The Next Generation Distributed Learning Environment: The Experiences

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Abstract
*In past centuries, education has been one of the most powerful tools to help propel economic development and improve social well-being. Modern educational systems have benefited from technological advancement, especially in information and networking technologies. Although, distance education has existed for more than 100 years it still continues to evolve, reaping the rewards of technological progress. This paper discusses the novel distant learning platform called "the next generation distributed learning environment (DLE) that we are creating, the technological decisions we've made, and the challenges encountered in establishing the DLE. Our DLE implementation is based on the next generation 4 * 10Gb/s Lambda network and ACCESS GRID, an increasingly popular collaborative system, with High Definition video enhancement.*

Introduction

Distance learning encompasses technology, pedagogy and instructional frameworks intended to deliver education to students who are typically at remote sites. Instructors may communicate with students either in real time or asynchronously. There are many distant-learning forms ranging from digital multimedia, e-learning, radio, television, video-conferencing, etc. The course offerings can be conducted by exchanging printed or digital materials at the pace agreed upon between students and teachers, or through technologies that enable the learning experience and class participation in real time. However, the degree of successful learning experience depends on pedagogical technique, precise knowledge delivery and interactive feedback.

In this paper, we describe our experiences in building a special distant learning platform called "the HD-capable distributed learning environment" that enriches students with immense and timely content and real-time interactivity over the next generation optical WAN. It is based on the Louisiana Optical Network Initiative (LONI), a 4*10Gb/s fiber optical network, and the Access Grid (AG), an ensemble of technological resources that are enhanced to deliver education in high-definition images and streaming video in a mode that is highly interactive. In fact, AG adoption in higher education and research institutes has been increasingly popular with more than 26,000 nodes currently registered. A typical use of AG is for large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials, and training.

The advent of optical WAN networks opens doors to new experiences with low latency, high bandwidth approaches that address previous barriers to learning in unprecedented highly interactive and rich environments. This enables distant learning to be more effective, especially in situations where a large amount of knowledge and information must be processed and disseminated. In section 2 of this paper, we discuss the background of one such distant learning form called "distributed learning environment" (DLE). Sections 3 and 4 describe AG and its architectural enhancements that form the HD-capable DLE. We present our construction experiences and previous results in Sections 5 and 6, respectively. Section 7 gives concluding remarks and ideas for future development.

Background

Distributed Learning Environments

Distributed Learning Environments (DLEs) can fall into multiple categories. Some courses are strictly online, providing content and course materials in a web-based environment. Others are a hybrid of classroom teaching, remote capabilities, and online resources. The course being developed at LSU is a hybrid course, a combination of classroom and other resources, but one that makes use of advanced technologies in order to make the best possible learning experience for students and professors.

The forerunner of the contemporary DLE is the correspondence course. But unlike the antiquated paper and pencil method, modern DLEs make use of sophisticated technologies that offer enhanced capabilities to their students. As the internet has grown and high speed bandwidth has become more ubiquitous, there is increased access to courses that use audio and video (both synchronous and asynchronous) and other methods that are bandwidth intensive.

Almost all DLE programs include expanding accessibility to remote or time-constrained students as a goal of their program. The program developed here shares these goals. However, our goal is to be able to address serious gaps in the availability of expertise in teaching high-performance computing. The primary goal of our course is to use technology to expand the impact our expertise can have collectively to students and institutions who might not otherwise have exposure to the level of technical expertise available through the course.

This type of attitude toward education also foreshadows changes predicted by the ubiquity of high-speed networks, and the continued trend toward a global marketplace. As technology and access to information become more commonplace, many theorists suggest that there will be a corresponding increase in on-line education as nation-states become less engaged in providing educational opportunities in the face of a global education market.

Trends

Since distance learning began making use of network systems, there has been a steady increase in the number of students and institutions offering distributed courses to their students. The National Center for Education Statistics (NCES) estimates that sixty-five percent of schools offering graduate courses face-to-face also offer graduate courses online. Sixty-three percent of schools offering undergraduate face-to-face courses also offer undergraduate courses online. Of all schools offering standard master's programs, forty-four percent also offer master's degree programs online. Additionally forty-three percent of business degree programs offer online degree programs as well.

However, the courses and programs described by NCES and the Sloane Foundation's report on online course offerings describe online education as having at least 80% of the course content delivered online. Since our course will be offered to its remote locations via LONI, it would be considered as an online course.

However, the LSU based course also uses a private network, and has resident professors who will interact with students on the local campuses, as the technical requirements of the course are high. These issues more aptly describe the course as a hybrid course.

There have been some arguments that the growth of online courses is due to an increase in non-degree related courses, and courses for continuing education. The penetration rate for Continuing Education courses being offered online is very high, approximately fifty-six percent. Master's enrollment however tops continuing education, with approximately sixty-six percent penetration rate in institutions that offer doctoral degrees [1].

However, the growth rates in all other forms of online education are increasing. The number of students that currently take at least one online course was over 2.3 million students in Fall of 2004. The observed rate of growth for online courses has been steady at around eighteen percent annually since 2002.[1]

In addition, the primary venues for online course offerings are public institutions. Smaller institutions and private institutions reported the least number of online courses and online programs. In addition, the percentage of tenure-track (core) faculty members who teach online courses is slightly higher than those who teach traditional courses in their departments. Approximately sixty-five percent of core faculty teach online courses compared to approximately sixty-two percent of tenure-track faculty who teach traditional courses[2].

[1] Ibid. Page 10.
[2] Ibid. Page 9.

The Access Grid (AG)

AG is a distributed collaboration platform that enables groups of people in remote locations to communicate and work together. A distinct characteristic of AG from other existing technologies is an ability to provide sophisticated videoconferencing using multiple displays, with a set of operator-controlled cameras at each location. AG was invented and introduced by a researcher at Argonne National Laboratories [11]. It typically consists of software and hardware resources that support group-to-group interactions over IP network. The AG has been deployed at over 20 thousands sites across 56 countries. A typical use of AG is for large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials, and training. Therefore, it is different from standard PC-to-PC conferencing tools such as Microsoft Windows Messenger or NetMeeting that focus on individual or small group communication.

Figure 1 illustrates a typical AG node which consists of a meeting room and operational closet. An AG room requires a quite complex setting. A normal AG system closet for each site includes 4 servers, running Linux and Microsoft Windows operating systems with a suite of software stacks. In addition, the meeting room is called an AG node and is equipped with a professional-grade audio system with echo canceling and audio control capabilities at various levels (e.g. a global and local level). The AG node audiovisual equipment includes multiple cameras, microphones, audio speakers, and 3 or more projectors. A crucial component is a high-speed network connection that carries digital, multimedia and communication data traffic across collaborative AG nodes. To setup an AG meeting or conference session, one must reserve for a virtual room or "venue" where participating institutions, from their AG nodes, can meet.

Figure 1 A typical AG node meeting room

The Access Grid enables broad-scale distributed conferencing, collaboration, lectures, colloquium, and tutorials. AG provides communicating means toward multiple, group-to-group interaction rather than individual interactions. Thus, the AG enables an advanced interactive venue where multiple sites and groups of people can collaborate, communicate and respond to each other at the same time. In our day-to-day operations, we employ AG for virtual conferences, and project meetings as well as distance-learning via remote lecturing between Louisiana State University (LSU) and other colleges and universities. One example is our engineering course in computational fluid dynamics co-taught by Professor Sumanta Acharya and several colleagues from his AG classroom at LSU and broadcast over AG node to Louisiana Tech simultaneously. The AG room at Louisiana Tech allows remote students to interact with Professor Acharya and his local students in real time.

It is obvious that effective network-enabled conferencing tools, especially AG, provide many benefits including *time and cost savings in travel, access to scientific creativity, participation with a growing community, enabling remote group interactions etc*. More detailed advantages can be found in [11].

Our existing networking and AG traffic is over Internet2 which provides 12 MB/s on the shared bandwidth. Thus, there are certain applications that require much richer, higher resolution and low latency & high bandwidth capability during collaborative or learning sessions. Such examples are interactive venues that require high-definition video or visualization image transmission, or remote musical classrooms where students or professors on both sides are interactively playing musical pieces together. Fortunately, the State of Louisiana has invested 40M dollars to build "LONI", the 40 Gb/s optical network connecting eight major higher education institutes and medical schools to the National Lambda Rail network. Although, a standard AG platform provides various benefits, the existing downside is its complexity that requires a precise setting, trained operational personnel and proper audiovisual tuning. However, we believe that these technical challenges will soon be overcome. Based on AG's growing popularity and existing user communities, we decided to build the next generation DLE based on an extension of AG technology. In next sections, we describe how LONI plays important roles in enhancing our current AG infrastructures for the next generation distance-learning and grid computing platforms.

The next-generation network-enabled distance/e-learning architecture & components

Architecture:

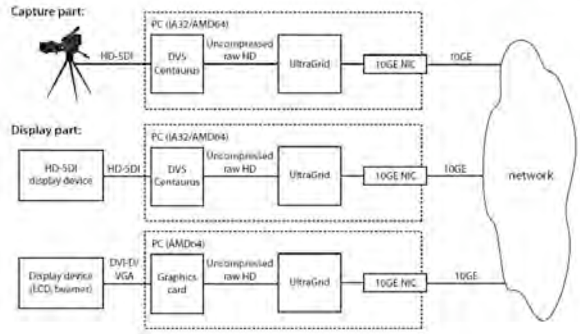
In our next generation DLE, we present a scenario to transfer uncompressed high-definition (HD) video between two sites or from point broadcast from one to multiple sites across a network capable of carrying

HD streams. Each such stream needs a bandwidth of 1.5 Gb/s. Figure 2 illustrates our DLE architecture which transmits HD streams over optical fiber.

The video is captured using an 1080i HD capable video camera whose output is fed to a HD capture card on a workstation on a sender side. The HD capture card can only take a HD-SDI signal, which can be either produced directly by the camera, or an analog to HD-SDI converter that is used to convert the component video signal from the HD camera to HD-SDI format. A modified 1080i version of Ultragrid software toolkit [9] is employed to send the captured HD video stream, using a 10 Gigabit Ethernet Network card to a fiber optic link.

The workstation or server type machine on the receiver side is running the the same modified 1080i version of Ultragrid toolkit to display the received stream to a HD capable display that can display the video at full 1080i or higher resolution. The optimum display device has native resolution of either 1920x1080 or 1920x1200 (i.e. letterbox wrapup of the image with black borders on top and bottom sides), so that no image scaling happens. The bandwidth capability at the receiver node is also 10Gb/s.

The video stream is fully uncompressed HD class and is of very low latency (less than 200 milliseconds not counting the network latency which depends on the distance between the sender and the receiver). There are many networking gears involved depending on the distance between the sender and receiver nodes, and Jumbo Ethernet frames must be enabled all the way throughout the network on all switches and routers used. There are multiple techniques that can be used to send a single HD stream to multiple receivers. A simple technique [13] is to setup a reflector node at a central network location, to which the sender will send the video to and all the receiver nodes can receive the same video stream. In order to improve scalability of the data distribution, the reflectors can be deployed as a network[12].



Source: High-Definition Multimedia for Mutiparty Low-Latency Interactive Communication, Elviser Science

Figure 2 our DLE architecture

Components:

The hardware components used in the scenario and our current implementation are as follows:

Sender Node:

- A workstation class machine with Dual AMD Opteron processors (can be Dual Core but not required) and that has a system board with at least 2 PCI-X and 1 PCI-E slot to hold the below components:
  - DVS Centaurus Capture Card - needs PCI-X slot at least at 100MHz
  - Chelsio N210 10GbE card - needs PCI-X slot at least at 100MHz
  - NVIDIA Quadro FX 3450 or higher class video card- needs PCI-E x16 slot (Optional)
  - Memory 4GB or higher

Receiver Node:

- A workstation class machine with Dual AMD Opteron processors (can be Dual Core but not required) and that has a system board with at least 1 PCI-X and 1 PCI-E slot to hold the above components:

- Chelsio T210 10GbE card - needs PCI-X slot
- NVIDIA Quadro FX 3450 - needs PCI-E x16 slot (Required; even lower end 5000, 6000, and 7000 series NVIDIA cards have been verified to work OK)
- Memory 4GB or higher

Other Hardware:

- HD Camera - Sony HVR-Z1U
- HD-SDI Converter – AJA HD 10A
- HD Display – Any LCD or HDTV that can handle a 1920x1080 or 1920x1200 resolution

Networking Components:

- Cisco Catalyst 6500-class switches at the sending and receiving sites
- Calient Fiber Optic Switch used for LONI (Louisiana Optical Network Initiative) to connect the sites

The construction – LONI and our weekly-meeting discussion and efforts

The Louisiana Optical Network Initiative (LONI)

In 2004 the Louisiana Board of Regents unveiled a plan to deliver a major network infrastructure connecting supercomputing resources across the state to the National Lambda Rail (NLR). Joining the NLR changed the entire network footprint and made it possible for other communities outside of Louisiana to connect as well. LONI connects eight campuses across Louisiana to the NLR. Louisiana State University (LSU), LSU Health Sciences Center (in both New Orleans and Shreveport), Southern University (SU), Tulane University, the University of Louisiana at Lafayette (ULL), Louisiana Tech, and the University of New Orleans (UNO). Figure 3 National LambdaRail Connectivity illustrates NLR topology and Figure 4 LONI Network and HPC systems shows current LONI connectivity.

Figure 3 National LambdaRail Connectivity

With NLR access, universities have the opportunity to create a virtual high-speed, data-intensive academic community to share teaching and research resources. In March of 2004, the Louisiana Board of Regents secured the $5 million NLR membership fee by allocating $700,000 from its own budget and receiving commitment from Tulane and LSU to contribute $150,000 each per year, over five years. In addition to its contribution of $3.5 million, SURA's two-year negotiations with AT&T yielded the donation of 6,000 miles of fiber from Jacksonville to Houston, which is valued at more than $1 million. Finally, during an open forum on LONI in September 2004, Governor Blanco surprised researchers from across the world by announcing her full support of the initiative and allocating $40 million to create and maintain the network. At this forum international representatives from funding agencies, industry, and academia gathered to discuss use of LONI.

Figure 4 LONI Network and HPC systems

With the acquisition of the new infrastructure, Louisiana's faculty has the ability to harness that power, placing the state's universities on a competitive edge in collaborative research and teaching. Supercomputers are used to simulate natural phenomena, analyze data, model scientific problems into three-dimensional images, and produce a variety of outcomes by simulating hypotheses in real time. Sophisticated animation, weather and economic forecasts, research and development of new pharmaceuticals and medical techniques generated from supercomputer models pervade daily life. The LONI network brings together supercomputers from various sites in Louisiana and the NLR to solve the large computational problems of researchers.

LONI Construction

The LONI Network is a Dense Wavelength Division Multiplexing (DWDM) system that runs along several hundred-mile sections around the state of Louisiana. As part of the build out of LONI there were certain sections of dark fiber along major highways donated to the LONI project from AT&T. Other sections were leased, and connections via Cisco Optical Routers were purchased at a substantial educational discount. Construction was temporarily delayed due to the effects of Hurricanes Katrina and Rita in 2005 in Southern Louisiana. There are three fiber loops that make up the LONI network. The southern loop connects the UNO, ULL, Tulane, and the LSU Health Science Center in New Orleans to LSU. The NLR loop connects SU, and LSU to the NLR pop in Baton Rouge. When it is completed, the Northern Loop will connect Louisiana Tech and the LSU Health Sciences Center in Shreveport back to the ULL and LSU. As of this writing, the Northern Loop is nearly complete, with only a handful of short sections of fiber left to be laid and lit. There are several IBM p5 series computers distributed throughout the network. There are P5-575 systems at LSU (Pelican), Louisiana Tech (Blue Dawg), UNO (Neptune), ULL and Tulane (Ducky). In addition, several new Dell HPC systems totaling 85 teraflops are to be deployed as part of LONI dedicated primarily to hurricane prediction and coastal modeling. LONI will install six clusters comprised of Dell PowerEdge 1950 servers at the six LONI member campuses: Louisiana Tech, LSU, ULL, UNO, SU and Tulane.

Bringing the Course Together

The principal investigators and leadership team for the course are distributed around the United States and extend into Eastern Europe, as our primary software development team resides in the Czech Republic. The team began meeting weekly in the Summer of 2006 to begin planning for the course. The first step was to determine which systems would be used by each campus, and how much bandwidth each campus could accommodate, as the video streams require a minimum bandwidth of 1.5 Gb/s.

The LSU team found that the systems we had used for the iGrid experiment [9,10] were no longer available in a configuration that would support our work. We had to start a new search for a system that included both a standard PCI slot and a PCI express slot. In the end we opted for the HP 9300 system with dual Opteron processors. The newly revised full equipment list required at a single location for the course is listed in section 4.

In the end it was decided that each remote site (Louisiana Tech, University of Arkansas, and Masaryk University in Czech Republic) would need only one sending and one receiving unit, and that the main course site at LSU would include one receiving unit for each remote site and a single sending unit. A new 10Gb switch was installed to serve the classroom from where the course will be held.

Weekly meetings focus on the procurement of the equipment components for the course, and updates on the network build out in each geographical area. The pedagogical elements of the course are being developed by the three primary course instructors, including Thomas Sterling, at LSU, Amy Apon at the University of Arkansas, and Box Leangsuksun at Louisiana Tech. The course will include the actual classroom time across the high definition network, additional course materials including ancillary video clips to help explain complex concepts, course notes being written by the instructors, and exercises that will be available through the course website.

Each local site will perform their HPC exercises on local machines, and all grading and class exercises will be monitored at each local site, by the professors listed above.

HD classroom previous experiments and results

As of this writing, there is a delay of a connection between LONI's northern and southern loops. We anticipate that LONI's connectivity will be completed around January 2007. Fortunately, the basic system presented here was tested and demonstrated in 2005 at the iGrid and Supercomputing conferences. The system was deployed at three sites - LSU in Baton Rouge Louisiana, Masaryk University in Brno Czech Republic and Calit2 in San Diego, California (iGrid) and Washington Convention Center Seattle, Washington (Supercomputing) connected by 10 Gb/s networks. This is similar to our DLE shown in Figure 2. The video distribution was implemented in software running on dedicated machines and took place in Chicago where all the network links met. The machines for video distribution are limited by the network, bus and CPU speed to a one-to-two distribution. Currently we are testing optical and standard (router-supported) multicast technologies in order to decide what is suitable for a wider distribution of the video contents, which is necessary for more than three participants.

Our experiments have shown that the uncompressed HD video system is excellent for distributed collaborative (videoconferencing, classroom) work and we have shown that it can even be utilized for more latency sensitive scenarios such as remote and collaborative visualization [9,10]. This success has motivated us to proceed to install the system in a production environment for the HD classroom in Spring 2007. We did encounter some difficulties, mostly related to hardware quality, network and hardware deployment and configuration which prompted us to start the procurement and configuration process much in advance of the scheduled start of the classroom.

Summary

We have begun deployment, testing and operational plans for a next generation distributed learning environment that exploits high-speed optical networks for interactive, responsive visualization across multiple campuses. This environment can be considered as the first DLE system of its kind capable of transmitting HD streams over a 4-lambda network capable of 40Gb/s aggregated transmission capacity. Our DLE is an extension of a popular group collaborative system called Access Grid. During the iGrid 2005 conference we demonstrated that a high-quality multiparty videoconference based on transmission of uncompressed HD streams is already achievable provided adequate networking resources are available. Although, at the time of this writing, our LONI construction is nearly completed, we have employed our lessons learned from the iGrid experiments to help refine the DLE architecture and design as well as minimizing issues that may arise during the implementation. We hope that by the beginning of Spring 2007 semester, our DLE will provide a new kind of learning experience to our students and demonstrate power and usefulness of our newly constructed LONI network.

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