BROADBAND PACKET-SWITCHING

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INTRODUCTION

In 1983, Viacom successfully implemented a value-added data communications service for the City of Mt. View, CA Police Department. Asychronous terminals were remotely linked to a host CPU for interactive file inquiries and updating. Sytek packet-switching broadband modems linked the terminals to the host over a subsplit institutional cable.

The subsequent success of the application proved that a subsplit system could be used for a value-added CATV communications service. In order to be economically viable, however, the service must cover a wider geographical area than the small subsplit institutional cable system in Mt. View. Since the service should potentially cover a wide metropolitan area, then it must be interfaceable to entertainment and institutional cable systems, two-way microwave links, and private broadband local area networks.

Viacom's Nashville CATV system is a subsplit, 1800-mile entertainment cable with AML microwave linking 6 hubs and 200 to 300 miles of plant to a master Headend. The service area has large geopolitical boundaries (an entire city and county), and therefore enough potential users to justify implementation of a two-way enhanced service.

This paper describes the implementation of this packetized broadband data communications service over a hybrid microwave and CATV system covering a large metropolitan area.

CURRENT BROADBAND PACKET TECHNOLOGY

Viacom chose the Sytek LocalNet 20 (TM) family of broadband modems and multiplexers because of the positive experience in Mt. View and the fact that the modems (called PCU's or Packet Communications Units by Sytek) could still function with a propagation delay equivalent to 35 miles of Coax. Each PCU is frequency agile, and can operate on any of 20, 300-KHz sub-channels within a 6 MHz pair. An upstream and downstream is necessary for two-way communications created by an RF frequency translator at the main broadband Headend.

Many modems can share the same 300 KHz subchannel since access to bandwidth is based on the Carrier Sense Multiple Access with Collision Detection method (CSMA/CD). Modem logic monitors (senses) the sub-channel for carrier presence, and transmits data packets via FSK modulated carriers. During transmission the modem checks its own received data packets for damage occuring when two modems transmit simultaneously, as happens when contending for channel access. When collisions occur, each PCU detects the damaged packet and waits for a predetermined backoff period before again requesting channel access. The random wait period varies with each modem according to an algorithm within PCU firmware logic.

The modems detect errors in packet transmission by a polynomial-based cyclic redundancy check (called CRC-16) which causes the receiving modem to not acknowledge (a nack) an improperly delivered packet. When the network is not inoperable due to ingress or outage conditions, this should ensure bit error rates of 1 in 10 to the tenth power or greater. Modem data transfers (sessions) cease or abort whenever an RF path interruption occurs. These sessions must be reestablished as soon as the CATV system restores service.

Input to the modems is via 2 to 32 EIA RS-232 ports operating at data rates selectable from 75 bits per second to 19.2 Kbps for asychronous devices and 1200 to 9600 bps for bisynchronous equipment. Multiple port host communications are supported by multiplexing the individually addressable input ports onto a 128-Kilobit RF output F connection to the 300 MHz wide broadband subchannel. Many more terminal ports may be on a subchannel than host ports since busy ports can be detected, and the calling modem can be passed or rotored to a non-busy host port. Port and bandwidth contention also allow very economical network cost per port figures.

The PCU converts the serial input into packets containing destination and sending addresses, data, sequence and control information, and CRC error detection check bytes. This seven-layered Open System Interconnect packetizing process defined by the I.S.O. allows end-to-end speed and flow control conversion between communicating devices. This value-added process differentiates CATV broadband packet communications from reqular analog twisted-pair tariffed services.

INTERFACING THE PACKET NETWORK TO THE CATV SYSTEM

Since Viacom had a franchise requirement of return video from each subheadend site, frequency modulating microwave transmitters were chosen to complete the two-way link. The FML transmitters and receivers were multiplexed with the Hughes AML downstream microwave so that the same antenna could be used for both links. The lower 4.5 MHz of the return microwave spectrum would be for video with the balance to be filled with packet channel subcarriers.

Experience with a successful two-way security service in its Dayton, OH franchise had prepared Viacom for the problems of end-to-end dynamic level ranges. Realistic CATV system dynamics with varying operating levels would potentially allow modems with higher carriers to dominate the network. Furthermore, excessive carrier levels fed from the coax network to a sub-headend return microwave path could cause transmitter overdeviation of the CARS carrier in excess of FCC standards.

Other problems with the 1800-mile CATV system include the noise floor contribution of over 4500 amplifiers funneling into the master Headend from remote hub sites. Ingress and distortion from any point in the system would interfere with the network sub-channel for all return packet carriers since the two-way bus is shared.

To minimize system dynamics and prevent microwave transmitter overdeviation, Viacom's engineering staff modified a Catel FM processor/limiter (See Figure 1) to convert the upstream data carrier to a microwave compatible subcarrier. Since the PCU's use FSK modulation, limiting maximum carrier levels would not damage data packets. The limiting also prevented overdeviation and widely varying carrier levels throughout the system.

Viacom's engineering staff also added a very important squelch circuit which prevented any output, including return noise and ingress, to the microwave transmitter when a sub-channel data carrier was not present. This meant only the return hub with modems transmitting packets would contribute to Headend return noise and ingress funneling degradation problems at the master Headend translator. The modified processors later proved to be fast enough and stable enough not to cause packet carrier errors.

Using subsplit frequencies but not CATV channel standards, the PCU transmits in the very upper portion of T-7 and lower 2/3rds of T-8. The translation chain converts the upstream transmit frequencies to the downstream receive frequencies with a 216.25 MHz offset. This places receive sub-channels in the upper portion of Channel K and lower 2/3rds of Channel L.

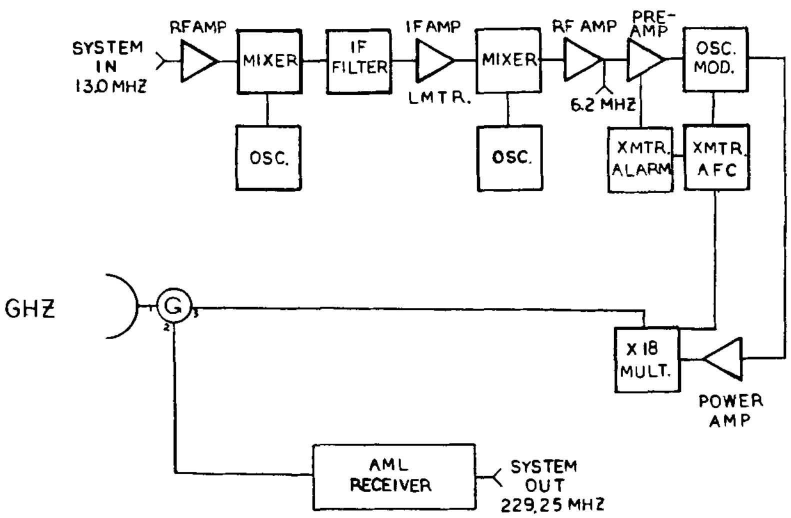
Not wanting to waste valuable CATV channels, the 10 sub-channels available for the T-8/Channel L combination with adequate guardband allocation were used to implement initial circuit testing. Using 13.0 MHz as the first transmit frequency, the upstream carrier is limited (See Figure 1) and then down-converted to a 6.2 MHz microwave subcarrier.

At the master Headend (See Figure 2) the FM microwave receiver feeds the 6.2 MHz subcarrier to a 6.2 to 13 MHz upconverter/limiter. A very stable translator then does the 216.25 MHz offset conversion with output turned downstream via AML links. Frequency stability tests have proven this translation chain to be within the modem specifications for frequency deviation tolerances.

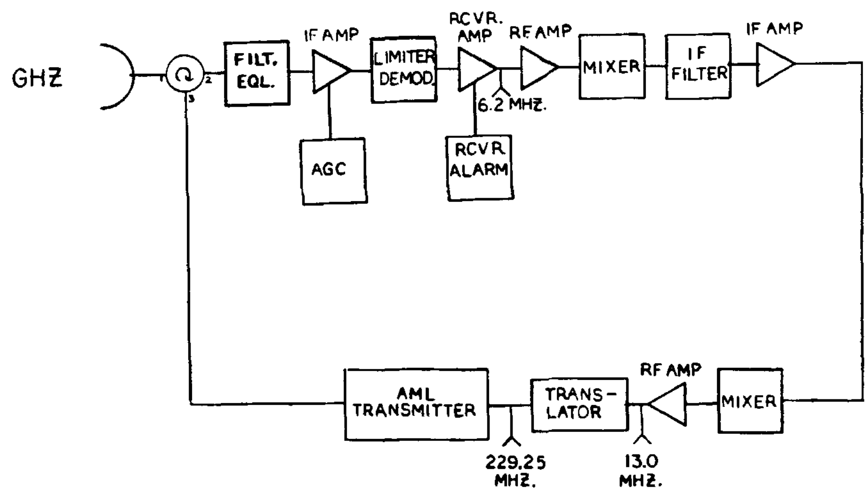
SERVICE TESTING AND IMPLEMENTATION

When Viacom's New Business Development staff began testing the packet network and translation chain, too many aborted and bad packets were detected by a network statistical monitor. The initial culprit was assumed to be a carrier-to-noise or carrier-to-ingress problem

Field and lab tests soon revealed the surprising source of the packet errors --- the PCU receiver. The receiver works very well even with C/N ratios as low as 15 dB. But if the absolute noise floor was greater than -36 dBmv (weighted into 300 KHz), then the receiver over-sensitivity caused noise to interfere with packet carrier detection. Since the modems could operate properly down to -23 dBmv, a standard -13 dBmv +- 3 dBmv receive level at a data C/N of 30 dB or better was chosen.



SUB-HEADEND DETAIL
FIGURE I



3 MASTER HEADEND DETAIL
FIGURE 2

The PCU's do not allow separate transmit and receive level adjustments, therefore Viacom constructed a diplex filter black box with separate pads in the upstream and downstream paths. This device allowed independent adjustment of modem transmit and receive levels where noise levels presented problems.

Field testing soon revealed positive results and minimum errors now occurred. Load tests on channel capacity also were positive and concluded that over 1000 simultaneous sessions transmitting at 9600 baud and a 10 percent duty cycle could share the 10 subchannels. Practically, many more interactive users could share the frequencies since lower baud rates and lower channel needs would be sufficient for many users.

HOOKING UP TEST CUSTOMERS

Since 1981, Viacom in Nashville has provided fixed-frequency synchronous RF links to the City of Nashville for 9600 baud data transfer between an IBM host and terminal servers. These circuits were point-to-point and point-to-multipoint bisynchronous links.

Recently, the fixed-frequency modems were replaced with the packet modems with good results thus far. The most difficult portion of the switchover was modem internal setup required by the PCU to be compatible with the character-oriented bisynchronous protocol between the host front-end communications processor and the remote terminal server.

Neither the host vendor nor the user were sure of such esoteric parameters as the hexidecimal value of the synchronization characters or the maximum block size. However, a Comit model 1500 circuit analyzer from Phoenix Microsystems captured a block of data and provided all the information necessary for modem parameter table set-up.

APPLICATIONS AND THE MARKET PLACE

That 128-kilobit packet communication services can be readily provided by Viacom is undeniable but currently risky due to State Regulatory unknowns. Despite the current National deregulatiory environment, State officials have varied reactions to data communications over CATV systems. However, even when return on investment requirements are commiserate with this risk, packet data communications over cable is potentially a cost-effective alternative to cross-subsidized data communications over a voice network.

Viacom has opted for a deliberate approach to packet communications until regulatory and de facto communications standards emerge more clearly. Meanwhile, the knowledge and experience gleaned from current testing has been marketed with less risk to the private network market place. Private networks include local area networks, campus area networks, and private cable systems. These users have well defined needs that often will involve multiplexing of many services onto the network including; entertainment and commercial video programming, T-1 links, security, energy management, teleconferencing, high-speed imaging, CAD/CAM and more.

One factor that could give many cable systems an edge in this private market is the fact that it is currently being served by unqualified retail outlets or small, poorly financed broadband contractors. Furthermore, their designs or installations are generally substandard compared to most CATV systems with two-way experience. Add the options to lease and provide on-going maintenance, then a very marketable broadband product and service can be provided by the CATV industry.

If Viacom can serve this market niche for private systems very well and slowly develop the backbone network, then a telecommunications maxim may ring true: 80 percent of communications are internal and 20 percent are external. The high-speed internal systems cannot be externalized by the analog, low-speed bottlenecks currently overpriced for bandwidth offered. A 128-kilobit to a 5-megabit external bus should be as affordable as a business telephone, especially when competition and production quantities bring down broadband modem prices.

Time, technology, and the marketplace will soon more clearly determine the future for data communications and the CATV industry.