Multi-Point Uncompressed HD Conferencing Using UltraGrid

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Talk Overview

Problem Statement

- high image quality multi-party collaborative environment based on open-source products
  - (at least) full HD image with close to maximum quality
    $\Longrightarrow$ 1920×1080 image resolution
  - low latency
    $\Longrightarrow$ uncompressed media streams
  - multi-party data distribution without need for network-native multicast
    $\Longrightarrow$ multi-party data distribution based on our UDP packet reflectors
  - open-source implementation on open-source platform
    $\Longrightarrow$ Linux-based implementation
  - for free

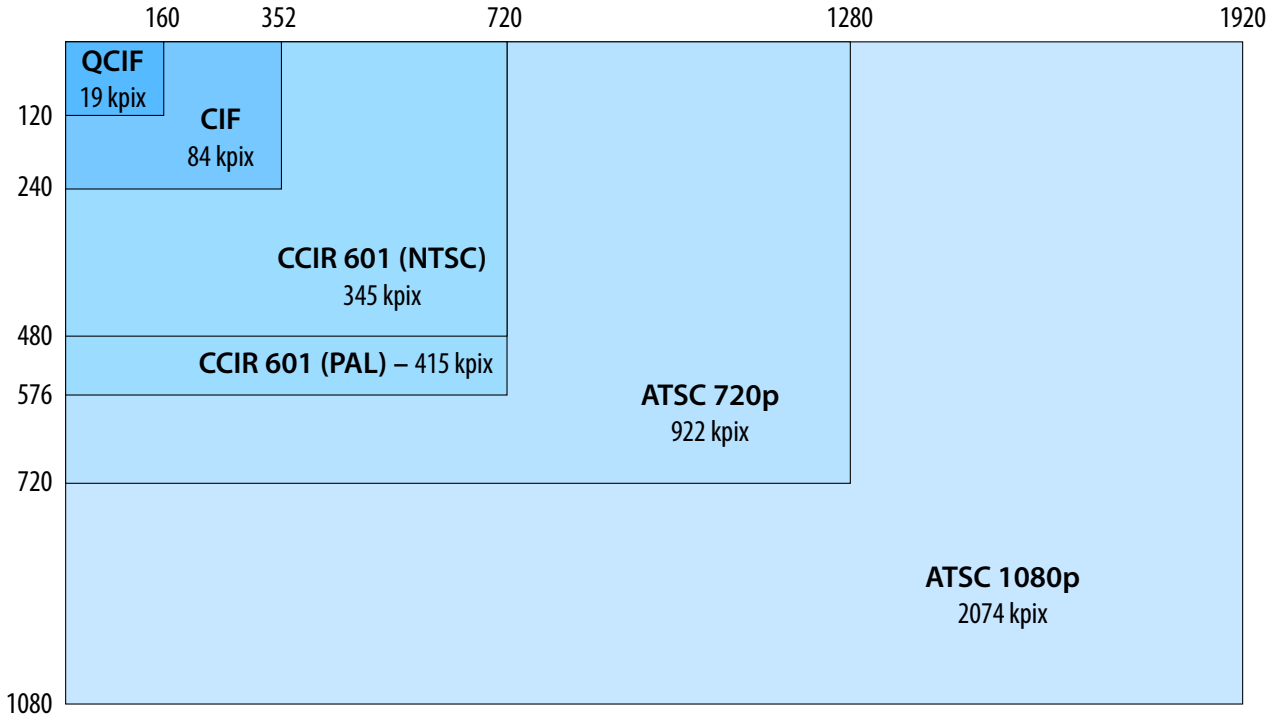
Compressed vs. uncompressed video

+ latency minimization
+ maximum quality preservation including pixel/field/frame independence
  - important esp. for further processing and (re)compression
+ fewer problems with artifacts (esp. in case of network dropouts)
  - DCT-based compression schemes have very characteristic response to data losses (for uncompressed video, you can see how the packet big/small is)
– bandwidth wasting
– higher demands on throughput-capability of end nodes


Talk Overview

HDTV

- multiple supported formats: 720p, 1080i(, 1080p)
  - common 1920 × 1080 @ 60i
- support for high-quality audio (e.g. 16 bit @ 48kHz with 5.1 channels)



What Is Uncompressed HD About?

Uncompressed HD: 1080i over HD-SDI, SMPTE 292M

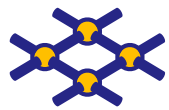
- Bandwidth calculation:

$$\underbrace{2200 * 1125}_{\text{total resolution}} * \underbrace{30}_{\text{bit/point}} * \underbrace{30}_{\text{fps}} * \underbrace{2/3}_{\text{4:2:2 sampling}} = 1.485.000.000 \text{ bps}$$

- Resolution: includes 1920×1080 of effective resolution, but also adds up blanking lines, totaling 2200×1125.
- Color depth: 10 bits/point/color plane $\Longrightarrow$ 30 bits/point
  - Computers are usually unable to render more than 8 bits/color plane.
- Frame rate: 24p, 25p, 29.97p, 30p, 50i, 59.94i, 60i
- Sampling: usually 4:2:2
  - 4:4:4 needed? You need double-link SDI (2.23 Gbps).

HD-SDI over IP

- Packetization specified in RFC 4175 (“RTP Payload Format for Uncompressed Video”)
  - encapsulation: payload/RTP/UDP/IP
  - augmenting common RTP headers with payload headers (e.g., additional packet numbers because of fast RTP counter wrap-arounds—0.5 s for HD-SDI)
  - per video-line processing
- Reasonable to use jumbo frames (best $>$8,500 B)
  - decreases packetization size overhead
  - decreases host load due to decreasing number of pps

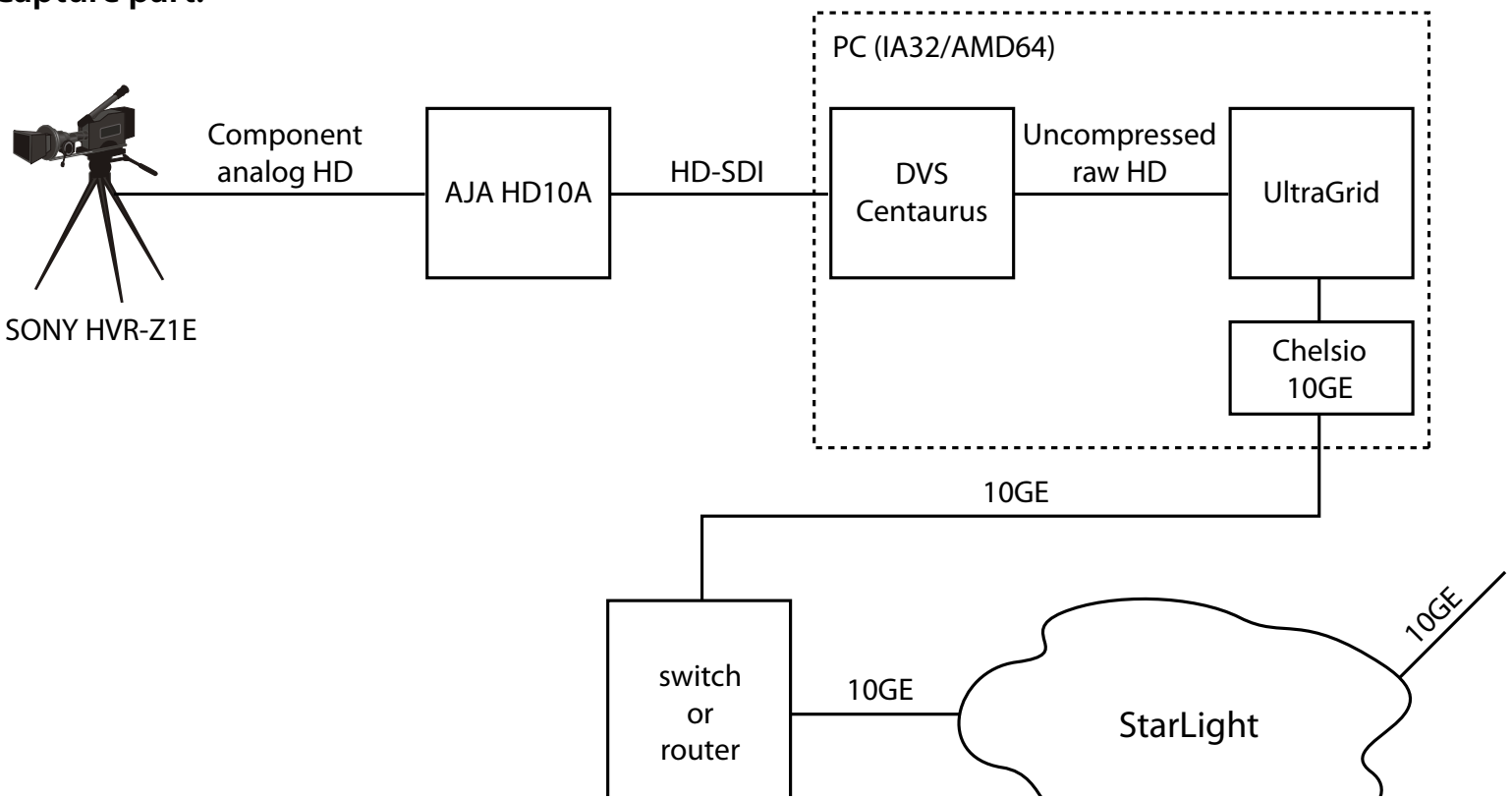


Implementation

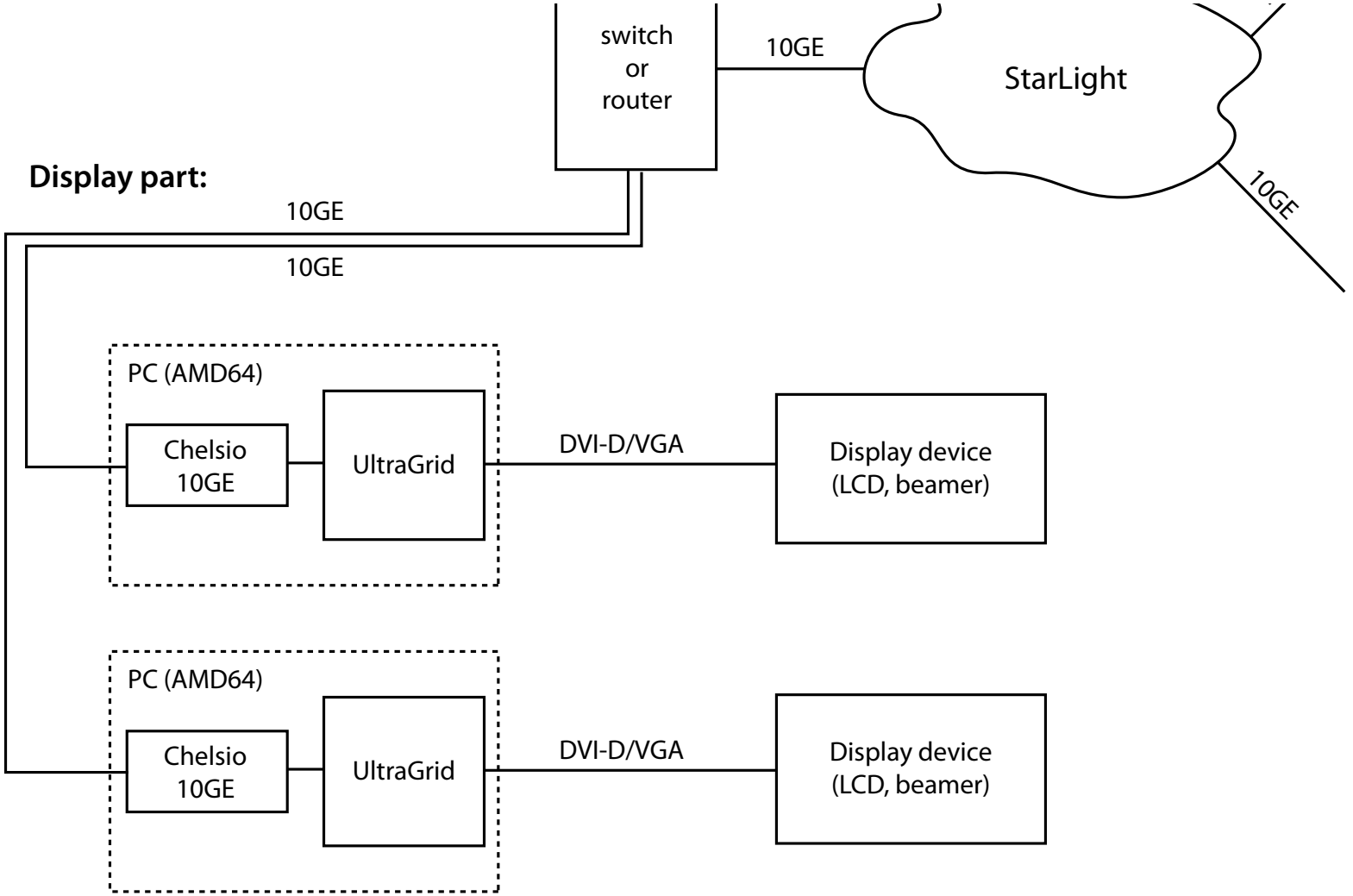
- Linux based
- comes from UltraGrid by Perkins & Gharai
  - extended to support full-HD 1080i
  - support for SW display including color space down-sampling and field de-interlacing (assembly optimized for AMD64)
  - number of other enhancements
- used with DVS Centaurus HD capture cards
  - problems with latency, since the card doesn't support DMA and requires buffering at least 4 fields for reliable operation
  - quite expensive
  - there are other cards but not officially supported in Linux

Application Workflow

Capture part:

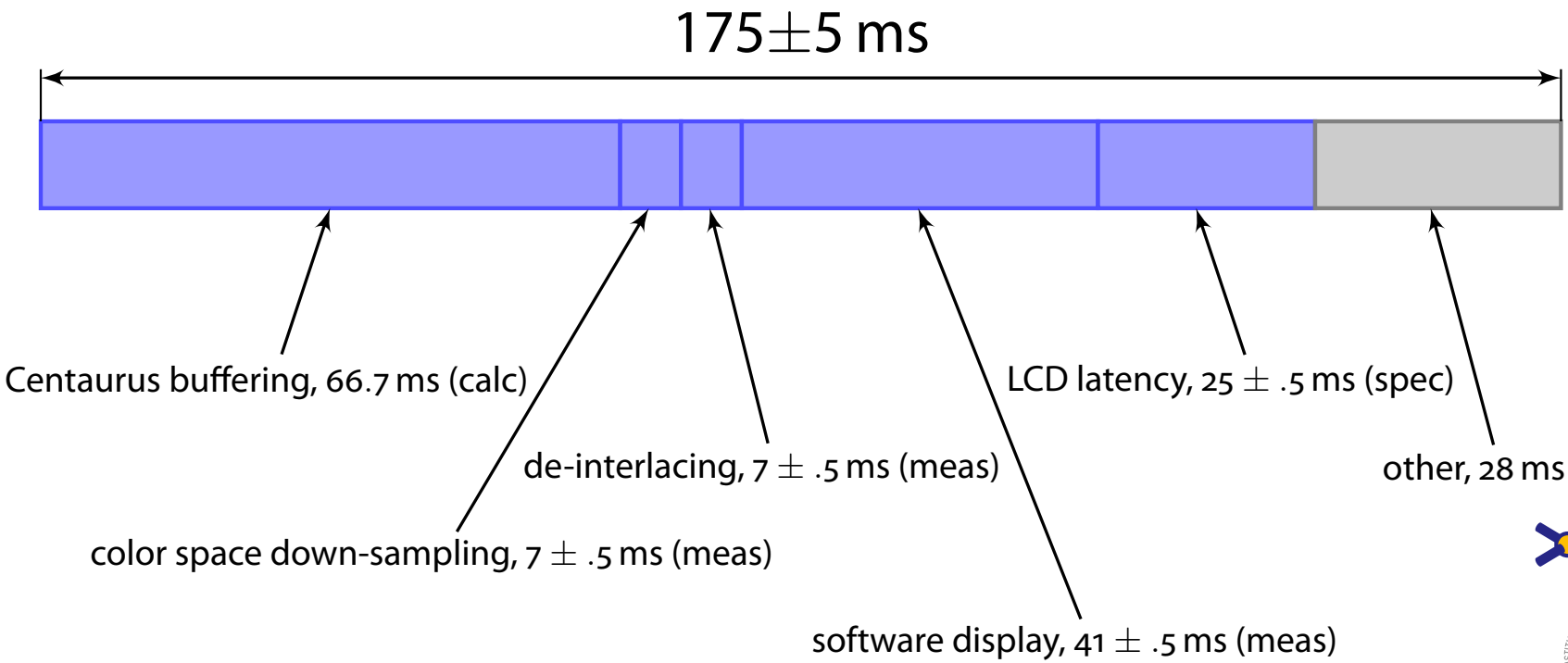


Application Workflow



Measured E2E Latency

- unidirectional latency measurement
  - SONY Z1E → AJA HD10A → PC → PC → LCD



Talk Overview

Network data distribution

- Point-to-point transmissions
  - natural for todays networks
- (Multi)Point-to-multipoint transmissions
  - requires distribution service either on network or application layer
  - IP multicast
    - native
    - UDP packet reflectors—Active Elements
    - optical splitters

Native multicast

\+ very efficient
- data go at most in one copy over any particular link
- source-based tree creates the optimum distribution tree

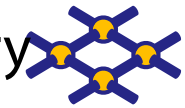
– hard to set up appropriately

– not user-empowered
- what if it is not supported in your network?
  what if there are some problems with it in your network?
  $\Longrightarrow$ you need the administrator!
- what if it is misconfigured outside your network?
- what if you need to apply some policy to the data distribution?

– doesn't support per-user processing

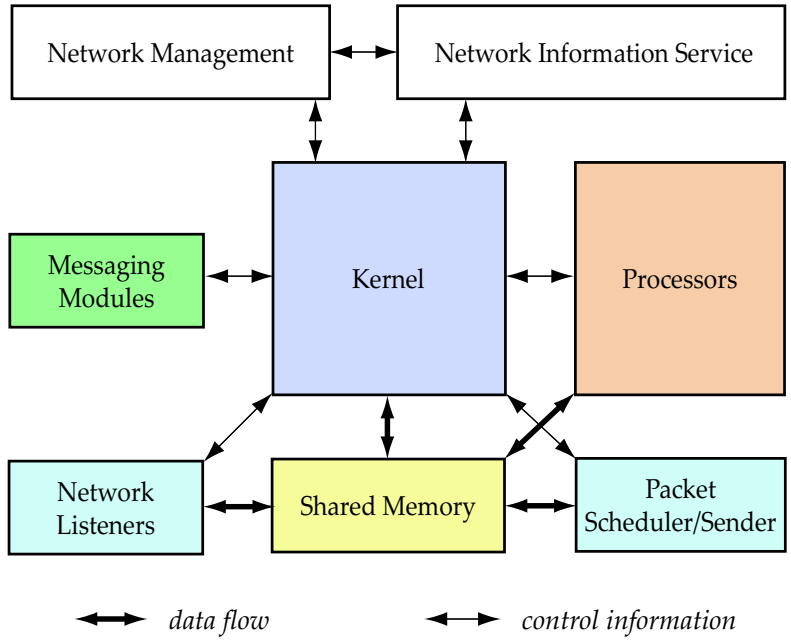
UDP packet reflectors

- lower efficiency
- hard to deploy for streams above 1 Gbps
+ designed as user-empowered solution
+ relatively scalable w.r.t. number of users when deployed as a network
+ supports per user processing
  - data format/bitrate conversions
  - strong encryption (per-user keys)
+ good robustness and fast recovery
  - can be more aggressive in failure detection and recovery
- support for hostile networking environments (firewalls, NATs)



Active Elements

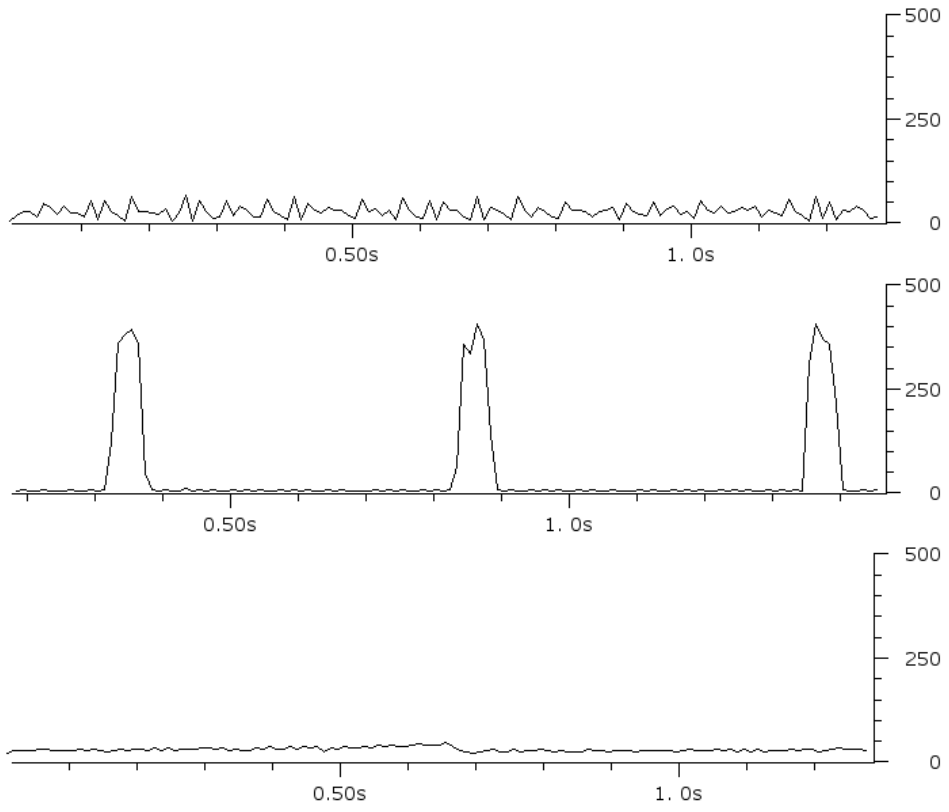
- User-empowered data distribution element
- Modular architecture
- Separated control plane and data plane



- Heavy optimization was needed for 1.5 Gbps stream
  - reducing per-packet overhead (calls/packet)

Real-World AE Performance

- Problem with bursts
  - required optimization of queue management
  - implementation of smoothing module for lower bandwidth



Real-World AE Performance

- With Chelsio T110 card:
  - duplication of the streams only
  - max. bandwidth for duplication: 1.2 Gbps with 1,500 B frames, 2.2 Gbps with 8,500 B frames
- With Myrinet 10GE cards:
  - supports up to 5 clients with 1.5 Gbps streams

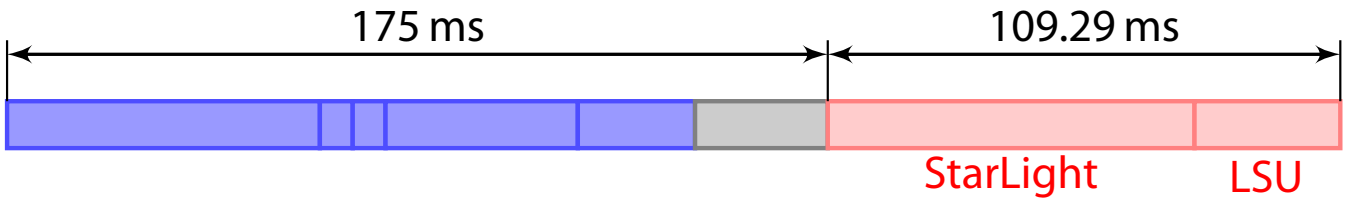
Talk Overview

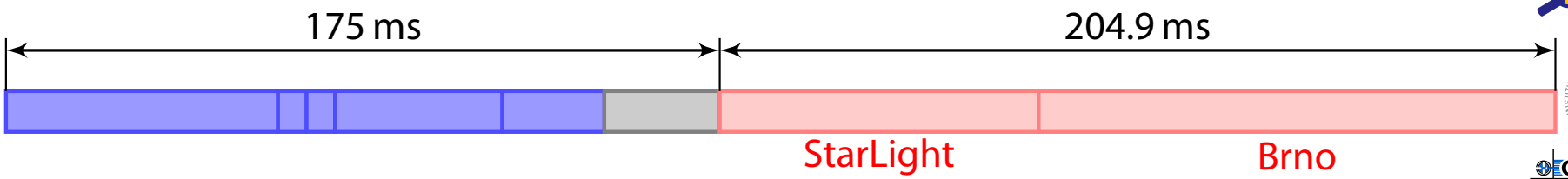
Applications

- Advanced collaborative applications
  - videoconferencing
  - remote teaching (e.g. math writing on the black/whiteboard)
- Scientific visualizations
  - common video compression techniques often perform badly for computer generated images
- Medical applications
  - tele-consulting during operations
  - esp. suitable for organ transplantation (resolution, low latency)
  - histology (color fidelity, resolution,…)

iGrid 2005: Experienced Latencies

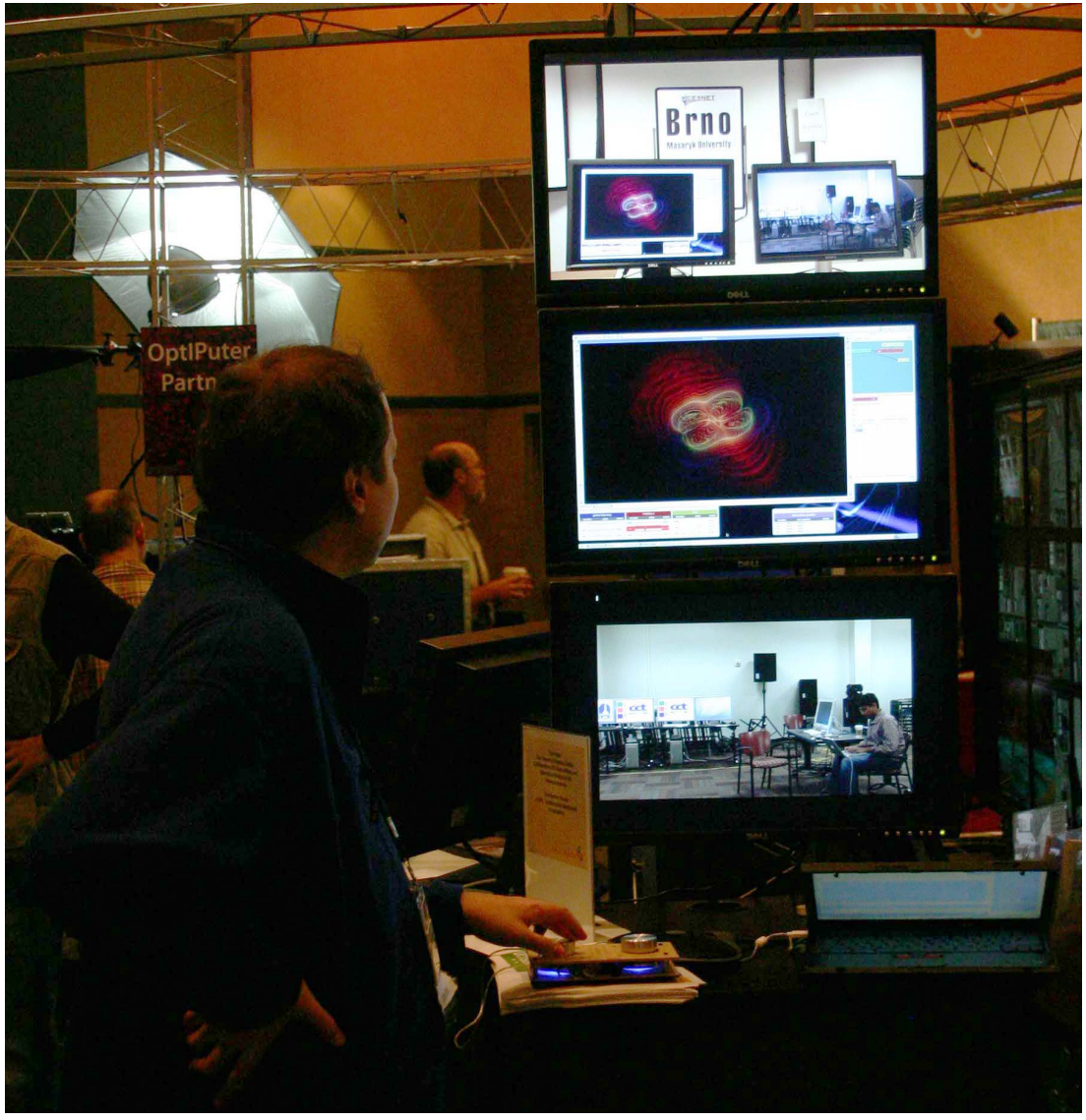
- Reflector latency: 13±2 ms
- Circuit latencies:
  - San Diego ↔ StarLight: 78.2±.2 ms (routed)
  - Louisiana ↔ StarLight: 31.09±.04 ms (switched)
  - Brno (CZ) ↔ StarLight: 126.7±.3 ms (routed)





iGrid 2005

SuperComputing|2005



SC06 Demos

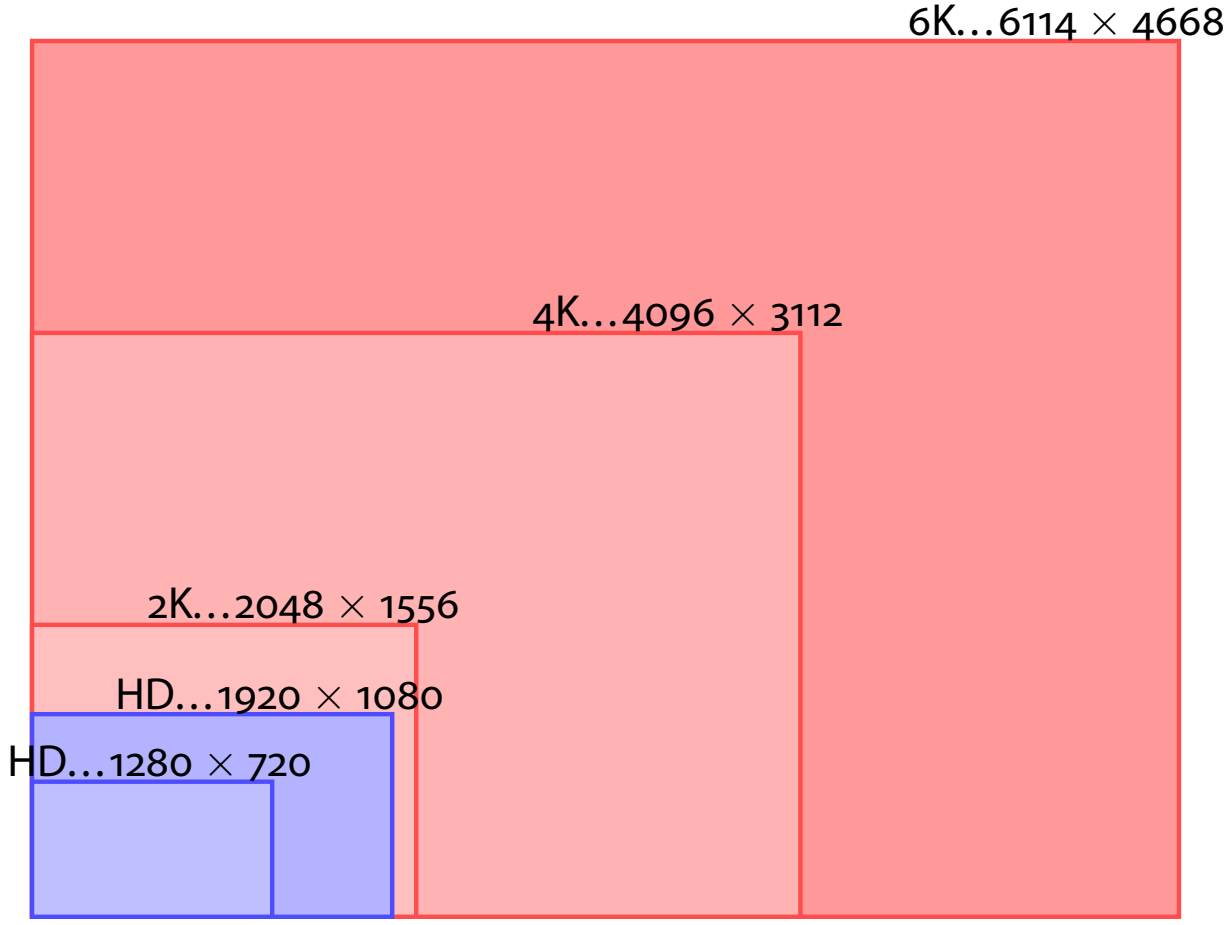
- Reflector-based demo
  - 18 Gbps aggregated throughput in iCAIR/StarLight
- "Optical-multicast" based demo
  - not-so-optical (O-E-O), problems with TDM behind drop-and-continue functionality on OME6500 (while it works on HDXc)
  - towards true optical multicast (splitters are cheap but not flexible, optical matrices are either expensive or lacking multicast functionality)
- Support for distributed collaborative visualization
- Thomas Sterling's course on HPC
  - advertised during SC|06
  - runs January – June 2007
  - includes LSU, LA Technical University, University of Arkansas, Masaryk University, other partners are interested


SuperComputing|2006

Talk Overview

Future Work

- Going beyond the HD resolution
  - 2K, 4K, 6K resolutions and ultra-HD resolution



Future Work

- Support for MacOS X and QuickTime low-latency API
- AJA XENA support (integration of Korean group work)
- Integration with SAGE for tiled displays
- Stereoscopic/holographic projections
- Incorporating high-definition audio
  - most of the current problems are with physical/electrical/acoustic installation of the non-computer equipment
  - higher quantization and sampling resolutions (24 b @ 192 kHz), multiple channels

Future Work

- Towards optical multicast
- We need a reasonable network control plane to interact with!
  - the control plane that is able to work across multiple administrative domains
  - manual optical currently requires tremendous effort by host of people
  - integration with reflectors (be it implemented on any level)

Who has been involved…

- Leading: Petr Holub and Luděk Matyska
- Miloš Liška, Lukáš Hejtmánek, Jiří Denemark, Tomáš Rebok
- others for the demos…

More details are in the special issue of Future Generation Computer Science by Elsevier Science dedicated to iGrid 2005.

Thank you for your attention!

Q?/A!

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