HD Collaborative Framework for Distributed Distance Learning

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Abstract

High fidelity collaborative environment based on a multi-point uncompressed audio and HD video capturing, transmission, and presentation systems has been deployed to support *Introduction to High Performance Computing* class given by prof. Sterling at LSU. The lecture has been transmitted live to several other universities in the USA and in Czech Republic. The data distribution used a dedicated high throughput (10GE) networks partly managed by the HARC software. The system worked very well most of the time, audio being the most problematic part to setup correctly.

1 Introduction

Teaching and learning are activities that could benefit from the availability of high fidelity collaborative platforms, as they are in essence a collaborative undertaking. This way, larger numbers of students dispersed geographically could get access to top scientist, without extreme demands on the scientist—to travel to each place and have a lecture separately—and on university budgets—to be able to pay the top scientists and also cover they travel expenses.

We have implemented a multi-point uncompress HD over IP transmission system complemented with other supporting technologies. As a pilot experiment, this high fidelity collaborative environment has been used by prof.

Thomas Sterling from the Louisiana State University, LA, to present his *Introduction to High-Performance Computing* class. The institutions participating in the class were mostly from LA and neighboring US states—University of Arkansas (UARK), Louisiana Technical University (LATECH), and recently also MCNC and North Carolina State University (NCSU)—and one truly remote—Masaryk University (MU) in Czech Republic. University (NCSU).

2 Interactive Collaboration Technologies

The collaborative system used is based on our implementation of a multipoint uncompressed audio and HD video capturing, transmission, and presentation. The audio part has been implemented by RAT [Hardman et al., 1995] at 16 b quantization and up to 48 kHz sampling rate in stereo. Thus data rates up to 1.6 Mbps were used. The audio is distributed in full N:N way, i.e., all participants can hear and talk to one another.

The uncompressed HD video was HD-SDI over IP transmission based on UltraGrid software [Holub et al., 2006], featuring full 1080i SMPTE 274M/292M video with effective resolution of 1920×1080, 60 interlaced fields per second, 4:2:2 color space sampling, and 10 b per color plane. The total data rate after packetizing the data using 8,500 B Jumbo Ethernet frames is about 1.5 Gbps including aggregate IP/UDP/RTP packet overhead (44 B per packet in total). As the video needs much higher throughput than the audio, a simpler distribution model is used: (1) 1:N from the lecturer to all participating sites and (2) N:1 from all sites to the lecturer only (the sites does hear but do not see each other).

The high demanding setup with data rates over 1 Gbps has been complemented with a backup solution based on Access Grid and webcasting in QuickTime format for those unable to participate at full rate (LATECH).

2.1 Network and Data Distribution Setup

Because of multi-Gigabit aggregate media data flows, the network has been implemented using experimental 10 Gigabit Ethernet (10GE) infrastructure and both statically and dynamically allocated λ-services. The network topology resembles star with center in StarLight (SL) in Chicago, IL. LSU and LATECH are using 10GE backbone Louisiana Optical Network Initiative

(LONI), which has an uplink to SL using a dedicated Enlightened wave running 10GE on National Lambda Rail (NLR). The Enlightened wave is being dynamically provisioned for the class and for the testing windows using a preliminary version of HARC [Battestilli et al., 2006], the software stack developed by the Enlightened project. UARK is connected via OneNet network and a wave on NLR running 10GE; again, the circuit is automatically setup before the class begins and shut down after it ends. MCNC and NCSU are connected to SL in the same way using NLR waves. MU is connected using a dedicated permanent circuit Prague–SL leased by CESNET and the Brno–Prague link is implemented using CzechLight experimental infrastructure using leased dark fiber lit by CESNET equipment. The whole infrastructure is switched L2 network and is transparent on the IP level. Measured network latencies are shown in Table 1 (data for LATECH are not provided as LATECH does not have 10GE link at the last mile).

From	*to StarLight*	*to LSU*
LSU	30.6 ms	–
Masaryk University	115.4 ms	145.7 ms
MCNC	23.5 ms	53.8 ms
University of Arkansas	19.3 ms	49.6 ms

Table 1: Network round-trip latencies (RTTs) in the 10 Gigabit infrastructure

The data flows are distributed with our user-empowered software UDP packet reflectors [Hladká et al., 2004, Holub et al., 2005]. The reflectors run on dual-Opteron computers equipped with either 10GE NICs. The schematics of the 1:N video distribution is shown in Figure 1. Note that there are actually two sites participating at LSU as not everybody can fit in a single room—thus the same technology is used for distributing the data locally on the campus between two buildings. There are also two streams being sent to MU—one of them is used for live video feed, while the other is used for full-quality recording (see Section 3).

2.2 Site Setup

Each site is equipped with one sender and one or more receivers for uncompressed HD video over IP transport system. The machines are essentially the

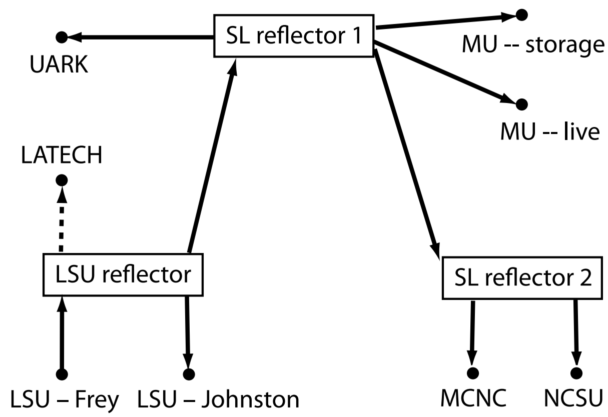

Figure 1: Overlay data distribution network for the 1.5 Gbps uncompressed HD video streams.

same as used for reference UltraGrid 1080i implementation [Holub et al., 2006], i.e., dual-Opteron computers with 10GE NICs. The sender computer is equipped with DVS Centaurus HD-SDI capture card, while the receiver uses NVidia graphics card to render the video on the attached LCD screen or projector—we used 24" to 30" LCD screens and plasmas or (at MU) the Projection Design Cineo3+ 1080i projectors. The video part runs flawlessly with very good user perception.

Though less challenging from the networking and processing perspective, the audio part creates many more problems namely on audio capture side. The worst problems are caused by bad audio installations (ranging from wiring problems to echo canceling and gain control problems and over-processing of the sound by various components before it gets to the computer—all this resulting in noises and distorted sound) used within the lecturing rooms primarily at LSU and wireless microphone interferences. Problems have also been encountered when using some on-board integrated sound cards, as their obviously half duplex behavior resulted in clicks and sound distortions. After appropriate corrective actions were undertaken, the sound quality becomes very high and pleasing to hear.

3 Data Storage

The lectures were given at 3pm Central American Time, which has 7 hour difference from the Central European Time[1] used at MU. That meant lectures given from 3:30PM at LSU started at 10:30pm, too late for regular lectures. Additional complication was due to difference in the beginning of a semester—the LSU start one month before the MU Spring semester. For the actual semester, we decided to overcome both problems recording live lectures in the full quality *at the receiving site* and displaying them later at more appropriate time.

The data storage—requiring at least 190 MBps read/write throughput—has been implemented using a very fast local disk array comprising 12 disks in RAID 0. The write performance of the array was 385 MBps and read performance was 414 MBps. The media streams (1 video and N audio streams) from the network are captured and stored as raw data on the disk array, with each 1.5 hour lecture requiring about 1 TB of stored data. Later, they are indexed so that seeking capability is available. The data is replayed later from the same disk array.

4 Conclusions

The original collaborative system described in this paper had been implemented in 2005 and redesigned by the beginning of year 2007. It has been used since then for supporting the HPC class. Due to running on highly experimental networking infrastructure, some sites had to resort to using backup solutions at times, but the infrastructure worked flawlessly most of the time. Another experience gathered from this class is how important is high quality audio installation at participating sites and how difficult it is to implement it properly. The low sound quality is much less tolerated when other means of communication are of high quality compared to common point to point communication tools.

[1]By coincidence, both time zones use the same acronym—CET.

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References

[Battestilli et al., 2006] Battestilli, L., Hutanu, A., Karmous-Edwards, G., Katz, D. S., MacLaren, J., Mambretti, J., Moore, J. H., Park, S.-J., Perros, H. G., Sundar, K. S., Tanwir, S., Thorpe, S. R., & Xin, Y. (2006). EnLIGHTened computing: An architecture for co-scheduling and co-allocating network, compute, and other grid resources for high-end applications. Available from: `http://enlightenedcomputing.org/index.php?n=Main.AboutEnLIGHTenedPage?action=download&upname=EnlightenedGrid07.pdf`.

[Hardman et al., 1995] Hardman, V., Sasse, A., Handley, M., & Watson, A. (1995). Reliable audio for use over the internet. In *Proceedings of INET'95* Honolulu, Hawaii.

[Hladká et al., 2004] Hladká, E., Holub, P., & Denemark, J. (2004). An active network architecture: Distributed computer or transport medium. In *Proceedings of 3rd International Conference on Networking (ICN'04)* (pp. 338–343). Gosier, Guadeloupe.

[Holub et al., 2005] Holub, P., Hladká, E., & Matyska, L. (2005). Scalability and robustness of virtual multicast for synchronous multimedia distribution. In *Proceedings of 4th International Conference on Networking (ICN'05)*, volume 3421 of *Lecture Notes in Computer Science* (pp. 876–883). La Réunion: Springer-Verlag Heidelberg.

[Holub et al., 2006] Holub, P., Matyska, L., Liška, M., Hejtmánek, L., Denemark, J., Rebok, T., Hutanu, A., Paruchuri, R., Radil, J., & Hladká, E. (2006). High-definition multimedia for multiparty low-latency interactive communication. *Future Generation Computer Systems*, 22(8), 856–861.