PACKETCABLE:
A NEW INTERACTIVE CABLE SYSTEM TECHNOLOGY

PAUL BARAN

PACKETCABLE INC.
10411 BUBB ROAD
CUPERTINO, CA

ABSTRACT

A new interactive two-way cable system technology is described. Alphanumeric text and graphic capability is provided for all users. A new architecture head end computer supports a large number of simultaneous data users. Full two-way remote addressable converter capability is provided for single and dual cable systems.

INTRODUCTION

Few expectations have been held as long and with such fervor as the advent of interactive two-way services on cable. It is our belief that the economic viability of new two-way services has been delayed by a "chicken and egg" predecessor problem.[1] New services can pay their own way only if the public has purchased the hardware required to deliver them. This is unlikely to occur, however, until after the services have been made available. Information providers, on the other hand, are reluctant to develop new services until enough potential users have the delivery hardware in place to form an economically viable constituency. Of course, test demonstrations can be run, and are being run today. But, the new industry can't take off until this chicken and egg problem is solved.

I would like to discuss ways to break this deadlock by providing the needed data delivery capability at a near zero cost to the cable operator. Most large new cable systems will need addressable converter capability to control pay TV delivery anyway. The new services support could come along as byproduct -- almost a free ride.

I would like to talk to you today about a system now in development that is called PacketCable.[2] This is a new digital control and communications system intended to support high speed, interactive broad band computer communications on both present and future cable systems. PacketCable will provide the functions of the addressable converter as well as the capability to support a wide range of new services including:

- Videotext (Teletext and Viewdata such as required to deliver Electronic Yellow Pages)
- Panic Alarm Type Services (Police, fire, medical aid)
- Electronic Mail
- Electronic Game Support
- Transparent Digital Communications
- Electronic Shopping
- Home Appliance Monitoring & Control

In the following description, it will be helpful to think of neither a single unit, nor a collection of units. PacketCable is better thought of as a distributed computer communications system, tying together geographically separated units to create a new set of capabilities. The tightly interconnected overlay structure of digital processes appears to make feasible the delivery of a range of sophisticated new services which, in the past, too often were called "blue sky."

To allow the television viewer access to new services without purchase of additional hardware, alphanumeric/graphic text generation is built into the basic system. Although two-way data based services are provided, initial emphasis is on pay TV control, including support for impulse pay-per-view for any channel. The full two-way communications and control capability could support an almost infinite variety of tiering and billing combinations. The addressable converter function is controlled by a remote wireless hand-held keyboard for 400 MHz or 50+ channel single or dual cable systems. Baseband decoding is used for remote control of sound volume. The system design seeks to be significantly less vulnerable to signal theft than conventional

one-way addressable converters by such design features as inbuilt electronic serial numbers. These can be used to pinpoint the location of each unit within the cable system if stolen.

SYSTEM DESCRIPTION

Figure 1 is a simplified block diagram of the system.

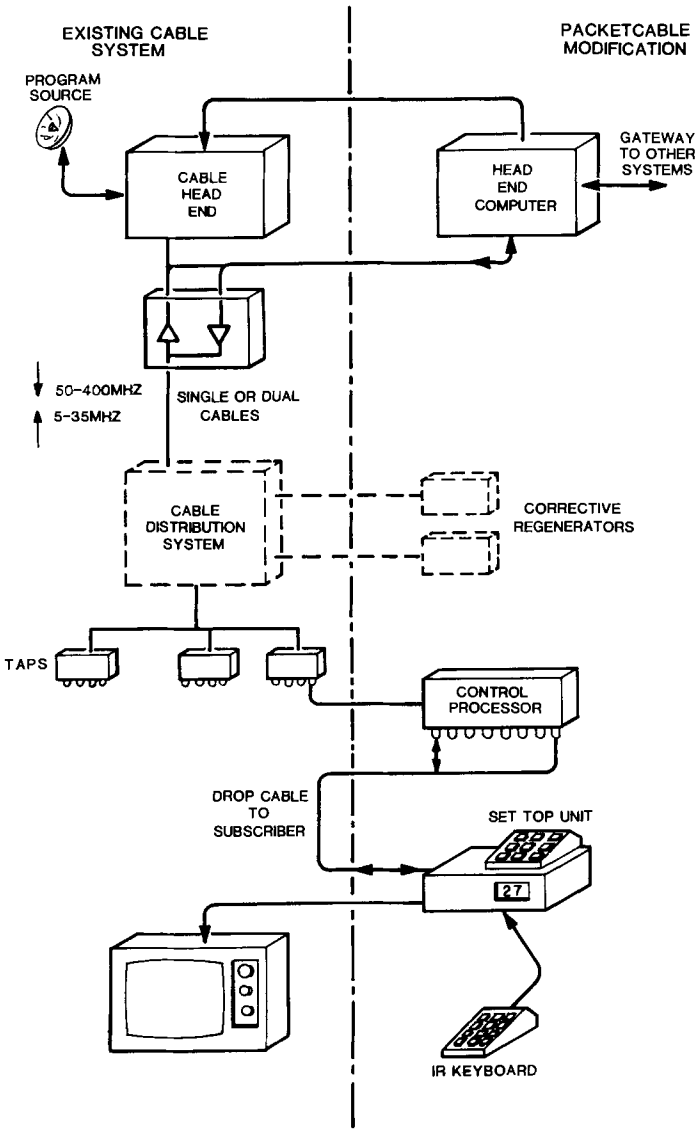

FIGURE 1. THE PACKETCABLE SYSTEM

On the left is a conventional single or dual TV cable system. On the right are shown the major new units that form the PacketCable system.

IR Keyboard

Starting upward from the bottom of the figure is an infrared keyboard. This wireless hand-held keyboard is used by the TV subscriber for remote stations or enhanced service selection. The user's TV set is most often initially tuned to channel 2, 3 or 4. Once tuned, the user's set forever operates as a totally electronically controlled set. This includes channel selection, sound volume and power on and off. TV signals can be selected from either of two 50+ channel cables. The same keypad used to select stations can select videotext frames. A local data base of up to several hundred thousand frames can be selected by the user, generally within two seconds. About 900 of these frames are sent in teletext fashion with a response time of under one second.

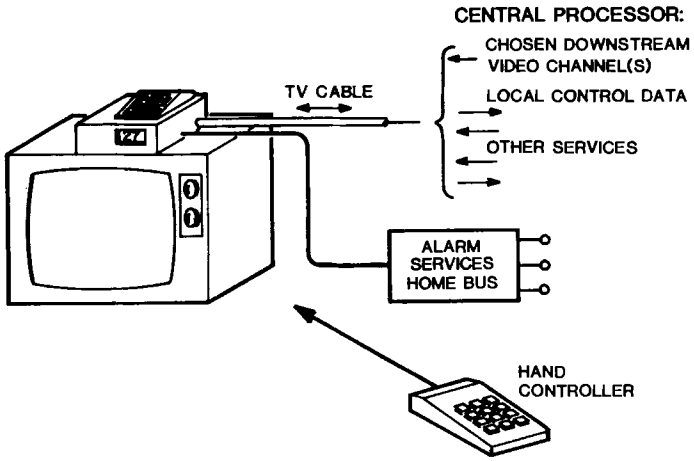

FIGURE 2. SUBSCRIBER TERMINATION

Aside from a slight difference in response times, the use of a common tree selection protocol permits these two modes to be indistinguishable to the user. An optional keyboard, including a full alphanumeric keypad is available for sending electronic mail. The basic PacketCable system contains an inbuilt alphanumeric generating capability, so some minimum text and graphic services are available to all users without need for additional hardware. The very short response time required by a fast keyboard user results in a high data rate in the data communications subsystem and the need for rapid processing in the data handling portions of the system.

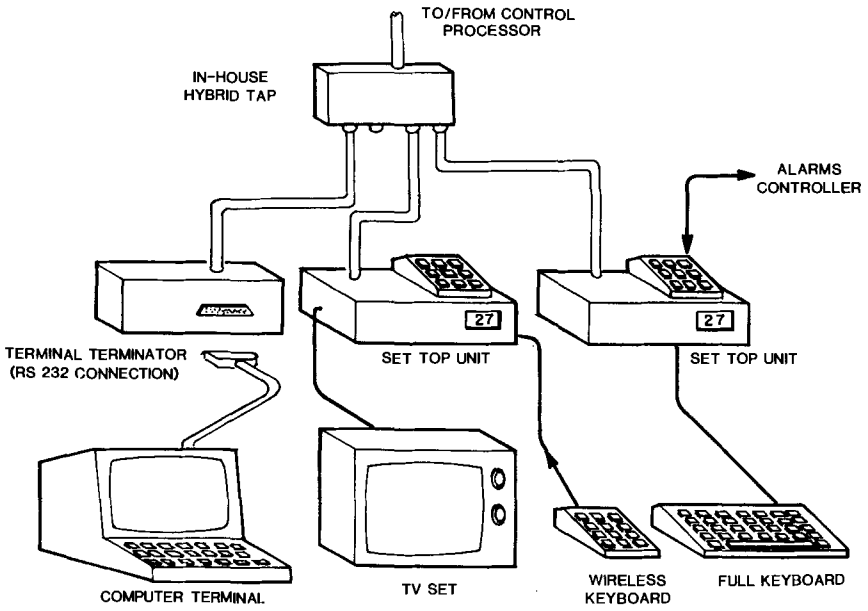

FIGURE 3. EXTENDED SUBSCRIBER SERVICE

Set Top Unit

The interconnection point between the subscriber's drop cable and the remote keyboard is the Set Top Unit. (See Figure 2, Subscriber Termination.) The Set Top Unit uses a pair of LED displays to indicate the channel number being watched, or else time. The Set Top Unit also contains an interface plug for connecting alarm sensor circuits, downloading games and controlling appliances. Provision is made for later inclusion of a "home bus," if and when there is industry agreement on an interface standard. The Set Top Unit intercommunicates with the remote Control Processor using short packets sent on the same drop cable as the selected TV signals.

Other Terminating Devices

Other optional interface terminators which may be used in lieu of or in addition to the Set Top Units are shown in Figure 3.

One example of another type of device used for terminating professional or home computer devices or terminals is imaginatively called a "Terminal Terminator" (TT). This TT unit contains a standard 25 pin RS232 connector and can connect a standard data terminal or similar standard computer to the system using standard ASCII characters. Speeds of up to 19.2 kilobits per second are possible with this unit using a clear-to-send protocol arrangement.

Control Processor

The Control Processor is a strand mounted unit that controls up to eight TV sets, each of which may have one or two TV channels per drop cable. The Control Processor has primary responsibility for transmitting and receiving data packets via the cable system. It connects between the house drop cable and the usual directional coupler tap. Parenthetically, it is never necessary to cut a distribution cable for installation or removal.

Data Transmission

Data transmission requires at least one 6 MHz downstream channel and one 6 MHz upstream channel. A gross data rate of approximately 2 Megabits per second downstream, and about 1 Megabit per second upstream is used. All data is organized as packets containing full routing and addressing data. Each packet contains a cyclic redundancy check field. Every packet requires an acknowledgment of correct reception, otherwise it must be re-sent. The communications protocols are designed for fast, error-free performance, including compensation and correction of any upstream noise problems.

Upstream Noise

Several different techniques are used in PacketCable to reduce the effects of spurious upstream signals:

1. Most 5-35 MHz upstream noise leaks in via the drop cables. Since the upstream transmitter is in the Control Processor, this source of noise is effectively removed.
2. Proprietary devices, which we call Corrective Regenerators, prevent defective packets from propagating upstream in the cable system.

3. Frequency agility is reserved for use in disastrous situations to change the upstream frequency.

4. If upstream noise does occur, the ingress point of noise is precisely determined and pinpointed for removal.

Head End Computer

The Head End computer is an unusual communications switch and information processor. It takes upstream packets, and then processes them to create downstream packets. The Head End Computer also supports gateway connection to other systems in the outside world. These gateways allow connection to a remote diagnostics computer as well as to remote data bases and data networks. The Head End Computer has local storage for a few hundred thousand pages of alphanumeric/graphic text. The Head End's heaviest processing load is in the pay-per-view billing, data communications, customer records maintenance and data retrieval.

Because of its central role in the system, the Head End Computer must be extremely fast and reliable, and we seek a maximum two second response for most subscriber data retrieval requests. Given a hypothetical "average" cable system of 10,000 users of which 20% of the users might simultaneously want data base services, the Head End Computer will face a throughput load ten times greater than today's largest time-sharing computers. Since no existing or shortly forthcoming computer could meet these performance requirements, plus meet the reliability and cost constraints, it was necessary to create a new computer architecture, tailored to the unique requirements and constraints of this application.

A New Computer Architecture

The challenge was to design a time-sharing computer capable of handling more users than the largest computer today, and to do so at an affordable price. Part of the solution was to utilize the remote processor capability distributed throughout the Control Processor portion of the system. A second factor was in the packetization of all data. This meant designing a computer to process standard form packets instead of 8, 16 or 32 bit words as in today's small machine practice. Another necessary simplification was to remove the provision for general purpose computation found in today's time-sharing systems. This provision is not needed in our application where subscribers do not present number crunching loads. The users who want such services can always get them by being connected to a remote computer. This reduction of function allowed tailoring the computer to handle the remaining tasks faster. This allows a quicker response time to more users for a given amount of hardware.

The decision to design a special purpose computer was not lightly made. It meant designing a new form of processor from the ground up, including all boards. One obvious alternative is to use one or a pair of off-the-shelf general purpose computers which could simulate some features of the system for the initial set of users. This alternative was rejected, however, because it punted on the critical issue: Can a composite hardware, firmware and software system with the properties required be built to serve thousands of simultaneous users in a wholly reliable manner? And, can it be built in a cost effective manner? Our objective was to solve the real longer range problem. We did not want to settle for a simple test demonstration system.

System Reliability

The single most important consideration in the PacketCable design is reliability. An unreliable two-way interactive system is nearly useless for most future high value services, such as electronic mail, alarms and data communications. This view of the importance of reliability is new in the cable industry. In the early days of cable, keeping capital costs to an absolute minimum was the single overriding consideration in achieving profitability. This is changing rapidly, and importance must now be particularly placed upon achieving the absolute highest reliability of any system element shared by many users.

Head End Reliability

The Head End Computer, for example, has been designed to be relatively immune to the effects of component part failures. When Head End hardware failures do occur, the affected parts are effectively bypassed. As the failed components do not go away by themselves, a remote monitoring capability is being implemented.

The Head End Computer software is being designed so that transitory failures cannot cause loss of billing data, nor create duplicate billing records. No single hardware failure will affect operation of the system. Duplicate boards

exist in all sections and replacement boards may be plugged in, and removed while the power is on, without causing transient errors.

Dual Cables

The PacketCable equipment is designed at the outset for use with either single or dual cables. The critical data channel can be received and transmitted on either cable if one should fail. Dual cables have the inherent possibility for greater system reliability, but only if failures in the A cable and the B cable are statistically independent. Ideally, different power feeds should be used for each of the two cables. While the failure characteristics of dual cables are better than those of single cable, their failures rarely will be statistically independent. If Cable A and B were statistically independent and each had a reliability of 0.999 or 8.76 hours outage per year, then the probability of both not being out of commission would be $(1-.999)^2 = .001^2 = .000001$. Thus, the annual down time changes from 8.76 hours to 31.5 seconds per year.

This concern with reliability is academic today. But, providing that it match or better the reliability of the telephone subscriber's line, cable could one day become the major transmitter of high value information. There is no reason, other than cost, why cable must be the unreliable network it is today. This cost tradeoff is changing, however, and the PacketCable system has been designed with this longer term system evolution in mind.

CRYPTOGRAPHY AND SIGNAL SECURITY

Digital Security

Any system used to convey highly personal electronic mail must be secure from the curiosity of a would be eavesdropper. Cable TV systems are particularly vulnerable to such "eavesdropping" since the upstream branches of the distribution tree concentrate near the Head End. Here, all contents of the system are exposed unless they have been fully protected. Safeguarding confidentiality also has an economic rationale. Any system that does not assure the privacy of information transmitted is nearly worthless. Sensitive private matter such as electronic mail is, as a rule, transmitted in digital form. Hence, cryptography can be effectively applied. While simple cryptographic schemes exist, we have chosen the U.S. National Bureau of Standards DES Algorithm. This is a certified security code for most U.S. governmental agencies, so there is no question as to its reliability. The drawback to the DES code is that it imposes a heavy processing load. Consequently, DES is used only with personal and highly sensitive information.

Video Security

Video encryption is a different matter. Theoretically, a good cryptographic scheme can be devised by using alternating, concatenated, reversible transformations.[3] This is easy in the digital domain where long keys can be derived from short key bases. As digital signals regenerate perfectly, irreversible distortion does not occur. This is not so in the analog world where few reversible transformations exist and imperfections become irreversible noise.

The difficulty with analog signal encryption is that the redundancy of the NTSC video makes it possible to undo the analog coding scheme with some cleverly designed post processing. More specifically, the NTSC video signal always contains:

1. the color burst
2. horizontal synch
3. vertical synch
4. line-to-line correlation, and
5. frame-to-frame correlation.

Having access to this tremendous amount of known or a priori information is tantamount to sending a key along with the lock. Any system that is to remain in the field for a decade or more, and which generates high revenues is begging to be ripped off by a smart computer freak or an innovative entrepreneur. As revenues on cable's high value services increase, the "breaker box" becomes an economic alternative.

In Silicon Valley where I live, designing and building devices to defeat protection schemes is not immoral. Rather, it is a high-status art form. The January 24, 1982, edition of the San Francisco Chronicle carried an interview with Mr. Steven Wozniack, the young cofounder of Apple Computer Company -- now a $330 million/year company. Wozniack describes his last business venture prior to forming Apple Computer -- designing and building blue boxes to defeat the telephone company's billing scheme for long distance calls.

Once a descramble defeat circuit is described, a large population is generally interested in its use. Radio Electronics Magazine, for example, reported a 40% in-

crease in newsstand circulation for its January 1981 issue, which featured an article on an off-the-air descrambler. The major difference between the use of blue boxes and one-way descramblers is that, with the blue box, there is a high risk of being caught, while a descrambler can be built and used in the privacy and immunity of one's own home. As the Chinese fortune cookie says: "He who trusts a TV scrambler is like man who believes in Chinese fortune cookies."

REMOTE DIAGNOSTICS

One feature of the PacketCable system is the use of remote diagnostics for all units. Thus, we always know the status of every unit in the field. Faults, including intermittent failures, are detected and noted at the Head End. Given that a fault is found remotely, we wanted the fastest possible swapout arrangement for a defective unit. The unit is fixed only where an automated diagnostic unit is used -- at the depot maintenance point. The Control Processor unit is designed so that it is not necessary to break into any cable -- only some F-type connectors need to be unscrewed for fast exchange. With a proper "cherry picker" vehicle, the swapout time will probably be about the same as for an indoor unit. Given that the subscriber is often not home during the day, it may be less.

Underlying our decision is the assumption that, with increasing social pressure to hire marginally competent workers, an ever greater percentage of service technicians will be incapable of handling even simple assignments. Some will manage to foul things up if given half the opportunity to do so. Therefore, our concept of servicing electronics is changing. We don't want a technician poking probes into a digital electronic unit. He'll often never find the problem -- and may just as often create new ones. We prefer to confine service work to depots equipped with proper test jigs and where the tasks can be routinized. It takes a computer to fix a computer. And that's what we have.

In light of this maintenance philosophy, we have designed an electronic serial number which will be built into each unit for on-line service use. This digital code tells us:

1. Who is the registered lessee?
2. History of manufacture - date, modifications, serial number,etc.
3. Features

This information is available through interrogation by the Head End.

Since different units can be plugged together by common F-type connectors, mistakes will occur. It is desirable for the Head End to know which unit is connected to what. This arrangement catches "screw-ups" made by service technicians who have connected the wrong units together. Many other defects can also be detected and pinpointed by this Head End Computer monitoring arrangement.

This option is useful not only for spotting misconnected units, but also for pinpointing the location of stolen units. Reconnecting a stolen PacketCable unit will not be the wisest thing to do. Monitoring arrangements guarantee detection of the stolen unit. The temporary owner never receives any services.

STATUS

The work reported here is a snapshot of a development program now underway. As such it is subject to the usual changes and modifications as the project evolves. The hardware is in laboratory prototype stage at present and an intensive shakedown period is envisioned prior to field testing.

FOOTNOTES

1. See P. Baran, "Broad-Band Interactive Services to the Home: Part II - Impasse," IEEE Trans. on Communications, January 1975, pp. 178+.
2. PacketCable is a trademark of PacketCable Inc., Cupertino, CA.
3. C. E. Shannon, "Theory of Secrecy," Bell System Technical Journal, 1949, pp. 656-715.