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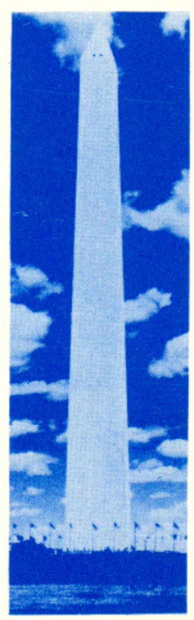

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HYBRID CABLE AND TELEPHONE
COMPUTER COMMUNICATIONS

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Abstract

Cable plant used for CATV entertainment distribution provides for a high bandwidth communications path to the consumer and only in some cases a return path. To provide for two-way interactive computer communications, a return path is required. This paper discusses the status of two-way hybrid systems using cable and telephone twisted pair. Included is a discussion of market requirements, system design, costs, and current progress on both the cable and telephone side.

Introduction

There is a growing demand for computer communications to the consumer with the explosive growth of home or personal computers, interactive home services (banking, shopping, etc.) and access to information sources such as Dow Jones, CompuServe, Dialog, etc. There are three elements of this expanding business area: the computer hardware in the consumer's location and at the central facility, the software necessary to support these applications, and the communication networks, protocols, etc. necessary to interconnect the systems. This paper focuses on the latter element.

Two-way cable communications have been available since 1974 and since 1977 have been a key element of the Warner Cable QUBE system. The two-way communication uses a broadband cable with a bandwidth of 350-400 MHz with the bottom 50 MH allocated as the band to communicate from the user to a headend and the upper for transmissions from the headend to the user. This apparent imbalance is due to the fact that most signals (e.g. TV) are broadcast and little data is transmitted from the home. In addition, the two-way cable is all channelized into 6 MHz channels. There are, at present, a limited number of two-way systems, the Warner QUBE system being the only two-way operational one with 400,000 subscribers.

The QUBE design is a polling system that uses a unique data link control protocol to control communications. It allows for adaptive polling so that it can accommodate an interactive user with 100-500 msec. delays. Other systems, such as those proposed by Cox, use CSMA/CD which has similar response times but are more costly in terms of the consumer premise equipment.

The limited availability of two-way cable, however, and the demand for two-way services, increases the need for hybrid designs using both telephone and cable. Recent developments, such as Bell's Local Area Data Transport (LADT), now provide a cost effective combination of telephone and cable. The LADT tariff filing in Florida in February of 1983 dramatically expands the synergy between cable and telephone.

Previously, telephone links had three major drawbacks for consumer computer communications:

- High costs based on usage (6-10 cents per minute) with low data rates.
- Disabling of the telephone not allowing the reception of incoming calls.
- Increased load on telephone control offices with computer-to-computer calls with increased holding times and increased arrival rates.

The hybrid cable/telco designs now being developed reduces these problems dramatically. This paper addresses the hybrid telco/cable designs by:

- providing market demands for services and providing system requirements.
- overviewing the technical status and current progress of two-way cable and LADT.
- projecting alternative telco hybrid developments and their impact on computer hardware and software.
- estimating the price/demand relationship for hardware and operating costs.

Market Requirements

There are two major market segments that the local cable system can address. The first is the commercial market that is presently served by the local Bell Operating Companies. The second is the consumer market which is also served by the Bell Operating Companies (BOCs).

On the commercial side there is a need for high data rates between locations in the metropolitan area. These areas may be between its own buildings and thus be intracompany, or may be between other locations. In the latter case, there are two distinct possibilities. First, it may be a totally local communications link. Thus, an extension of the local loop. In the latter case, this local data communications may be to a long distance carrier such as a value added network carrier (such as Telenet or SPCC).

The commercial data requirements are typically based upon the standards that the BOCs offer. In particular, these are such links as 9.6 Kbps, 56 Kbps, T-1 carrier and the other standard repertoire. In the past year, cable companies have been introducing such data services into the local markets. Such companies as Warner in its Pittsburgh system with a set of T-1 links for Westinghouse Corp., Cox Communications in Omaha with its joint effort with MCI in the Comline area, Manhattan Cable in New York City with its extensive data services and the Rogers Cable system in Portland, Oregon. In all of these cases, there has been no attempt to integrate the cable and Telco plant together.

The key impediment is the pressure by the local Public Utility Commissions to try and regulate cable as a common carrier. Unfortunately, cable systems in most of the large metropolitan areas are losing large sums of money due to excessive give-aways to local municipalities in the form of local studios, free access to the plant, support of local arts and education groups and other endeavors. The most recent example is the withdrawal of United-Tribune from the Sacramento franchise. It had promised to provide $97 million in give-aways. In the clear morning air, it found that it could not get the funding and withdrew. Now the city is trying to get someone else to bid. Clearly, the city is now at a major disadvantage.

The intracompany market is comprised of interoffice data communications networks and the possible extension of local area networks (LAN). For the most part, the requirements on these networks are limited to standard data communications protocols. As discussed is the basic limitations that result from the perception of the BOCs being the only supply of interconnect. The local intercompany networks are even more poorly defined at this stage.

The second overall potential market is on the consumer side. This includes both local loop voice and data traffic. The voice traffic is limited by the fact that with a cable, the multiple access of voice traffic is a costly affair that requires that the voice be digitized. The availability of the digitized VLSI chips is not apparent in the near future. The data traffic, however, is a true market as of today. There are two cable multiple system operators (MSO) who provide interactive data communications to the consumer at this time. They are Warner Amex Cable in the cities of Columbus, Cincinnati, Houston, Dallas, Pittsburgh, Chicago (suburbs), and St. Louis (suburbs). This two-way plant is a polling system that has the capacity to handle large amounts of data traffic. The second system is that of Cox Cable in San Diego and Omaha. Unfortunately, both of the Cox systems are inoperable at the time of this writing due to regulatory and technical reasons.

On the consumer side of the market, there are two major demands that are developing. The first is the need to interconnect personal computers to networks and in turn to gateways. The second, is the need for such things as interactive home services (IHS). These services include such things as banking, shopping, travel and ticketing, real estate and investment services. The consumer can interact with these services in a manner that is dramatically different than those in the commercial area.

The key differences center around the differences in data rates up and downstream and the nature of the material presented to the consumer. The upstream traffic from the consumer is the low data rate that results from the limited response repertoire that is available. The consumer responds to a preformatted set of questions about a shopping selection or some similar question about their bank account. This response is about 100 bits in length with the responses per consumer who is active occurring once every 15 seconds on average. This clearly is a very slow data rate. It is dramatically different from those in an interactive session in a commercial timesharing environment.

The data traffic to the active consumer, however, is considerably larger. For each consumer response a data stream that consists of 8,000 to 10,000 bits has to be transferred in less than one-half a second. Thus, the downstream rate is almost 200 times faster than the upstream rate. This asymmetry makes for a significant challenge both in terms of the computer system architecture and the communication channel.

The presentation layer that arrives at the consumer also is in direct relation to the types of markets that are being addressed. In the area of banking, it is clear that for the most part, this requires only the ability to present alphanumeric data to the consumer. However, in the area of shopping, a much more sophisticated screen needs to be developed. At one extreme is ATT with their alphageometric screens. They believe that the consumer will be satisfied with a limited amount of graphical information of the item that they are interested in.

At the other extreme, is the need to provide the consumer with a full motion video presentation of the product. The major difference in these two schemes is that text "informs" whereas video "promotes and persuades". This is the key difference both to the consumer and the supplier of the product. The ideal situation is a combination of the text and video. This scheme has been called Enhanced Videotex.

What this brief analysis of the consumer market does bring out is the fact that the consumers data communications link can be handled by a low data rate channel such as the telephone. Yet the channel bringing information into the home has to be able to support both high data rates, 24 Kbps, as well as video. These requirements follow from an analysis of the consumer market.

System Design

As described in the last section, the primary focus of this paper is the consumer. It provides a current basis for evaluating the potential of a cable Telco hybrid (CTH) for the purposes of providing a large real time computer communications network. Before proceeding to the considerations of the system design, let us look at some of the system sizing issues.

1. A typical system may have to support 100,000 users to such a service.
2. For such a service, the peak number instantaneously on the system is 3% or 3,000 users.
3. The users spend on average 15 seconds between responses. Thus, on an average, there are 200 users instantaneously responding.
4. For each instantaneous user, the upstream traffic is 100 bits in 100 to 300 msec. or at most, 1,000 bps. Thus, from each, the rate is 200 Kbps.
5. For each instantaneous user, the downstream data traffic is 26 Kbps for an aggregate of 5.2 Mbps.

The typical telephone link can support 300 bps easily and in many cases, can support 1200 bps. AT&T has recently been expanding its network capabilities with the intent to go with an ISDN type network. The major limitation of the telephone network is that there are loading coils that are used to balance the frequency response of the twisted pair. These loading coils, however, limit the response of the typical twisted pair to 3400 Hz., which is the typical voice band.

Thus, the telephone network can support the upstream traffic from the home over the twisted pair using the 1200 bps traffic. The downstream traffic, however, cannot be supported. In some recent trials of videotex systems, AT&T in Ridgewood, NJ, tested 1200 bps channels with 8000 bit downstream traffic. This, however, results in a six to eight second delay to the consumer in viewing the screen information. This has been viewed as unacceptable to the consumer. In addition, this type of channel cannot support the full motion video channel.

The most recent entry in telephone communications is the local area data transport (LADT) systems which is a packetized synchronous data communications source to the home. It comes in two major forms; an alternate voice or data (AVD) forms at 1200 bps or a data over voice (DOV) type at 9800 or 9600 bps. The major concern is in sending data traffic to the home because in a videotex modem videotex screens require 8000 bits per screen. At 1200 bps, this requires a data transmission time of 6-8 seconds. This is generally unacceptable to the consumer. These higher data rates are required. These can be provided by a cable system.

The downstream cable data can be transmitted in two ways. First, the vertical blanking intervals (VBI) can be used and they allow simultaneous use of video and data. The VBI rates vary, depending on who has control origination, from 32 kbps to 96 kbps. This reduces the delay to 0.25 seconds or less per screen. The second approach is to use a separate data channel on the cable. This approach has been used in the Warner Qube System with a polled and packetized 256 kbps link.

Figure 1 depicts the proposed LADT architecture. The hybrid scheme is shown in Figure 2. The hybrid scheme is comprised of the following:

1. A 48 kbps VBI data stream down from the cable headend.
2. A hierarchical cable network with hubs acting as distribution points. In this case, we have 10,000 homes per hub, 2,000 subscribers per hub and 60 homes instantaneously. This yields four 8 kbit screens per second.
3. The upstream data traffic is at 1200 bps with 100 bits per response.

Table 1 is a summary of the upstream and downstream data traffic. The key factors are delays and overall response times. There are two general network architectures.

1. Centralized - in this case, all data bases are resident in one location and the home unit interfaces directly with that. Table 2 shows the timing budget for this centralized local scheme. It demonstrates a very fast response time.
2. Distributed - in this case, all data goes through a local gateway and into other distributed data bases. Table 3 depicts the timing budget.

The computer software necessary to handle this communications network is a straight forward extension of the ISO model. The data link layer is synchronous or asynchronous on both the VBI and LADT circuit. On LADT, HDLC is used at the DLC layer. On the VBI, the acknowledgement path is in the Telco path. The network layer on the Telco path is X.25.

The headend software must support communications processing, sequencing and scheduling, fault isolation and performance monitoring and linkages into the applications processing.

Costs

The costs of this consumer based service is composed of two items; capital and operating expense. The key capital items in these networks are:

1. Home Terminal - the target cost of this is between $150-$300. The present ATT terminal in Knight Ridders test in Florida is $600, which is twice the maximum acceptable consumer price.
2. Telco Interface - as needed, this interface provides a multipart interface to LADT. Its price range is $80-$120 per unit.
3. Cable Plant - the cable plant capital may or may not be capitalized, depending upon the business arrangements. The cable plant costs are based on the following assumptions:
   a) There are typically 50-100 homes per mile.
   b) Installed cable costs $10,000 to $25,000 per mile depending on population density, bandwidth, etc.
   c) This yields an average capital investment in plant of $300 per home passed or, at 50% market penetration, $600 per subscriber.
   d) Plant has a 15 year life, so that annual depreciation is $40 per subscriber per year.
   e) A typical single cable has 56 channels, so that the depreciation expense is 75¢ per sub per channel per year.
   f) With interest and operating expenses , this yields $1.50 per sub per channel per year. This gives an estimate on channel costs to a cable operator.

The operating expenses are dominated by LADT tariffs. These tariffs are presently limited to two types:

- Type I - 1200 bps with 1.6¢ per minute, AVD.
- Type II- 4800/9600 bps; $28 per month fixed and then a per packed charge, DOV.

For the consumer, the 1200 bps is the better buy.

Conclusions

We have argued in this paper that there are many technical challenges in the CATV areas as applied to hybrid telco/cable networks. The issues of access are not readily settled and are still in regulatory evaluation. The key driving forces are the yet to be understood consumer market and the rapidly changing regulatory environment.

This paper has tried to argue that the consumer market requirements will play a dominant factor in how hybrids evolve on the residential side. Such issues as peak loading, data rates and formats, interconnect and gateways will play a significant role in growth. The issue of centralized versus distributed control plays not only a technical role but is key to how this new industry will evolve.

The regulatory environment is also critical. Will the PUC's regulate cable as a common carrier. If it does, will that regulation stifle growth as it has in many markets or will it protect cable from the problems of local franchise control boards. How is the public interest best served. What is the potential of a hybrid Telco/Cable system. Cable can easily distribute full motion video on demand. Telco can provide a reliable two way data path in low data rates. How can these best be combined.

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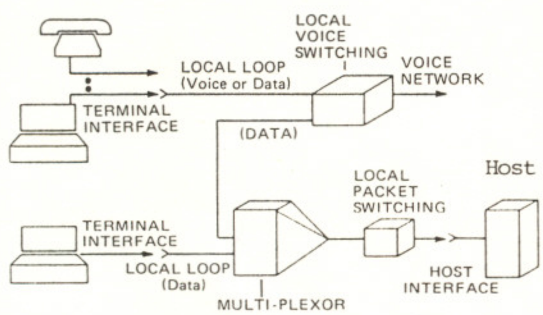

Figure 1: LADT ARCHITECTURE

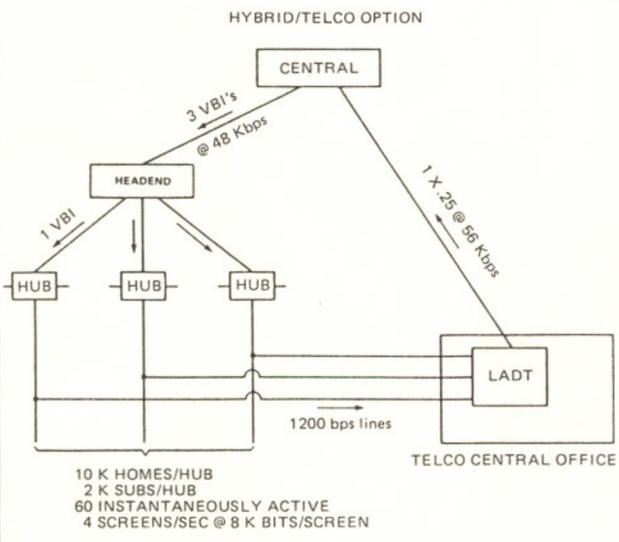

Figure 2: HYBRID/TELCO OPTION

DATA LOADING

	From Home	To Home
TOTAL USERS	100K	100K
ANNUAL USAGE PER USER (HRS.)	90	90
ANNUAL HOURS (HRS.)	5840	5840
PERCENT ACTIVE.	1.5	1.5
PEAK TO AVERAGE	2.0	2.0
PEAK USERS	3000	3000
RESPONSES/SECOND	1/15	1/15
BITS/RESPONSE.	100	8000
TOTAL DATA RATE	20 Kbps	1600 Kbps
RATE/ACTIVE USER	6.67 bps	533.3 bps

Table 1: DATA LOADING

VIDEOTEX TIMING (LOCAL)

Function	Average	99.9%
REQUEST RECEIVED BY FEP . . .	0.10	0.20
REQUEST PROCESSED BY FEP . . .	0.10	0.25
REQUEST PROCESSED BY CPU . . .	0.5	1.5
DATA RETREIVED FROM DISK . . .	0.15	0.30
DATA PROCESSED BY FEP	0.10	0.25
DATA RECEIVED BY TERMINAL . .	0.25	0.75
HT LOADING/PROCESSING	0.10	0.15
TOTAL	1.30 SEC.	3.40 SEC.

Table 2: VIDEOTEX TIMING (LOCAL)

GATEWAY VIDEOTEX TIMING

Function	Average	99.9%
REQUEST RECEIVED FEP	0.10	0.2
REQUEST PROCESSED BY FEP	0.10	0.25
REQUEST PROCESSED BY CPU	0.5	1.5
GATEWAY PROCESSED BY BEP	0.1	0.3
TRANSMITTED TO REMOTE	0.10	0.25
REQUEST PROCESSED BY FEP	0.1	0.25
REMOTE PROCESSED BY CPU	1.0	2.0
RETURNED PROCESSED FEP	0.1	0.25
TRANSMIT TO CENTRAL	0.3	0.75
PROCESSED BY BEP	0.10	0.3
PASSED TO FEP BY CPS	0.10	0.2
FEP PROCESSED	0.10	0.2
DATA TRANSMITTED	0.35	0.75
HT LOAD/PROCESS	0.1	0.2
TOTAL	3.15 SEC.	7.40 SEC.

Table 3: GATEWAY VIDEOTEX TIMING