VIDEOTEX ON TWO-WAY CABLE TELEVISION SYSTEMS - SOME TECHNICAL CONSIDERSTIONS

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ABSTRACT

An interactive videotex system for two-way cable television is technically feasible today. This discussion focuses on characteristics of cable television systems that influence their performance as data networks and data communications concepts as they apply to this use of cable. It is intended for those considering the merging of the two technologies. Network topology, signaling, and protocols are covered in the cable TV context.

INTRODUCTION

Today's cable television systems technology is capable of providing much more than improved reception and additional channels of TV. A number of experiments on two-way interactive CATV services have been underway since the mid 1970's. The Viewdata and Teletext concepts have been under development for a decade. Combining cable TV and videotex into a fully interactive two-way data communications link for consumers and small businesses is a logical next step in the progression of both technologies.

The gap between what can be and what is on cable TV is mainly the result of economic factors. Until recently cable operators, equipment manufacturers and others evaluating the business were not convinced that an investment in advanced systems would pay off. This is changing.

A number of factors are combining to motivate the cable television industry to use the two-way capabilities required by the FCC since 1972.

- Home Box Office and other premium offerings distributed by satellite have made cable TV attractive to urban and suburban dwellers.
- Cable operators have promised to provide two-way services in their proposals to help win franchises.
- The number of personal computers is increasing rapidly along with public sophistication about computers and computing.
- Social factors such as the increase of two-income families and the perception of the home as a refuge from the stress of modern life make an interactive communication capability in the home attractive to the consumer.
- QUBE and some other experiments have proven that it is technically possible to provide a variety of two-way services on cable.
- The utility of the telephone for data communications in the home is limited by the certainty of increased cost for telephone service in the future and the reluctance of consumers to tie up their phones for long periods of time while they access data services.
- Cable operators want the additional revenue that provision of new services will bring.

Consequently, establishing low cost, reliable data channels has become a high priority goal for multiple systems operators (MSOs), cable TV equipment manufacturers, communications and computer companies, and potential service providers. Videotex is a very attractive vehicle for many of the proposed services, therefore, an optimal adaptation of this technology to the cable TV environment is needed.

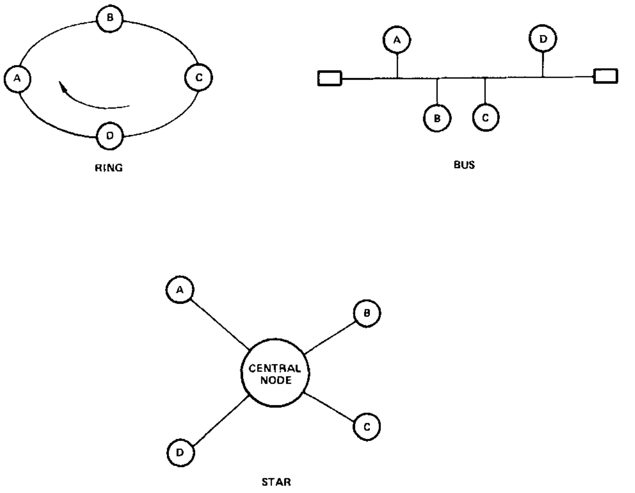
The exact nature of this optimal adaptation is not yet clear. The existing interactive offerings provide a rather limited degree of interaction. QUBE, for example, can support a tree search of a videotex database with its "multiple choice" buttons, but its response is slow and the upstream channel is limited to a few characters at a time.

A genuine two-way interactive system must provide the means to send as well as to receive lines of text. For subscribers to realize the full potential of consumer data services on cable TV they need something rivaling the performance of the acoustically coupled telephone modems sold in computer stores for about $175. I will focus on that level of capability in this paper. I am convinced that anything less between the subscriber and the host computer is not enough to make two-way videotex on cable a viable service offering in the long run.

First, I will describe the physical aspects of CATV Systems - their topology and electrical characteristics. Next, I will discuss ways of transmitting data signals in the CATV environment. Finally, I will briefly explain the concept of communications protocols and describe two types of protocol that can be used in these systems.

PHYSICAL CHARACTERISTS

In general, there are three types of communications network topology.[1] They are the ring, the bus, and the star. They are illustrated in Figure 1. A single point-to-point line can be classified as a special case of the bus or star. The common elements of all three are a transmission medium, two or more nodes or stations communicating over the medium, and a set of rules for interchanging information called a protocol. The medium can be wire, optical fiber, radio or even pneumatic tubes. The nodes can be data terminals, voice terminals, host computers, or any other device capable of sending and/or receiving signals. While a particular configuration may favor a particular type of traffic, in principle, any type of traffic could be carried on any of the three.



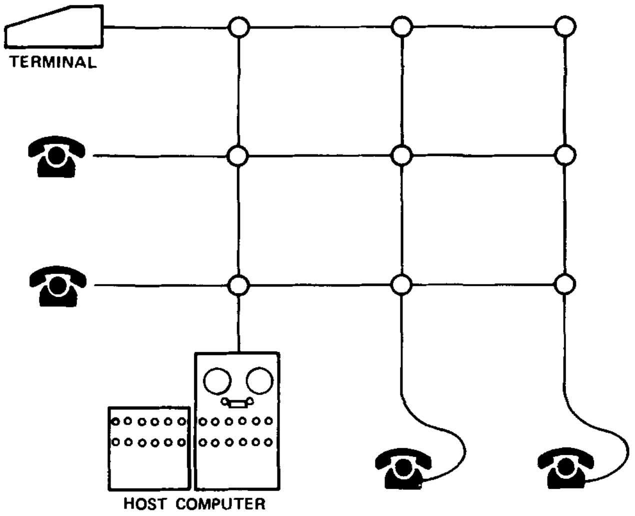
1. Three Types of Data Networks

All traffic on a ring network travels in one direction. If A wants to send a message to C, it must first be received by B and then relayed to C. One function of a protocol is to indicate how a station can recognize a message intended for it since each station on the ring sees all messages. Usually a ring is designed so that a message started by A will go all the way around the ring and finally return to A for removal. This way A knows its message got all the way around the ring. The ring works fine as long as all the stations are working properly, but, since each station is an active repeater, when a station fails, the ring is broken until the failed station is located and repaired or bypassed.

On a bus network each station is a passive listener. When A sends its message to C it travels along the bus in both directions. All stations hear the message and, again due to a protocol, C can recognize that the message is intended for it. C copies the message and acts on it, the others recognize that the message is not for them and ignore it. This configuration is somewhat similar to a CATV system in that all stations hear all messages. The difference is that a bus has no central node. All nodes have equal access to all other nodes. A CATV system is more properly considered as a type of star network.

In a star network A's message to C first goes to a central node and then from the central node to C. In one class of star network the central node contains a switching system that connects A's line directly to C's. This is called circuit switching. The public switched telephone system is the prime example of a circuit switched star network. In the other class of star network, all messages from the stations go to the central node, and all messages leaving the central node are broadcast to all stations in the star. This is exactly what happens in a two-way cable TV data link system.

In a switched system like the telephone network there is a direct, exclusive physical connection between two stations for the duration of their communication. A schematic of a switched system is shown in Figure 2. Any subscriber can connect to any other subscriber by joining lines together with switches represented here by circles at the intersections. Whole hierarchies of switches exist permitting worldwide connectivity. Most technical considerations for implementing a data communications system on a cable TV network stem from the fact that it is not a switched system.

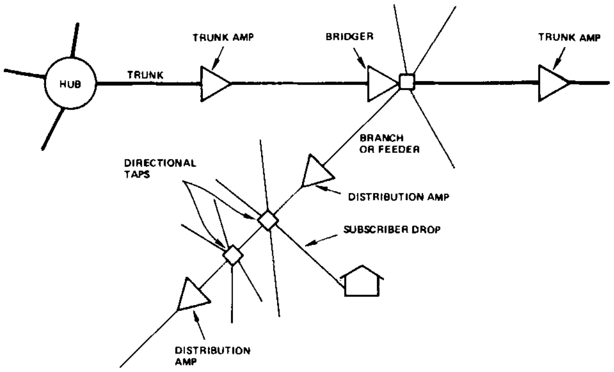


2. A Switched System

The central node of the CATV star is the head end or hub. The lines radiating from the hub are called trunks. The trunks are not single lines but complex systems in their own right. Amplifiers are placed at intervals along the trunks to maintain signal levels. Since attenuation is greater at higher frequencies, and since the signal level varies with changes in temperature, the amplifiers are equipped to compensate for these factors. There is a limit to the number of amplifiers that can follow one another along a given path and this number decreases as the system bandwidth increases. The permissible distance between amplifiers also decreases as bandwidth increases.[2] In a 400 MHz system the maximum length of cable is about 4 or 5 miles. Systems covering areas of larger radius must have multiple hubs connected by "supertrunks."

This length limit has an important implication for data communications. The time it takes for a message to travel from the outermost user terminal to the hub is determined by the distance from the hub. This delay influences the performance of a data link and is an important consideration in the design of protocols. In a 400 MHz cable system this delay is held to a reasonable upper bound. In systems of lower bandwidth the delay can severly limit performance and may even prevent many older systems from being used for two-way interactive services even if they are equipped with return channels. More will be said about the effects of delay in the section on protocols.

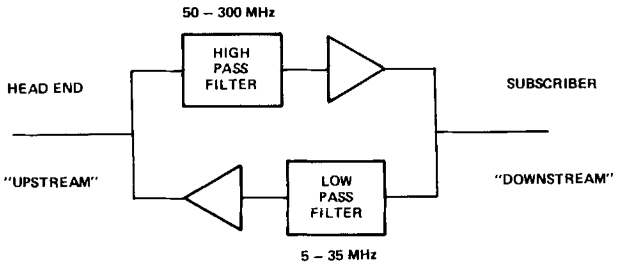
Amplifiers located at points where branches leave the trunks are called bridgers. In some systems the bridgers are equipped with remote controlled switches so a technician at the hub can isolate sections of a trunk, bridger by bridger, to find a source of interference or other fault. The signal level on a feeder is maintained by distribution amplifiers. Groups of subscriber drops are connected to taps inserted along the feeders between amplifiers. Figure 3 is a schematic representation of a trunk line and feeder segment.



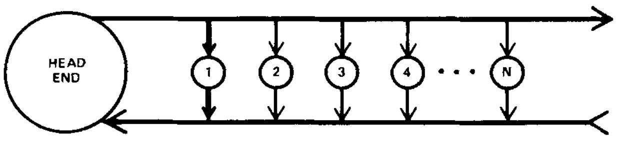
3. Schematic of Trunk Line and Feeder Segment

What we have then is a one to many structure with a hierarchy of nodes ranging from a main hub/head-end at the top followed by subhubs, trunk ends, bridgers, distribution points and subscriber drops. There is a natural division into physical subgroups. The subgroups can be treated as logically separate systems for data communications purposes and assigned dedicated controllers. This way a system can gradually grow larger as demand for service increases. Moreover, many relatively inexpensive devices can take the place of a large high performance processor.

The return channel is implemented by assigning part of the band to upstream traffic. The band is split by filters in each amplifier housing (Figure 4). Then two seperate amplifier modules send their portion of the band along the cable in the appropriate direction. The taps that couple signals into the subscriber drops are directional taps designed to pass signals only from the head-end to the individual drop and back. One drop cannot communicate directly with another. An upstream and a downstream channel are paired so the signal path can be represented schematically by Figure 5, with each station receiving on the downstream line and sending on the upstream line. A processor located at the head-end can control all communications or the head-end can simply retransmit what it receives on the upstream channel back out on the downstream channel. If that happens every user receives what any user sends after a delay proportional to its distance from the hub. The former case is centralized control and the latter distributed control. Both of these broad classes of control will be discussed further in the protocol section.



4. Basic Amplifier System for Two-Way CATV (Backfeeding)



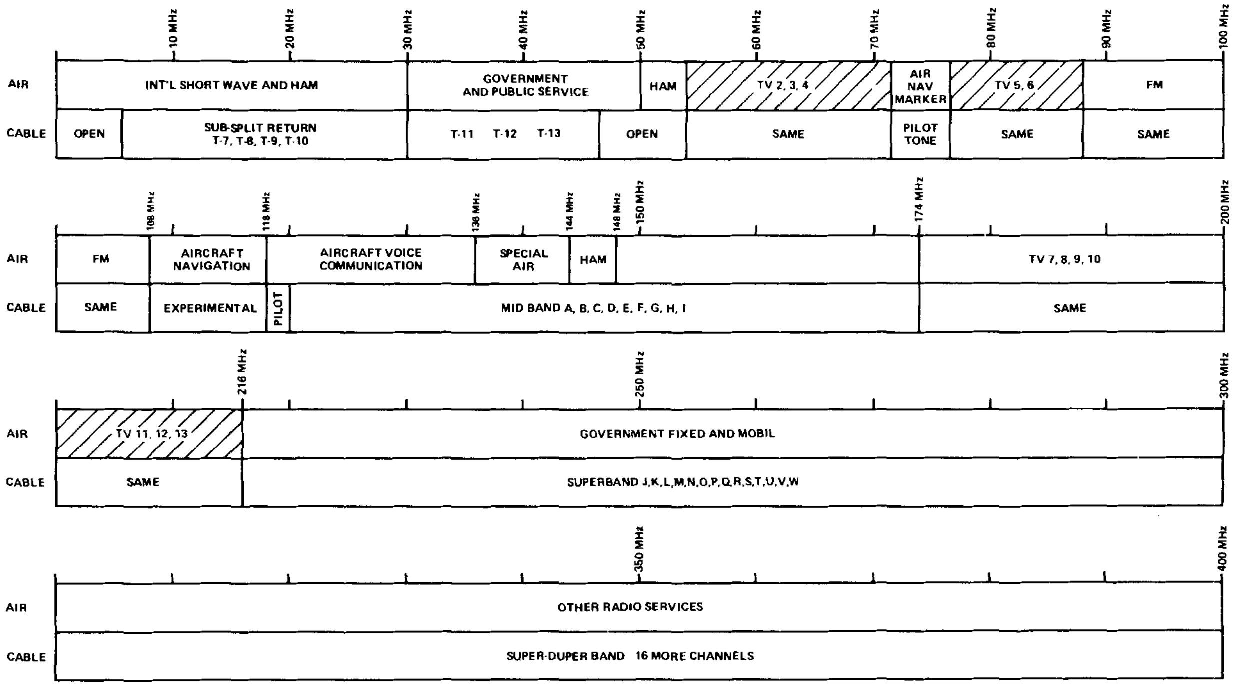
5. Two Way Signal Path

Each subscriber contributes a small amount of noise to the upstream channel resulting in a large amount of noise at the trunk end. When this is added to the noise from other sources on and off the cable, the return channel can be quite noisy. It is essential to keep noise ingress down to a minimum on a two way system through proper maintenance of lines, connectors and terminations. Even with proper maintenance the noise accumulation may interfere with upstream data transmission. One way to limit the effect of noise buildup is to switch off all but one bridger at a time on a trunk, permit access only to those users on that branch group during that time, then go on to the next group and so on in cycles. Another solution is to place active repeaters at each bridger to reconstitute the data signal before the noise can overwhelm it. The bridger switching method is slow and the repeater scheme is expensive. If the return data rate is sufficiently low so that a bit interval is long relative to the period of the noise, it may be possible to tolerate the ambient noise of the system. One other step that can be taken to reduce noise ingress is to block the return path from subscribers not set up for two-way data with inexpensive line filters.

BANDWIDTH AND CHANNELS

In the United States, a television channel - picture and sound - occupies 6 MHz of bandwidth. This number was chosen in the early days of television development and reflects the tradeoff between picture definition, spectrum availability, and the state-of-the-art of electronics at that time. There will probably be a wider bandwidth channel assignment set up in the near future to accommodate high definition television (definition is a function of bandwidth), but the 6 MHz slots will continue to be the basic divisions.

The cable spectrum runs from 5 MHz to about 400 MHz. Most older systems stop at around 220 MHz with 12 to 24 channels. The newest wideband systems have as many as 58 channels. Even more are possible by going beyond 400 MHz. At higher frequencies, however, distortion and other problems increase, so channels beyond the 58th are usually put on a second cable. A chart of the spectrum from 5 MHz to 400 MHz is shown in Figure 6. The lower half of each segment shows the assignments on the cable and the upper half shows some of the transmissions that are "on the air" at those same frequencies.



6. The CATV Spectrum

Channels T-7 through T-10 are used for upstream transmission in what is called a subsplit. The other three channels in the T group are attenuated by the filters separating the upstream from the downstream channels and are not suitable for video. T-11 can possibly be used for data. In some cases a midsplit is used. Here the T group 2-6 and the FM band are used as upstream channels, 7 and up go downstream and A-I are lost due to filter crossover.

A practical data link system will most likely use a total frequency allocation equal to one or more 6 MHz channels in each direction. Given such an allocation one can assume that anything done within the allocated channels is acceptable as long as it will not interfere with the other channels in the system. The choice for allocation within the 6 MHz band is between a single high-speed channel with sufficient guardbands, two or three channels of about 1 Mb/s each or many slower channels with frequency agile tuners at subscriber terminals able to tune to the least active available channel upon starting a session. The ultimate choice will be a tradeoff between system performance and hardware cost.

Cox Cable Company has chosen a multiple low speed channel approach for their INDAX system. They divide the main channel into a number of slots 300 kHz wide with a 28 kb/s signaling channel in each slot. This arrangement can be built at low cost because a low-speed microprocessor can be used as a communication controller along with other parts made in large quantities for other consumer applications. Faster signaling demands higher performance components.

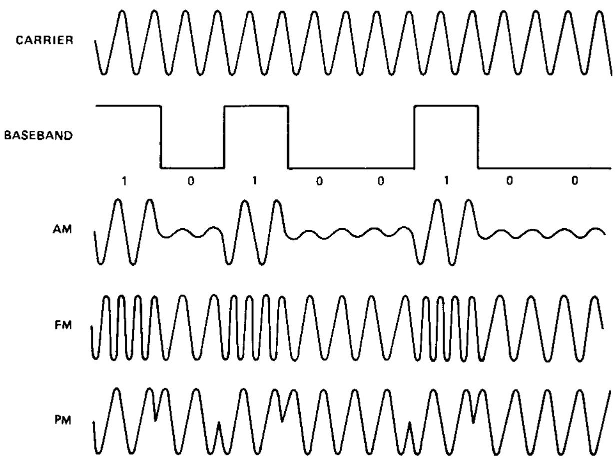
DIGITAL SIGNALING

Morse code represents all characters of the alphabet with three symbols - dot, dash and space. Similarly a digital code represents all information by combinations of two distinct states- "on" and "off" or 1 and 0. Therefore, a digital system need only recognize two distinct levels. An analog system, in contrast, is required to reproduce a continuous range of levels. Thus, a television signal is made up of a rapidly changing voltage or current where the signal varies in proportion to the picture brightness. The latter task is more vulnerable to distortion than the former. So, in a given channel, it is easier to transmit digital information.

A digital pulse train will travel along a wire, as will an analog signal, for a limited distance without distortion. Signals must be modulated for longer distances, for combining many independent signals on a wideband cable, or for radio transmission. The popular buzzword MODEM refers to a device that performs MOdulation and DEModulation.

There are three basic types of modulation- amplitude (AM), frequency (FM), and phase (PM). All methods work by modifying a characteristic of a single frequency carrier [Figure 7(a)] in response to changes in an information bearing signal called the baseband signal [Figure 7(b)]. The examples in Figure 7 illustrate the digital case. The analog case is the same in principle, but intermediate values are represented as well as the maximum and minimum.

In amplitude modulation [Figure 7(c)] the peak to peak value, or amplitude, of the carrier is altered in response to the baseband. Binary 1 is maximum and binary 0 minimum. In frequency modulation [Figure 7(d)], binary 1 is twice the frequency of binary 0. This is indicated by the larger number of transitions of the carrier under the ones in the figure. Finally, in phase modulation [Fgure 7(e)], the order of occurrence of the swings of the carrier is altered.



7. Types of Modulation

A variety of techniques combining phase and amplitude modulation are used in the digital radio equipment intended for high capacity microwave transmission applications and in high-performance telephone modems. These schemes permit data rates greater than the frequency rate of the carrier. This is referred to as getting more than 1 bit/Hz. Some day it will be economically feasible to use these techniques in subscriber systems. For now, modems operating at less than 1 bit/Hz will suffice. They can be produced, in quantity, in a price range that a consumer can afford. Bandwidth, which from a data communications point of view is cheap on cable, is traded for modem complexity.

The most common modulation technique for low-cost data modems is frequency shift keying (FSK). It is a form of FM where the carrier is always at either one of two distinct frequencies. The 300 bit/s modems that attach to a telephone handset use FSK. FSK can be implemented with simple circuits and performs well in a noisy environment. AM can also be implemented inexpensively, but it suffers more from noisy line conditions. A noise burst can easily be interpreted as a transition from low to high amplitude.

A cable TV data modem should do the following:

1. Receive a modulated carrier from the cable at one or more frequencies.
2. Detect the modulation and pass the baseband information on as a bit stream.
3. Tell when it is receiving a carrier and indicate that to the terminal.
4. Generate a carrier at one or more frequencies accurately.
5. Accept a baseband bit stream and use it to modulate its carrier.
6. Switch its carrier onto and off the cable when required.

Clearly, operating an end to end digital communications path requires more functions than those performed by the modems at each end. These additional functions are performed by special purpose computer peripherals under control of software. The hardware devices are called communications processors and the software programs are called interfaces and protocols.

PROTOCOLS AND INTERFACES

Webster defines protocol as "A rigid long-established code prescribing complete deference to superior rank and strict adherence to due order of procedure." The connection between this definition of protocol in human interaction and the definition in machine interaction is the phrase "due order of procedure."

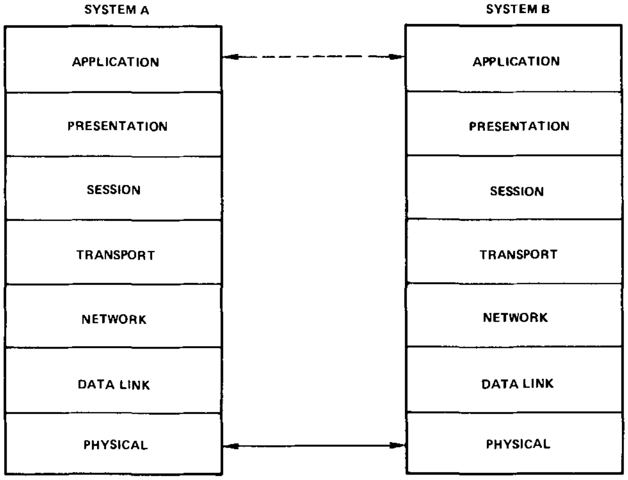
Communication protocols are sets of rules governing information flow in a communication system. Among the specifications included in protocols are:

- Procedures for establishing and altering relationships between devices in a system
- Formats for messages sent in a system
- Means for identifying devices
- Means for allocating permission to transmit among devices sharing a line
- Means for recovery from errors or failures
- Means to control the flow of data when a station is temporarily unable to process more

Protocols and interfaces are functionally similar. Protocol refers to a set of rules for communication between similar devices or processes while interface refers to rules for communication between dissimilar devices and processes. Thus two host computers communicate using a protocol, and a terminal communicates with a host using an interface. The word interface is also used to refer to the physical connections between devices. Cables, connectors and circuits make up the interfaces in this context.

To simplify matching in this world of diversity, the International Standards Organization (ISO) has developed a set of recommendations for interconnection[3] called Open Systems Interconnect (OSI). The OSI model divides systems into seven levels or layers based on functions. If these functional divisions are maintained in the design of a system, and all communications pass through the layers, two systems can interconnect by passing messages between themselves at a matching layer.

The layer concept is illustrated in Figure 8. It shows two independent systems and their seven layer structures. Suppose A is a computer running a program at its application layer that generates a report and it requires some numbers from a database system running as an application on B. Computer A passes its request down through its functional layers using its interfaces. The request is sent to B where it is received and passed up through B's layers. B's application layer gets the requested information and passes it back down in a message to A. The information is eventually passed up to A's application. The application layer can be either an application program, a person using a terminal, a peripheral or a combination of any of the three.



8. ISO OSI Reference Model Applied to Two Systems in Communication

It is beyond the scope of this paper to deal with any but the physical and data link layers in detail. In videotex the definitions of character sets, screen formats, and graphics facilities are specified in the presentation layer as in Bell's "Presentation Level Protocol." The details of the other layers depend on the characteristics of the systems and access media involved. The OSI model is only a recommendation and things do not split neatly into the layers in most real systems. It is still a good design and discussion aid. Some newer protocols such as X.25 have been designed explicitly to follow the recommendation.

The apparent connections between processes at each level are called logical or virtual connections. The passage through the layers is said to be transparent to the communicating layers. Many virtual connections can exist over a single physical circuit. Connecting and disconnecting these virtual circuits is called virtual switching. In a cable TV data system, virtual switching takes the place of the physical switching of the telephone network.

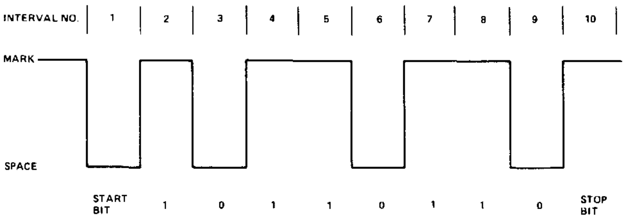
The two layers of protocol needed to transmit data over Cable TV lines are the physical and data link. There are several defined standards for the physical layer. One of them, RS-232, in one of its several variations, can be used for this application. There is no data link standard yet although some are under development.

The function of the physical layer is to send and receive data bits without regard to their format or meaning. The formal specification[4] defines an interface, in the physical sense, between a Data Terminal Equipment (DTE) and a Data Communication Equipment (DCE). DTE is a generalized term for any device that sends and/or receives data. DCE is a generalized term for a modem capable of transmitting bits over a medium. Neither the medium nor the transmission technique is specified.

The specification document for RS-232 is mainly a description of a 25 wire connection between a DTE and a DCE. It defines the electrical and mechanical characteristics of the hardware components of this connection. It also defines the function of each circuit involved and a list of standard groups of these circuits required for some general application cases.

One important distinction among the many variations of RS-232 is whether they are intended for synchronous or asynchronous operation. Adjacent bits are distinguished from each other by their time of occurrence with respect to a time reference or clock. In a synchronous channel the timing information is transmitted along with the data, while on an asynchronous channel each station has its own clock running as close as possible to a specified rate. Thus a synchronous RS-232 is wired with circuits to pass clock signals to and from the DTE.

Asynchronous communication is simpler to implement than synchronous. It is used with most microcomputers and so called "dumb terminals" communicating over the public switched telephone network. It is also known as start/stop communications. Each character is represented by an 8-bit code preceeded by a "start" bit and followed by a "stop" bit (Figure 9). The line is held in the high or mark state between transmissions. When a character is received the "start" bit causes the line to go to the low or space state. The receiver recognizes the transition as the start of a bit and sets the local clock to sample the line at the center of each bit interval. If the transition is due to noise, the line will be high at the sampling instant and the receiver will reset itself. If the transition is a real start bit, the line will still be low and the receiver will sample the next 8 bit intervals, and store the results in a memory or buffer. At least one interval of mark, the "stop" bit indicates the end of a character. The process starts over when the line goes low again at the next "start" bit.



9. Asynchronous Data Representation for One Character

The same version of asynchronous RS-232 used to couple low cost telephone modems to terminals will serve as the physical level for connecting videotex decoders, terminals, and microcomputers to a cable TV modem. To accommodate terminals without their own microprocessor, a microprocessor based communications processor will be included with a modem and tuner in a typical cable data converter. The data converter may also be included in special versions of addressable cable TV converters as a single package sharing a common power supply, microprocessor, and other components. Both of these converters will also have a read only memory programmed with the cable TV data link protocol that will control its interactions with the rest of the system.

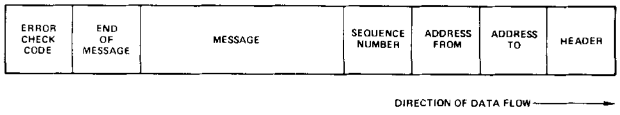
The task of the data link layer is to take a raw transmission facility and turn it into a reliable line that can move data from one location to another. Part of this task is formatting raw data in the form of bits into units suitable for transmission. A second part of the task is to verify successful receipt of data. In a cable TV environment the data link layer must also set up and maintain a virtual circuit between two communicating devices since the physical circuit is shared by all stations on the network.

A user dialing into a host computer on the telephone has exclusive use of a line during the session. The data link protocol degenerates to almost nothing in this case and is often considered part of the physical layer. In a typical dial-up videotex terminal, the unit of transmission is the single start/stop character of Figure 9. Upon each keystroke the selected character is sent to the modem. It travels over the line to the host where it is stored in a buffer. The host also sends the character back on the return channel (echo). This echoed character is received at the terminal, stored in the display memory and displayed on the screen. When the user hits the carriage return or enter key, the host acts on the data and responds by sending information to the display memory by the same return path. The echo serves as verification of successful receipt at the host.

The data link level on cable must get the data to the right place at the right time. This is a virtual switching task. Getting data to the right place is accomplished by assigning a unique address to each station. A message is sent to a particular station by attaching the station's address to the message. The address of the sending station can be included also if the message could have come from more than one place. Each unit on the network checks all messages and copies those that have been addressed to it.

Allocation of transmission time to insure that only one valid message is on the line at a time is the function of an access scheme. Polling and contention are two types of access schemes that are being applied to cable TV videotex systems. It is beyond the scope of this paper to evaluate the relative merits of the two. The right choice in any instance depends on the goals of the system designers.

The unit of data transmission in both polling and contention is a block of characters rather than a single character. Figure 10 is a representative message format. The block is divided into fields. The header is a control character or group of characters that unambiguously indicates the start of a block. The two address fields identify the destination and source of the block.



10. Typical Message Format

The sequence number permits detection of the loss of a block from a series of blocks that belong together. The receipt of each block is verified by an acknowledge message (ACK) from the receiver back to the sender. If a block is missing from a sequence or arrives in a damaged condition, a not acknowledged message (NACK) is sent instead and the block is retransmitted. Each block is saved in a buffer at the sending station until it is acknowledged, and its buffer space can be safely rewritten with a new block.

The message field holds the actual data that is being transferred. In this case it is delimited by an "end of message" control character. Fields in a format can be delimited by control characters or by character count. In the later case, a character count field will be located ahead of the message field.

Error check codes of various types are used to determine if an error occurred during transmission. Some error coding methods can correct errors; others only detect them. If an error is detected a NACK can be returned and the erroneous message retransmitted.

In polling, a central processor controls all access to the line. In its most elementary form, role call polling, the processor goes through a list of all stations in a system and sends each station a polling message. If the polled station has something to send in its buffer, it sends it. If not, it sends a message indicating it has nothing to send. Even if no data is sent, each transaction takes an interval of time equal to the sum of the duration of the polling message, the time it takes to reach the polled device (propagation time), the duration of the response, and the propagation time for the response. In a system with a large radius and many terminals the polling cycles are very long. QUBE has a 6s polling cycle in the Columbus system. This may not seem like much, but it can be painfully slow to someone searching a large tree structured videotex database or reading a multipage electronic message.

Polling can be speeded up dramatically by only polling those terminals that are actually in use. Newly active stations can be brought on line by issuing a "free poll" once or twice in each cycle and adding the newcomers address to the roll call list. Terminals logging off are removed from the list.

Further improvement is possible by taking advantage of the fact that most of the users on line at any instant are not sending or receiving data; they are typing or reading. Group or generalized polling[5] only polls those terminals that have something to send. The users are divided into groups based on the digits of their addresses. The polling processor polls each group. If a station in that group wants to send, it transmitts a burst of carrier or other signal. The processor responds by polling a subgroup of that group and listening for a reply. If there is none, it polls a second subgroup and so on until it isolates the requesting station. The process continues until all terminals ready to send in that cycle have been polled and then a new cycle begins. The statistics of terminal use are such that the number of steps in each cycle will be much less than in rollcall polling.

In contention, all stations on a network compete on an equal basis for the right to transmit. The entire channel capacity is available to all users, and, usually, any user can send a message directly to any other user. When two or more users attempt to transmit at the same time it is called a collision. Upon detection of a collision each user involved waits for a randomly determined interval and retransmits.

There are four types of contention. In the first type, called Aloha, users transmit at will. Receivers can recognize overlapping messages so, upon collision, no acknowledgments are sent. The transmitting stations, hearing no reply within a predetermined time, wait for an additional short interval and try again. The short interval is different at each station so the likelihood of a second collision is small. This form of contention can achieve 18% efficiency. It was originally intended to be under control of a central processor but works in a distributed environment as well.

Slotted Aloha is an improved version of Aloha. All stations are synchronized to conform to intervals or slots of time. A transmission can begin only at the beginning of a slot so, if a collision occurs, one slot is lost. Without the slots the beginning of one message could collide with the end of another causing the loss of nearly twice as much time. By limiting the time lost per collision, slotted Aloha can be 37% efficient. Keeping the stations synchronized requires a central clock controller, and if the stations are at various distances from the control clock, maintaining sync is impossible.

In Listen-before-talk or Carrier Sense Multiple Access (CSMA) each station listens to the return line and sends only when the line is quiet. Collisions do occur, however, because there is a finite propagation time. When the line appears quiet there may be another message coming up the line that will collide with the one just sent. For long messages this method achieves 90% efficiency.

The ultimate contention scheme is Listen-while-talk or Carrier Sense Multiple Access with Collision Detection (CSMA-CD). Here a station that is transmitting continues to listen to the return line. It can recognize its own message, so if it hears anything else, it knows a collision has occurred and it stops sending instantly. The time wasted by unsuccessful transmissions is kept to an absolute minimum. This method can reach an efficiency of 95%.

CSMA and CSMA-CD are particularly sensitive to the size of a system. If two stations start transmitting at the same time their transmissions must reach each other before they detect a collision, stop sending, and free the line. Because a cable TV system is a star its area of coverage increases with the square of its radius. Thus, the average round trip delay is weighted towards the maximum delay.

If the round trip delay is small compared to the duration of the message, the time a message is exposed to the possibility of a collision is small. That is why these systems favor long messages. The minimum delay to message ratio for good performance is about 5%.[6] The maximum message length must be set to break very long transmissions into smaller units to prevent stations with a lot of data to send from dominating the system.

CONCLUSIONS

In summary, all the technical elements for setting up high performance videotex links on cable TV systems are available. Two-way capability is well understood and already in place in many areas. Consumer grade integrated circuits and discrete components are on the market for all the necessary hardware functions. Low-cost microprocessors have sufficient power to handle the protocols. What remains is the task of combining these elements into a reliable, economical system. Now is the time to experiment to determine the right combination of components; attractive and useful information offerings; and managerial skills required to operate a consumer-oriented data service that will compete successfully in the coming information marketplace.

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