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INTEROFFICE MEMORANDUM

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From: Jim Albrycht @MSO
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Dept: Enet DECTV
Tel No: 223-8520

~~Mary Baranek 8515~~
Lowe 8553
Carter 8524
Ericcson 8515
Johnston 8539

TO: See Below

Subject: CABLE TELEVISION'S VIEW OF THEIR FUTURE

Folks...

For you folks who have been requesting information on the cable television industries' vision of their future, from their perspectives, ...attached is the best paper (with references) that I have been able to obtain in the past year.

Keeping in mind that the paper is a year old and does not take into consideration many new technical advances, and public policy changes, such as;

* all-digital high definition systems...going into full cable/satellite network testing this month...

* the advent of "software-defined-television" with data compression...available on PCs..

* what Digital is bringing to the marketplace with ETV and "Ethernet Everywhere" with the CMN information utility initiatives...

* plus new computer industry initiatives in all-digital video-on-demand...multiplying full multimedia programming capabilities everywhere...

* Judge Green backing off from many previous information industry constraints...

The paper is being passed on to you in full unedited, unaltered content, please be discrete in utilizing the material for your business plans and for your general business and technical knowlege about the cable television industry.

Thanks,

Jim

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FROM: BROADBAND FIBER OPTICS COMMUNICATIONS/LOCAL AREA NETWORKS 90

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[paper presented at BROADBAND (FOC/LAN) 90, The Second Broadband Exposition and the Fourteen Fiber Optic Communications and Local Area Networks Exposition, held September 24-28, 1990, at Baltimore Convention Center, Baltimore, MD., Organized by Information Gatekeepers, Inc., 214 Harvard Avenue, Boston, MA. 02134 USA; Telephone 617-232-3111; FAX 617-734-8562] pp. 106-117.

CABLE TV FACILITIES AS INTEGRATED BROADBAND NETWORKS

Gary Kim

Multichannel News

Denver, CO

SUMMARY

This paper examines methods whereby cable television (CATV) networks can provide integrated broadband services. It especially explores the important issue of how CATV networks could provide voice services. Changes in network topology and investment that would have to be made to provide video, voice and data services to residential as well as business customers also will be explored.

Emphasis is placed on network upgrading already taking place, in particular the replacement of coaxial cable with fiber optic media and changes in network topology. The business impact these fundamental changes will have, especially regarding the introduction of switched services, will be noted. Although many regulatory and technical issues remain unanswered, the conclusion reached is that CATV networks can, in fact, be adapted to provide integrated broadband services.

DUAL NETWORKS?

Providers of video, voice and data services to business and residential customers cannot rule out the possibility that they may within the decade face a regulatory regime vastly different from today's. Most significant among the possible changes is a breaching of the barriers that have separated the electronic mass media from the telecommunications common carrier industries. Key among these possible changes is Bell operating company permission to provide cable TV services within their own telephone services areas. At the same time, it is possible that CATV companies will not be prohibited from offering data communications or switched voice services to their existing--or new--customers.

Proposed broadband integrated services digital networks provide one vision of how such information can be provided over a single network. But B-ISDN is not the only possible path to such a future. Indeed, one might argue that the "social investment cost"--the cost to the nation--to install a 21st century broadband communications infrastructure would be optimized by combining the capabilities of the existing CATV and telephone networks. [1] Such a "hybrid" network, it is said, would be capable of providing every telecommunications service a customer could desire and arguably could be created swiftly and at minimal total capital cost since both networks are already in place and need only to be integrated in some fashion.

In testimony presented to the Federal Communications Commission and U.S. Senate earlier this year, Thomas Gillette, Cable Television Laboratories Inc. vice president, argued that the best way to create a modern information age telecommunications infrastructure is by combining the best features of independent networks--including CATV, telco, private fiber networks and DBS.

CableLabs is the cable TV industry's research and development organization, and is funded by CATV operators representing over 85 percent of all U.S. CATV customers.
Although interworking and interface capabilities are required so that all the networks can be integrated, there's no reason an "integrated service" has to be provided by a single network. In fact the better approach is to deliver such services by "cooperative yet independent networks," Gillette argued. [2]

Likewise, Tele-Communications Inc. Senior Vice President John Sie has repeatedly argued in numerous policy forums that the massive investment a B-ISDN network would require is not justified financially when all proposed services could more inexpensively be provided by some combination of features provided by current CATV and telephone networks, with integration and control of the two separate services provided by some new type of customer premises equipment equipped with the intelligence to receive all signals, format them and forward them to the proper customer terminals--be they telephones, PCs or TVs. [1] TCI is the largest U.S. CATV - operator with some 11 million customers in wholly owned systems and partnerships.

Taking a somewhat different tack that essentially offers the same sort of service integration. Jerrold Communications, the largest supplier of CATV equipment, especially in-home terminals, believes that such CPE may represent a major opportunity for the CATV industry and already has announced its interest in pursuing such types of integrated control electronics. [2] In the Jerrold vision, service integration in the home would use infrared, electrical wiring, twisted pair and coaxial cable to move messages between intelligent devices in the home. [3]
Such in-home automation CPE would interwork with developing home automation systems proposed by the Electronic Industries Association as part of the "Consumer Electronics Bus." As an early example of such CPE, Jerrold has developed a TV remote control that also functions as a cordless telephone.

INTEGRATED NETWORKS

But it is by no means certain that such an "integrated services, dual networks" course, logical though it may be, will ultimately prevail. Indeed, technologists in CATV and in the telephone industry must prepare for other contingencies. Broadband ISDN (integrated services digital network) represents a conceptual model for how the telephone industry could provide all possible services by means of one integrated facility.
CATV industry strategists have spent far less time--and vastly less money--to ponder how video entertainment networks might be adapted to provide voice or data communications services. But such thinking is not without some precedent.

There was much talk of CATV's role as an "information highway" into homes during the middle - 1970s. And while it is popularly believed that the CATV industry has not had much interest in non-entertainment services including vidotex, local loop bypass services, meter reading, home security, interactive opinion polling and other two-way services, in fact the industry has experimented with all these services but has found either a lack of genuine consumer demand or overwhelming resistance from telephone companies to pursuing such services. [4]

But a changing regulatory climate may ultimately result in head-to-head competition between CATV, telephone and possibly other companies for broadband services to the home. [5] Under such conditions, the CATV industry may change its mind about the types of services it provides to customers. [6]

In fact, CATV companies already start with a major advantage: They already have installed broadband facilities that pass over 80% of U.S. homes and provide service to well over 54% of those homes. [7] Furthermore, the industry expects that by 1995 it will have achieved penetration--based on video entertainment services alone-of 70 percent or better. [8]

Although traditionally a provider of one-way video services, the U.S. CATV industry already has begun the process of rebuilding its networks in ways that will allow graceful migration into switched services of many types, should the market emerge and regulatory regimes allow such lines of business. [9]

A key element of this new strategy is rapid migration towards hybrid networks that combine optical fiber technology with conventional radio frequency technology in ways that maximize the technical and business advantages of each. [10] Much as the U.S. telephone industry introduced optical fiber first on the longest routes and gradually brought lightwave technology closer to the local loop, so CATV operators are introducing lightwave first on the backbone portions of their networks.

At the same time, CATV operators are finding ways to integrate lightwave technology in a way that dramatically boosts the technical and business value of the existing coaxial cable already in place, increasing the physical bandwidth available to homes from the previous ceiling of 550 MHz (80 TV channels) to 1000 MHz (120 channels or roughly 1 Gbps). [11]

At the same time, CATV companies are introducing numerous involments in network technology that--while aimed at improving picture quality -- also have the net effect of improving network reliability and robustness. [12] And because it never has been a regulated "rate-of-return" industry run on utility models, CATV operators instinctively deploy cost-effective technology on a "pay-as-you-go" basis, deploying new technology only as revenues to support those investments emerge. [13]

Unlike some other potential broadband competitors, CATV:
* already has current broadband services revenue streams
* already has broadband capacity to the home
* can increase physical bandwidth to 1000 MHz at low cost
* could put fiber close to the home at relatively low cost [14]

NETWORK WEAKNESSES

That isn't to say current CATV networks are ideally suited to delivering switched services. They just aren't. So it is significant that dramatic changes in CATV network architecture are occurring. [15] Indeed, the changes--while clearly aimed at protecting today's business--offer a clear evolutionary path for possible provision of broadband services of many kinds. [16]

But the challenges are significant. The CATV "tree-and-branch" architecture is marvelously efficient for delivery of one-way services, much as power and water systems similar are optimized for one-way service. [17] They have severe limitations in a two-way environment however. As a traditional telephone network is optimized for duplex communications, a traditional CATV network is optimized for simplex communications.

But many technologists in CATV believe that the existing tree-and-branch networks can evolve towards more sophisticated topologies - while retaining their basic form -- in a way that matches the likely growth of consumer markets requiring greater degrees of signal switching. [18]

Traditional CATV networks have "tree-and branch" (T/B) topologies that are designed to efficiently move signals on a point-to- multipoint (broadcast) basis. Like over-the-air broadcasting, water and electrical power systems, T/B architectures are most efficient when a uniform product is delivered to many distributed users. While switched-star architectures used by telephone companies are far more efficient for providing "any-to-any" communications requiring the establishment of direct circuit connections between any two users, T/B is the most efficient way to deliver multiple channels of broadcast type video and will probably prove to be the most cost-effective architecture for delivery of "pay-per-view" or other types of "on-demand" video, especially if the market for such services ultimately proves to be "blockbuster[" movies and "event" programming.

Indeed, T/B costs are hard to match. Current state-of-the-art cable TV systems using conventional coaxial cable technology can be designed and built to deliver 80 6-Mhz TV channels (550 MHz of bandwidth total) for a cost of about $600 a subscriber, including all outdoor plant and construction costs. [19]
Coaxial cable and radio frequency (RF) electronics also are well-understood technologies with highly-standardized specifications supplied by a number of vendors whose competition keeps prices competitive. [20] While the current generation of amplifiers can support 550 MHz (77 to 80 channels) of bandwidth, the industry expects to develop newer devices capable of supporting bandwidths from 750 to 1,000 MHz sometime during the next two years. [21]

Arguably the toughest current problem CATV networks face is the high signal attenuation caused by coaxial cable and the non-linear signal reproducing capabilities of RF amplifiers operated in series (cascades) to combat the attenuation-inducing problems of coaxial cable. Furthermore, coaxial cable attenuates signals differentially. Signals at higher frequencies are attenuated more than signals carried at lower frequencies. [22] So as CATV bandwidth has expanded from three channels(in the 1950s) to 12 channels (in the 1960s) to 35 channels (in the 1970s) to the current 77 to 80 channels, CATV operators have had to work harder at repeating the increasingly "lossy" signals at the upper reaches of the transmitted frequency spectrum. [23]

The results is a bandwidth limitation of about 550 MHz for today's CATV systems, even though the cable itself clearly can carry 1,000 MHz or more. At frequencies above 550 Mhz attenuation increases so rapidly that cascades of 10 and greater devices simply are impractical.

Unfortunately, signal gain cannot be applied indiscriminately, any more than the volume on a home stereo can be turned up to maximum without risking distortion (unwanted degradation) of the signals. CATV networks therefore must be designed around a window of operating tolerance that balances noise performance against distortion performance. Too little gain and the resulting signals are too weak. A TV picture looks "snowy". Too much gain and the signals are impaired--signals from two or more channels interfere with the desired channel. [24]

So long as the total number of RF amplifiers operated in series is not too large (30 to 40 about the practical limit) [25], signals can be carried distances of about 12 miles before the distortion and noise parameters converge and require termination of the line. [26] But relatively high attenuation and the signal impairing effects of amplifiers used to combat attenuation are not the only drawbacks coaxial cable has. Since the amplifiers are operated in series, each is dependent on the correct performance of the device in front of it. Should amplifier 16 be knocked out of action, amplifiers 17, 18, 19 and so forth also are knocked out. This of course means that device outages can ripple through the system.

Long cascades of amplifiers therefore are responsible for a number of system limitations:
* bandwidth restrictions
* signal quality impairments
* signal reach limits
* network reliability shortcomings

CATV NETWORK REDESIGN

In response to these perceived limitations, CATV networks have begun to deploy optical fiber technology to break the transmission bottleneck and improve system reliability. Equally important fiber also allows networks to be redesigned in important new ways.

Although cable TV's interest in fiber exploded in 1988, it has been talked about and used on a limited basis in the cable TV industry since the early 1970s and was tried on a "fiber to the home" basis in the early 1980s in Alameda County, Calif. [27] Like other network operators such as telephone companies, CATV technologists have looked at optical fiber cost issues and discovered that the most obvious financial payback occurs when fiber is deployed first on the backbone routes, which spreads the cost of opto electronics over the widest number of subscribers or customers.

In cable TV, that has meant deploying fiber optics first as a "supertrunking" medium to link earth stations and headends, headends with other headends or hubs. But CATV also is beginning to deploy lightwave technology further into the distribution network, in some cases using optics as a full replacement for the entire trunking network. A key impetus for such deployment has been the development since late 1987 of AM fiber optic technology capable of carrying 20 to 60 channels of standard video in a format that is easily comparable with the existing base of RF gear used by CATV companies.

At least 1,500 AM systems have been ordered since they first became commercially available during the fall of 1988 and the pace of introductions is expected to develop almost exponentially over the next five years as effective prices drop and more operators get experience with the new technology.

Today, a number of operators are using fiber to slice the longest amplifier cascades [28] from 35 or more to 20 or less. Others, taking a more aggressive approach, are using fiber to break a single large cable TV system up into neighborhood -sized units of several hundred to several thousand homes. [29]

Cable industry estimates of the cost of installing "fiber backbone" capacity vary, but if fiber introduction is timed to coincide with a scheduled system upgrade--which requires a rebuild of the network--the cost per subscriber can range from $30 to $130. [30] A fiber backbone might use lightwave technology to move signals from headends deep into the network, converting signals from light back to radio frequency format and running them through four to seven conventional RF trunk amplifiers and two line extenders before delivering them to the customer premises.

Already, though, technologists at American Television & Communications (the second largest U.S. cable TV operator) have found ways to build passive optical networks that completely replace all coaxial cable in trunk networks for a cost no greater than--and in many cases cheaper than--conventional 450 MHz coaxial cable plants. [31] Such a "Fiber Trunk and Feeder" design uses optical media to deliver signals from a CATV headend (roughly equivalent to a telephone central office) out to optical receive nodes (roughly equivalent to telco remote terminals). From there, signals are converted to electrical form and run no more than a mile to any given customer's home. Over a period of time, industry technologists predict that lightwave might gradually find its way out to curbside locations as well (typically four-home taps).

The significance of the new FTF design is that where earlier optical architectures were most easily cost-justified in channel upgrade situations, FTF can be cost-justified for new plant, line extension plants, or rebuilt plants as well, dramatically expanding the range of immediate applications for fiber.
So CATV companies will find it economically feasible to deploy fiber in such a manner in all service areas, not just new housing construction areas, as will be the case in the telephone industry for quite some time to come.

DATA SERVICES FOR BUSINESS CUSTOMERS

It is reasonable to project that video entertainment will continue to be cable TV's strength over the next few decades. On the other hand, it is logical to assume that a fiber reinforced CATV network might be used to provide high-bandwidth transport services for business customers in downtown core areas. At some later point, it is conceivable that voice services might be provided for residential customers as well. Delivery of compact disc audio services and data base services already is occurring and there is no reason to believe provision of these types of services to residential customers will pose difficult network challenges.

Indeed, the mushrooming number of "alternative access providers" (APAs), suggests a model CATV companies might pursue. APAs build optical fiber networks in downtown business cores and provide high bandwidth transport services to business customers. Already 20 companies operate such networks in 15 cities, including San Francisco, Los Angeles, Chicago, Boston, New York, Philadelphia and Washington, D.C. [32] Facilities are under construction in Dallas, Houston and several cities are served by more than one APA. A recent report by the Boston-based research from the Yankee Group estimated that APA revenues will grow from $60 million to $150 million by 1991. [33]

Business customers typically use APA networks for three applications:
* To provide redundant network capability for data communications transport.
* To directly connect with one or more long distance (interexchange or IXC) carriers, thus avoiding the payment of local access charges.
* To get point-to-point bandwidth from one facility to others in the same metropolitan area.

In cities such as Philadelphia and Chicago, a MAN operator using single mode optical fiber can connect more than 20 interexchange carriers points-of-presence (POPs) and several dozen major office buildings by running only about 10 kilometers of cable. [34] The POP is a traffic hand-off point where local traffic is transferred to the IXC's network. Around the country, traffic carried on MANs ranges from relatively low speeds DS-0 services at 64Kilobits per second (voice-grade) up to DS-3 at 45 megabits per second. [35]. Among the most popular bandwidths today is T1 (DS-1), transmitting at 1.544 mbps. Some 66.3 percent of business users using high bandwidth transport facilities say they use this type of facility. [36] And that trend seems likely to grow. A survey of 1090 communications managers at large companies found that 84.8 percent of those companies networked PCs locally; 28 percent on a MAN basis; and 56.6 percent on a wide area basis. [37]. Typically, APAs also offer transports of 135 Mbps, 405 Mbps and 560 Mbps. [38]

The network topology used by APAs is quite straight forward. Since virtually all the traffic is of a point-to-point nature, the networks resemble rings or mesh networks. Traffic destined for buildings within the metropolitan area can be picked up and dropped off the ring. Traffic destined for IXCs can be direct- wired to the POP. In some cases a "supernode" feeds subsidiary nodes, each of which is equipped with a digital cross connect switch to move traffic from one fiber segment to the next. In fact the characteristics of high-bandwidth data traffic would seem to resemble video traffic more voice. Much of the need is for dedicated point-to-point access with no requirement for circuit switching. Lower-volume MAN traffic typically can be handled using local area network techniques for dropping and inserting packets on a "broadcast" topology bus or ring. In either case, the required network topology would seem to resemble the bus (tree and branch is a type of bus topology) CATV network better than the circuit-switched star telephone network.

In fact, telephone industry planners seem to recognize the advantages broadcast topologies represent where MAN or alternate access is concerned. The current proposals for MAN architectures in downtown core

areas include a dual bus standard (IEEE 802.6) as well as formal ring topologies. [39]

In Spain, for example, MAN architectures are seen as best suited to a bi-directional ring topology in which cross-connect switches are used to groom traffic on and off the primary ring. [40] For distribution, a secondary network can be designed as either a star (from the the cross connect) or a subsidiary ring. In the United States, Bell South already has installed a ring topology network used by the central office serving the Sawgrass business park near Weston, Fla.

The point is that ring and bus topologies, which work very well for video and high volume data applications, seem well-suited for networks serving business customers with high needs for bandwidth. Already, the Rogers Cablesystems optical architecture is a dual ring, and American Television and Communications engineers envision some sort of ring network to link main hubs. Such architectures are ideally suited to providing MAN or APA services to business customers. Other architectures, such as the Jones Cable Area Network, also are positioned to provide point-to-point transport services for business customers, using the spare fibers already carried in the existing cables.

For those who object that CATV technologies don't know that much about requirements for data communication networks, the experiences operators already are having with simple point-to-point bandwidth leasing should prove reassuring. Typically, the end user maintains all the termination equipment on either end of the link, be that multiplexers, channel banks or cross connects. What the CATV operator must provide is a reliable, clean transportation path--nothing more; nothing less.

The business opportunities here should not be underestimated. Says Gaspare Lovasco, Pacific Bell associate director, "LAN interconnection (MAN services) is the first major manifestation of the broadband marketplace." More directly, NYNEX Corp. staff director Emmett McDonough says: "The real competition between cable TV and telcos during the 1990s is for the metropolitan area network customer, who needs data transfer at moderate speeds and lower-speed broadband services."

Indeed, the opening shot has already been fired by Jones Lightwave, a subsidiary of Jones Intentional, parent of Jones Intercable, the 10th -largest cable TV operator in the United States.[41] Jones has applied for a permit from the Georgia Public Service Commission to operate a MAN in the high- growth Gwinnett County area north of Atlanta, Ga. In Canada, Rogers Telecommunications intends to provide similar services, as well as cellular telephone service and long-distance services, through various subsidiaries.

Traditionally, the lack of plant in downtown cores has proven a physical barrier to CATV offerings of this type, although reluctance to tangle with regulatory authorities has probably been a bigger hurdle. Ironically, though, the lack of plant might now be an advantage. With no embedded base of equipment to worry about an all-fiber network can be designed from scratch with the proper ring or mesh topology best suited to APA systems. And to avoid PUC entanglements, separate subsidiaries can be created to manage such businesses, thus preserving the distinction between the CATV and APA business units.

RESIDENTIAL VOICE SERVICES

Far tougher, though, is the challenge of overlaying switched voice capabilities for a residential customer. If there is any application for which a switched-star network is ideally suited, it is the task of moving voice messages around from any single point to any other single point. Conversely, if there is any application for which a tree-and-branch network is not ideally suited it is the switching of voice messages. Nevertheless, several new developments seem to offer a method for delivering voice services.

Absolutely central is the introduction of optical fiber backbone or feeder networks. Three elements are crucial. First, such a network breaks serving areas up into smaller units. Second, a fiber-based network offers reliability advantages and reduces the problems of reverse-path signal ingress which have traditionally bedeviled CATV network planners. Third, a fiber backbone puts node locations out into the network that can be used as convenient signal switch points, creating a sort of mesh of control locations. Fourth, such nodes might also function as sites for radio antennas if some sort of digital cellular technique were to be used.

Consider for the moment a wireline alternative. How should the industry provide the switching fabric? Certain constraints must be accounted for. It would make little sense to lay a new, companion star-switched network beside the existing tree-and-branch network, for obvious reasons dictated by the amount of capital this would entail. Telephone industry analysts say the cost to add a single residential customer can cost upwards of $ 1,200, and that's just the cost of the network. The cost of central office switches is extra, and could bring the cost per-sub up to almost $4,000 or $5,000.

So it would make sense to embed the switching fabric into the existing network, if this can be done. As a backdrop, what trends in switching and processing power can be observed in the computer, data communications and even telephone industries? In computing, there has been a massive shift away from centralized processing to distributed processing; from mainframes to PCs and workstations; from single-site control to networked independent co-processing. In the area of processors, there has been a continual increase in performance and decrease in cost, so that the power of older mainframes is incorporated in devices that can sit "on the desktop."

In fact, since the 1960s, the level of chip integration has lead to "a doubling of the number of components per chip about every 18 months." [42] If one extrapolates from this data, it's possible to predict that by the year 2000 it will be possible to put "about 100 million transistors on a processing chip" says Gordon Moore, the founder of Intel.[43] The significance of such developments is that one fights the trend in supposing that centralized processing makes sense. One big central office may be needlessly complex given the availability of cheap, distributed processing.

In data communications, a similar trend can be noted. Suppliers in the local area network industry often say "the network is the computer," meaning that the distributed power of networked intelligent workstations is a functional substitute for a centralized mainframe.

Indeed, the switching that occurs in a LAN setting is ideally suited to a broadcast medium such as CATV. Unlike circuit switching systems--such as the current local telephone network--that actively switch messages, broadcast networks--bus, ring or tree-and-branch--address all messages passively.

Instead of creating an actual signaling path by opening up a physical channel, as a circuit-switched system does, a broadcast LAN uses message headers to identify all traffic it carries. All messages sent by any single station all broadcast to all stations on the network. All listen for their own addresses. Finding none, the packets are allowed to continue streaming by. Only when any given station "hears" its own address appended to a packet does that station grab the message.

Even telephone switching strategies are moving in the direction of "virtual" distributed intelligence, even if the actual software control remains centralized. The much-touted SONET (synchronous optical network) interface, a physical layer standard intended to promote interconnection of optical transmitting equipment manufactured by numerous vendors, while ostensibly aimed at promoting device compatibility with networks, also will have the effect of allowing customers to reconfigure their access services more flexibly.

Extrapolating from these trends, it is reasonable to argue that the best way a CATV operator could provide switched voice services to residential customers is by distributing the switching intelligence and using access techniques borrowed from the LAN industry. In place of a central office switch, CATV operators might be able to use each fiber feeder node as a switch location. This switch might be thought of as a neighborhood PBX and might serve a few hundred customers; possibly a few thousand.

It should also be possible to develop a switching fabric that puts the actual intelligence into each terminal (phone), much as LANs now put switching capability into each network interface. Telephone numbers would in essence be a property of a device, not a physical location on the network, much as current cellular phones have a unique address that is location independent. Calls would be set up much as two terminals on a LAN presently make connections.

A message bearing the address of the calling terminal would be broadcast on the network. The intended receiving terminal would hear its address and instruct the phone set to start ringing and send an acknowledgment packet back to the sending terminal, which would then generate a mirroring "phone is ringing" message. A session ("circuit") would be established when the receiving phone goes off hook. Addressing routines would, of course, need to be more complex as the total number of stations on the network increased, but such increases in terminal population could be accommodated in much the same manner as now is used by stations on the TCP/IP "Internet," a nationwide data communications network linking universities, colleges and other research agencies.

Messages intended for more distant sites simply have additional header material appended that instructs gateway devices to forward packets to other gateways with known matching addresses. In a single metropolitan area, it is likely that cells of 500 to 2,000 users could be served by any single hub. Messages intended for other locations in the city would be forwarded by a bridge, a device that can recognize headers destined for terminals within the hub-served area and headers intended for terminals served by other hubs.

Yet another option would seem to be the use of digital "microcell" technology to provide a wireless connection for voice messages. Already, a time division multiple access (TDMA) standard has been proposed for upgrading analog cellular telephone systems in the United States to digital format, with the corresponding advantage of increasing channel capacity by four to 10 times. Other technologies, such as code division multiple access (CDMA), can include channel capacity 20 to 40 times compared to a conventional analog system. [44]

These techniques should expand the number of customers who can be served, reduce interference problems, reduce the per subscriber cost as well as the cost of the user terminals. Note that the Rogers Cablesystems fiber architecture is specifically optimized for sharing of bandwidth between the CATV operator and other Rogers telecommunications units, such as CNCP Telecommunications, a nationwide Canadian data and voice network expected to provide long distance service in Canada. Spare fibers put into place as part of the Rogers fiber architecture will be used as the local loops for CNCP.

That same network also is used to transport cellular telephone traffic generated by Cantel, the cellular telephone company Rogers Communications also owns. Properly situated optical receive nodes used for CATV also can be used to integrate cellular telephone services. Although Cantel uses an analog signaling technique, (he network design principles are analogous to those that would be useful for a microcell voice network.

In the microcell concept, lower-power transmitters are used to localize the service area covering areas as small as a single department within a company, a single floor of a building (a wireless PBX concept); an entire building or perhaps a city block or collection of blocks. Such a concept fits nicely with the neighborhood service area a fiber feeder architecture makes possible. Current experiments with such technology include the Pan-European Digital Cellular system, which uses about 25 MHz of spectrum in the 900 MHz band (890-915 MHz 935-960 MHz) with 200 KHz channel spacing. Transmissions occur at 271 Kbps and eight to 16 channels are multiplexed per carrier. Other proposals suggest the use of frequency in the 1.7 to 2.3 GHz bands for continent-wide digital service in Europe.

IMPLICATIONS FOR INTEGRATED BROADBAND NETWORKS

CATV operators may someday decide they must move beyond provision of entertainment video and become providers of other types of services as well. To prepare for this possibility, the cable TV industry now is positioning its networks for flexible migration to architectures that will cost effectively provide video and other high bandwidth services to residential& subscribers.

It may well be that at least two separate network thrusts may be undertaken. First, all-fiber ring topology networks may be constructed in urban areas to provide high bandwidth services for business customers.
Such networks may be provided by business units separate from the CATV companies. Alternatively, it is possible that dark fiber leasing may be pursued by CATV companies to achieve the same result.

Integrated services for residential customers may follow a separate path. During the 1990s, CATV operators will install optical fiber for the supertrunking ("long haul") as well as trunking ("feeder") portions of their plant. Such networks will essentially transform CATV from a tree-and-branch network to a star backbone or star feeder design. The bus network fed from the star might also be configured as a logical star by the addition of switching capability. Fiber will improve reliability but also allow new bandwidth possibilities and facilitate the introduction of switching technology. And that will make CATV a stronger contender for new types of digitally-based services that may develop as new consumer markets.

The CATV industry also is deploying such technology on a "pay-as-you-go" basis.
Virtually all the network improvements will improve the quality and market position of the entertainment video business CATV already has, while simultaneously laying the foundation for services that require greater switching. Indeed, industry technologists already are discussing methods for delivering switched digital video over existing fiber reinforced networks using a combination of video signal compression technology and switching done at both headends (equivalent of telephone network central offices) and at distributed locations scattered throughout the network.[45]

The CATV industry's position in the residential market, supported by low capital and operating cost advantages, may also be enhanced by the asymmetrical nature of most envisioned broadband services, which require modest upstream capability--mostly for signaling--and high bandwidth downstream. It may ultimately prove to be the case that residential subscribers do develop a taste for on-demand video services, perhaps in an HDTV format. And it may prove to be correct that a digital signally rate of 90 to 150 Mbps is required to deliver these services to the home.

Perhaps residential subscribers will acquire a taste for new types of interactive digital services of some type and be willing to pay money to get them. Do these possibilities necessarily imply that a fiber-to-the-home telephone network must be constructed to deliver such services? I believe the answer is "no." With the exception of two-way video, all other proposed broadband services require limited bandwidth upstream. The real demands for bandwidth are in the downstream direction.

This may indicate that a flexible migration of current CATV network architecture--heavily based on downstreamed bandwidth--may be a convenient, low cost way to deliver the requested services. A human can type on a keyboard no faster than 15 characters a second, which requires only 120 bps transmission rate. That's clearly adequate for ordering commands to access a database, participate in a poll or enter a response to an interactive video or text program. If the means of response were by lightpen, perhaps 150 bps would be required.[46]

Despite the vast potential store of information in databases, a human can read only up to 250 characters a second requiring the ability to transmit 2,000 bps. A residential customer making a plane reservation or checking stock quotations might require 10 bps signaling capability. That same customer ordering merchandise for a video catalog might require a 40 bps signaling rate. The sending of a fire or burglar alarm would take about 40 bits in total while a library book order could take 200 bits. An electronic funds transfer might require about 500 bits; an interoffice memo about 3,000 bits.

The point here is simply that even if residential customers someday acquire an appetite for broadband services, it is by no means certain that an integrated network-- especially an all-digital network--is the only way, or the most cost-effective way, to deliver them. In point of fact, almost all the bandwidth is required in the downstream direction. Even the medium-bandwidth applications, such as facsimile or still photo transmission, requires only about 200,000 bps.

An argument may eventually be made that it makes most sense, as an interim step, to use existing cable TV networks for downstream delivery and the telephone network for upstream, integrating the services provided by the two networks in the home or on the side of the home by means of new customer premises equipment.

SUMMARY

If CATV operators are given the clear authority to provide data and voice services to business and residential customers, it should be feasible to provide such services in several ways. The clearest near-term markets are the providers: large business telecommunications users in urban cores. The existing network topologies used to serve these customers with high-capacity data links, network redundancy or LEC bypass are simple enough. Both APAs and telcos agree that ring or mesh networks operating on a non-switched basis and based on single-mode fiber are ideal.

CATV could be a player in this market without undue difficulty, especially if it specializes in transmission services only and does not provide network termination gear or network integration services. From the standpoint of long-distance carriers, local access costs per trunk were about $600 to $700 a month. CATV operators should be able to provide some cost savings for IXCs in this area.

The market for residential voice is less clear, although it seems feasible to consider both wireline distributed switching techniques as well as digital microcell technology as ways of providing such services. In 1988, about 40 percent of BOC revenue was produced by residential customers, although it should also be kept in mind that about three percent of customers (businesses) provide about 30 percent of revenues for the typical Bell operating company. About 25 percent of annual BOC revenues were generated by access charges. On average, a residential customer provide& about $25 a month revenue while a business customer provided about $55 a month revenue in 1988.

If an operator's average revenue per month from a video customer is $30, then the value of a $25 per month voice customer looms as a significant contributor to earnings.

***

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From: BOMBE::HALL "Judy Hall 05-Aug-1991 0917" 5-AUG-1991 09:19:24.56
To: CRA::FULLER
CC: CRA::DELUCA,RDVAX::GANNON,RDVAX::LANDINE,HALL
Subj: Invitation to meet with RAD members on September 13

Sam,

The RAD committee members are getting together for one last meeting on Friday, September 13, and I hope very much that you can join us.

The plan is to meet for some part of the 1-5 slot that we always reserve, and then visit informally. Part or all of this will be at Les Fox's house, which is very close to the BXB facilities, just off 111.

There are several topics we could discuss with you. When you and I met to prepare for your EC meeting, you talked to me about the strategy you were going to use. I was very pleased with your intentions to talk about core competencies, long-range strategy, etc. I am sure the members would appreciate hearing what you talked about, and learning about the reaction that you received. Everywhere I go, people question whether there is any strategy in the company, or any thought beyond the current fiscal year. If you could convince these senior people that there is, I think they could help to restore other engineers' confidence in the future.

As individuals, the members are still interested in furthering technology, and we could have a discussion about how to do that. We could also talk about what the individual PBUs are doing in the way of long-range A/D.

And of course, people are interested in what you think about RAD. Should we declare it "dead" or merely "resting"? At what point would it make sense to propose it again? Is the present approach the right one, and should it just sit on the shelf until business is better?

If you are interested in joining us, please let me know what's best for you. We have the Site conference room in BXB-1 from 1 to 5. I imagine we'd need 2 hours or so. Probably the best choice would be to meet at 3, and then continue informally past 5 for those who can stay. But we'll try to work around your schedule.

Judy Hall

Printed by Sam Fuller

I N T E R O F F I C E   M E M O R A N D U M

Doc. No: 008687
Date: 02-Aug-1991 03:06pm EDT
From: Jim Albrycht @MSO
ALBRYCHT.JIM AT A1 at IAMOK at PKO
Dept: Enet DECTV
Tel No: 223-8520

TO: See Below

Subject: CABLE TELEVISION'S VIEW OF THEIR FUTURE

Folks...

For you folks who have been requesting information on the cable television industries' vision of their future, from their perspectives, ...attached is the best paper (with references) that I have been able to obtain in the past year.

Keeping in mind that the paper is a year old and does not take into consideration many new technical advances, and public policy changes, such as;

* all-digital high definition systems...going into full cable/satellite network testing this month...

* the advent of "software-defined-television" with data compression...available on PCs..

* what Digital is bringing to the marketplace with ETV and "Ethernet Everywhere" with the CMN information utility initiatives...

* plus new computer industry initiatives in all-digital video-on-demand...multiplying full multimedia programming capabilities everywhere...

* Judge Green backing off from many previous information industry constraints...

The paper is being passed on to you in full unedited, unaltered content, please be discrete in utilizing the material for your business plans and for your general business and technical knowlege about the cable television industry.

Thanks,

Jim

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CABLE TV FACILITIES AS INTEGRATED BROADBAND NETWORKS

Gary Kim

Multichannel News

Denver, CO

SUMMARY

This paper examines methods whereby cable television (CATV) networks can provide integrated broadband services. It especially explores the important issue of how CATV networks could provide voice services. Changes in network topology and investment that would have to be made to provide video, voice and data services to residential as well as business customers also will be explored.

Emphasis is placed on network upgrading already taking place, in particular the replacement of coaxial cable with fiber optic media and changes in network topology. The business impact these fundamental changes will have, especially regarding the introduction of switched services, will be noted. Although many regulatory and technical issues remain unanswered, the conclusion reached is that CATV networks can, in fact, be adapted to provide integrated broadband services.

DUAL NETWORKS?

Providers of video, voice and data services to business and residential customers cannot rule out the possibility that they may within the decade face a regulatory regime vastly different from today's. Most significant among the possible changes is a breaching of the barriers that have separated the electronic mass media from the telecommunications common carrier industries. Key among these possible changes is Bell operating company permission to provide cable TV services within their own telephone services areas. At the same time, it is possible that CATV companies will not be prohibited from offering data communications or switched voice services to their existing--or new--customers.

Proposed broadband integrated services digital networks provide one vision of how such information can be provided over a single network. But B-ISDN is not the only possible path to such a future. Indeed, one might argue that the "social investment cost"--the cost to the nation--to install a 21st century broadband communications infrastructure would be optimized by combining the capabilities of the existing CATV and telephone networks. [1] Such a "hybrid" network, it is said, would be capable of providing every telecommunications service a customer could desire and arguably could be created swiftly and at minimal total capital cost since both networks are already in place and need only to be integrated in some fashion.

In testimony presented to the Federal Communications Commission and U.S. Senate earlier this year, Thomas Gillette, Cable Television Laboratories Inc. vice president, argued that the best way to create a modern information age telecommunications infrastructure is by combining the best features of independent networks--including CATV, telco, private fiber networks and DBS.

CableLabs is the cable TV industry's research and development organization, and is funded by CATV operators representing over 85 percent of all U.S. CATV customers.
Although interworking and interface capabilities are required so that all the networks can be integrated, there's no reason an "integrated service" has to be provided by a single network. In fact the better approach is to deliver such services by "cooperative yet independent networks," Gillette argued. [2]

Likewise, Tele-Communications Inc. Senior Vice President John Sie has repeatedly argued in numerous policy forums that the massive investment a B-ISDN network would require is not justified financially when all proposed services could more inexpensively be provided by some combination of features provided by current CATV and telephone networks, with integration and control of the two separate services provided by some new type of customer premises equipment equipped with the intelligence to receive all signals, format them and forward them to the proper customer terminals--be they telephones, PCs or TVs. [1] TCI is the largest U.S. CATV - operator with some 11 million customers in wholly owned systems and partnerships.

Taking a somewhat different tack that essentially offers the same sort of service integration. Jerrold Communications, the largest supplier of CATV equipment, especially in-home terminals, believes that such CPE may represent a major opportunity for the CATV industry and already has announced its interest in pursuing such types of integrated control electronics. [2] In the Jerrold vision, service integration in the home would use infrared, electrical wiring, twisted pair and coaxial cable to move messages between intelligent devices in the home. [3]
Such in-home automation CPE would interwork with developing home automation systems proposed by the Electronic Industries Association as part of the "Consumer Electronics Bus." As an early example of such CPE, Jerrold has developed a TV remote control that also functions as a cordless telephone.

INTEGRATED NETWORKS

But it is by no means certain that such an "integrated services, dual networks" course, logical though it may be, will ultimately prevail. Indeed, technologists in CATV and in the telephone industry must prepare for other contingencies. Broadband ISDN (integrated services digital network) represents a conceptual model for how the telephone industry could provide all possible services by means of one integrated facility.
CATV industry strategists have spent far less time--and vastly less money--to ponder how video entertainment networks might be adapted to provide voice or data communications services. But such thinking is not without some precedent.

There was much talk of CATV's role as an "information highway" into homes during the middle - 1970s. And while it is popularly believed that the CATV industry has not had much interest in non-entertainment services including vidotex, local loop bypass services, meter reading, home security, interactive opinion polling and other two-way services, in fact the industry has experimented with all these services but has found either a lack of genuine consumer demand or overwhelming resistance from telephone companies to pursuing such services. [4]

But a changing regulatory climate may ultimately result in head-to-head competition between CATV, telephone and possibly other companies for broadband services to the home. [5] Under such conditions, the CATV industry may change its mind about the types of services it provides to customers. [6]

In fact, CATV companies already start with a major advantage: They already have installed broadband facilities that pass over 80% of U.S. homes and provide service to well over 54% of those homes. [7] Furthermore, the industry expects that by 1995 it will have achieved penetration--based on video entertainment services alone-of 70 percent or better. [8]

Although traditionally a provider of one-way video services, the U.S. CATV industry already has begun the process of rebuilding its networks in ways that will allow graceful migration into switched services of many types, should the market emerge and regulatory regimes allow such lines of business. [9]

A key element of this new strategy is rapid migration towards hybrid networks that combine optical fiber technology with conventional radio frequency technology in ways that maximize the technical and business advantages of each. [10] Much as the U.S. telephone industry introduced optical fiber first on the longest routes and gradually brought lightwave technology closer to the local loop, so CATV operators are introducing lightwave first on the backbone portions of their networks.

At the same time, CATV operators are finding ways to integrate lightwave technology in a way that dramatically boosts the technical and business value of the existing coaxial cable already in place, increasing the physical bandwidth available to homes from the previous ceiling of 550 MHz (80 TV channels) to 1000 MHz (120 channels or roughly 1 Gbps). [11]

At the same time, CATV companies are introducing numerous involments in network technology that--while aimed at improving picture quality -- also have the net effect of improving network reliability and robustness. [12] And because it never has been a regulated "rate-of-return" industry run on utility models, CATV operators instinctively deploy cost-effective technology on a "pay-as-you-go" basis, deploying new technology only as revenues to support those investments emerge. [13]

Unlike some other potential broadband competitors, CATV:
* already has current broadband services revenue streams
* already has broadband capacity to the home
* can increase physical bandwidth to 1000 MHz at low cost
* could put fiber close to the home at relatively low cost [14]

NETWORK WEAKNESSES

That isn't to say current CATV networks are ideally suited to delivering switched services. They just aren't. So it is significant that dramatic changes in CATV network architecture are occurring. [15] Indeed, the changes--while clearly aimed at protecting today's business--offer a clear evolutionary path for possible provision of broadband services of many kinds. [16]

But the challenges are significant. The CATV "tree-and-branch" architecture is marvelously efficient for delivery of one-way services, much as power and water systems similar are optimized for one-way service. [17] They have severe limitations in a two-way environment however. As a traditional telephone network is optimized for duplex communications, a traditional CATV network is optimized for simplex communications.

But many technologists in CATV believe that the existing tree-and-branch networks can evolve towards more sophisticated topologies - while retaining their basic form -- in a way that matches the likely growth of consumer markets requiring greater degrees of signal switching. [18]

Traditional CATV networks have "tree-and branch" (T/B) topologies that are designed to efficiently move signals on a point-to- multipoint (broadcast) basis. Like over-the-air broadcasting, water and electrical power systems, T/B architectures are most efficient when a uniform product is delivered to many distributed users. While switched-star architectures used by telephone companies are far more efficient for providing "any-to-any" communications requiring the establishment of direct circuit connections between any two users, T/B is the most efficient way to deliver multiple channels of broadcast type video and will probably prove to be the most cost-effective architecture for delivery of "pay-per-view" or other types of "on-demand" video, especially if the market for such services ultimately proves to be "blockbuster[" movies and "event" programming.

Indeed, T/B costs are hard to match. Current state-of-the-art cable TV systems using conventional coaxial cable technology can be designed and built to deliver 80 6-Mhz TV channels (550 MHz of bandwidth total) for a cost of about $600 a subscriber, including all outdoor plant and construction costs. [19]
Coaxial cable and radio frequency (RF) electronics also are well-understood technologies with highly-standardized specifications supplied by a number of vendors whose competition keeps prices competitive. [20] While the current generation of amplifiers can support 550 MHz (77 to 80 channels) of bandwidth, the industry expects to develop newer devices capable of supporting bandwidths from 750 to 1,000 MHz sometime during the next two years. [21]

Arguably the toughest current problem CATV networks face is the high signal attenuation caused by coaxial cable and the non-linear signal reproducing capabilities of RF amplifiers operated in series (cascades) to combat the attenuation-inducing problems of coaxial cable. Furthermore, coaxial cable attenuates signals differentially. Signals at higher frequencies are attenuated more than signals carried at lower frequencies. [22] So as CATV bandwidth has expanded from three channels(in the 1950s) to 12 channels (in the 1960s) to 35 channels (in the 1970s) to the current 77 to 80 channels, CATV operators have had to work harder at repeating the increasingly "lossy" signals at the upper reaches of the transmitted frequency spectrum. [23]

The results is a bandwidth limitation of about 55O MHz for today's CATV systems, even though the cable itself clearly can carry 1,000 MHz or more. At frequencies above 550 Mhz attenuation increases so rapidly that cascades of 10 and greater devices simply are impractical.

Unfortunately, signal gain cannot be applied indiscriminately, any more than the volume on a home stereo can be turned up to maximum without risking distortion (unwanted degradation) of the signals. CATV networks therefore must be designed around a window of operating tolerance that balances noise performance against distortion performance. Too little gain and the resulting signals are too weak. A TV picture looks "snowy". Too much gain and the signals are impaired--signals from two or more channels interfere with the desired channel. [24]

So long as the total number of RF amplifiers operated in series is not too large (30 to 40 about the practical limit) [25], signals can be carried distances of about 12 miles before the distortion and noise parameters converge and require termination of the line. [26] But relatively high attenuation and the signal impairing effects of amplifiers used to combat attenuation are not the only drawbacks coaxial cable has. Since the amplifiers are operated in series, each is dependent on the correct performance of the device in front of it. Should amplifier 16 be knocked out of action, amplifiers 17, 18, 19 and so forth also are knocked out. This of course means that device outages can ripple through the system.

Long cascades of amplifiers therefore are responsible for a number of system limitations:

* bandwidth restrictions
* signal quality impairments
* signal reach limits
* network reliability shortcomings

CATV NETWORK REDESIGN

In response to these perceived limitations, CATV networks have begun to deploy optical fiber technology to break the transmission bottleneck and improve system reliability. Equally important fiber also allows networks to be redesigned in important new ways.

Although cable TV's interest in fiber exploded in 1988, it has been talked about and used on a limited basis in the cable TV industry since the early 1970s and was tried on a "fiber to the home" basis in the early 1980s in Alameda County, Calif. [27] Like other network operators such as telephone companies, CATV technologists have looked at optical fiber cost issues and discovered that the most obvious financial payback occurs when fiber is deployed first on the backbone routes, which spreads the cost of opto electronics over the widest number of subscribers or customers.

In cable TV, that has meant deploying fiber optics first as a "supertrunking" medium to link earth stations and headends, headends with other headends or hubs. But CATV also is beginning to deploy lightwave technology further into the distribution network, in some cases using optics as a full replacement for the entire trunking network. A key impetus for such deployment has been the development since late 1987 of AM fiber optic technology capable of carrying 20 to 60 channels of standard video in a format that is easily comparable with the existing base of RF gear used by CATV companies.

At least 1,500 AM systems have been ordered since they first became commercially available during the fall of 1988 and the pace of introductions is expected to develop almost exponentially over the next five years as effective prices drop and more operators get experience with the new technology.

Today, a number of operators are using fiber to slice the longest amplifier cascades [28] from 35 or more to 20 or less. Others, taking a more aggressive approach, are using fiber to break a single large cable TV system up into neighborhood -sized units of several hundred to several thousand homes. [29]

Cable industry estimates of the cost of installing "fiber backbone" capacity vary, but if fiber introduction is timed to coincide with a scheduled system upgrade--which requires a rebuild of the network--the cost per subscriber can range from $30 to $130. [30] A fiber backbone might use lightwave technology to move signals from headends deep into the network, converting signals from light back to radio frequency format and running them through four to seven conventional RF trunk amplifiers and two line extenders before delivering them to the customer premises.

Already, though, technologists at American Television & Communications (the second largest U.S. cable TV operator) have found ways to build passive optical networks that completely replace all coaxial cable in trunk networks for a cost no greater than--and in many cases cheaper than--conventional 450 MHz coaxial cable plants. [31] Such a "Fiber Trunk and Feeder" design uses optical media to deliver signals from a CATV headend (roughly equivalent to a telephone central office) out to optical receive nodes (roughly equivalent to telco remote terminals). From there, signals are converted to electrical form and run no more than a mile to any given customer's home. Over a period of time, industry technologists predict that lightwave might gradually find its way out to curbside locations as well (typically four-home taps).

The significance of the new FTF design is that where earlier optical architectures were most easily cost-justified in channel upgrade situations, FTF can be cost-justified for new plant, line extension plants, or rebuilt plants as well, dramatically expanding the range of immediate applications for fiber.
So CATV companies will find it economically feasible to deploy fiber in such a manner in all service areas, not just new housing construction areas, as will be the case in the telephone industry for quite some time to come.

DATA SERVICES FOR BUSINESS CUSTOMERS

It is reasonable to project that video entertainment will continue to be cable TV's strength over the next few decades. On the other hand, it is logical to assume that a fiber reinforced CATV network might be used to provide high-bandwidth transport services for business customers in downtown core areas. At some later point, it is conceivable that voice services might be provided for residential customers as well. Delivery of compact disc audio services and data base services already is occurring and there is no reason to believe provision of these types of services to residential customers will pose difficult network challenges.

Indeed, the mushrooming number of "alternative access providers" (APAs), suggests a model CATV companies might pursue. APAs build optical fiber networks in downtown business cores and provide high bandwidth transport services to business customers. Already 20 companies operate such networks in 15 cities, including San Francisco, Los Angeles, Chicago, Boston, New York, Philadelphia and Washington, D.C. [32] Facilities are under construction in Dallas, Houston and several cities are served by more than one APA. A recent report by the Boston-based research from the Yankee Group estimated that APA revenues will grow from $60 million to $150 million by 1991. [33]

Business customers typically use APA networks for three applications:
* To provide redundant network capability for data communications transport.
* To directly connect with one or more long distance (interexchange or IXC) carriers, thus avoiding the payment of local access charges.
* To get point-to-point bandwidth from one facility to others in the same metropolitan area.

In cities such as Philadelphia and Chicago, a MAN operator using single mode optical fiber can connect more than 20 interexchange carriers points-of-presence (POPs) and several dozen major office buildings by running only about 10 kilometers of cable. [34] The POP is a traffic hand-off point where local traffic is transferred to the IXC's network. Around the country, traffic carried on MANs ranges from relatively low speeds DS-0 services at 64Kilobits per second (voice-grade) up to DS-3 at 45 megabits per second. [35]. Among the most popular bandwidths today is T1 (DS-1), transmitting at 1.544 mbps. Some 66.3 percent of business users using high bandwidth transport facilities say they use this type of facility. [36] And that trend seems likely to grow. A survey of 1090 communications managers at large companies found that 84.8 percent of those companies networked PCs locally; 28 percent on a MAN basis; and 56.6 percent on a wide area basis. [37]. Typically, APAs also offer transports of 135 Mbps, 405 Mbps and 560 Mbps. [38]

The network topology used by APAs is quite straight forward. Since virtually all the traffic is of a point-to-point nature, the networks resemble rings or mesh networks. Traffic destined for buildings within the metropolitan area can be picked up and dropped off the ring. Traffic destined for IXCs can be direct- wired to the POP. In some cases a "supernode" feeds subsidiary nodes, each of which is equipped with a digital cross connect switch to move traffic from one fiber segment to the next. In fact the characteristics of high-bandwidth data traffic would seem to resemble video traffic more voice. Much of the need is for dedicated point-to-point access with no requirement for circuit switching. Lower-volume MAN traffic typically can be handled using local area network techniques for dropping and inserting packets on a "broadcast" topology bus or ring. In either case, the required network topology would seem to resemble the bus (tree and branch is a type of bus topology) CATV network better than the circuit-switched star telephone network.

In fact, telephone industry planners seem to recognize the advantages broadcast topologies represent where MAN or alternate access is concerned. The current proposals for MAN architectures in downtown core

areas include a dual bus standard (IEEE 802.6) as well as formal ring topologies. [39]

In Spain, for example, MAN architectures are seen as best suited to a bi-directional ring topology in which cross-connect switches are used to groom traffic on and off the primary ring. [40] For distribution, a secondary network can be designed as either a star (from the the cross connect) or a subsidiary ring. In the United States, Bell South already has installed a ring topology network used by the central office serving the Sawgrass business park near Weston, Fla.

The point is that ring and bus topologies, which work very well for video and high volume data applications, seem well-suited for networks serving business customers with high needs for bandwidth. Already, the Rogers Cablesystems optical architecture is a dual ring, and American Television and Communications engineers envision some sort of ring network to link main hubs. Such architectures are ideally suited to providing MAN or APA services to business customers. Other architectures, such as the Jones Cable Area Network, also are positioned to provide point-to-point transport services for business customers, using the spare fibers already carried in the existing cables.

For those who object that CATV technologies don't know that much about requirements for data communication networks, the experiences operators already are having with simple point-to-point bandwidth leasing should prove reassuring. Typically, the end user maintains all the termination equipment on either end of the link, be that multiplexers, channel banks or cross connects. What the CATV operator must provide is a reliable, clean transportation path--nothing more; nothing less.

The business opportunities here should not be underestimated. Says Gaspare Lovasco, Pacific Bell associate director, "LAN interconnection (MAN services) is the first major manifestation of the broadband marketplace." More directly, NYNEX Corp. staff director Emmett McDonough says: "The real competition between cable TV and telcos during the 1990s is for the metropolitan area network customer, who needs data transfer at moderate speeds and lower-speed broadband services."

Indeed, the opening shot has already been fired by Jones Lightwave, a subsidiary of Jones Intentional, parent of Jones Intercable, the 10th -largest cable TV operator in the United States.[41] Jones has applied for a permit from the Georgia Public Service Commission to operate a MAN in the high- growth Gwinnett County area north of Atlanta, Ga. In Canada, Rogers Telecommunications intends to provide similar services, as well as cellular telephone service and long-distance services, through various subsidiaries.

Traditionally, the lack of plant in downtown cores has proven a physical barrier to CATV offerings of this type, although reluctance to tangle with regulatory authorities has probably been a bigger hurdle. Ironically, though, the lack of plant might now be an advantage. With no embedded base of equipment to worry about an all-fiber network can be designed from scratch with the proper ring or mesh topology best suited to APA systems. And to avoid PUC entanglements, separate subsidiaries can be created to manage such businesses, thus preserving the distinction between the CATV and APA business units.

RESIDENTIAL VOICE SERVICES

Far tougher, though, is the challenge of overlaying switched voice capabilities for a residential customer. If there is any application for which a switched-star network is ideally suited, it is the task of moving voice messages around from any single point to any other single point. Conversely, if there is any application for which a tree-and-branch network is not ideally suited it is the switching of voice messages. Nevertheless, several new developments seem to offer a method for delivering voice services.

Absolutely central is the introduction of optical fiber backbone or feeder networks. Three elements are crucial. First, such a network breaks serving areas up into smaller units. Second, a fiber-based network offers reliability advantages and reduces the problems of reverse-path signal ingress which have traditionally bedeviled CATV network planners. Third, a fiber backbone puts node locations out into the network that can be used as convenient signal switch points, creating a sort of mesh of control locations. Fourth, such nodes might also function as sites for radio antennas if some sort of digital cellular technique were to be used.

Consider for the moment a wireline alternative. How should the industry provide the switching fabric? Certain constraints must be accounted for. It would make little sense to lay a new, companion star-switched network beside the existing tree-and-branch network, for obvious reasons dictated by the amount of capital this would entail. Telephone industry analysts say the cost to add a single residential customer can cost upwards of \$ 1,200, and that's just the cost of the network. The cost of central office switches is extra, and could bring the cost per-sub up to almost \$4,000 or \$5,000.

So it would make sense to embed the switching fabric into the existing network, if this can be done. As a backdrop, what trends in switching and processing power can be observed in the computer, data communications and even telephone industries? In computing, there has been a massive shift away from centralized processing to distributed processing; from mainframes to PCs and workstations; from single-site control to networked independent co-processing. In the area of processors, there has been a continual increase in performance and decrease in cost, so that the power of older mainframes is incorporated in devices that can sit "on the desktop."

In fact, since the 1960s, the level of chip integration has lead to "a doubling of the number of components per chip about every 18 months." [42] If one extrapolates from this data, it's possible to predict that by the year 2000 it will be possible to put "about 100 million transistors on a processing chip" says Gordon Moore, the founder of Intel.[43] The significance of such developments is that one fights the trend in supposing that centralized processing makes sense. One big central office may be needlessly complex given the availability of cheap, distributed processing.

In data communications, a similar trend can be noted. Suppliers in the local area network industry often say "the network is the computer," meaning that the distributed power of networked intelligent workstations is a functional substitute for a centralized mainframe.

Indeed, the switching that occurs in a LAN setting is ideally suited to a broadcast medium such as CATV. Unlike circuit switching systems--such as the current local telephone network--that actively switch messages, broadcast networks--bus, ring or tree-and-branch--address all messages passively.

Instead of creating an actual signaling path by opening up a physical channel, as a circuit-switched system does, a broadcast LAN uses message headers to identify all traffic it carries. All messages sent by any single station all broadcast to all stations on the network. All listen for their own addresses. Finding none, the packets are allowed to continue streaming by. Only when any given station "hears" its own address appended to a packet does that station grab the message.

Even telephone switching strategies are moving in the direction of "virtual" distributed intelligence, even if the actual software control remains centralized. The much-touted SONET (synchronous optical network) interface, a physical layer standard intended to promote interconnection of optical transmitting equipment manufactured by numerous vendors, while ostensibly aimed at promoting device compatibility with networks, also will have the effect of allowing customers to reconfigure their access services more flexibly.

Extrapolating from these trends, it is reasonable to argue that the best way a CATV operator could provide switched voice services to residential customers is by distributing the switching intelligence and using access techniques borrowed from the LAN industry. In place of a central office switch, CATV operators might be able to use each fiber feeder node as a switch location. This switch might be thought of as a neighborhood PBX and might serve a few hundred customers; possibly a few thousand.

It should also be possible to develop a switching fabric that puts the actual intelligence into each terminal (phone), much as LANs now put switching capability into each network interface. Telephone numbers would in essence be a property of a device, not a physical location on the network, much as current cellular phones have a unique address that is location independent. Calls would be set up much as two terminals on a LAN presently make connections.

A message bearing the address of the calling terminal would be broadcast on the network. The intended receiving terminal would hear its address and instruct the phone set to start ringing and send an acknowledgment packet back to the sending terminal, which would then generate a mirroring "phone is ringing" message. A session ("circuit") would be established when the receiving phone goes off hook. Addressing routines would, of course, need to be more complex as the total number of stations on the network increased, but such increases in terminal population could be accommodated in much the same manner as now is used by stations on the TCP/IP "Internet," a nationwide data communications network linking universities, colleges and other research agencies.

Messages intended for more distant sites simply have additional header material appended that instructs gateway devices to forward packets to other gateways with known matching addresses. In a single metropolitan area, it is likely that cells of 500 to 2,000 users could be served by any single hub. Messages intended for other locations in the city would be forwarded by a bridge, a device that can recognize headers destined for terminals within the hub-served area and headers intended for terminals served by other hubs.

Yet another option would seem to be the use of digital "microcell" technology to provide a wireless connection for voice messages. Already, a time division multiple access (TDMA) standard has been proposed for upgrading analog cellular telephone systems in the United States to digital format, with the corresponding advantage of increasing channel capacity by four to 10 times. Other technologies, such as code division multiple access (CDMA), can include channel capacity 20 to 40 times compared to a conventional analog system. [44]

These techniques should expand the number of customers who can be served, reduce interference problems, reduce the per subscriber cost as well as the cost of the user terminals. Note that the Rogers Cablesystems fiber architecture is specifically optimized for sharing of bandwidth between the CATV operator and other Rogers telecommunications units, such as CNCP Telecommunications, a nationwide Canadian data and voice network expected to provide long distance service in Canada. Spare fibers put into place as part of the Rogers fiber architecture will be used as the local loops for CNCP.

That same network also is used to transport cellular telephone traffic generated by Cantel, the cellular telephone company Rogers Communications also owns. Properly situated optical receive nodes used for CATV also can be used to integrate cellular telephone services. Although Cantel uses an analog signaling technique, (he network design principles are analogous to those that would be useful for a microcell voice network.

In the microcell concept, lower-power transmitters are used to localize the service area covering areas as small as a single department within a company, a single floor of a building (a wireless PBX concept); an entire building or perhaps a city block or collection of blocks. Such a concept fits nicely with the neighborhood service area a fiber feeder architecture makes possible. Current experiments with such technology include the Pan-European Digital Cellular system, which uses about 25 MHz of spectrum in the 900 MHz band (890-915 MHz 935-960 MHz) with 200 KHz channel spacing. Transmissions occur at 271 Kbps and eight to 16 channels are multiplexed per carrier. Other proposals suggest the use of frequency in the 1.7 to 2.3 GHz bands for continent-wide digital service in Europe.

IMPLICATIONS FOR INTEGRATED BROADBAND NETWORKS

CATV operators may someday decide they must move beyond provision of entertainment video and become providers of other types of services as well. To prepare for this possibility, the cable TV industry now is positioning its networks for flexible migration to architectures that will cost effectively provide video and other high bandwidth services to residential& subscribers.

It may well be that at least two separate network thrusts may be undertaken. First, all-fiber ring topology networks may be constructed in urban areas to provide high bandwidth services for business customers.
Such networks may be provided by business units separate from the CATV companies. Alternatively, it is possible that dark fiber leasing may be pursued by CATV companies to achieve the same result.

Integrated services for residential customers may follow a separate path. During the 1990s, CATV operators will install optical fiber for the supertrunking ("long haul") as well as trunking ("feeder") portions of their plant. Such networks will essentially transform CATV from a tree-and-branch network to a star backbone or star feeder design. The bus network fed from the star might also be configured as a logical star by the addition of switching capability. Fiber will improve reliability but also allow new bandwidth possibilities and facilitate the introduction of switching technology. And that will make CATV a stronger contender for new types of digitally-based services that may develop as new consumer markets.

The CATV industry also is deploying such technology on a "pay-as-you-go" basis.
Virtually all the network improvements will improve the quality and market position of the entertainment video business CATV already has, while simultaneously laying the foundation for services that require greater switching. Indeed, industry technologists already are discussing methods for delivering switched digital video over existing fiber reinforced networks using a combination of video signal compression technology and switching done at both headends (equivalent of telephone network central offices) and at distributed locations scattered throughout the network.[45]

The CATV industry's position in the residential market, supported by low capital and operating cost advantages, may also be enhanced by the asymmetrical nature of most envisioned broadband services, which require modest upstream capability--mostly for signaling--and high bandwidth downstream. It may ultimately prove to be the case that residential subscribers do develop a taste for on-demand video services, perhaps in an HDTV format. And it may prove to be correct that a digital signally rate of 90 to 150 Mbps is required to deliver these services to the home.

Perhaps residential subscribers will acquire a taste for new types of interactive digital services of some type and be willing to pay money to get them. Do these possibilities necessarily imply that a fiber-to-the-home telephone network must be constructed to deliver such services? I believe the answer is "no." With the exception of two-way video, all other proposed broadband services require limited bandwidth upstream. The real demands for bandwidth are in the downstream direction.

This may indicate that a flexible migration of current CATV network architecture--heavily based on downstreamed bandwidth--may be a convenient, low cost way to deliver the requested services. A human can type on a keyboard no faster than 15 characters a second, which requires only 120 bps transmission rate. That's clearly adequate for ordering commands to access a database, participate in a poll or enter a response to an interactive video or text program. If the means of response were by lightpen, perhaps 150 bps would be required.[46]

Despite the vast potential store of information in databases, a human can read only up to 250 characters a second requiring the ability to transmit 2,000 bps. A residential customer making a plane reservation or checking stock quotations might require 10 bps signaling capability. That same customer ordering merchandise for a video catalog might require a 40 bps signaling rate. The sending of a fire or burglar alarm would take about 40 bits in total while a library book order could take 200 bits. An electronic funds transfer might require about 500 bits; an interoffice memo about 3,000 bits.

The point here is simply that even if residential customers someday acquire an appetite for broadband services, it is by no means certain that an integrated network-- especially an all-digital network--is the only way, or the most cost-effective way, to deliver them. In point of fact, almost all the bandwidth is required in the downstream direction. Even the medium-bandwidth applications, such as facsimile or still photo transmission, requires only about 200,000 bps.

An argument may eventually be made that it makes most sense, as an interim step, to use existing cable TV networks for downstream delivery and the telephone network for upstream, integrating the services provided by the two networks in the home or on the side of the home by means of new customer premises equipment.

SUMMARY

If CATV operators are given the clear authority to provide data and voice services to business and residential customers, it should be feasible to provide such services in several ways. The clearest near-term markets are the providers: large business telecommunications users in urban cores. The existing network topologies used to serve these customers with high-capacity data links, network redundancy or LEC bypass are simple enough. Both APAs and telcos agree that ring or mesh networks operating on a non-switched basis and based on single-mode fiber are ideal.

CATV could be a player in this market without undue difficulty, especially if it specializes in transmission services only and does not provide network termination gear or network integration services. From the standpoint of long-distance carriers, local access costs per trunk were about $600 to $700 a month. CATV operators should be able to provide some cost savings for IXCs in this area.

The market for residential voice is less clear, although it seems feasible to consider both wireline distributed switching techniques as well as digital microcell technology as ways of providing such services. In 1988, about 40 percent of BOC revenue was produced by residential customers, although it should also be kept in mind that about three percent of customers (businesses) provide about 30 percent of revenues for the typical Bell operating company. About 25 percent of annual BOC revenues were generated by access charges. On average, a residential customer provide& about $25 a month revenue while a business customer provided about $55 a month revenue in 1988.

If an operator's average revenue per month from a video customer is $30, then the value of a $25 per month voice customer looms as a significant contributor to earnings.

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