Line by line processing of video on IT Hardware

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Introduction

- Existing hardware able to process video on a line-by-line basis, sometimes less
  - Inherently property of minimising line buffers in hardware
  - Allows for O(lines) processing
- Advent of Uncompressed IP makes this doable using IT hardware
  - Lines are inherently packetised
- COVID world, focus on higher compression H.264/HEVC rather than Intra VC-2/JPEG-XS

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Who we are?

- Company specialising in software-based encoders and decoders for Sport, News and Channel contribution (B2B)
- Based in Central London
- Build everything in house
  - Hardware, firmware, software
- Not to be confused with:

Open Broadcaster Software

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Commercial/Operational Drivers

- Operational requirements for lower and lower latency with reduced budgets
- REMI/Remote Production for sports
  - Backhaul feeds to one or more locations for now socially distanced production
- Editorial requirements for news
  - Harder to interrogate politicians with latency
  - Disadvantage in debates for remote contributors

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Benefits of IT Approach

- More flexible approach to infrastructure
- A decoupling of video processing from physical hardware
  - Move processing resources to people's homes
- Uncompressed IP deployments allowed for simple scale up and down during lockdown
  - Point and click
- Less disrupted supply-chain for IT equipment (larger pool)

Activation log

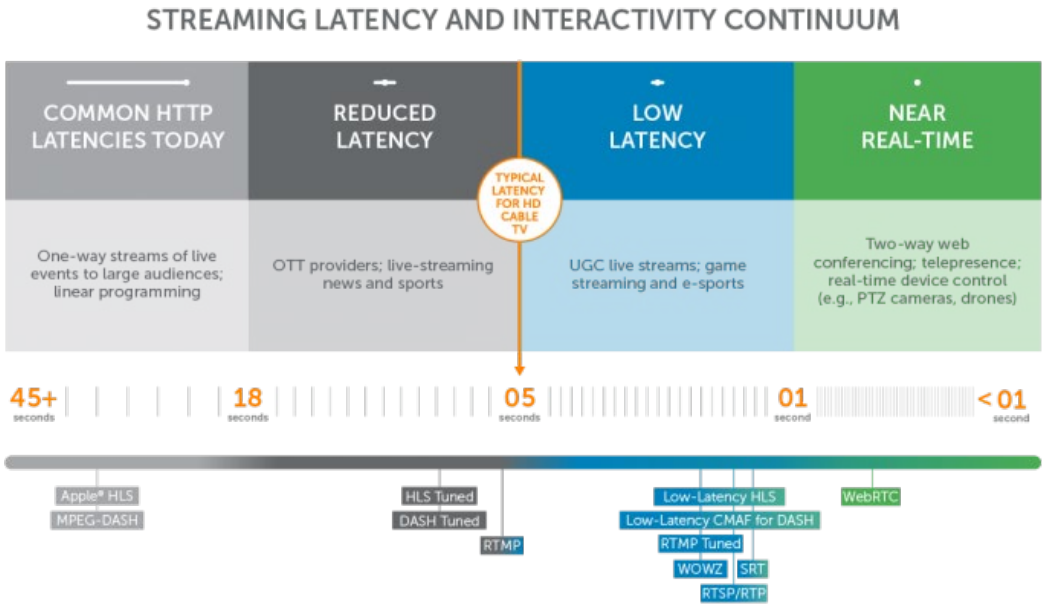
IP address	Extra data	Type	Date activated
[redacted]		Activation	March 31, 2020 — 8:54 pm (+01:00)
		Deactivation	March 31, 2020 — 8:51 pm (+01:00)
		Activation	March 31, 2020 — 8:41 pm (+01:00)
		Activation	March 31, 2020 — 8:21 pm (+01:00)
		Activation	March 31, 2020 — 7:44 pm (+01:00)
		Activation	March 31, 2020 — 7:08 pm (+01:00)
		Deactivation	March 31, 2020 — 7:04 pm (+01:00)
		Activation	March 31, 2020 — 6:59 pm (+01:00)
		Activation	March 31, 2020 — 5:47 pm (+01:00)
		Deactivation	March 31, 2020 — 5:43 pm (+01:00)
		Activation	March 31, 2020 — 5:31 pm (+01:00)
		Activation	March 31, 2020 — 11:52 am (+01:00)
		Activation	March 31, 2020 — 11:23 am (+01:00)

Downsides of IT approach

- IT industry does not work on line-by-line approach, common frameworks (DirectShow, GStreamer, FFmpeg) etc all frame based
  - Wait for frame buffer to arrive, do processing, output it, wait for it to arrive, decode it
  - Frames add up quickly

- Small niches of IT understand this
  - Cloud Gaming
  - DSC (Display Stream Compression) – 1 line latency!
    - Used in DisplayPort and HDMI
  - Will be interesting to see if podcast/YouTube world changes this

“Latency” according to the streaming industry



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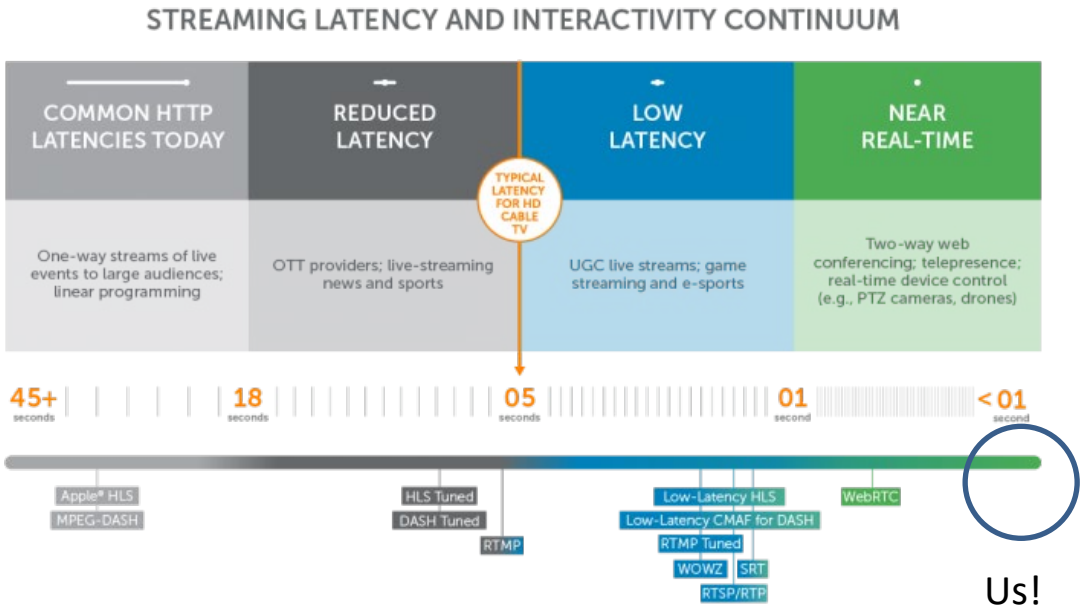
Latency according to the ~~streaming~~ broadcast industry



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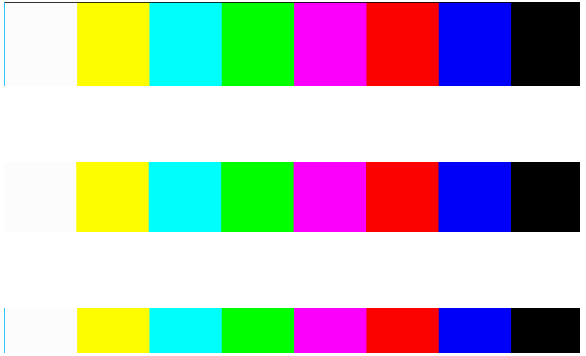
Uncompressed IP line by line

- Theoretically could busy loop and read line at a time. Quite costly.
- In practice, have to do 2022-7 and maybe wait for audio, so 5-10 lines is acceptable
- Decapsulate whilst the next chunk arrives
- Ideally go straight from 2110 packet pixel format to internal encoder pixel format (or decoder -> 2110)
  - Difficult to do in practice with modular codebase
- All of this sounds easy but it's hard!



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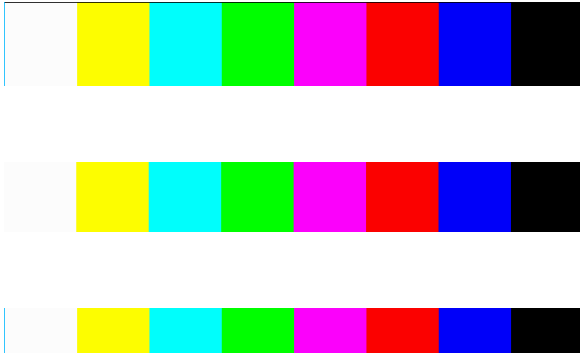
Uncompressed IP line by line (2)

- Receive chunks
- Do processing on them, insert a logo, whatever
- Release on next PTP epoch
- Plenty of time to do pixel processing
- Again not widely done in IT industry frameworks
- Can’t use most fashionable programming languages with garbage collection that takes 5ms



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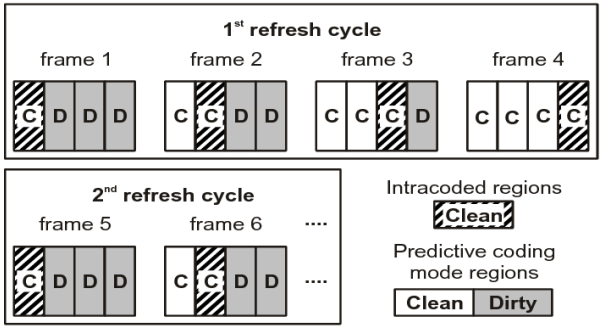
Some quick thoughts on SDI

- Likewise most standard SDI capture/output boards work on a frame-basis
  - One Chinese manufacturer supporting “early reads”
  - Got to wait for a frame, then convert it to the pixel format you need (~5-10ms)
- Built our own with ~32 line buffer
  - Also can convert to desired pixel format whilst frame arrives on wire, reduces latency further
- Go through a similar codepath to Uncompressed IP

H.264/HEVC Encoding

- A need for < ~100ms encode/decode (glass-to-glass) but at “COVID-friendly bitrates”
- Encode a frame or a field at a time
- Use intra-refresh modes, intra frame spread over stripes, small VBV (= low latency)
- Unlike intra modes, best to allow ratecontrol to work on entire frame
  - Some hardware vendors doing sub-frame encode
- Uncompressed audio essentially mandatory
  - Audio encode latency too high (except Opus)
- **No hit to compression efficiency for frame/field**



Motion adaptive intra refresh for the H.264 video coding standard Ralf M. Schreier, A. Rothermel

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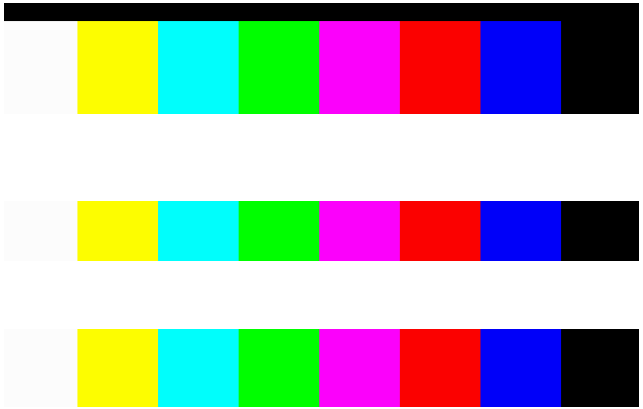
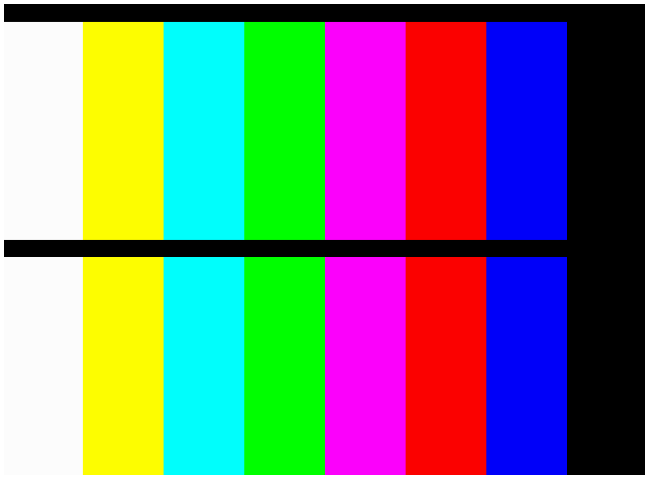
Decode frame as it arrives on the wire (1)

- Slices arrive at destination

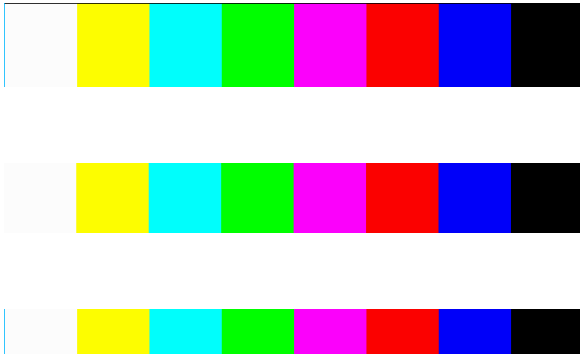


- Complete frame is built



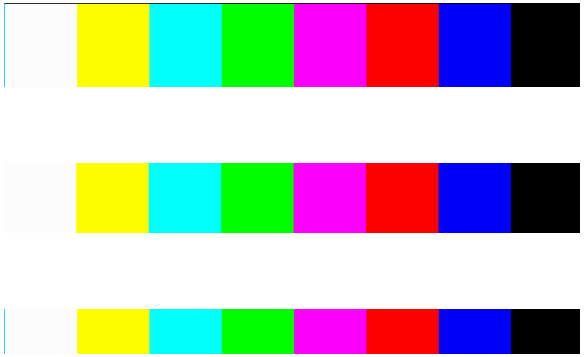
Decode frame as it arrives on the wire (2)

- Avoid deblocking on slice boundaries
  - Independently decodable slices
- On high bitrate streams latency/throughput tradeoff
  - May need to buffer slices and decode simultaneously to gain enough throughput to decode in realtime
- Decoders output chunks when done
  - Uncommon in IT decoders
  - Cloud gaming uses this
- Render slices when buffer is big enough



Decode frame as it arrives on the wire (3)

- Compressed video likely not PTP locked, so have to frame synchronise before outputting as 2110
  - Have to resample audio as well, also have to decode audio as it arrives on the wire…
  - Again a concept not supported in IT
- Some applications (where not used for production, e.g monitoring, PTZ control) could free-run to lower latency
  - Output slices to network as soon as it's done
  - Illegal 2110 stream



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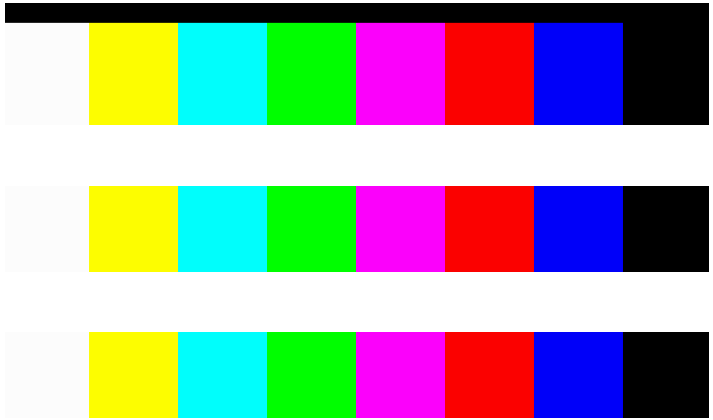
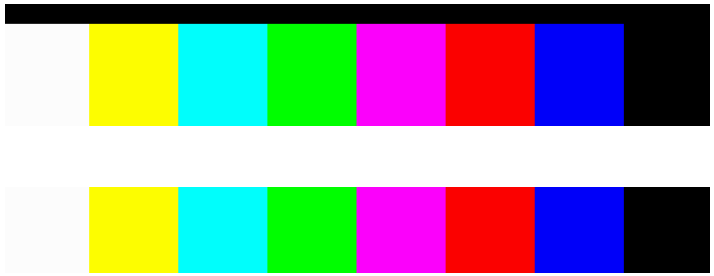
VC-2/JPEG-XS

Source



Destination



- Similar except chunks encoded as they arrive
  - 32-128 lines of latency
  - ~100-200Mbps of bitrate

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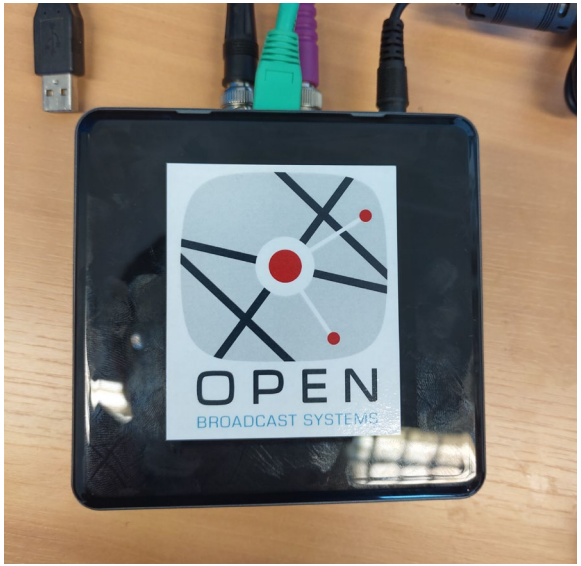
COVID Tradeoffs

- Some operations will take place in a home or non-traditional environment
  - Could be that 5-7 round trip time of RIST/Zixi is tolerable, gives Zoom-like experience, low-latency with the odd hit here and there. ~200ms end to end not bad.
- Start seeing broadcast products having home focus instead of Zoom and others being used as stopgap
- Use of 4:2:2 10-bit, SDI and other things not usually used at home
  - Again for lower latency than PC/cellbonding based products
  - Remote editing/grading etc
  - Employers paying for dedicated connections



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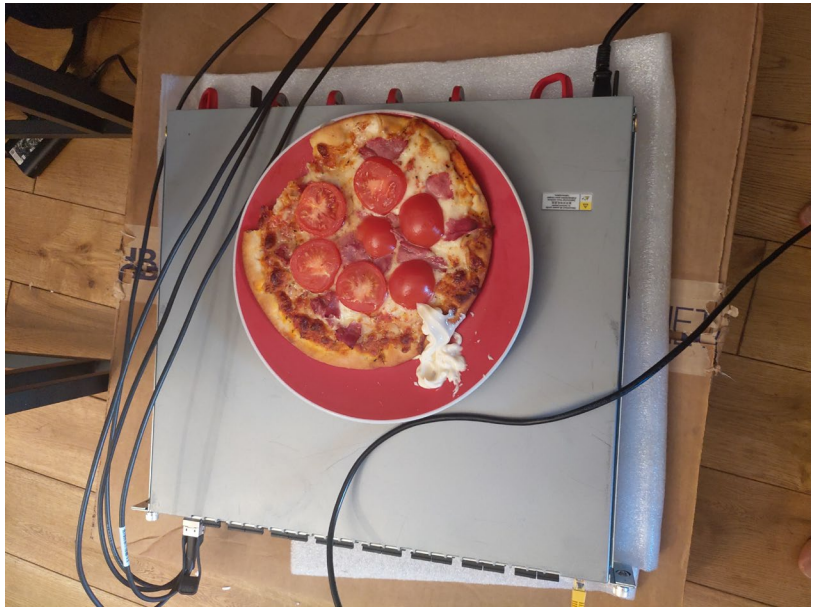
COVID Tradeoffs (2)



- Quite a few domestic issues with 100GbE switches at home
  - Probably not going to see much 2110 in a home environment

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Conclusions

- In the end best of both worlds
  - COTS hardware but sub-frame encoding and decoding
- Right image 5 frames end to end at modest bitrate (sub-100ms), can cut more frames in the future
  - 2110 in and 2110 out
  - Could be SDI
- 2110 -> MPEGTS -> 2110 remote production

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