Perspectives on Broadband Network Technologies and Applications

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This article introduces three broadband multimedia initiatives launched in late 1994. While there are literally dozens of trials evaluating multimedia in the context of telecommunications and data transmission services across the United States,[1] the testimonials and projects described in this feature were collected only from participants of three in the California San Francisco Bay Area: Sprint's Silicon Valley Test Track, Pacific Bell's Media Park, and the California Research and Education Network (CalREN).

Although each multimedia experiment is unique, there are common threads running through each of them. First, each encourages the participants to experiment with new communications technologies and services. For example, in the Test Track, there is a strong emphasis on research and development of new products for SONET and ATM networks, but the discovery and development of new applications is also important. And, in Media Park, technology development is highly dependent on "mapping" current business processes to ephemeral, network-based "virtual studios" (see Figure 1).

Figure 1
Media Park Home Page

Source: Pacific Telesis Group

In all cases, participants are asked to use the tools at their disposal, not necessarily to evaluate the economic viability of the network usage. While a true market test produces data for a precise cost/benefit analysis, these experiments will not. Subsequent trials may be developed for marketing purposes, and, based on participant experiences, some conclusions may be drawn about the economic risks involved.

It should be made clear from the onset that two of the three initiatives discussed—Sprint's Silicon Valley Test Track and Pacific Bell's Media Park—are technology tests, or "trials," in the truest sense of the word, i.e., they are Public Utility Commission-condoned experiments designed to test equipment reliability, feature sets, and compatibility. The California Re-

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search and Education Network is a demonstration project based on more stable, "proven" technologies.

Following is a brief synopsis of each project, along with perspectives and insights from some of the people from companies involved in each.

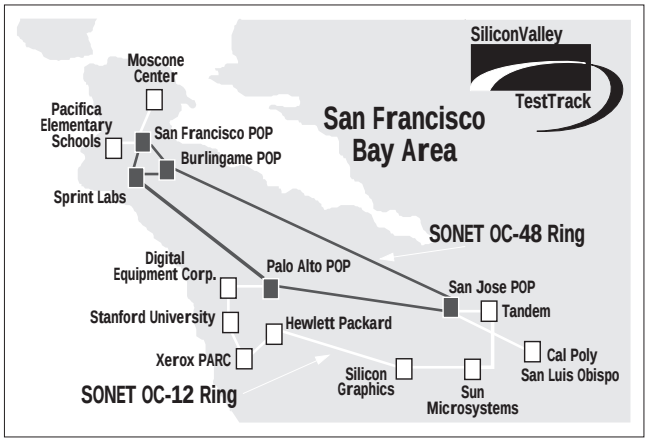
Silicon Valley Test Track

The Test Track, a fiber-optic ring traversing the Silicon Valley from San Francisco to San Jose, is intended to be a "proving ground" for advanced computer hardware and software (especially SONET technologies) currently being developed (see Figure 2). Companies involved in this project from the beginning include the following, with additional members expected to join this summer.

- Digital Equipment Corporation's Systems Research Center.
- Hewlett-Packard's Labs.
- Silicon Graphics.
- Sun Microsystems Laboratories.
- Sprint's Advanced Technology Laboratories.
- Stanford University Center of Telecommunications.
- Tandem Computers, Inc.
- Xerox PARC.

Sprint's Advanced Technology Laboratory is the focal point for the Test Track project. Companies participating in the trial have access to ATM switches made by eight separate vendors, as well as SONET terminals from five manufacturers. The primary objective is to evaluate the interoperability of these devices and new products under development. Participating companies can either work independently or with each other on joint projects.

Figure 2
Silicon Valley Test Track



Source: Pacific Telesis Group

Sprint

For Sprint, the Silicon Valley Test Track has already met one of its major objectives: to determine if SONET works sufficiently well for nationwide deployment. "We have found that, even up to 2.5 Gigabit speeds, SONET ring technology is stable and works in terms of self healing and electronic provisioning," says Terry Kero, Director of Sprint's Advanced Technology Lab in Burlingame. "Now, we are testing ATM switching. The initial results are very positive, and with our collaborators, we are continually testing additional advances in the ATM arena."

In addition to monitoring and testing new network components under a variety of conditions provided by the Test Track, Sprint is also conducting an experiment in conjunction with eight elementary schools in the Laguna Salada School District (Pacifica, California) and Cal Poly Technical. The distance learning system under development since January 1994 began providing video-based courseware to students in classrooms in the fall of the same year.

A video file server sends compressed video streams to a set-top box in the classroom via ATM switches and SONET transmission upon request. "This all had to be integrated into a very trouble-free and easy-to-use system," Kero assures. "For instance, we designed and implemented new client/server technology so that the set-top boxes could reliably receive the content."

Acquiring and organizing over 200 courses took several months. Once content from the archives of local and national public broadcast stations (as well as many other suppliers) was evaluated and selected by a special school board subcommittee, it had to be digitized, compressed in MPEG-1 format, and loaded on a Silicon Graphics Challenge server in Burlingame. "Materials, such as 15-minute long episodes of *Reading Rainbow*, are being contributed to the project during the evaluation phase," explains Kero. If this were a commercial operation, school districts would have to pay for the rights to view the content.

Today, fiber runs from the Sprint Laboratory to each of the Pacifica elementary schools, and there is one set-top box in each of the eight schools. They are

now working to increase the number of set-top boxes to 103. By the time the children return to school in the fall of 1995, 103 teachers will have a box in their classrooms for use any time of the day. Laguna Salada superintendent, Marc Liebman, predicts that the system will be accessible to all 3,000 K-8 students in the school district.

The second phase of the distance learning project aims to decrease the bandwidth required via MPEG-2 compression so as to increase the number of video channels. The goal is to increase the level of feedback and interactivity between instructors and students. It is hoped that eventually there will be one video channel per student to facilitate on-line testing for content comprehension. "There will also be an opportunity to modify the interface and increase the level of interactivity," Kero says.

Students, teachers, and school district officials report that participating in such trials with an industry leader such as Sprint opens up exciting new approaches for teaching, including:

- Personalized video (e.g., from field trips or lessons) can be integrated by students with stock resources.
- Lessons can be translated for non-English speaking students by overlaying a new voice track.
- It provides an on-demand resource for teacher continuing education programs.

Another Silicon Valley Test Track project is aimed at testing the use of this technology for asynchronous learning in higher education.

Stanford University

Dr. Dale Harris is a professor of electrical engineering and the Director for the Center of Telecommunications at Stanford University. With the assistance of a grant from the Sloan Foundation, Harris has been experimenting with the College of Engineering's Communications Design course to determine the feasibility of providing enriched educational resources to students outside the traditional classroom environment.

Harris says he has primarily been experimenting with different codecs and transmission systems to find the optimal quality and functionality for instructors and students to see and hear each other, as well as collaborate on course materials without distraction from the enabling technology.

In the first phase of the experiment, there needed to be two media types on the screen at the same time. The objective was to have course materials available prior to and during class, plus support the ability to make modifications and take notes during the didactic session carried via video and audio. Harris and his students first experimented with the use of modems and analog telephone lines, but these solutions lacked sufficient bandwidth.

"We started with a commercial real-time encoder system that, in our estimation, produced too many artifacts in the video stream," Harris recalls. "When we digitized audio and video and compressed it in real-time with a Rockwell Communications DS-3 encoder, we found the quality to be every bit as good as television." But the transmission required a high-speed network such as ATM provides, hence, the need to join a technology trial.

The teleseminars project is also, in part, supported by Stanford's participation in BAGNet (Bay Area Gigabit Network), a CalREN-sponsored network. "What sets BAGNet apart from other CalREN projects," said Laura Sanford of Pacific Bell's San Ramon headquarters, "is that the participants are amongst the most technical in the computer and networking industries. They are more interested in the nuts and bolts of ATM—how the switches perform and so forth—than the other CalREN participants."

"Our classroom connection to BAGNet served the students' needs for file transfers and interaction (via electronic pointers to highlight items on the users' screens), while the SONET-based Test Track carried the DS-3 audio and video," Harris explained.

This distance learning experiment found that the most difficult problems to resolve were those related to audio feedback. After tweaking the various pieces of equipment and trying different echo cancellation systems, these were overcome, and the team settled on an optimal configuration. "The major objective for us was to try the different technologies and see if all this could be done in our environment. We are very happy with the results," Harris concludes.

In their next phase of research, Stanford University students and faculty are digitizing and storing videotaped classes on servers and allowing distance learners to access them over ATM connections. However, there are many issues that must be resolved. For example, there are currently very few ATM interfaces for desktop computers.

Ultimately, Harris says the goal is to offer a diverse curriculum that can be customized to meet the indi-

vidual needs of students. The students will be connecting different platforms—including Macintosh, Windows-based PCs, and UNIX workstations—over different networks with different bandwidths. For example, some would connect over ATM networks, the Internet, and eventually some might dial in directly over telephone lines. "Depending on the connection, students will receive different qualities of audio and video content," says Dale Harris. The technological issues will be addressed systematically, and, gradually, learning—as well as teaching—will adapt to take advantage of the variety of new products and services.

Xerox

At Xerox Corporation's Palo Alto Research Center (PARC), technologies underlying ATM switching are within the purview of Dr. Brian Lyles, a member of the Computer Science Lab research staff. "PARC has the responsibility for providing options to Xerox, by both generating enhancements to current products and by inventing new technologies," asserts Lyles. In his view, ATM is essential in the domain/scheme of electronic imaging. He sees the research facility's involvement in the Silicon Valley Test Track as a way of, over the long term, developing the underlying technology so that when Xerox customers need the features ATM offers, the company will be ready with products.

In the course of working with Sprint, Lyles and his colleagues at Xerox PARC will demonstrate technologies of interest internally to the company's customers as well as to Sprint. For example, research in collaborative technology for producing complex documents has been the basis of a commercial product called LiveBoard. To have such interactive surfaces combined with video promises to further enhance the collaborative process. The ATM switches necessary for broadband services (e.g., required for DS-3 quality video) are going to be important for Xerox internal use, for the company's customers who develop complex documents, and for Sprint to supply suitable infrastructure for broadband digital video transmission.

After careful analysis of video-mediated applications, Lyles' team has chosen to design and prototype hardware which will run high-resolution Joint Photographers Expert Group (JPEG) compressed video streams. One of the reasons for this choice is that the JPEG algorithm compresses video frames individually—intraframe. Consequently, the artifacts that result from interframe compression don't exist. The downside of this is that the codec produces a video stream that requires greater bandwidth than that required for transmission of interframe compressed video.

Another research effort within Lyles' group at Xerox PARC is to examine how ATM service may be designed to reverse a widely-held view of multimedia application requirements. In the past, bandwidth limitations have defined the feasibility of different applications. "So far," Lyles says "most interactive applications using compressed digital video have had to be shoehorned into certain bandwidths defined by telecommunications industry platforms such as T-1 and DS-3. We believe application users should define the quality they need for a particular session, and underlying technologies should be available to transparently provide the bandwidth required for that quality of service."

In time, after the research has progressed a little further, Sprint's SONET ring may also be used in a Xerox technology showcase. Specifically, Lyles hopes to demonstrate some experimental next-generation digital document services on the section of the Silicon Valley Test Track between PARC and Sprint's lab in Burlingame. Xerox PARC is pleased to be working with Sprint on BISDN. The Sprint Silicon Valley Test Track is a major facility for enabling the understanding of next-generation applications and requirements.

"We've learned a lot already," Lyles says, summarizing his perspective of the technology test. "The thing I'm looking forward to, as a participant, is when PVCs (permanent virtual connections) are replaced by switched virtual circuits (SVCs). The process of establishing PVCs is labor intensive, error prone, and inhibits the rapid setup of experiments. When we get SVCs fully up, the environment will be much more favorable for daily use and repeatable demonstrations."

Pacific Bell's Media Park

Media Park is a technology test for California's entertainment, marketing, creative, and production communities. Its 30 initial participants include:

- Apple Computer, Inc.
- Paramount Studios—one of the world's largest resources of original contemporary stock footage.
- A music and sound effects licensing service.
- A video transmission service.
- A law firm.
- An advertising agency.

- Over 20 other small, medium, and large companies that specialize in creative services for marketing and entertainment.

Companies involved in this project are connected to Pacific Bell servers and hard disk farms (on which projects up to five gigabytes in size can be stored) through one of three network services—ISDN, T-1, or ATM. Developing an accessible and interoperable interface and architecture for all three services to enable sharing the same visual content is one of the challenges Pacific Bell seeks to address in this trial. In its earliest implementation, all participants used Macintosh computers, as this was the platform most familiar to many of them.

Paramount Studios

Soon after being connected, Paramount Studios' head film librarian for post production, Michelle Davidson, had proof that Media Park's "virtual studio" environment saves time and money. In the midst of producing *Vampire in Brooklyn*, a Paramount feature film, the editors requested a picture of a sunrise over a New York City skyline. Typically, Davidson would begin the search in the company's archives (the majority of which is on 35mm film). At the same time, Davidson would phone the request to commercial stock film providers, verbally describing as best she could what was needed. After a few hours or perhaps a day, researchers would call her back with the results of their searches. If the results sounded close enough to be a possible match, Davidson would ask them to send her a tape or film to view, introducing yet another delay.

"Media Park saves us a lot of production time," says Davidson. "We can conduct a search through footage from another production house (e.g., Energy Productions), even outside normal business hours." In the case of the sunrise over Manhattan, Davidson looked at QuickTime movies of Energy's original clips on her monitor. She could immediately discern the quality of light a shot offered, continuing the search until she found exactly what she believed the editors wanted.

"Time is money in every business," observes Davidson. "Just being able to look through the clips faster on the server than on the videotape saves a lot of time. And, this way, the editors get only what I have selected, and not a lot of segments that are not appropriate because someone *else* was searching too loosely, hoping that they would pull up something we liked without really understanding what we needed."

Davidson also cites serendipity as a side benefit of searching off-site archives herself. "Right now, I'm working on a lot of requests for *The Watcher*, one of our UPN shows. Sometimes I'm looking for something for one project, and I'll find exactly what I need for another project," she recounts.

Independent Television News

Linda Hannan, president of Independent Television News (ITN), speaks of her company's involvement with Media Park from the perspective of someone who already has ample experience with video transmission over networks. "As a participant who uses a variety of transmission technologies for broadcast, news, and entertainment in a big way—and on a daily basis—we welcome the opportunity to work with other complementary businesses in exploring new ways to produce a superior finished product," Hannan says. "The only limit to the potential uses of Media Park is the imagination!"

On Media Park, ITN operates both as a service provider and customer for other trial participants, depending on circumstances. "If, during production, our client—the Sports Channel, for instance—needs some stock footage of swimmers or golf, producers can browse or search the database for material," Hannan explains. When clients find what they want, ITN negotiates terms directly with the Media Park participant and, if possible, arranges transfer of the full-resolution digital clip over the company's dedicated network." In fact, ITN has a thriving private network business, providing digital transmission services over broadband (DS-3) circuits and leased lines.

ITN has a T-1 connection to the Media Park server. "We view the virtual studio as a place to gain immediate access to clips, to make rapid decisions, primarily for our corporate customers," Hannan says. "Our DS-3 circuits have different uses. They are essential for sending broadcast-quality information to satellite uplinks, or for live applications—things which the Media Park is not designed to handle."

Like Davidson, Hannan feels very positive about her involvement in Pacific Bell's technology trial. "We set up a special [Macintosh] Quadra 950 for use with Media Park, and we like having [Media Park] available any time," concludes Hannan. "It allows us immediate access to the other people on Media Park, and they to

us. It gives us a permanent connection to a community with which we anticipate doing a lot of work in the future."

According to other Media Park participants not included in this analysis, the challenge for Pacific Bell remains one of getting more interaction among the trial participants. For this purpose, the PUC has extended the technology trial for another six months.

CalREN

In contrast to the other two trials, CalREN is a program designed to stimulate the development of new applications, rather than testing technologies, per se. Through a $25 million fund, a total of 54 projects unite over 100 institutions and nearly 1,000 people directly as well as indirectly—without telecommunications charges. Based in both the San Francisco Bay Area and the Los Angeles region, these projects cross the healthcare, education, community/government, and commercial sectors. All the participants have access to a wide range of broadband technologies, including frame relay, SMDS, Switched Digital Service-56, ISDN, and ATM. In exchange for providing complimentary service, Pacific Bell expects that the benefits of collaboration between customer and service provider and early access to the new communications services will spur exploration and the development of new applications.

Lockheed/Sandia Labs

Two aerospace technology giants have come together to show how future electronic collaboration will take place. The Lockheed Missiles and Space Company in Sunnyvale and Palo Alto, California is partnering with the Department of Energy's Sandia National Laboratory in Livermore, California to demonstrate how future wargamers and engineers will exploit the high bandwidth data highway being built with the emerging Asynchronous Transfer Mode (ATM) technology. Because of the potential applications of these technologies, the government's Advanced Information Technologies Program Office has taken a keen interest in Lockheed and Sandia's planned experiments.

Under the CalREN program, Lockheed and Sandia are implementing and testing two high-bandwidth ATM applications:

(1) Distributed interactive simulation.
(2) Concurrent collabrative design.

In addition to their aerospace applications, Joyce Capell, the Lockheed project leader, believes that there are significant commercial opportunities for these two CalREN projects. "Our first application utililizes the IEEE 1278 protocol for Distributed Interactive Simulation (DIS) to connect multiple 'players' (simulated military entities), located all over the world, into a single simulated wargame. By simulating individuals instead of units, we are able to much more realistically examine the interactions that would occur in an actual engagement. This same technology could be used on a wide variety of commercial applications. For example, we could support disaster recovery simulations, e.g., earthquakes or forest fires, to plan how the rescue players might interact in an emergency situation. High-fidelity, multi-player interactive video games are another potential high-payoff application of this distributed simulation technology."

ATM technology is the key to alleviating the bottlenecks caused when the number of "players" increases. ATM's high transmission rates may be able to support as many as 100,000 players, opening the possibility for very large, very realistic exercises. In addition to implementing and demonstrating the basic DIS technology, the Lockheed/Sandia CalREN project is also investigating security techniques that will guarantee the integrity of the data transmitted over ATM networks.

The second Lockheed/Sandia application is focused on demonstrating how geographically separated design engineers can work collaboratively with computer assisted design/computer assisted manufacturing (CAD/CAM) tools. This project, involving engineers in several remote locations working on the same design, utilizes a "shared whiteboard" to provide instant updates of design changes which all participants can see and work with. Eventually, engineers will be able to see a "virtual reality" 3-D view of the object being designed and work with distant engineers as if they were in the same room. Capell says, "We are working with Pacific Bell to test new kinds of telecommunications services and show that utilizing ATM technologies (which can transmit as much as 155 megabits—the contents of a large book—every second) can change the way people work."

In fact, Capell is hoping that the Lockheed/Sandia CalREN applications will be ported to the Department of Defense's Advanced Technical Demonstration (ATD) Network, which encircles the Washington, D.C. area, so that these applications can be demonstrated to other organizations working in the same field. "We

feel our ATM applications will be of high interest to the people in D.C., as well as the to rest of the country," predicts Lockheed's Capell.

CityNet

CityNet (Cupertino, California), one of CalREN's government application projects, is a non-profit corporation using Pacific Bell's BRI-ISDN lines to connect the CityNet information services system with the Cupertino City Hall's central file server plus multiple city and local school sites. The objective of the project, according to the project's leader and Cupertino City Mayor, Wally Dean, is to create a "virtual community" by linking citizens electronically with their government, schools, law enforcement, and local businesses.

"Everything that can be done at City Hall can be done here, on-line; it's like one-stop shopping for government," says Dean. Being the first city in the nation to offer applications such as interactive city council meetings where citizen's can participate electronically, Cupertino's CityNet has received a great deal of recognition for its achievements.

But, for Cupertino city residents and, soon, those in surrounding communities, the focus is practical. For example, every aspect of the U.S. Postal Service is now available on-line, including smart interactive forms with which residents can order anything the Post Office offers, from labels to delivery service and IRS forms.

Said one Cupertino resident and CityNet user, Nadine Kazuko Grant, "When I left the high-tech corporate world after 25 years to start my own business, I knew that I needed access to e-mail as a communications device. CityNet provided the perfect tool." Kazuko Grant says she would eventually like to see greater Internet capabilities added, but only after some key issues, such as security and more user-friendly graphical interfaces, are resolved.

Graphics and the integrated use of audio and animation play an important part in the CityNet "virtual town hall." "Cupertino is a multi-cultural community," explains CityNet's volunteer consultant and board member, Chuck Thompson. "It's one of our goals to offer as much as possible in universally accepted symbols, and to have text explanations in several languages, as well as aurally, for those who might have difficulty reading."

As far as video is concerned, the implementation issues are still difficult to overcome. "We see several limiting factors. For example, hard disk space for storage and the customer's bandwidth would severely limit the frame rate during transmission," says Dean.

For the time being, the 800 residents signed up for the service are not complaining. The services can be reached over an analog modem (14.4 b/s), Switched 56, or cellular. "One of our goals is to continually increase the speed at which people can gain access," explains Thompson. "We want to have more speed than the average community resident will have available, so that we're sure to meet their needs as they adopt new systems." Through the support of CalREN, this should be a realistic goal.

Conclusion

It's still quite early in the history of multimedia. Many applications tested to date have been examples of reverse-engineering what is already being done in print and in television.

In time, however, there will be nearly as many unique applications of networked multimedia technologies as there are people using the printed word today. Above, we describe the ongoing activities of seven innovators testing broadband networks as part of three independent carrier-sponsored projects in the California Bay Area.

To bridge the gap between yesterday and tomorrow requires tremendous investment and, for the most part, it is starting with the resources of regional and interexchange carriers. Technology tests such as the Silicon Valley Test Track, Pacific Bell's Media Park, and CalREN benefit both the participants who can explore research and development activities without substantial financial risk, and the carriers who gain experience with these sophisticated applications prior to commercialization.

Another key aspect of these trials is that they support equal access to technological advancements, with less emphasis on an innovative company's ability to pay.

While testing these applications and technologies is important, the participants and carriers all realize that technical feasibility doesn't necessarily imply economic viability. For this reason, questions about return on investment remain unanswered. It will be a while longer before most of these applications reach our desks, or those of our children. ntq

[1] J. Van Tassel, "Test Tubes for Interactive Television," *New Telecom Quarterly*, Vol. 2, No. 3 (August 1994), pp. 7-21.