UNIGRAF

FEC & DSC

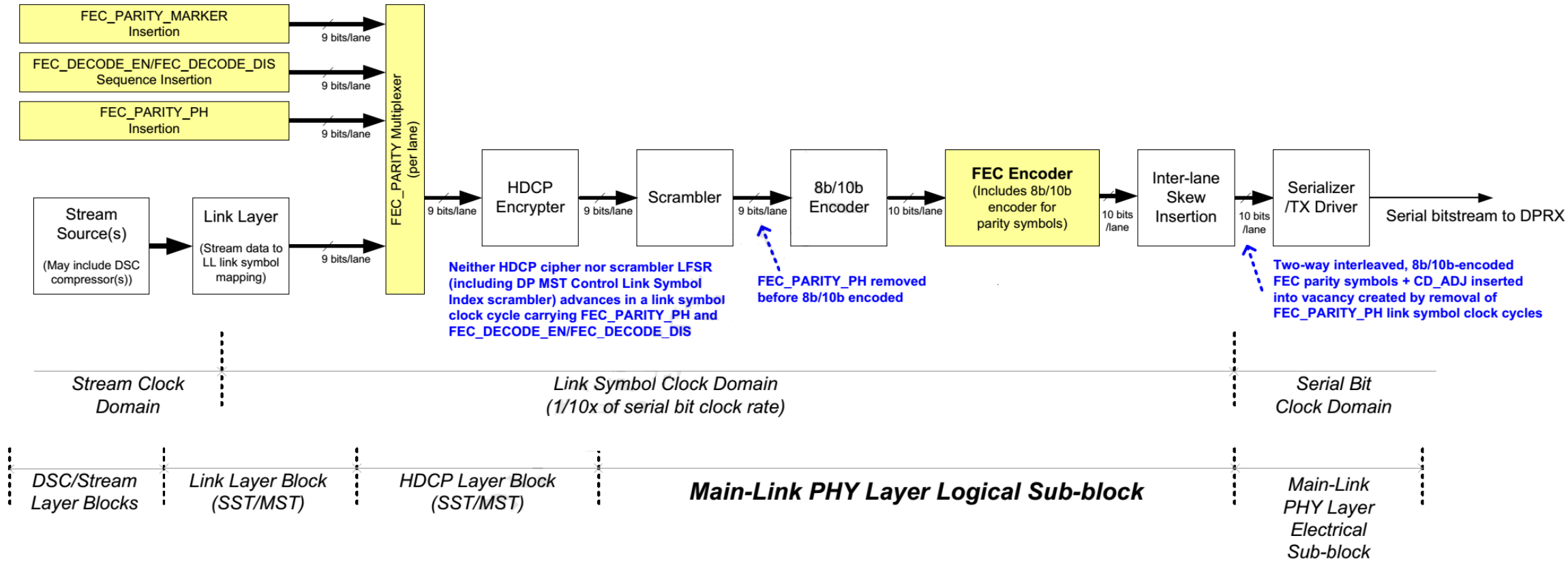
Forward Error Correction & Display Stream Compression

FEC Characteristics

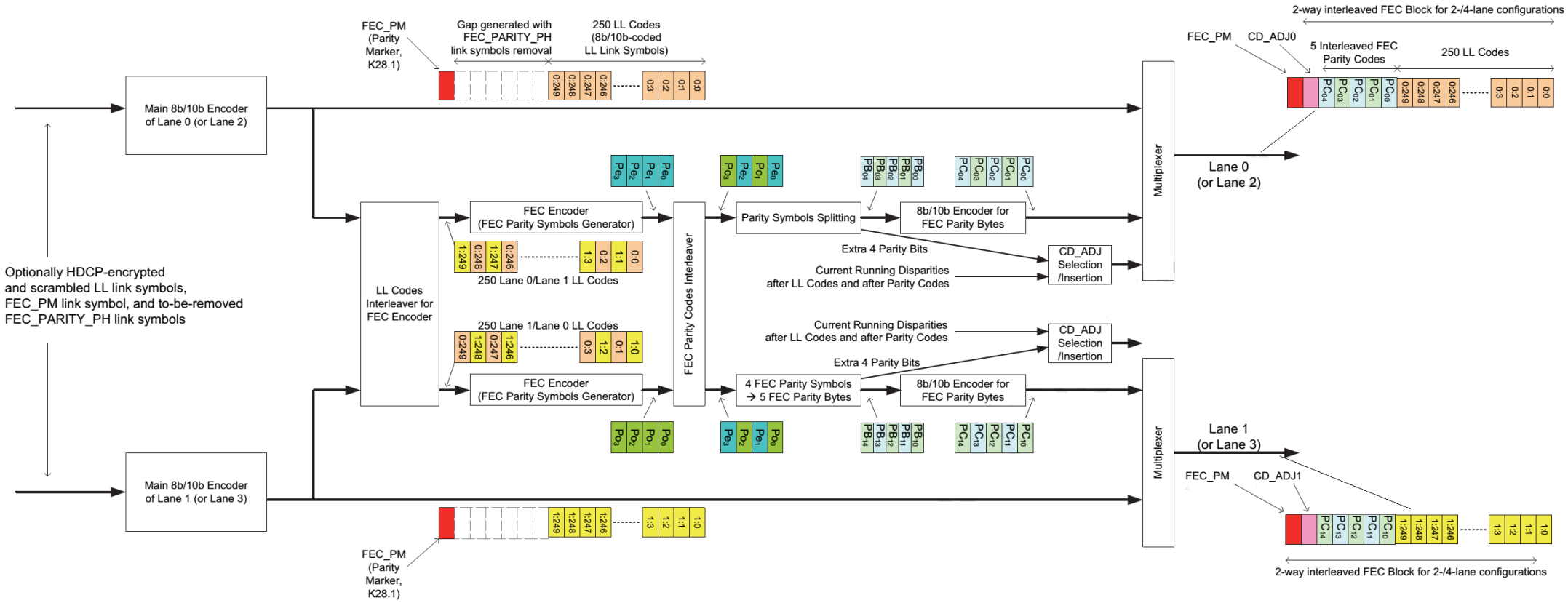
- FEC (Forward Error Correction) was introduced in DisplayPort v1.4
- Based on Reed-Solomon RS(254,250) Forward Error Correction code
  - FEC block 250 symbols >> 4 RS parity symbols >>
    5 FEC parity code + 1 CD_ADJ (disparity) code

- Creates 2.4% overhead
- Is able to correct 2 errors
- Works as SST or MST
- Uncompressed or DSC bitstream (use of FEC is normative with DSC)

FEC Applied Just Before Serializer



Inserting FEC Parity Bits



FEC DPCD Registers

DPCD Address	Register
00090h	FEC_CAPABILITY
00120h	FEC_CONFIGURATION
00280h	FEC_STATUS
00281h and 00282h	FEC_ERROR_COUNT

DSC Characteristics

- DSC (Display Stream Compression) was introduced in DisplayPort v1.4
- Real time, frame-by-frame
  - Image can be split to slices
- 3 pixels per clock (4:4:4)
- Typically 1:2 or 1:3 compression ratio, Visually Lossless
- DSC v1.2a supports:
  - 4:4:4, 4:2:2, 4:2:0, either RGB or YCbCr color format
  - 8 to 16 bits per color component
- Works as SST or MST
- VESA provides C-source code as example implementation

Compression Has Advantages

- The initial application for DSC compression is in portable, battery powered systems with an embedded display.
- Advantages of Compression
  - Save system power and extend battery life
  - Reduce weight and cost by decreasing the number of interconnect wires
  - Decrease frame buffer size and decrease cost.
- E.g. DisplayPort 1.4a supports 8K video at 60 Hz and 24-bit color using a low 2:1 compression ratio

VESA Selected DSC Compression

- Appreciated features of DSC:
  - Visually lossless
  - Independently decodable regions
  - Many color formats and bit depths
  - Easy and inexpensive implementation in realtime
- Disadvantage of MPEG-2, H.264, JPEG-2000 and VC-2
  - Requirement to store many pixel rows makes it expensive
- Disadvantage of JPEG-LS:
  - Cannot guarantee constant bit rate
  - Quality not good enough in lossy modes

Comparing DSC Versions

Features	DSC 1.1	DSC 1.2a	VDC-M 1.1
Visually lossless compression performance verified by subjective testing			
30 bit color, compression ratio (bits/pixel)	3.75:1 (8 bpp)	3.75:1 (8 bpp)	5:1 (6 bpp)
24 bit color, compression ratio (bits/pixel)	3:1 (8 bpp)	3:1 (8 bpp)	4:1 (6 bpp)
IC complexity	Low	Low	Medium
Backwards compatibility	DSC 1.x	DSC 1.x	N/A
Both encoder and decoder are specified	✓	✓	✓
Normative C language code	✓	✓	✓
Frame-by-frame compression	✓	✓	✓
Bits per color support	8/10/12	8/10/12/14/16	8/10/12
High Dynamic Range-ready	✓	✓	✓
RGB and YCbCr 4:4:4 native encoding	✓	✓	✓
YCbCr 4:2:0 or 4:2:2 native encoding	No	✓	✓
Image test data base available from VESA	✓	✓	✓
Compliance test guideline and test scripts	✓	In development	
Publicly known adopting standards	MIPI DSI 1.2 DSI-2 1.0 VESA eDP 1.4b	HDMI 2.1 VESA DP 1.4a	MIPI DSI-2 1.1

✓ Available now

DSC Source Bitrates

Color Depth Used	Minimum Bit Rate for 8, 10 or 12 bpc (bpp)	Maximum Bit Rate for 8, 10 or 12 bpc (bpp)
4:4:4 or Simple 4:2:2	8	3 × bpc
Native 4:2:2	7	2 × bpc
Native 4:2:0	6	1.5 × bpc

Image Split Into Slices

- Horizontal slices processed simultaneously > need more resources
- Slice height does not affect resources usage
- More vertical slices improves compression effectiveness
- Sliced structure supports regional update scheme

Slice	Slice	Slice	Slice
Slice	Slice	Slice	Slice
Slice	Slice	Slice	Slice
Slice	Slice	Slice	Slice

Declared Sink Capabilities

- Version: 1.1 or 1.2
- Rate Control Buffer Size
- Number of slices pupported: 1 to 24
- Color Depth and Format: 8 to12 bpc, 4:4:4 / 4:2:2 / 4:2:0
- Block Prediction Support (optional)
- Decompressor Throughput (default 340 MP/s)
- Max Slice Width: (2560 pix default)
- BPP Increment

DSC DPCD Registers

DPCD Address	Register
00060h – 0006Fh	Receiver DSC Capabilities (Sink sets)
00160h	DSC Enable (Source sets)
0020Fh	DSC Status (Sink sets)

Slice Calculation Examples

- 3840 × 2160 @60 Hz = 594 MP/s
  - 3840 pix > 2560* pix => 2 slices required
  - 594 MP/s > 340** MP/s => 2 slices required
- 1920 × 1080 @ 60Hz = 148.5 MP/s
  - 1920 pix < 2560* pix => 1 slices required
  - 148.5 MP/s < 340** MP/s => 1 slices required

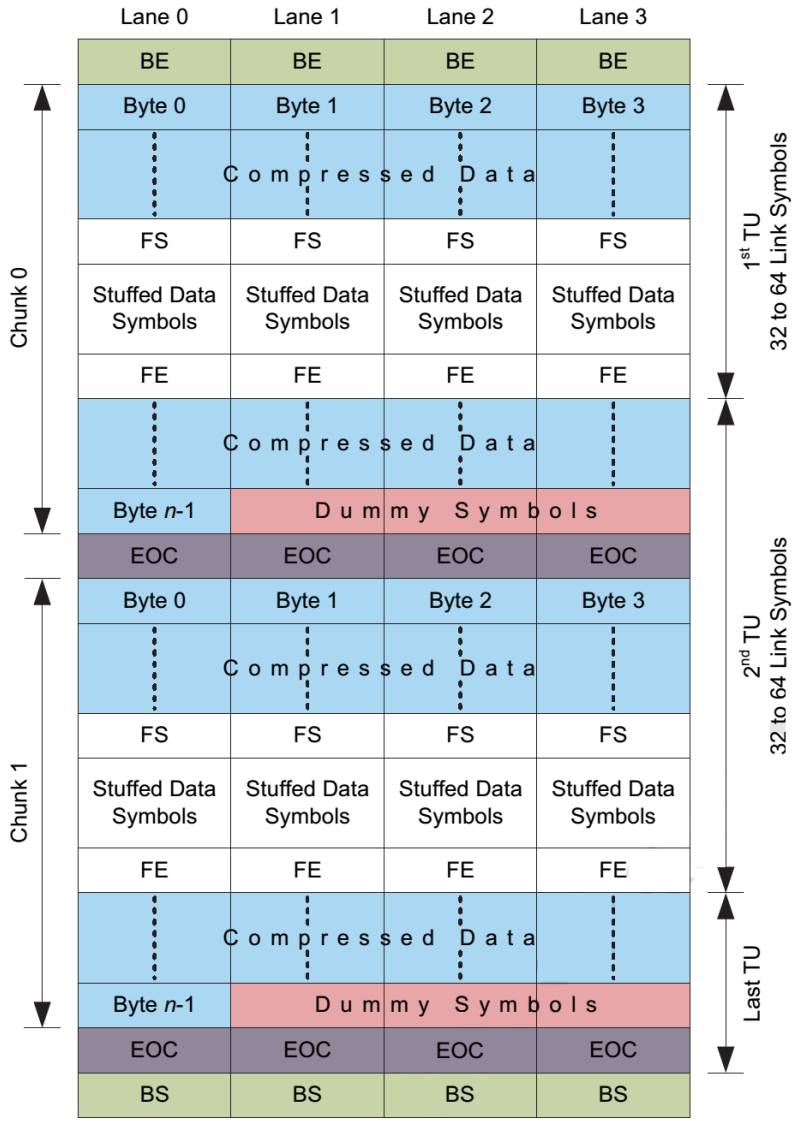
**) Max Slice Width, 2560 pix default*

***) Decompressor Throughput, default 340MP/s*

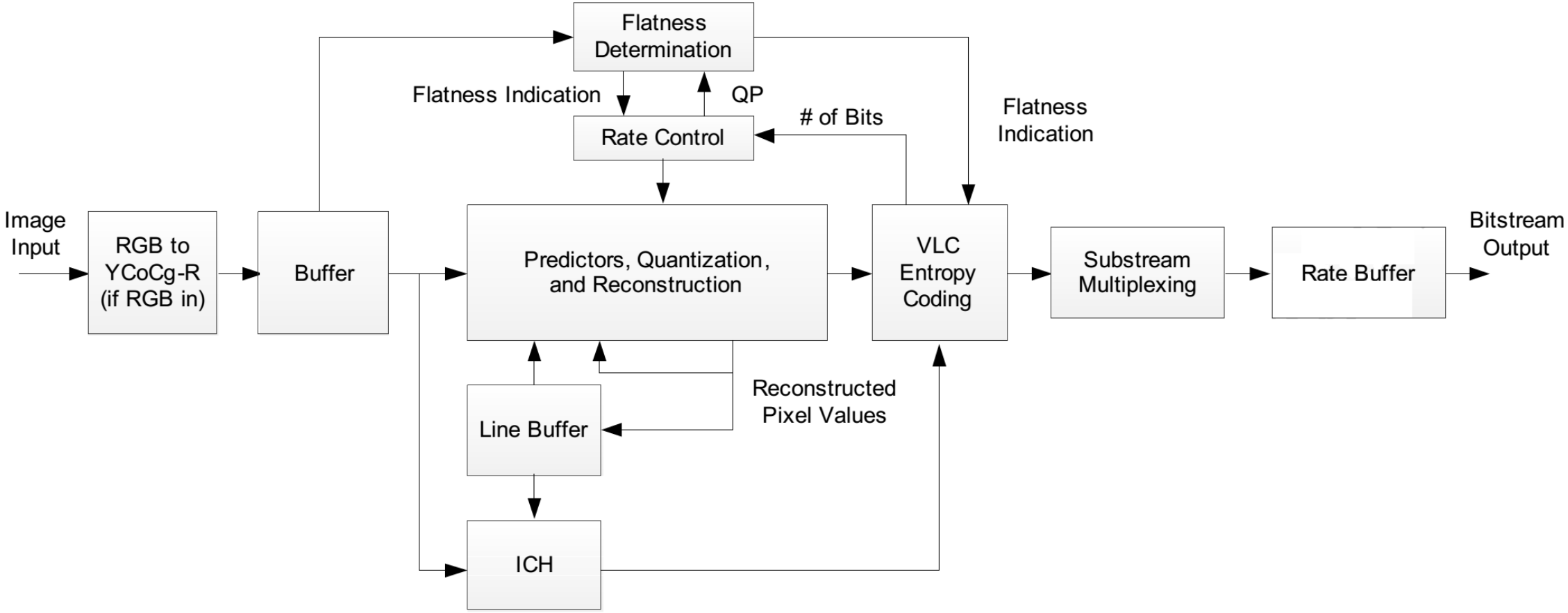
Bandwidth Example

- Two Lanes, 5.4Gbps, 42 timeslots in MTP (multistream), 3% overhead:
  - 2 × 540 MBps × 42/64 × 0.97 = 687.4875 MBps
- 3840 × 2160 (RB) 60Hz
  - 4000 × 2250 × 60 = 540 MPs
  - 687.4875 MBps / 540MPs = 1.273 B/pixel = 10.185 bpp
- Max DSC bitrate => 10 bpp w/ 1 bpp increment precision (overhead absorbed in horizontal blanking)

DSC Stream Transmission



DSC Encoding



DSC Encoding – Main Steps

Color space conversion:

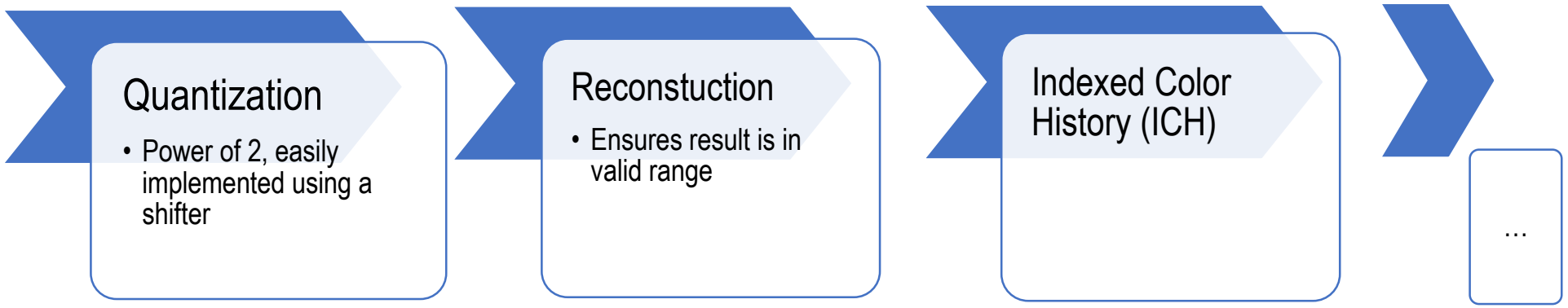
- RGB->YCoCg-R
- Simple with only shift and addtion needed

Prediction:

- Modified median-adaptive prediction
  - Supports 3 pixels parallel
- Block Prediction (optional)
  - Predicts samples from previously reconstructed pixels
  - Search costly in HW => optional
- Midpoint prediction
  - Perdict samples from component midpoint
  - Number of bits required bound even in worst case

…

DSC Encoding – Main Steps



DSC Encoding – Main Steps

Rate Control

- Ensures maximum quality without buffer over/underflow

Flatness Detection

- Reduces quantization artifacts

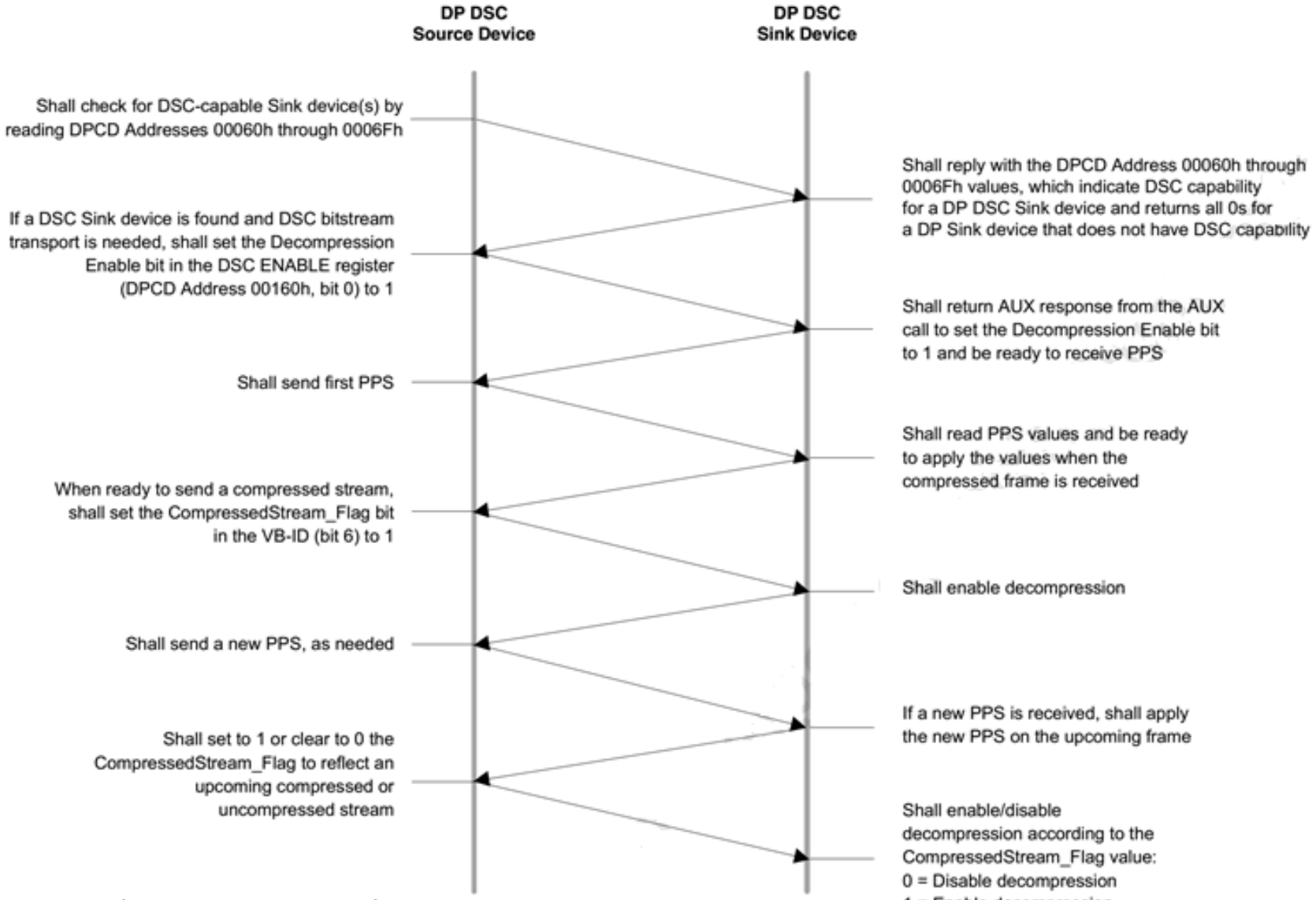
Entropy Encoder

- Codes prediction residuals

Substream multiplexing

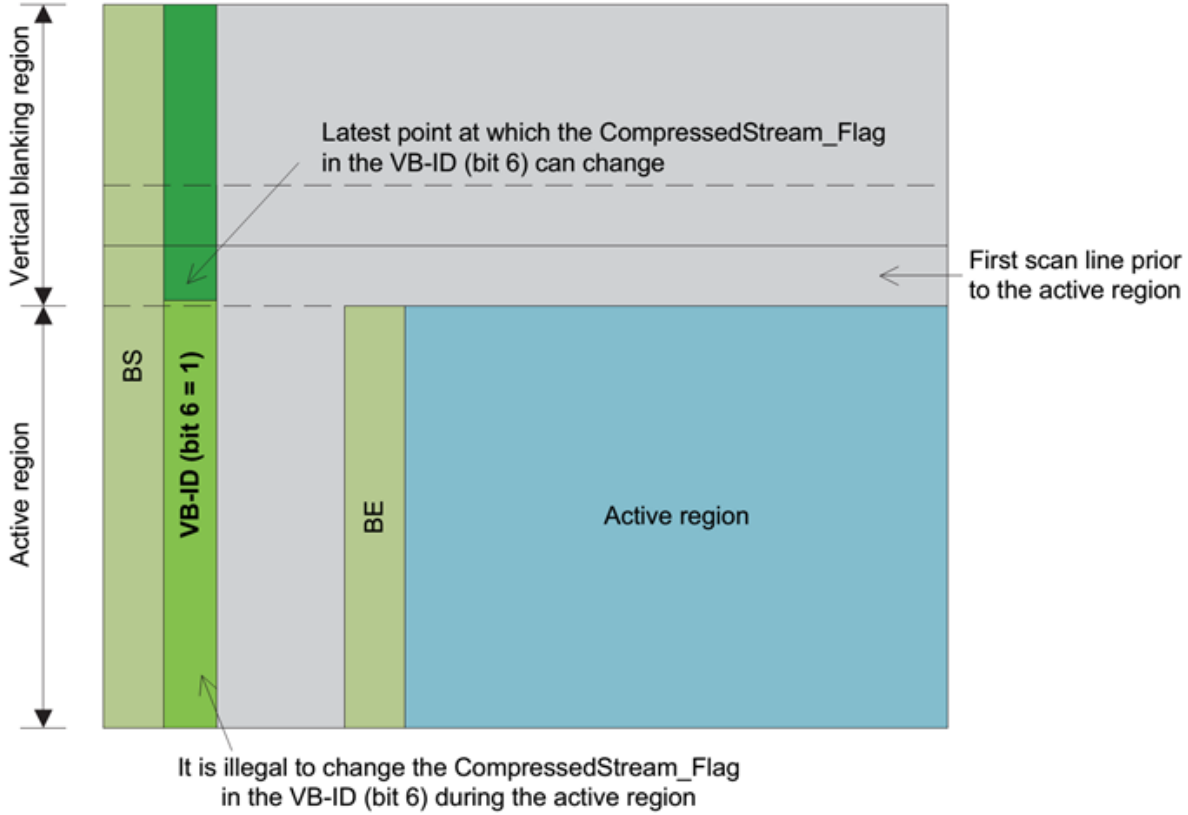
- Allows 3 entropy decoders to run parallel

Enabling DSC



PPS = Picture Parameter Set. Sent as SDP. Set of parameters that provide information necessary to decode the picture

Location of VB-ID Signal



VB-ID Bit #	Bit Definition
0	**VerticalBlanking_Flag** Shall be set to 1 at the end of the last active line of a video frame and remain set during the vertical blanking period. A Source device may clear this bit in the VB-ID either immediately prior to the first active line of a video frame (i.e., the first BE of a video frame) or immediately after the first active line (i.e., the first BS ending the first active line of a video frame). A Sink device shall be able to handle either case. This bit is also set to 1 when there is no video stream (as indicated by bit 3 being set to 1).
1	**FieldID_Flag** This bit shall be cleared or set, as follows: • Cleared to 0 after the last active line in the top field • Set to 1 after the last active line of the bottom field See Section 2.2.4.2 for definitions of the top and bottom fields. For progressive (non-interlaced) video, there is no bottom video and this bit remains cleared to 0.
2	**Interlace_Flag** Shall be set to 1 when the main stream is an interlaced video. For non-interlaced video or no video, this bit shall remain cleared to 0.
3	**NoVideoStream_Flag** Shall be set to 1 when preceding BS is inserted while no video stream is transported. When this bit is set to 1, the Mvid7:0 value shall be "don't care." ***Note:*** *An audio stream may be transported even when no main video stream is being transported.*
4	**AudioMute_Flag** Shall be set to 1 when the audio is to be muted.
5	**HDCP SYNC DETECT** Used by HDCP-capable DPRXs to detect CP lock status. See HDCP Specification 1.3 – Amendment for DisplayPort and HDCP on DisplayPort Specification 2.2.
6	**CompressedStream_Flag** New to *DP v1.4* to support Display Stream Compression (DSC). (See Section 2.7.3.3 and Section 2.7.3.4 for details.)
7	**RESERVED** Read 0.

DSF File Header

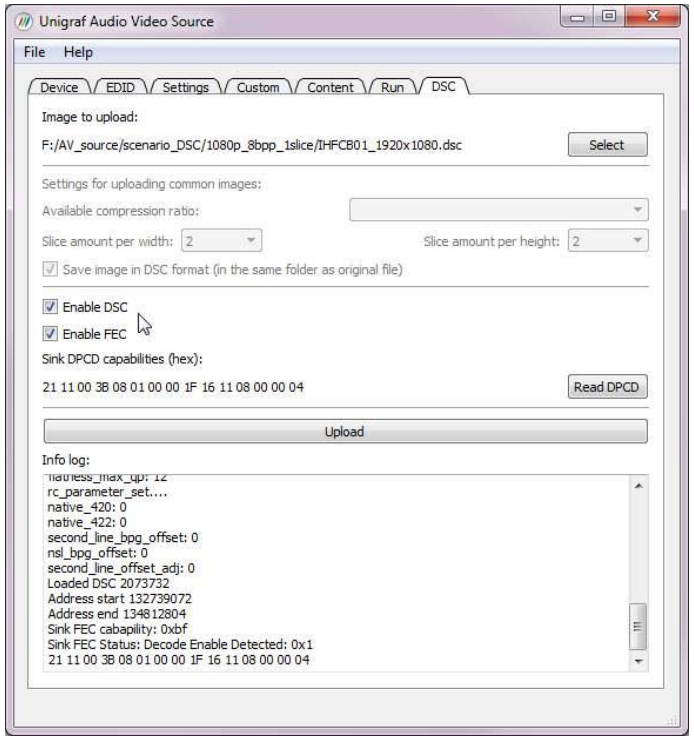
0	44	53	43	46	12	00	00	88	30	80	04	38	07	80	02	1C
10	03	C0	03	C0	02	00	03	58	00	20	3A	4C	00	0D	00	0F
20	00	39	00	1C	18	00	10	F0	03	0C	20	00	06	0B	0B	33
30	0E	1C	2A	38	46	54	62	69	70	77	79	7B	7D	7E	01	02
40	01	00	09	40	09	BE	19	FC	19	FA	19	F8	1A	38	1A	78
50	1A	B6	2A	B6	2A	F4	2A	F4	4B	34	63	74	00	00	00	00
60	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
70	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
80	00	00	00	00	00	C0	40	40	00	82	80	00	00	00	00	00
90	80	00	00	00	00	00	08	20	82	08	20	82	00	00	00	00
A0	00	00	00	00	00	00	00	00	08	20	82	08	20	82	00	00
B0	00	00	00	00	00	00	00	00	00	00	08	20	82	08	20	82
C0	08	20	82	08	20	82	00	00	00	00	00	00	00	00	00	00
D0	00	00	08	20	82	08	20	82	00	00	00	00	00	00	00	00
E0	00	00	00	00	08	20	82	08	20	82	00	00	00	00	00	00
F0	00	00	00	00	00	00	08	20	82	08	20	82	00	00	00	08
100	00	00	00	00	00	08	00	00	08	20	82	01	FD	FD	00	00
110	FF	FF	FF	FF	00	00	FF	FF	FF	FF	FC	04	10	41	04	10
120	3D	C0	00	8F	C3	00	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF
130	FF	FF	11	F8	60	02	3F	0C	00	47	E0	DC	00	8F	C3	00
140	11	F8	60	02	3F	0C	00	47	E0	DC	FF	FF	FF	FF	FF	FF
150	FF	FF	FF	FF	FF	FF	00	8F	C3	00	11	F8	60	02	3F	0C

DSC Testing with Unigraf Tools

- UCD-400 can be used as a DSC capable DP Source and a DSC capable DP Sink.
- DSC encoding and decoding will be done in a PC application.
  - DSC compressed file will be uploaded to UCD-400 for transmit.
  - DSC compressed stream will be downloaded to PC for decoding.

Sending DSC Compressed Streams

- ***AVSource*** application used for sending the stream to UCD-400
- Use either compressed dscf image files or
- Compress a bitmap with AVSource.
  - Set vertical and horizontal slice amount
  - Set required compression ratio.



Receiving DSC Compressed Streams

- ***AppTSI*** application for capturing DSC compressed streams.
- AppTSI reads one captured video frame from UCD-400 for decompression
- AppTSI enables preview and saving of decompressed frames