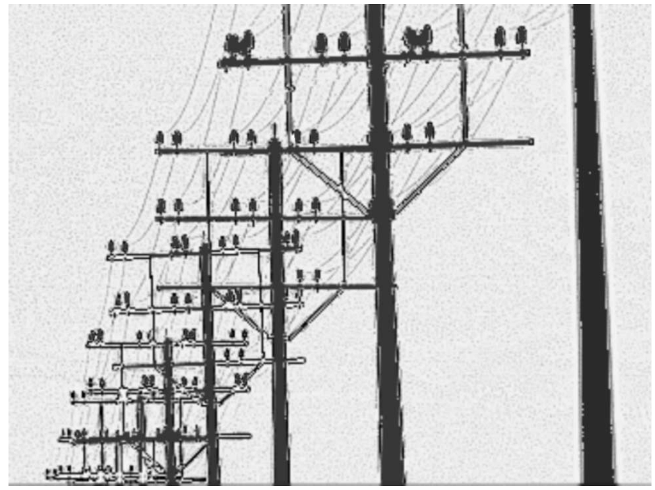
# METROPOLITAN AREA NETWORK ARCHITECTURES FOR INTERACTIVE DISTANCE LEARNING



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Ironically, as the Information Superhighway lurches ahead toward deployment, most of its potential 21st century users currently attend schools that are ill-equipped to teach them how to make use of the technology. This is arguably a matter of economics and funding, since a variety of cost-effective high tech solutions currently exist but have not yet been implemented on a large scale.

A recently released report from the General Accounting Office cites the crumbling infrastructure within American schools as a sizeable pothole on the Infobahn. According to Dr. Linda Morra, Director of Education and Employment for the GAO, "There are only a handful of schools that are even close to being fully equipped. Many of our schools are wired for nothing more complicated than film projectors." The U.S. Education Department estimates that upgrading instructional technology in the 125,000+ K-12 and college/university facilities throughout the nation could cost up to $4 billion annually.

According to the GAO study, fiber optic cabling is currently found in only 13% of U.S. schools. However, as the demand for new services, speed, bandwidth, and cost containment grows, fiber optic transport methods will begin to surpass media like twisted pair, coaxial cable, satellite, and microwave, and play an ever-expanding role in instructional technology.

This article features fiber optic architectures in metropolitan area networks for "in-cluster", inter-facility, interactive distance learning. It will examine several leading analog and digital fiber optic approaches, their advantages, disadvantages, and relative capital and operational costs.

Whooooa, Nellie.....good ol' *Analog* ??? With all the media hype surrounding the digitization of the planet, there is a widespread misconception that analog fiber optic technologies have seen better days. Not true! One only needs to look to the recent widespread acceptance of the HFC (hybrid fiber/coaxial cable) analog architecture by the telephony community as proof.

While all-digital approaches may ultimately prevail, for the most part they are still prohibitively expensive to install and operate, especially in the hyper price-sensitive educational marketplace. Modern analog fiber optic transmission systems, whether FM or AM-based, are being deployed today in increasing numbers of interactive distance learning networks. These multimedia ramps onto the Information Superhighway are robust, very cost-effective, and carry a multitude of concurrent audio, video, and high speed data payloads.

### Interactive Distance Learning Metropolitan Area Networks (IDL MANs)

Many view the role of distance learning as a vital means to prepare America's work force to better compete with their global counterparts. Others view distance learning as "the great equalizer" to narrow the gap between larger, resource-rich urban schools and smaller, under-developed rural schools.

Control of funding and network design also vary considerably, due to the wide variety of state-directed initiatives and state-level planning. However, a common thread is interactive video distance learning, a core requirement of nearly every state program.

Another common feature of IDL MANs is broadband capacity, or the capability to transport a multitude of concurrent voice, video, and data services. In the telephony world, there are a variety of complex broadband network architectures, most of which are time division multiplexed (TDM) and digital in nature. In the CATV world, a “broadband” network (or HFC network) is actually a subset of the total universe of broadband network architectures. A CATV-style VSB-AM RF broadband network is based on frequency division multiplexing (FDM), carries mainly analog video signals, but has a large capacity for concurrent high speed digital data services.

According to Telesystems Associates (Hastings, MN), “Experience has shown that nearly 90% of interactive education coursework emanates from intracluster participating schools. The remaining 10%, consisting of teacher in-service, video-conferencing, and other limited time applications, is transmitting into the cluster from remotely located, non-cluster members.”

Despite this fact, a third common trait of IDL MANs is that they have access to statewide or regional OC-48 SONET transport fiber rings, allowing for interconnectivity to resources outside of the MAN “cluster”, into a WAN (wide area network), for long-distance teleconferencing applications. High capacity SONET infrastructures carry concurrent voice, audio/video, and data traffic generated to/from residential, business, and institutional customers. These will soon be accessed by planned “full service” HFC networks (CATV MSOs, Ameritech, Pacific Bell, GTE, and SNET), FTTC networks (Bell Atlantic), and/or overlay HFC/FTTC networks (US West).

Today, most fiber-based IDL MAN projects contract with local telephone companies, cable TV companies, alternate access providers, or utilities for access to optical fiber. Less often, the IDL MAN shares spectrum space aboard private networks established by business or government. Very occasionally, schools districts have purchased and installed the necessary fiber themselves.

By the year 2000, more than 25% of all schools, libraries, and hospitals will be interconnected by fiber optic networks, according to a recent survey conducted by Deloitte & Touche LLP (Washington, DC). During that time, IDL MANs will be deployed in one of three architectures (or, more likely, hybrid combinations of the three) for intracluster communications and WAN backbone access: 1) uncompressed FM baseband circuits; 2) CATV VSB-AM broadband circuits, and; 3) compressed switched digital video circuits. (See Figure 1.)

In Figure 1, #1 and #2 are primarily analog fiber optic networks. They are compatible with digital equipment, but are much more flexible for educational instruction purposes. Analog networks can transmit one or more full-motion TV pictures with data, fax, and other services from any location in the cluster to all other sites in-cluster, simultaneously, and vice versa.

Current digital architectures (#3) are not as well suited for distance learning scenarios, since they make it both cumbersome and very expensive to simulate the basic interactive synergy of a typical classroom . T1/DS-1, T3/DS-3, and OC-3 applications are primarily single channel (only) because of cost parameters. This allows the instructor site to be viewed at all remote nodes simultaneously, but does not allow easy video return from remote sites without the use of switchers,

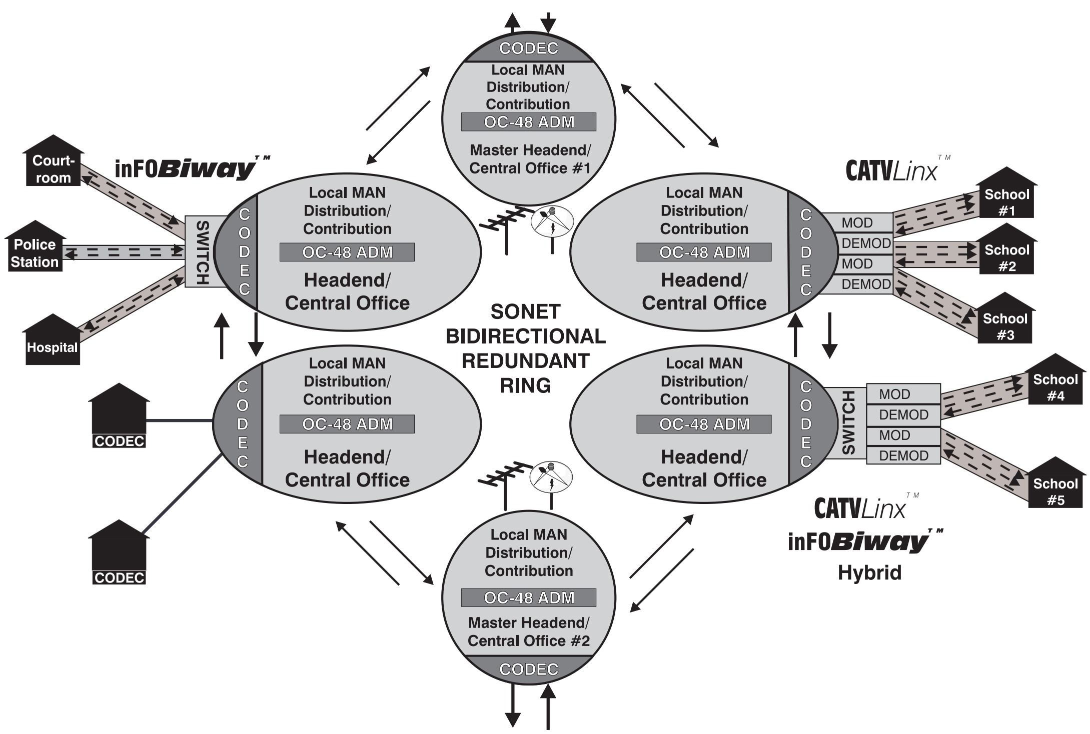


Figure 1 - Interactive Distance Learning Metropolitan Area Network Architecture

sequencers, multiplexers, or additional codecs. In addition, simultaneous live video to and from all sites is virtually impossible to achieve using all-digital networks.

## Uncompressed FM Baseband Circuits for IDL MANs

Analog FM baseband transmission systems with single mode fiber optics have been used extensively over the past 10 years by the CATV industry to provide supertrunk interconnection and consolidation of headend facilities. The FM format has proven to be a simple, efficient, reliable, and very economical fiber optic transport medium for high quality audio/video signals.

Duplex FM baseband circuits, such as the inFO*Biway* system, utilize this uncompressed FM baseband technology to transport bidirectional, real time, near-studio quality, full-motion audio/video over long distances (60 miles+) via single mode optical fiber. The system can support up to 1000 regional IDL MAN hub-node interconnection circuits via centralized video router switching and/or connection into the public switched network via connection to a codec at the central office or headend site. (See Figure 2.)

The up-front hardware cost for each uncompressed FM baseband circuit varies between $4,000-$8,000. In most instances, access rates by service providers are based on negotiated, low rate, non-tariff pricing.

In addition to being very robust, FM signals can be easily intermixed with AM and modulated data signals in fiber optic transmission systems. Recent developments have made it both feasible and cost-effective to combine optional high speed data services with audio/video signals to meet the growing datacom needs of students, teachers, and administrators.

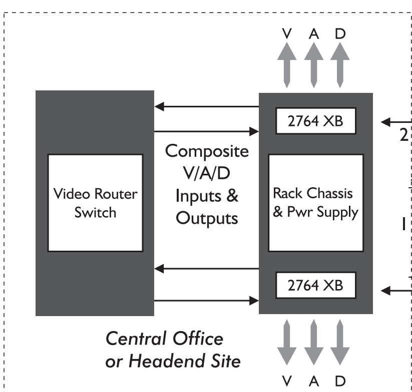


Figure 2 - inFO*Biway* Videoconference Transceiver 2 x 2 System Example

Based on a January, 1995 survey of 4000 K-12 principals by *American School & University* magazine, these datacom requirements are not currently being met. "While telephones may not exist in classrooms, most schools have set up modern telephone systems in their administrative offices.... Almost every school responding (95.2%) has at least one administrative computer, but less than half (45%) are linked to a district-wide central system.... 58.2% of the respondents said there is at least one computer in every regular classroom...but most are stand-alone operations. Just 32% are linked to a school-wide network and 22% to a district-wide network."

For example, one Ethernet (10 Mb/s for point-to-point LAN interconnectivity) or up to three T1 (1.5 Mb/s for transmission of digitized voice to interconnect PBXs) or up to twenty-four EIA530 (56/64 kb/s fractional T1 for workstation interconnects, Internet access, phone circuits, fax delivery, etc.) services can be incrementally multiplexed into an inFO*Biway* audio/video circuit for between $3,000 to $10,000 per node site. No additional fiber optic transmission equipment or additional optical fibers are required.

## CATV VSB-AM Broadband Circuits for IDL MANs

Robust, coaxial cable-based, two-way, RF frequency division multiplexed networks known as "broadband LANs" were all the rage during the mid-1970's through the mid-1980's. Championed by vendors like IBM, DEC, and Wang, major campus and metropolitan area networks were deployed in thousands of universities, factories, utilities, offices, and municipalities to transport hundreds of concurrent audio, video, and high speed data "channels". A large number of these same broadband RF LANs continue to function today as CATV distribution pipelines at major colleges and universities, traffic control networks in large urban settings (i.e. New York City, Columbus, OH, etc.), and as the primary LAN backbones at Ford, GM, Procter & Gamble, etc., factories worldwide.

With the advent of lower cost, higher capacity distributed feedback (DFB) lasers, the broadband RF LAN architecture has been revitalized. Hard-to-maintain cascades of 10-20 coaxial cable trunk amplifiers have been replaced by low cost, reliable, wide bandwidth fiber optic transceivers. Embraced by telcos and CATV MSOs alike, the "new" architecture has been re-christened "hybrid fiber/coaxial cable" or HFC, and is the basis of $ tens of billions of current residential network construction activity in the US alone.

In the educational arena, reliable all-fiber VSB-AM broadband circuits, like the **CATV**Linx series, are increasingly being deployed to deliver 20 (200 MHz), 40 (330 MHz), 60 (450 MHz), or 80 (550 MHz) 6 MHz channels per single mode fiber for high-quality audio/video distribution over distances which can exceed 20 miles. When deployed in a hub-node format through a central office or headend, cost-effective Fabrey-Perot (FP) and/or DFB laser-based transceivers offer full-duplex, multichannel communications via a pair of single mode fibers. The cost per circuit range of $9,000 to $22,000 varies widely, depending on channel loading, distance, and choice of return path. In most instances, access rates by service providers are based on negotiated, low rate, non-tariff pricing.

Alternately, a cost-effective, full-duplex IDL WAN circuit can be established over one single mode fiber by employing dual optical windows (1300nm/1550nm) and wave division multiplexing (WDM) technology. The forward (hub to node) path uses VSB-AM fiber optics @ 1300nm, while the return (node to hub) path utilizes uncompressed FM baseband fiber optics @ 1550nm, making the circuit a **CATV**Linx/**inFO*Biway*** hybrid. The cost per circuit varies from $7,000 to $18,000, depending on application specifics.

Like compressed FM baseband circuits discussed previously, VSB-AM broadband circuits can be used to deliver more than just audio/video service. The ultimate difference between the two approaches is capacity. A plethora of payloads can be assembled on each VSB-AM broadband duplex circuit, by reallocating 6 MHz video channel slots for high speed data use. Frequency agile (10-550 MHz) RF modems, such as the **CATV**Lan series, function much like traditional CATV video modulators and demodulators. Into each 6 MHz slot, one Ethernet (10 Mb/s) or up to three T1 (1.5 Mb/s) or up to twenty-four EIA530 (56/64 kb/s) services can be incrementally FDM multiplexed into a **CATV**Linx audio/video circuit for between $3,000 to $10,000 per node site. No additional fiber optic transmission equipment or additional optical fibers are required.

## Compressed Switched Digital Video (SDV) Circuits for IDL MANs

The advantages of compressed switched digital video (SDV) circuits are well-known. SDV is almost identical to the traditional POTS telephony network architecture, and offers interoperability and interconnectivity of multiple services aboard the public switched network, making it particularly well suited to wide area network (WAN) and long-distance teleconferencing scenarios.

A video codec (or compression/decompression device) is required to compress a digitized video signal down to speeds that can be effectively managed by the network fabric. IDL MANs based on compressed SDV circuits, such as the well-known North Carolina Information Highway (NCIH) project, utilize dedicated T1/DS-1 (1.5 Mb/s), T3/DS-3 (45 Mb/s), and/or OC-3 (155 Mb/s) fiber optic access lines for public network access.

The current cost of interconnecting via compressed SDV technology is very high. It will continue to remain so for the foreseeable future, because of the high cost of the video codec. Tariffed pricing, controlled by state PUCs, is prohibitively expensive for multi-site continuous presence within an IDL MAN. In addition, high monthly tariff service rates often render SDV services impractical for inter-LATA use for interactive distance learning purposes.

A T1/DS-1 or T3/DS-3 codec may cost $30,000 or more to transmit and receive one channel of video. OC-3 implementation may be even higher. According to Fujitsu, the NCIH network vendor, "The first sites cost $105,000 each to hook up. As more sites have come on-line, though, that cost has fallen to about $80,000 per site. In addition to a one-time hook-up fee, the state charges school sites approximately $4,000 per month for OC-3 service.... This cost has led many principals to hesitate in bringing their schools on-line."

SDV signals have the ability to travel further, but at a significantly higher cost than their analog counterparts. There is a widespread misconception that digital video systems also offer superior picture quality because they convert the video signal to a digital bit stream. To the contrary, the compression process can degrade SDV signal quality, as compared to uncompressed analog techniques, unless very high speed digital transport (i.e. very expensive) services are employed.

Asynchronous transfer mode (ATM) is being touted as the SDV broadband technology that will deliver voice, video, multimedia and local area network interconnection services. It is hoped that ATM, as an open system, will permit interconnectivity and interoperability of transmission equipment made by different vendors. Major implementation obstacles include conflicting standards, affordability, and standardization of the MPEG-2 video compression algorithm, and availability of ATM test procedures and equipment. These issues must all be addressed prior to mass deployment of a robust ATM architecture for network transport, switching, and access.

## Conclusion - "If you build it, they will come."

Leading industry technologists, including Microsoft chairman Bill Gates, estimate that it will take a minimum of 8-10 years before switched digital broadband network implementation will reach critical mass and economic viability.

At that time, as service providers drive fiber closer to the home, mass deployment of switched digital video in a fiber-to-the-curb topology will become more economical for both residential and interactive distance learning MAN applications. Asynchronous transfer mode will, in all likelihood, become the ultimate broadband technology of choice for network transport, switching and access.

In the meantime, the nationwide fiber optic cabling infrastructure will be constructed with robust, cost-effective, transitional analog technologies — available TODAY. Hybrid fiber/coaxial cable (HFC) architecture will continue to work its way into the residential marketplace, while uncompressed FM baseband video circuits and/or CATV VSB-AM broadband circuits will interconnect hundreds of thousands of educational, institutional, and commercial customers nationwide via high capacity SONET backbones.

Ed Kopakowski is the vice president of Sales & Marketing at Force, Incorporated. He originally prepared the paper from which this article is excerpted for the August 1996 issue of *Fiber Optic Product News*.