operating in the southeast with a subscriber base of 350,000, and is employing the Imedia technology for grooming and local program insertion. Here they are doing a CherryPicking operation, but they are also able to combine that process into an output multiplex containing video streams from a video server of local content at their local headend. This video server contains video programs and interstitials. They are combining it with pay per view (PPV) programming from TVN.

The remaining structure is similar, a locally controlled headend which is going through the same process as the previous one. What this shows is that there's broad flexibility in being able to bring in feeds from video servers and that also, in the future, VOD and real-time encoded feeds could just as easily be included in the CherryPicker. The CherryPicker can also be used in nationally controlled headends where the DAC6000 would not be needed.

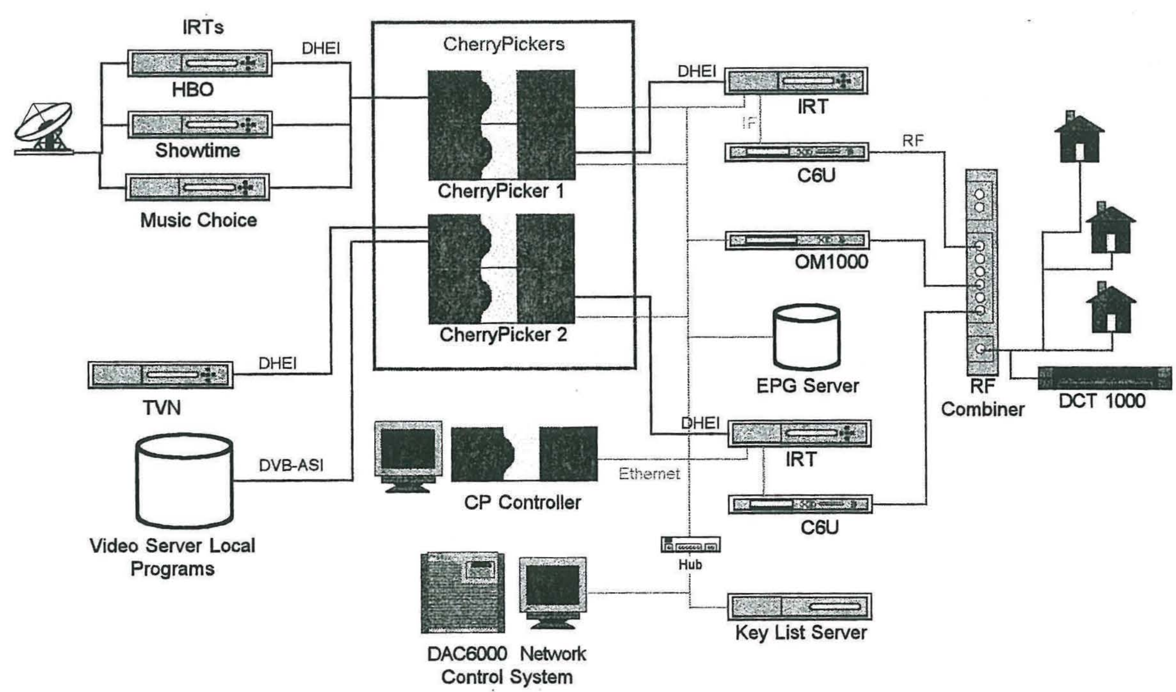

Figure 4: *Customer B: GI Headend with Video Server*

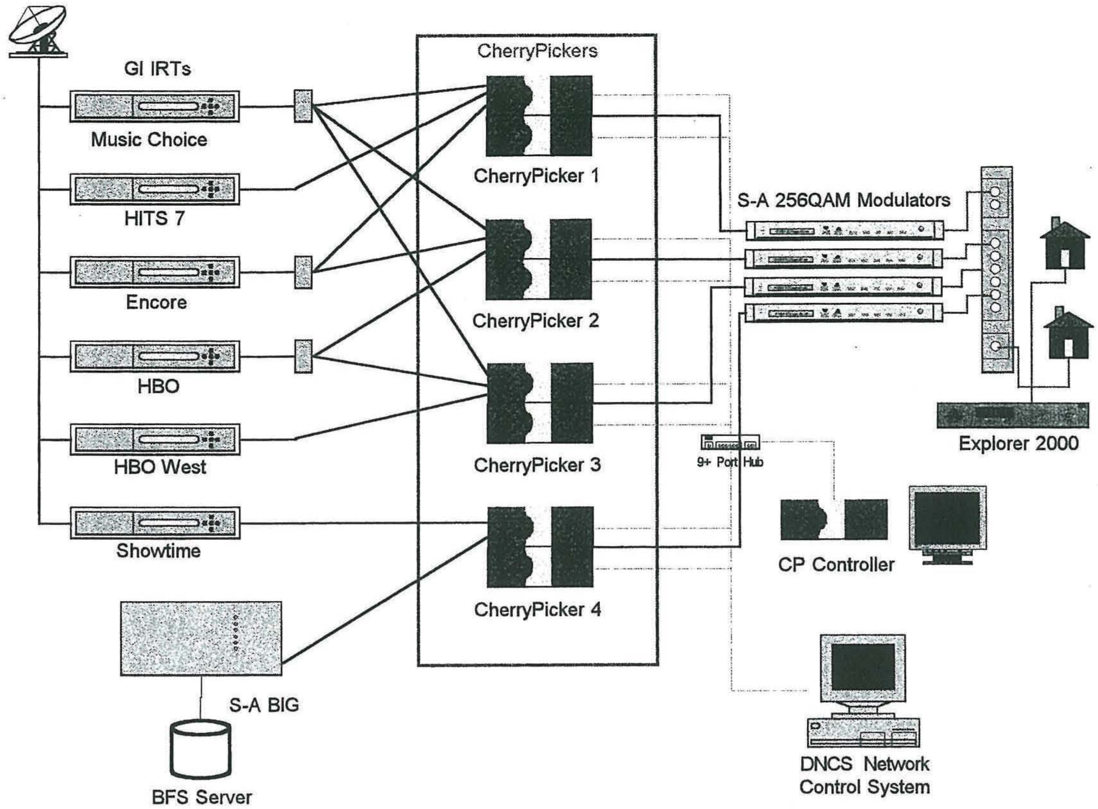

Figure 5: *Customer C: GI Inputs with S-A 256-QAM Outputs*

Located in upstate New York, this small MSO with 85,000 subscribers has built a S-A (Scientific Atlanta) headend environment that supports 256-QAM. They have six satellite feeds coming into their headend. When they need to cherry pick certain programs from those six feeds, they can output that onto four 6Mhz channels.

There's a measurable bandwidth difference between the incoming 27 Mbps and the outgoing 38.8 Mbps. In Figure 5 they are dividing the cable bandwidth to the maximum because of the bandwidth difference, so they need to take these 27 Mbps streams and add other programs on top of it to get it to fill up and complete the 38.8 Mbps stream. They are gaining a high rate of efficiency here in the mismatch between the data rates and it is the CherryPicker that makes that feasible.

Here you can see the types of interconnects they have established linking the four CherryPickers. This reveals what sort of breakup in the programming they're going to do, and how it then goes out to four S-A 256-QAM Modulators. These units not only enact the encryption, but they also perform the modulation. This customer is doing a translation from a GI front end to a S-A back end. The IRTs are General Instrument but the cable modulators are Scientific Atlanta. This system is controlled by the Scientific Atlanta DNCS Network Control System and is also taking in some information from their BIG (Broadband Integrated Gateway) and BFS Server, ultimately going into a combining network and out to the subscribers' homes via an Explorer 2000.

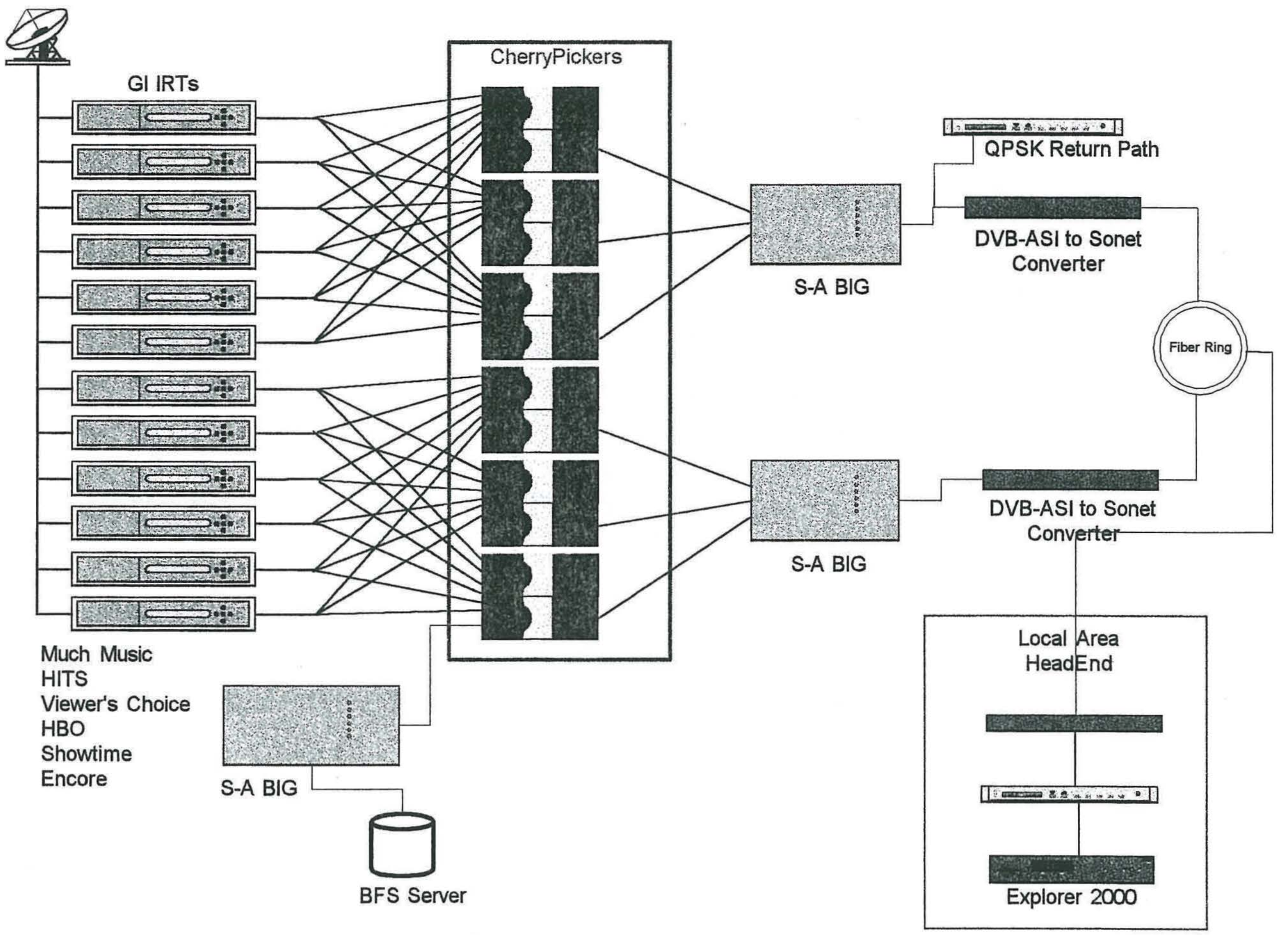

Figure 6: *Customer D: Fiber Ring Distribution*

This New England-based customer has exploited the scalable expandability of the Imedia system to direct a dozen IRTs with six CherryPickers to transmit and distribute through a Fiber Ring. In Figure 6, the CherryPickers take feeds going from GI IRTs at one data rate to an S-A BIG at a different data rate, but the remultiplexing operation for redistribution is output over a Fiber Ring rather than going out over a standard cable system.

The S-A BIG is needed because it can take in many multi-program transport streams from different sources and output it into the type of format for distribution over a Fiber Ring. A local area headend can take off the programs from the Fiber Ring and distribute it over the headend. This provides an optimal network for distribution to a lot of headends, and serving an even wider constituency of subscribers. Their unique SONET Fiber Ring configuration efficiently encircles Vermont through six nodal cities, effectively grooming the entire state.

Every operator that deploys digital television will face a different set of challenges, each delivering new limitations and opportunities. What these customers share in common is their proven abilities for problem solving through building installations that support flexible and effective methods for switching, splicing and grooming MPEG-2 digital video streams and the ability to optimize bandwidth efficiency while preserving picture quality using statistical re-multiplexing.

DIGITAL TELEVISION GLOSSARY

CONSTANT-BIT-RATE (CBR)
a value where one TV program is allocated a certain number of bits-per-second at all times (no statistical multiplexing)

CHANNEL CODING
tries to minimize channel transmission errors by using error-correction and error-detection algorithms

DATACASTING
transmission of digital data

DCT
Digital Consumer Terminal

DHEI
Digital Headend Expansion Interface

GROOM
assemble programs from a variety of multiplexes and feeds and create a customized group of programming delivered as single or multi-program transport stream

GUI
graphical user interface

HITS
Headend In The Sky

IRT
Integrated Receiver Transcoder

Mbps
Megabits-per-second

MPEG-2
a decoding and compression standard, also known as ISO 13818 or H.222.0, developed by the Moving Picture Experts Group, using mathematical algorithms which represent TV frames composed of macroblocks and blocks, and taking advantage of predictability in the picture and in picture motion

MODULATION
the method of putting the bits on the channel

MULTIPLEXING
involves combining multiple TV programs together before modulation and transmission over the channel

MUX
a Multiplexer

PARSER
A function that identifies the individual parts of an MPEG-2 compressed transport stream including systems, video, and audio layer information

QAM
Quadrature Amplitude Modulation

QPSK
Quadrature-Phase-Shift-Keying modulation

SOURCE ENCODING
assigns bits to represent video (and audio), taking into account redundant or predictable characteristics

SPLICING
where two different streams are combined together into one stream

STATISTICAL MULTIPLEXING
permits each TV program in a multiplex to share the multiplex according to its moment-by-moment bit rate requirements

STATMUX
a Statistical Multiplexer

TRANSCODING
the ability to modify the incoming data rate of a video stream to a different (lower) outgoing data rate

VARIABLE-BIT-RATE (VBR)
Compression bit rate allocation that is much more efficient because it allocates only the number of bits required at a certain time to a TV program to achieve a target picture quality

VOD
video on demand