INTER BRIDGER TRUNKING
FOR
INFORMATION SERVICES

Robert R. Brown Jr.

Cima Telephone and Television

ABSTRACT

The challenge of CATV interactive services may require a new plant topology. A circuit switching network that bypasses the headend for information flow, while using the existing tree structure of CATV plant for supervision and control, is proposed.

The method involves the installation of a "dumb" switching node at each bridger and interconnecting these nodes within a hexagonal mesh overlaying the city. The node will route signalling upstream to a supervisor in the headend. The supervisor will activate nodes downstream according to a routing algorithm. In this fashion subscriber terminal information from one bridger can be trunked through the mesh to a subscriber terminal off another bridger.

Introduction

The techniques used to develop this network were originally derived as a method to interconnect several remote telephones with a single cable pair. Two minima problems, minimum spanning and Steiner's Problem, were studied. Minimum spanning offered the most economical path between points, but Steiner's solution suggested adding additional points for further economy. The geometry of Steiner's solution, with its many 120 degree angles and tree forming a nearly hexagonal structure, could conform to a routing arithmetic. Demand for not only two way, but point to point wideband communication on CATV plant makes some form of switching network prime for consideration. A brief look at some general properties of telephone and CATV plant will show the kinds of communication available now.

Sharing subscriber communications from each bridger station into a distributed coaxial switching network can be accomplished now. While numerical analysis of traffic loading is beyond the scope of this work, the proposed network has sufficient flexibility and bandwidth to outperform present CATV plant.

Communication

First we must define what is meant by communication. There must be a source of information, a sink for information, and a path to transfer the information from source to sink. This simple process, illustrated in figure one, becomes the objective of the proposed network.

FIG. I

The Desired Communication

Demand for new services has resulted in video, computer, teletype, and alarm information, among others, sharing spectrum with home entertainment on CATV plant. Some of these new services are point to point communication - a single source wishing to transfer a block of information to a single sink. This information could be private and some means must be provided that only the desired sink receives the information. The reverse can also be true, some sinks only wish to receive information intended for them.

When sources or sinks are computer terminals, large bandwidth is required for timely transfer. The standard TV channel has large amounts of information when compared to other forms of communication such as voice. The paths for these new services must be able to pass this information. Up to circuit limits, increasing the signal to noise ratio of a channel will allow more information to pass in a given time. However, large blocks of information required for video or computers ultimately require large bandwidth for efficient operation. Another kind of communication, between computers, requires a large block of information to be transferred in a short time with only an acknowledgement of reception in return.

Suitable plant should provide short duration, high band width, one way, secure point to point communication with provision for acknowledgement in return. Given this kind of communication, what options are now available to the average industrial consumer, or experimental user? Two large communication networks, telephone and cable television, already have much of the country wired.

Telephone Plant

Basically a multicenter multistar network, telephone plant provides two way point to point communication. Several subscribers are connected by separate cable pairs to a central switching office, the configuration resembling a star.

Important parts of the communication or call, are supervision, signalling, and information. These parts are not isolated. Going off hook, a supervisory signal to the switching center, starts the call. The dial tone signal informs the subscriber as to the progress of the call. The subscriber responds by dialing a control signal which some offices store in a register. The switching center uses the address in the register to connect the calling and called cable pairs. Finally the called subscriber hears the ringing signal, answers the phone and the talk path is completed.

The communication involves a single source to a single sink along a temporarily dedicated path within the central office. The connection is two way, or full duplex, the dedicated path providing a margin of security. When calls are made to subscribers not serviced by an originating office, interoffice trunks are used. When required interoffice trunks are busy, calls are routed to higher offices in the hierarchy until a connection can be made. This alternate routing provides great flexibility.

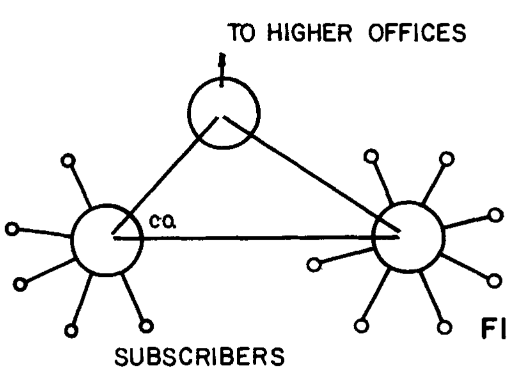


FIG. 2

While quite versatile in forming a great number of paths the star arrangement has drawbacks. A call to a subscriber across the street can require the use of several miles of cable to the central office and back to the called subscriber. To conserve this excessive use of cable, multiplexing, time or frequency division, can be used on a link to the central office. A method named concentrating relies on the property that most lines are idle much of the time and a few links to the central office can service several subscriber lines with a remote switch as shown in figure three.

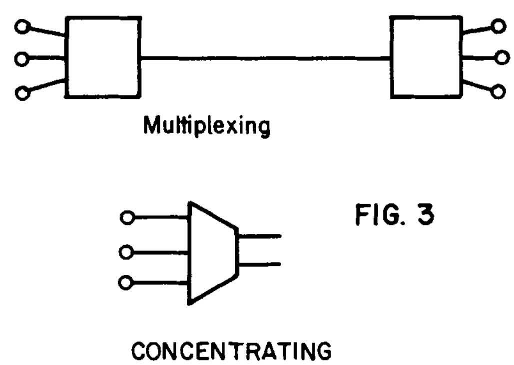


FIG. 3

Another drawback, bandwidth of the subscriber line is small. For a fee, the line can be conditioned to provide greater bandwidth but nowhere near the six megahertz required for a standard television channel. Cost presently prohibits the installation of large bandwidth cable for subscriber lines. Telephone plant with its inherent switching has the versatility required for point to point data communication but is lacking in bandwidth.

CATV Plant

Basically a tree network, CATV plant provides one way single source to multisink communication. The reverse path provides multisource to a single sink communication. Examples of these communications would be a baseball game on the forward path to homes. On the reverse path, home security alarm information would be sent to a common point in the headend.

The outside plant has trunklines for information to reach an area, feeder lines that bridge off trunklines to cover an area, and subscriber drops for the final connection on the forward path. Each of these lines has their own character or properties. The transition from one part of plant to another crosses a network boundary.

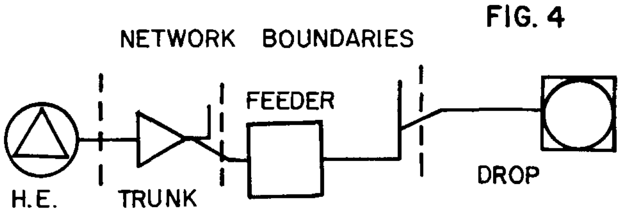


FIG. 4

Typical plant has headend switching for source or program material but no provision for subscriber point to point communication. A subscriber can originate a message to the headend on a given channel by sharing total upstream plant for brief intervals. By selectively energizing a premium addressable tap downstream, a message can be routed to a single subscriber and blocked to all other subscribers. Thus, by using total physical plant for brief intervals point to point communication is possible.

Bandwidth is large, anywhere from two to four hundred megahertz systems can be found. Bandwidth in any part of the plant is typically the same. CATV plant has the necessary bandwidth for point to point data communication but is wasteful by sharing all cable for each communication.

What Kind of Plant?

Starting from basics, it is desirable that every subscriber have the possibility of communicating with any other subscriber. Direct paths between all subscribers would be physically impossible. Routing individual subscriber coaxial cables to a central switching office is physically impractical.

For switching schemes that route messages through the headend-trunk boundary, total plant is tied up for the duration of the communication. This sharing of plant would be impractical for large systems with heavy traffic requirements. If traffic demands are small, sharing the headend-trunk boundary would be an efficient use of plant.

In CATV plant the trunk-feeder boundary concentrates several subscribers to a common point, it also distributes from a common point to several subscribers. The proposed network would pickoff and insert messages at the trunk-feeder boundary. Contention onto the network could be resolved with a polling scheme. Addressable premium taps and addressable terminals could be used as security to prevent "bridgercasting." Using this boundary minimizes shared plant per call while still taking advantage of already having the subscriber connected.

Setting the constraint for an information network interconnect at the CATV trunk-feeder boundary, what form should it take? Given tree, mesh, and star networks the mesh will be investigated here.

There are three regular tiling patterns in the plane, triangle, hexagon, and square. To create a switching mesh each of these would have their vertices assigned to irregularly located bridger stations and their edges deformed to accommodate a primarily rectangular street grid. Of these, the hexagon would use the least cable to connect all stations. This occurs because the triangle mesh requires six edges per vertex, the square would require four, and the hexagon only three.

Every bridger will have a switching node assigned to its location. These nodes will be interconnected with trunks forming a hexagonal mesh. Information from a subscriber will bypass CATV trunk, enter the node, travel through the mesh, be upconverted to enter a bridger, and finally reach a subscriber. The communication will be controlled and supervised from the headend.

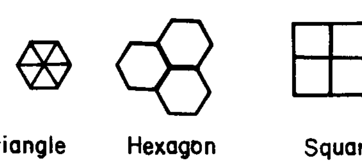


FIG. 5

Sample Communication

The speed with which a call takes place requires the user to assemble all information into a device and let the call proceed automatically. The standards by which terminal equipment access a network are outside the scope of this paper. The more the headend supervisor conforms to preferred standards the less equipment the system operator will have in the home to maintain.

Assume the subscriber has an information send/receiver. The sender would transmit both signal and message information. Likewise the receiver would be required to take in both signal and message information. In figure six, T7 and an arbitrary VHF 2 are standard CATV channels but T10 and VHF 1 need only occupy a narrow part of a standard channel.

Signalling routes through CATV trunk between the headend supervisor and subscriber. Messages remain on the path between subscribers. It is advantageous to look at the network from a signalling and message viewpoint. For subscriber "A" calls subscriber "B", figure seven shows signalling and message paths. The sequence of major events of a call without contention are detailed in Table One.

The headend supervisor connects the node trunks only after source and sink have been confirmed. This prevents unnecessary construction of paths. The method to build paths depends on a routing algorithm.

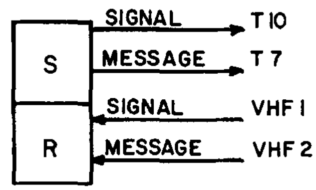


FIG. 6

SUBSCRIBER SEND/RECEIVER

Table One

A node is polled on VHF 3
OFFHOOK ENABLE sent on VHF 1
OFFHOOK ENABLED sent on T10 by A
DIAL TONE sent on VHF 1
A sends address signals on T10
B node is polled on VHF 3
B terminal polled on VHF 1
B sends RECEIVE ENABLED on T10
B addressable tap opened by VHF 4
Required nodes connected by VHF 3
TRANSMIT ENABLE sent on VHF 1
A sends info burst on T7
B receives info burst on VHF 2
Circuit times out
B terminal polled on VHF 1
(N)ACK sent on T10
(N)ACK sent on VHF 1
Call completed

A CALLS B

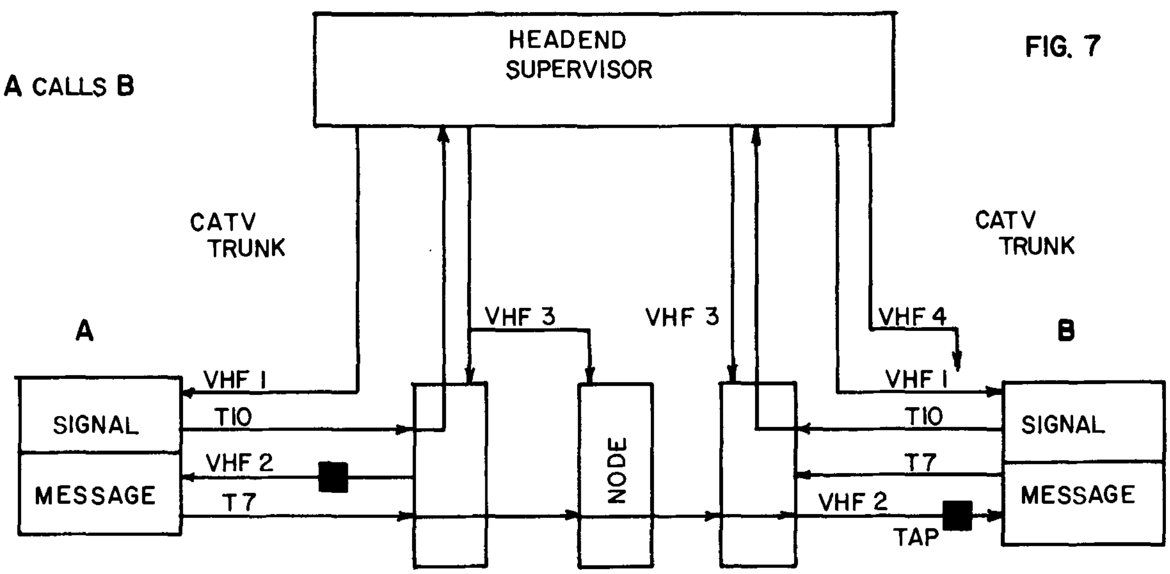


FIG. 7

Vector Space Switching Arrays

Vector space switching arrays assign position vector numbers to equipment located at a vertex. Each trunk connecting equipment becomes a unit edge.

Three unit vectors in the plane, ($\underline{r}0$, $\underline{r}1$, $\underline{r}2$), make it possible to generate paths between any two vertices of the triangular mesh shown in figure five. Creating a path from any calling party A to any called party B resolves the switching problem.

These unit vectors have the properties that their exponents add according to addition modulo three and:

$$\underline{r}0 + \underline{r}1 + \underline{r}2 = 0 \qquad (1)$$

which leads to:

$$-a\underline{r}^{n} = a\underline{r}^{n+1} + a\underline{r}^{n+2} \qquad (2)$$

For n=0, in abbreviated form:

$$(-a, 0, 0) = (0, a, a) \qquad (3)$$

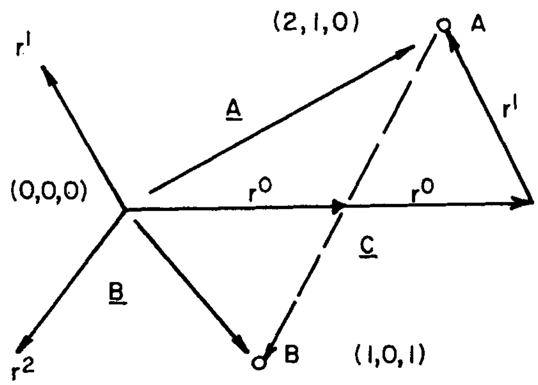


FIG. 8

Assume party A at position (2, 1, 0) wishes to call party B at position (1, 0, 1). The calling path from A is vector $\underline{C}$ such that:

$$\underline{A} + \underline{C} = \underline{B}$$

or,

$$\underline{C} = \underline{B} - \underline{A} \qquad (4)$$

For example,

$$\underline{C} = (1, 0, 1) - (2, 1, 0) \qquad (4)$$

$$\begin{array}{rl} (1, 0, 1) & \\ (0, 2, 2) & (3) \\ \underline{+(1, 0, 1)} & (2) \\ = (2, 2, 4) & \\ & \\ = (0, 0, 2) & (1) \end{array}$$

The calling path must include A, B, and all points necessary to reduce vector $\underline{C}$ to 0. A strategy for generating those points starts with the largest component of $\underline{C}$ in a <u>counterclockwise</u> order. Add a <u>unit</u> of this component to $\underline{A}$ and decrement $\underline{C}$ accordingly. Table Two summarizes this process.

Table Two

A register	C register	Path Node
INPUT $\underline{A}$,		
(2, 1, 0)		(2, 1, 0)
CALCULATE $\underline{C}$,		
	(0, 0, 2)	
ADD LARGEST OF C TO A, DECREMENT C		
(2, 1, 1)	(0, 0, 1)	(1, 0, 0)
ADD LARGEST OF C TO A, DECREMENT C		
(2, 1, 2)	(0, 0, 0)	(1, 0, 1)
STOP, C = 0.		

The unit vectors as defined cannot generate a hexagonal path. Rotating the unit vectors 180 degrees will produce new unit vectors, ($-\underline{r}0$, $-\underline{r}1$, $-\underline{r}2$). Alternating these new unit vectors every other point with the regular unit vectors will produce a hexagonal path. See figure nine.

The path from 0 to A is simply:

$$\underline{r}0 + (-\underline{r}2) = \underline{A}$$

but,

$$-\underline{r}2 = r0 + r1$$

by substitution,

$$\underline{r}0 + (\underline{r}0 + \underline{r}1) = \underline{A}$$

$$2\underline{r}0 + \underline{r}1 = (2, 1, 0) = \underline{A}$$

As all points of a hexagonal unit mesh coincide with points of a triangular unit mesh, all hexagonal points can be expressed with triangular unit vectors.

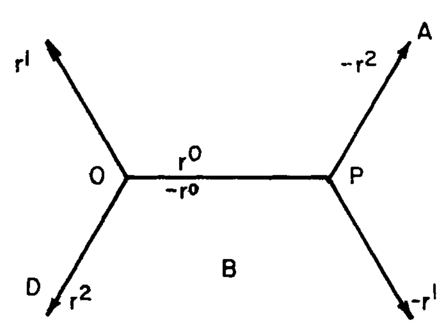


FIG. 9

The routing strategy must be changed to compensate for the negative vectors. Also some vector positions are positive, some negative, and some are omitted from the array. With the origin at (0, 0, 0) and positive, the test for position vector status is:

sum of components	= 0 mod 3	positive
"	= 1 mod 3	negative
"	= 2 mod 3	excluded

The routing algorithm for the headend supervisor is illustrated in figure ten. Table Three summarizes this process for party A calls party D.

Table Three

A register	C register	Path Node
INPUT A,		
(2,1,0)		(2,1,0)
CALCULATE C,		
	(0,1,3)	
A POSITIVE		
ADD LARGEST OF C TO A, DECREMENT C		
(2,1,1,)	(0,1,2)	(1,0,0)
NEGATIVE		
DECREMENT SMALL OF C TO A, SUM C		
(1,1,1)	(1,1,2)	(0,0,0)
POSITIVE		
ADD LARGEST OF C TO A, DECREMENT C		
(1,1,2)	(1,1,1)	(0,0,1)
STOP C = 0		

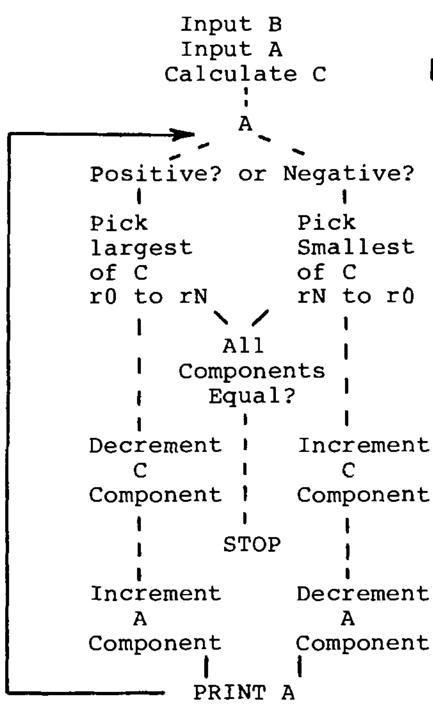


FIG 10

The Node

The node makes connections required for a call. It must provide amplification for line losses and conversion of a reverse path channel to a forward path channel.

On commands from the headend supervisor, a tone decoder selects crosspoints for connection. With reference to figure eleven, only one crosspoint on a horizontal line may be enabled. All vertical lines remain unbroken, passing through the crosspoint.

A local call (involving just one bridger) would go through crosspoints "A" and "C". An interbridger call initiated from this station would go through crosspoint "A" and for example "G". An internode path would involve, for example, crosspoints "D" and "I".

For internode paths that encounter a busy node, the supervisor merely skips forward one component. Two crosspoint connections of a given channel are not possible on the same trunk.

A single channel node was shown; more channels are required for greater capacity.

System Growth

As traffic on the network increases blocking of long calling paths will become a problem.

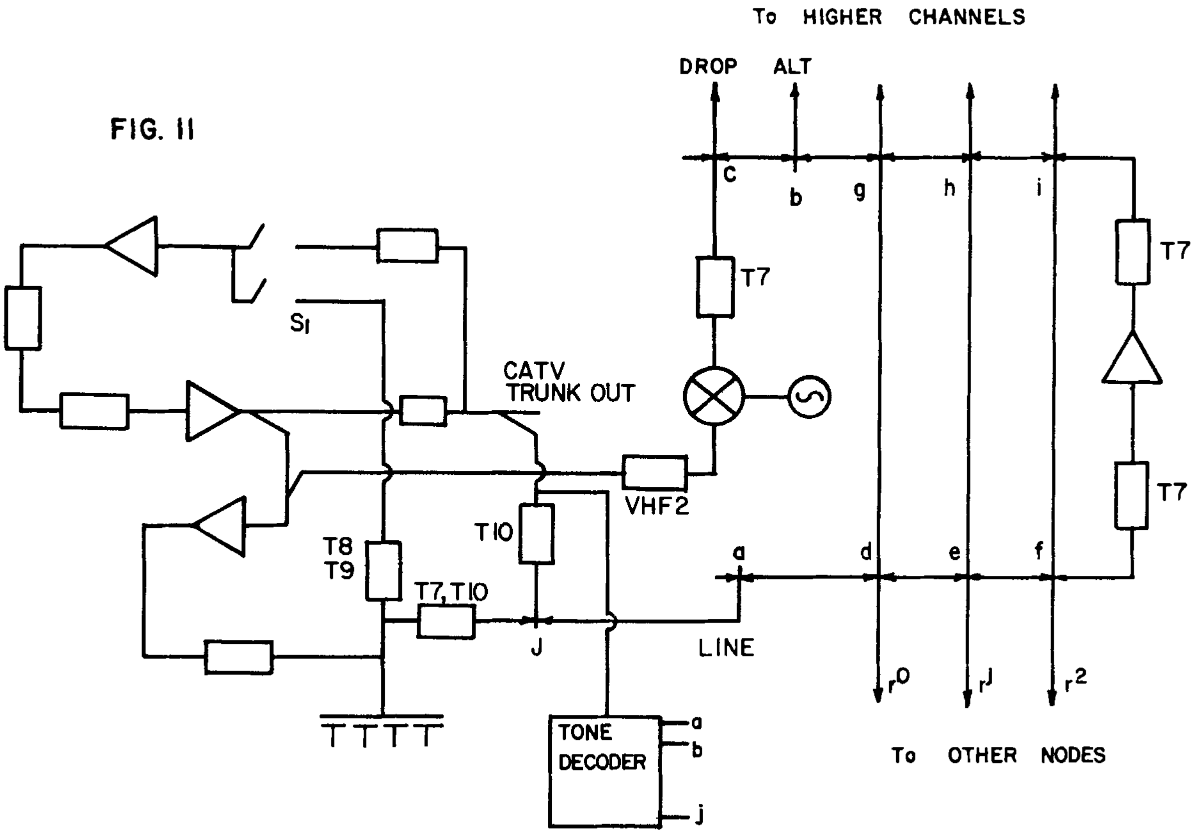
When the mesh was constructed each trunk line could carry more than one channel. The concept of dedicated forward and reverse channels no longer applies. Putting higher channels on the trunk means they all must be able to travel opposite directions. Allowing a 30 megahertz channel spacing makes the single trunk equivalent to eight or ten tiers of trunk.

As channels are added in selected portions of the mesh, a map of the system will start appearing like a honeycomb with hills and valleys.

It is also possible to build dedicated trees on higher tiers of the mesh for high volume, constant path, subscribers. Dedicated drops from these tiers direct to the subscriber will prevent these users from overloading the network.

As the system grows, cascadability will become a problem. Alternate routing outside the mesh will become necessary. The problems are complex enough to require a continuing traffic study and most design by a vendor.

FIG. 11



CONCLUSION

The concept of constructing a hexagonal interbridger trunk mesh appears lucrative. The resulting network can outperform existing CATV plant for point to point wideband communication. The network allows existing CATV plant, technology, and personnel to make the transition to a new communication.

Bibliography

<u>Handbook of Electronic Systems Design</u>
Charles A. Harper

<u>Groups and Their Graphs</u>
Israel Grossman, Wilhelm Magnus

<u>Graphs and Their Uses</u>
Oystein Ore
Connector Problem
Mosaics

<u>What is Mathematics?</u>
Richard Courant and Herbert Robbins
Steiner's Problem
Soap Film Experiments 4

<u>Selected Articles From the Lenkurt Demodulator Volumes I, II, and III</u>
GTE Lenkurt