

The EduPop:

Improving Streaming Video for an Electronic Community

The EduPop architecture provides a bridge across educational institutions, ISPs, and high-speed networks

By Hubert Daugherty, Julie Cohn, and G. Anthony Gorry

Colleges and universities across the country have invested heavily in information technology to support their academic and administrative programs, resulting in generally good access to computers and digital information resources on campus. Members of the academic community, however, often work at home—students living off campus or faculty furthering their research and preparing their teaching. The development of wide-area networking helped overcome the typically cumbersome nature of working from home, and many educational institutions have, in recent years, developed infrastructure to enable members of an academic community to have remote access to e-mail and various campus information resources such as library catalogues. New advances in technology, however, threaten once again to disadvantage those who work off-campus.

On many campuses, increased network capacities can now accommodate the effective distribution of various multimedia assets. In these settings, students can use the network to watch video demonstrations, listen to audio annotations, and hear musical scores. Such enrichment can be a boon for students, but beyond the edges of the campus, inadequate bandwidth diminishes the value of such resources to students and faculty alike. Furthermore, networking limitations inhibit new academic initiatives that might serve not only students and faculty but other members of the community as well.

Working with Houston academic institutions, the Center for Technology in Teaching and Learning (CTTL) at Rice University has created a new networking architecture called the EduPop to improve the dissemination of multimedia assets—

most notably digital video—to faculty, students, and others throughout the greater Houston area. The EduPop supports a community of individuals who use a variety of institutional and commercial providers for Internet access from their homes and elsewhere. Institutions in other cities can use our architecture to achieve similar benefits.

The architecture alleviates a number of problems to achieving smooth and consistent video streaming to off-campus users. For example, congestion and packet loss at busy Internet switching and control centers can disrupt the reliable flow of audio and video data to users outside the campus network. To mitigate problems of latency and speed that diminish the quality of multimedia delivered over the Internet, we established network peering relationships between Internet service providers and the Texas GigaPop, a gateway created by major educational institutions in the Houston area to connect to Internet2, a national high-performance network established to enhance collaboration among research universities and institutions over a network. In a peering relationship, two networks share traffic as equals instead of one acting as a provider and the other as a subscriber, which is commonly the case.

Through this bridge—the EduPop—traffic moves between the commercial ISPs for routine Internet access and the Texas GigaPop institutions for the delivery of digital multimedia from campus repositories. To the extent possible, we want the network path between a campus server and an off-campus user to be “wide and smooth” so that the stream of data packets arrives at the client computer in the right order and at the right time.

We activated the EduPop router in

May 2001, and it has operated continuously since then. The following service providers and academic institutions peer at the EduPop router: Rice, Baylor College of Medicine, the University of Texas Health Science Center at Houston, the Houston Independent School District (HISD), the Aldine Independent School District, Spring Branch Independent School District, Texas Education Service Center Region IV, Houston Road Runner, HALNet, and PDQ.Net. We are working to enlist other service providers in the EduPop, including Southwestern Bell Internet Services and other members of the Texas GigaPop network.

Here we give some examples of the need for enhanced streaming video in the greater Houston area and discuss how the EduPop architecture meets this need. We also catalogue some of the organizational and political challenges we faced in implementing this architecture. Our report provides a general framework for other institutions in metropolitan areas seeking enhanced off-campus access to their digital resources, and our experience with the technical and organizational aspects of the EduPop can help these institutions implement such an architecture.

Streaming Video in the Academic Community

Campus repositories of digital video are increasingly important for academic, research, and medical communities in the greater Houston area. We know from discussions with colleagues at other institutions that similar needs are widespread. When good teachers come together with bright and eager students to share ideas and knowledge, the essential purpose of a teaching institution is

served. But only a relative few can experience the interchange of the classroom, laboratory, or even the lecture hall because the technologies of chalk, pencils, and books still largely determine the ways in which students learn. Methods of teaching developed decades—if not centuries—ago predominate. A missed class or presentation is usually a permanent loss, mitigated only by the second-hand experience of another student's notes. An interest in a subject outside a major often remains unexplored because of difficulties in scheduling relevant courses. Alumni or others outside the university interested in a given subject might be able to obtain reading lists or papers, but rarely can they get much of the flavor of the teaching that takes place on the campus. In a sense, the university is producing a valuable but ephemeral product—the classroom experience.

Rice, for example, routinely films significant presentations, particularly lectures by prominent visitors to departments and academic centers on the campus. A production crew handles all the details of the filming—the management of one or more cameras, the lighting, and the sound recording. The result is a high-quality, professionally produced video. We have digitized many of these videos for a campus repository called the Media Server, and we stream them on demand to faculty and students. The bandwidth of the campus network accommodates transmission of high-quality video, so we developed the EduPop in part to improve streaming of these assets over the Internet to users off the university's campus.

A second motivation for the EduPop was our Electronic Community of Teachers (ECOT). Many school districts across the country have invested heavily in computing technology, hoping that teachers will find ways to use the technology to support good teaching. Even with the newest computers, however, teachers often face daunting challenges in the classrooms. Even motivated teachers can find it hard to use computers effectively in their teaching. In addition, distance and busy schedules make it difficult for teachers to help each other

We are working with various content providers to ensure appropriate access control for digital assets

learn. As a result, teachers often confront the technology alone, cobbling together ideas and techniques from scattered sources—with only modest results.¹ We created ECOT to help teachers learn from one another and from educational specialists and technical personnel. ECOT is an electronic teachers' lounge where teachers can exchange stories, ideas, suggestions, and problems, regardless of distance and time.² Access to multimedia resources is a significant factor in teacher participation in ECOT. Today ECOT includes almost 800 teachers from many different schools in HISD.

Access to multimedia resources is a significant factor in teacher participation in ECOT. We are collaborating with the Annenberg Foundation and the Corporation for Public Broadcasting to enrich the multimedia resources for teachers in the community. The foundation funds and distributes educational video programs with coordinated Web and print materials for the professional development of K–12 teachers. The collection currently includes more than 800 hours of video designed to help teachers increase expertise in their fields and assist them in improving their teaching methods. CTTL hosts a mirror site of this collection in digital format and makes it available on demand to area educators. Likewise, Rice hosts a mirror site for a portion of the Survivors of the Shoah Visual History Foundation collection of more than 120,000 hours of video interviews of Holocaust witnesses and survivors. This material will be used by university researchers for academic investigations in fields ranging from history to computer science.

Our work with materials such as the Annenberg and Shoah collections

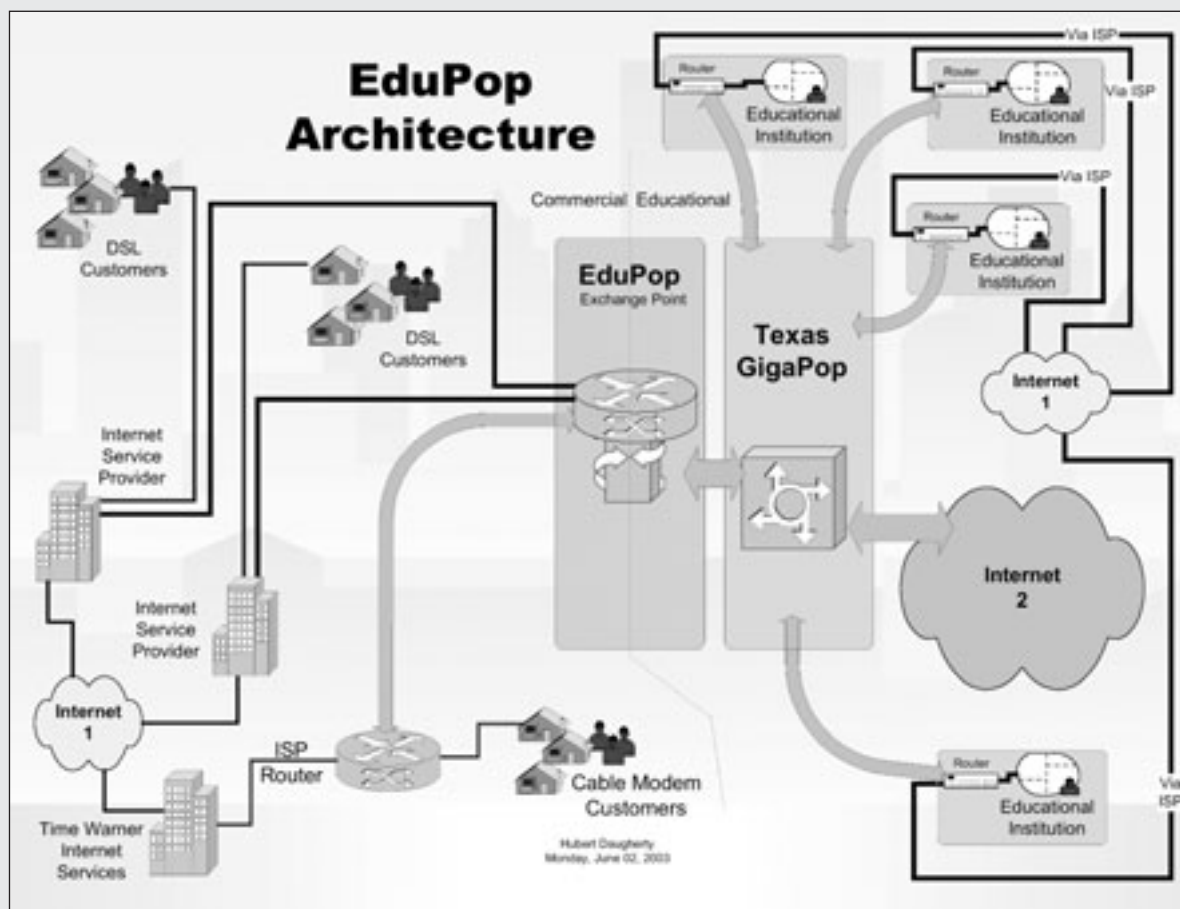
enables us to explore the protection of intellectual property in a new, networked environment. The EduPop only enhances previously approved access to campus digital repositories, but in doing so it may heighten concerns about the protection of copyrighted or otherwise restricted material. We are therefore working with various content providers to ensure appropriate access control for digital assets.

Rice faculty, ECOT participants, and others can also create their own multimedia demonstrations to share with the community. Teachers use a built-in classroom system we designed, called the Media Machine, that captures presentations as they happen. This system integrates computer display (slides, Web pages, simulations and the like), electronic annotation, and video of the teacher into a single high-quality digital file. We then convert the captured video into several other digital formats appropriate for storage and streaming distribution from the Media Server.

Medical institutions in Houston have similar needs for streaming video. Faculty, researchers, and students want off-campus access to medical records, which increasingly contain multimedia information. In many instances, however, health information privacy rules demand a virtual private network to protect patient information. By encrypting and decrypting information, such a network can provide secure transmission over public networks, but normally the added computational overhead would degrade network performance for off-campus users. The EduPop, by contrast, enables high quality and secure access to multimedia resources over the public network.³

A number of local school districts have joined the Texas GigaPop network as part of the Internet2 K–20 Initiative. High-speed connections between participating schools and research centers like Rice, NASA, and the Smithsonian are bringing exciting new video resources, like the Annenberg collection, to the classroom. Many teachers prepare lessons from home, however, and would not be able to work with these resources over slower telephone-modem connections. Three school districts joined the

Figure 1



EduPop project to enable their educators to have extended access to the video resources now available in the classroom.

The EduPop Architecture

The EduPop was designed to address the problems of congestion and packet loss that are the primary causes of degradation when streaming multimedia beyond the campus network. Figure 1 shows a simplified representation of the EduPop architecture (a complete diagram is available on the Web⁴). As the diagram indicates, the EduPop establishes a new Internet routing point that provides a “preferred alternate path” for off-campus users when they access resources from campus repositories. Before we implemented the EduPop, the “commercial” and “educational” domains depicted in the diagram had no direct connection. The new high-speed, low-delay alternate path of access provided by

the EduPop is particularly important in the case of streaming digital video.

The institutions participating in the EduPop, like many other large organizations, maintain more than one link to the Internet. Each of the academic institutions working with us has at least one connection to Internet2. The gateway into the Internet2 network in the Houston area is the Texas GigaPop, which enables educational institutions to share the cost of an Internet2 connection by combining regional traffic into a single connection. The EduPop exploits this integration by bridging traffic between commercial ISPs and the Texas GigaPop peering institutions.

At each participating academic institution, a router at the border of the local network uses a special Border Gateway Protocol to choose the best path—for example, regular Internet or Internet2—for data to travel. The EduPop routing

point exists outside the networking borders of all participating institutions. To those organizations, it appears as another routing point offering a potential third Internet path to the border routers. The EduPop router uses the protocol to notify institutional border routers that a shorter path is available. In this way, the EduPop facilitates a high-speed, low-delay alternate path between many educational and commercial institutions in the Houston area.

To use a familiar analogy, the EduPop is like a ten-lane bypass between existing toll-roads on the information super-highway. Without the EduPop, some geographically local Internet traffic must go to one of the major, national routing points in Chicago, San Francisco, or New York to get from one side of Houston to the other. For e-mail and short messages, this routing causes few problems. But unnecessarily long network paths can impede the smooth flow of streaming

video and multimedia. The EduPop provides a high-speed bypass for this cumbersome network topology. Consider, for example, a Rice faculty member who uses Road Runner for Internet access from home. Through the peering relationship, Road Runner routes traffic for Rice (or any of the other participating academic institutions) to the EduPop, which in turn passes it through the Texas GigaPop network and then to Rice. This traffic only passes through the GigaPop network infrastructure and is not routed, by design and by policy, through the Internet2 network.

With peering to a number of the important ISPs in Houston, the EduPop offers members of the academic community improved access to streaming video. The commercial ISPs in the Houston area who maintain peering connections are able to promote themselves as providers of improved connections to educational resources. Now the “final mile” of the off-campus connection—cable modem, DSL service, or conventional dial-up service—determines service quality, not a convoluted network topology.

Building the EduPop

In building the EduPop, we faced organizational as well as technical challenges. The EduPop is intrinsically a cooperative venture, so we needed to win organizational support from academic and commercial institutions. We were fortunate to have a grant of \$750,000 from the Texas Telecommunications Infrastructure Fund Board that defrayed the equipment costs for the new network architecture. This lowered the cost of participation, but we still needed to overcome a variety of organizational and logistical obstacles to the new network configuration. Our personnel commitments over two years consisted of 10 percent of our network architect (Daugherty), 10 percent of our project manager (Cohn), and 10 percent of a member of the Rice technical staff.

We have described how the implementation of the EduPop offers participating academic institutions enhanced off-campus access to multimedia repositories, but it is essential to emphasize that participation in the EduPop also

demand work by the local technical staffs. For the schools, the work of establishing an EduPop connection with the institutional network can be difficult. Typically consultants design and implement the network infrastructure for the schools, but they seldom train district staff to deal with the configuration of complex routing systems. In an institution of higher learning, the technical staff is generally qualified for such work, but tight budgets and competing institutional priorities may push them toward other initiatives.

For more than one participating institution, the activation of the EduPop connection created anxiety about network security and stability. This was particularly true for the school districts, which must provide reliable network services to hundreds of classrooms during the school day. District staff worried that the EduPop connection would lead to a breach in their firewall or that EduPop-related Internet activity would overload their networks. Only through vigorous selling of the EduPop concept and the support of a few enthusiasts within the participating institutions were we able to move the project forward. Once we began to show positive results from the new architecture, we found it easier to gain the needed organizational commitments among the academic participants: Users reported improved off-campus service; the EduPop connection did not increase traffic to the participants—it only routed traffic more efficiently; and the EduPop connection did not breach network security because it does not introduce new traffic to the institutions.

On the commercial side, the technical problems are few; it is the organizational problem that looms largest. We found it easy to make the case for EduPop connectivity to the technical staffs of the local ISPs. Our challenge was to move this understanding to sufficiently high levels in the companies to get the approvals and actions we needed. Again, persistence proved most important.

To ease logistical problems, we located the EduPop peering point at the GigaPop peering point at Rice. This location also facilitated access for the participating med-

ical institutions, located in the Texas Medical Center a few blocks from Rice. Some ISPs, such as Time Warner Cable's Road Runner, already owned major network nodes adjacent to Rice. Time Warner Cable built a short connection to Rice's main network to peer with the EduPop. Other providers, however, such as Academic Planet, which offers deeply discounted services to a majority of K–12 educators and which maintains its network hub far from the Rice campus, did not participate due to the high cost of a new link.

The three school districts and Region IV needed both Texas GigaPop connections and EduPop connections, but none of these institutions is located close to the Texas GigaPop. Texas A&M University built the needed connections for the Aldine and Spring Branch districts with other funding, and we used our grant funds to bring GigaPop network services to HISD and Region IV.

As expected, we faced an assortment of other mundane but exasperating obstacles, including delays in construction permits, uncertainties regarding right-of-way, and obstructions by other municipal construction projects.

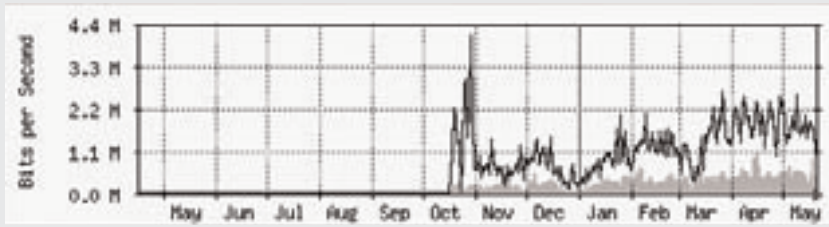
Some Benefits of the EduPop

Early indications show that the EduPop is fulfilling our expectations. It has improved off-campus access to institutional resources, particularly streaming video, and has enabled more extensive use of virtual private networks for secure transmission of information. The EduPop has also improved the flow of traffic between academic networks and commercial service providers in the greater Houston area. As we add other providers and academic institutions to the network, its overall value will increase.

The improvement in off-campus access is illustrated by the experience of a group of teachers widely dispersed throughout Houston. We chose 54 teachers who were accessing video files from home through either DSL or cable-modem accounts. A typical trace route dropped from 19 “hops” to 5 after the teacher's DSL or cable-modem provider began peering at the EduPop. After connection to the EduPop, teachers

Figure 2

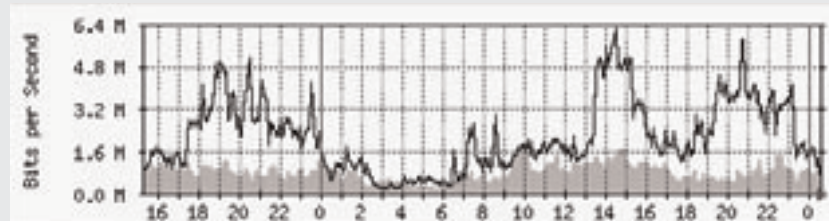
Average Daily Traffic Exchange Between the EduPop and Road Runner (May 2002 to May 2003)*



* Solid filled region represents traffic from Road Runner to the EduPop (bits/second); line represents traffic from the EduPop to Road Runner (bits/second).

Figure 3

Daily Variation of Traffic Exchange Between the EduPop and Road Runner (5-minute averages, May 23, 2003)*



* Hours are marked on the X-axis, with midnight denoted by 0.

reported significant improvements in a range of variables, from speed of connecting, to speed of video downloading, to quality of streaming video files. When assessing streaming video at various sizes, the teachers found the streaming videos to be as good in quality as CD-ROMs and more convenient. Such an improvement can benefit students as well as teachers, of course. With the adoption of higher-speed home connections such as DSL and cable modems, more and more people can have adequate access to the digital resources of the participating academic institutions.

For the medical institutions, virtual private networks are necessary for off-campus access to many of their campus resources, such as patient records. In this case, assessment of the EduPop is straightforward. Before the implementation of

the router, a high-speed version of this service was impractical. Now the medical institutions are steadily increasing their use of this vital service.

The commercial service providers benefit from EduPop connections because the EduPop offloads network traffic that they would otherwise have to carry over other Internet connections. For example, Figure 2 shows the rising density of traffic interchange between the EduPop and Road Runner, one of the principal ISPs in Houston. The substantial traffic from the EduPop to Road Runner enables the latter to avoid cost and yet provide better service to a group of its customers.

One general question will continue to engage us regarding the impact of the EduPop: How does the availability of an enhanced wide-area network for video distribution affect the way people work?

As the examples above suggest, different groups in the EduPop community will answer this question in different ways, but the interchange between the EduPop and Road Runner for a recent day suggests part of the answer. As Figure 3 shows, network traffic increases from the EduPop to Road Runner during the evening. This increase indicates that faculty, researchers, students, and others are using video and other multimedia resources from the participating institutions from home. Even preliminary results such as these are important in that they encourage continued organizational support for the EduPop.

Conclusion

Wide-area networks help integrate academic and medical institutions with their various constituencies—faculty, students, patients, and others—throughout the surrounding community. Because digital assets—particularly video—are increasingly important in the endeavors of these organizations, we want the best possible network to distribute these assets to off-campus users. Such a network must bridge campus networks and commercial service providers to reach a widely dispersed user community. For these users, high-speed, low-latency access to educational institutions can make the difference for use of multimedia technology tools in teaching and learning.

We developed the EduPop as such a bridge for academic and commercial entities in the greater Houston area. Our experience shows that advanced technology coupled with sustained organizational cooperation can greatly enhance off-campus access to resources such as streaming video. As we have suggested, this improved access, in turn, can help the participating institutions better serve their constituencies and better accomplish their missions. *e*

Acknowledgment

The Texas Telecommunications Infrastructure Fund provided money for the EduPop equipment.

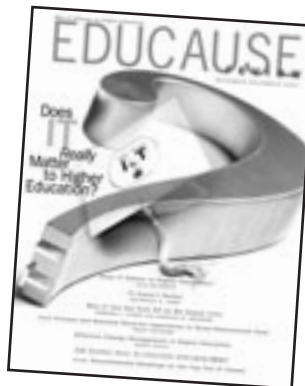
Endnotes

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- **IT Doesn't Matter**
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