HDTV in StreamIT: A Case Study

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Resources/Acknowledgements

 ATSC (Advanced Television Systems Committee) Standard A53, revision B (HDTV standard)

Vanu PowerPoint presentation on their HDTV implementation

Outline

"Cultural" Overview

Reed-Solomon

Convolutional Interleaving

Trellis Coding/Viterbi Decoding

HDTV

HDTV == ATSC A53 rev. B standard

Spec was created by "Digital HDTV Grand Alliance"

- AT&T (now Lucent Technologies), General Instrument, North American Philips, Massachusetts Institute of Technology, Thomson Consumer Electronics, the David Sarnoff Research Center (now Sarnoff Corporation) and Zenith Electronics Corporation
- (<u>http://www.atsc.org/history.html</u>)

A53 Revision b



A53 Revision b (cont.)

- A53b describes service multiplexing and transport along with channel coding.
- ISO/IEC IS 13818-2, International Standard (1996) describes MPEG-2
- A52a describes AC3 encoding
- Doesn't describe **decoding**.

A53 Revision b (cont.)

- Channel coding has static rates.
- Comes in 2 flavors
 - 8-VSB for terrestrial cable television
 - 16-VSB for satellite television
 - (the 8 means that a transmitted symbol can take on 1 of 8 values.)
- We focus on the channel encoding and decoding of 8-VSB.

8-VSB Channel Coder

Channel Coder



Source: ASTC Standard A53 revision b

8-VSB Channel Decoder



Source: Vanu HDTV presentation



Data frame = 2 data fields, each with 313 segements (1 sync, 312 data)

Data frame:



Data rates (cont.)

Each data segment encodes 188 bytes of MPEG-2 stream (1 sync, 187 data).

Transmitted as 828 8 level symbols



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Reed-Solomon Codes

- Also in CDs, Cellphones, ADSL, DVD, etc.
- FEC (forward error correction)
- (eg it appends parity symbols to data symbols)
- Irving S. Reed and Gustave Solomon (researchers at Lincoln Labs) published original paper in SIAM, 1960.
- (http://www.siam.org/siamnews/mtc/mtc193.htm)

Reed-Solomon Codes (cont.)

- Specified as RS(n,k)
- Takes k symbols of data and produces an n symbol codeword (e.g. it adds n-k parity symbols)
- Can correct up to t symbol errors, where 2t = n - k



StreamIT Implementation

- Copied *rscode*, an open source RS implementation (written by Henry Minsky, formerly of the AI lab)
- Converted the rscode from c to Java and fooled with fields.
- Works, and corrects artificially introduced errors as promised.

http://rscode.sourceforge.net/

RS Stream Graphs

Monolithic, coarse grained implementation.



StreamIt Implemention Notes

Both the encoder and decoder have the same code b/c you can't share static code among streams.

 It was fairly straightforward for the c to Java conversion – nice feature for migrating existing applications.

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Convolutional Interleaver

Spreads a burst of channel errors out in space over encoded data.



I found it easier to understand the convolutional interleaver this way:

Delay

Need to "prime" with 30 elements.

Interleaver Stream Graph

Deinterleaver Stream Graph

StreamIt Implemention Notes

The stream graphs closely resembles the block diagram, which is good.

It was very easy, once we figured out what a convolutional interleaver did, to implement in StreamIt.

No way to ignore first 30 elements

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Trellis Encoding

- In HDTV, the trellis encoder is a convolution encoder followed by a symbol mapper.
- This provides good noise immunity (somehow)
- HDTV encoder uses 12 trellis coders in parallel

Convolution Encoding

- Input is an *m* bit symbol
- Output is an n bit symbol
- *m*/*n* is the rate (HDTV uses 2/3)
- K is the reach: the number of output symbols that each input symbol affects (HDTV has K=3)

Trellis Encoding (cont.)

Trellis Encoder used in HDTV

Trellis Encoder Stream Graph

Trellis Split-Join Stream Graph

Trellis Decoding

Not specified by A53b, I chose to use Viterbi decoding.

(after Andrew Viterbi, founder of Qualcomm. B.S., M.S. MIT '57, PhD USC '62. Also VI-A at Raytheon)

- Uses a dynamic programming approach
- Reads in a lot of input before producing a lot of output.
- Not fine grained (currently?).

Trellis Decoder Stream Graph

StreamIt Implemention Notes

The stream graph is reasonably close to the block diagram. The Ungerboeck decoder (which implements the Viterbi algorithm) is monolithic.

The encoders are naturally written to operate on bits (implementation uses integers) and so it is very inefficient.

HDTV Decoder (again)

Source: Vanu HDTV presentation

Whole Stream Graph

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Source Code Comparison

	StreamIT		Vanu		
Block	Code lines	Total lines	Lines(?)		
RS Encoder	190	364	(?)		
RS Decoder	195	367	~450		
Interleaver	41	83	(?)		
Deinterleaver	49	83	~250		
Trellis Encoder	52	118	(?)		
Trellis Decoder	207	417	~500		
Randomizer(?)			~210		