UNITED STATES

The evolution of cable television to interactive communications service provider

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The first foray into cable television appears to have taken place simultaneously in both Pennsylvania and Oregon in the late 1940s and early 1950s. At the time, the fledgling television industry provided broadcast signals only to the most populous (that is, economically advantageous) areas. For those regions that had poor TV reception either because of obstructions or long distances from signal transmitters, cable television provided a workable solution. Essentially, the early cable providers constructed large antennas on hilltops or buildings for improved TV reception, and then strung coaxial cable from the antenna to the local community. Out of this environment the acronym CATV, representing Community Antenna Television was born.

With the advent of satellite broadcasts to cable systems in the 1970s, cable operators were able to provide more channels than were available over the traditional airwaves. Because of these value added capabilities, cable television made significant inroads into markets where TV reception was already reasonably acceptable. Additional services such as specialty channels and pay-per-view have brought the cable industry to where it is today: approximately 63% of American households have cable TV, and cable service passes by about 95% of all U.S. residences.

The cable industry is less than 50 years old, and yet with such a large market penetration, is already reasonably mature. In searching for growth opportunities, the much ballyhooed National Information Infrastructure (NII) or "Information Superhighway" provides an opening for cable television to build upon its extensive architecture and experience to deliver the necessary features for the upcoming information age.

System architecture

Traditional cable television systems can be divided into five major sections. Figure 1.1 depicts graphically the "tree and branch" architecture.

The *headend* is the center of CATV activity. It is here where external signals such as satellite, microwave, and local TV station broadcasts are received from the various types of deployed antennas. Additionally, locally produced and pre-recorded programs can be introduced into the mix. Ultimately it is the headend's responsibility to process, combine, and assign a channel frequency to all signals destined for cable distribution.

A number of *trunks*, originally constructed out of large diameter coaxial cable, carry the signals from the headend to a series of distribution points. Trunk cables share the same properties as do generic transmission lines with regard to attenuation; in order to maintain adequate signal strength over long distances, amplifiers are required at regular intervals. Much experience has shown that on average, amplifiers need to be spaced approximately 2,000 feet apart. Only a finite number may be cascaded (approximately 30-40), as each amplifier introduces additional noise and distortion to the signal. There are well known thresholds of signal distortion, above which, TV picture quality will be affected.

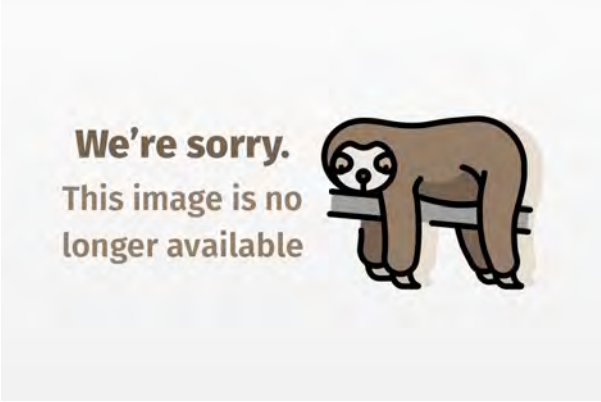

Figure 1.1 - traditional cable television architecture

The smaller distribution or *feeder cables* branch out from the trunks and are responsible for serving local neighborhoods. To avoid excessive attenuation and noise, feeder cable is also severely limited in length, since usually a maximum of two amplifiers, called line extenders, are allowed per feeder. The statement that 95% of households can be reached by cable services means that those homes are sufficiently close enough to a

feeder cable.

Feeder cables are tapped at periodic locations to furnish the familiar coaxial *drop cables* that enter directly into the customer's premises. Drop cables too are limited in length to about 150 feet. *Terminal equipment* (consumer electronics) is connected to the drop cable inside the home. Among the more common devices are televisions, VCRs, set-top boxes, converters, descramblers, splitters, and cable modems.

Cable television advantages and disadvantages

Compared to the telephone industry, cable television systems do have, and have had for 50 years, a truly high-bandwidth delivery system to the home. The simple reason for this fact is that television is, even by today's standards, a high-bandwidth application. During the 1940's, when broadcast standards were being set by the NTSC (National Television Systems Committee), technology and compromise dictated that each television channel be assigned a 6-MHz portion of the electromagnetic spectrum. Since that time, much has improved to increase utilization of the spectrum, but the standards still remain the same -- it would be very difficult to force all consumers to replace their NTSC compliant equipment for devices based upon newer albeit better standards.

Figure 1.2 graphically represents the television spectrum allocation. The 6-MHz-wide channels were prudently assigned to avoid inter channel interference. The remaining unallocated terrestrial spectrum is dedicated to a host of other communication services.

Figure 1.2 - television spectrum frequency allocation

Cable television, however does not utilize the terrestrial spectrum, but rather uses coaxial cable to broadcast its signals. Coaxial cable has the ability not only to "emulate" over-the-air spectrum, but is designed such that its sealed environment does not interfere with other signals. Consequently, it is possible for cable operators to safely re-use previously allocated spectrum, or to deploy multiple cables, each of which contains its own separate impervious spectra.

Regrettably, the original cable systems architecture was never really envisioned to be a general purpose two-way communications medium. Its primary goal was simply to deliver high bandwidth video signals to residences. In order to accommodate upstream communications, the existing cable plant must be upgraded.

Recent cable system developments

As is often the case in industry, the chief motivation for change revolves not necessarily around technology but around business. In cable television's case, the late 1980's marked the time that it made business sense to begin replacing the coaxial cable distribution plant with fiber optics. Since signals transmitted by optical fiber can be carried for significantly longer distances, fewer amplifiers are needed. This results in fewer points of failure, lower maintenance costs, and better signal quality.

Fiber optics also facilitate a larger broadcast spectrum and bi-directional communications. Recall that Figure 1.2 does specify a portion of the spectrum for upstream purposes. Two-way amplifiers can be incorporated into the cable distribution plant such that any signals falling into the range of downstream frequencies can be amplified downstream, while those that fit into the upstream range, can be amplified in the opposite direction.

A current state-of-the-art cable architecture is a hybrid fiber/coax (HFC) combination. Trunk cables can be upgraded to fiber optics without replacing existing feeder and drop lines. As cable franchises run fiber deeper into their network, they are capable of serving areas with custom programming and services tailored to individual neighborhoods.

These service areas are usually in the range of 500 to 2,000 subscribers.*11*

Cablevision's Access Plaza

In the fall of 1995, Cablevision introduced a pilot program called Access Plaza and made it available to a subset of its Long Island subscribers. Access Plaza is a combination of hardware and software that lets users surf the Internet, get interactive news, and do home banking all through the coaxial drop cable that enters their homes. Although still in its early stages, it is Cablevision's plan to provide this service and perhaps additional ones for a flat monthly fee.

Cable modems

The key piece of terminal equipment that enables such access is the cable modem. Figure 1.3(a) shows how a generic cable modem might be incorporated into an existing home drop cable, and connected to a general-purpose computer. Figure 1.3(b) represents the implementation that was provided at the author's residence. Specifically, Cablevision installed a second drop cable, not for the reason that the data network is on a separate distinct distribution wire, but because they wanted to ensure sufficient signal strength to the cable modem. It is no mystery that cable TV subscribers will split the incoming signal several times to accommodate the various video devices, legal and illegal, in their homes. Each split contributes to a well-known reduction in signal power and quality.

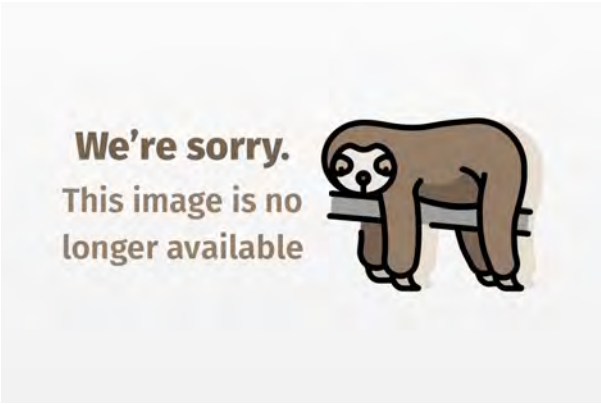

Figure 1.3(a) - Generic cable modem connection. **Figure 1.3(b) - Cablevision implementation**

The modem supplied by Cablevision is a Zenith HomeWorks model. The modem itself contains two physical connectors. One end is used to join the modem to the coaxial

drop cable, the other is a proprietary high-speed interface including an IBM PC ISA card which must be installed into an IBM compatible personal computer. Already limiting hardware to IBM PC compatibles, network device drivers are available only for the MS-Windows 3.1 and 3.11 operating systems, further restricting choice. Clearly, the implementation does not take an open systems approach, but future-generation cable modems, discussed later, will address this shortcoming and much more. Cablevision's choice of the Zenith HomeWorks modem was a function of price and availability. At roughly 00, the HomeWorks model is the most affordable, and one of the few that is available in quantity.

It is important to stress that distribution and support channels for cable modems will not, for the foreseeable future, be comparable to those for consumer electronics and software. As an example, the author attempted to get detailed information on the Zenith HomeWorks modem in the hopes of writing a device driver for the Solaris x86 operating system. Not only was the author refused such information, he was treated rather rudely for even inquiring!

The network details

In constructing a hybrid fiber/coax architecture, Cablevision uses the term "node" to refer to the endpoint of fiber connectivity within their infrastructure. Each node is capable of custom services, which, in data communications parlance means that it can have its own independent network. Currently, there are approximately 400 nodes on Long Island, each of which supports, on average, about 500 subscribers. Only a small number of these nodes are part of the Access Plaza pilot, and each active node is assigned its own separate subnet.

The hardware and datalink layer of communications for Access Plaza is implemented using a "modified Ethernet" similar to what one is accustomed to with local area networks, but suited to deal with transmitting packets over much longer distances than traditional LANs. Network-layer communications are TCP/IP based where each remote host currently receives its own dedicated class B IP address. All hosts are part of the cvnet.com domain, but are not assigned character host names within that domain. As a result the only real way of locating any node within the Access Plaza network is by its IP

address.

Like many other organizations, Cablevision is facing an IP address shortage. Only one class B network is allocated for the entire Access Plaza program, limiting the maximum number of hosts to 64K. In its aim to alleviate this problem, Cablevision is investigating potential solutions like DHCP (Dynamic Host Configuration Protocol) to temporarily lease IP addresses to hosts only for the duration of their connect time on the network. The imminent IPNG (Internet Protocol Next Generation) standard, which dramatically increases the number of available IP addresses, would also help ease many of the problems IP network administrators have today.

Referring back to Figure 1.2, upstream and downstream communications must be assigned frequencies that do not interfere with other channels. Accordingly, the author has been allotted a transmit, or upstream, frequency of 19.25 MHz, fitting into the portion of spectrum allocated for upstream channels. The receive, or downstream, band is centered at 649.25 MHz, extending well beyond the hyperband TV channels. 649.25 MHz is, incidentally, indicative of a state-of-the-art underpinning, since older cable plants could not effectively support signals at such high frequencies.

Performance

Individual performance within the cable data network is a function of many variables. Among the most important are bandwidth of the upstream and downstream frequencies, baud rate efficiency of the cable modem and, of course, the amount of simultaneous usage on the network.

Cablevision has chosen transmit and receive bands of 1.5 MHz, effectively dividing a traditional 6 MHz TV channel into 4 separate data slices. As will be seen later, cable modem vendors are quoting a wide range of performance numbers, each based upon how efficiently they can utilize the allocated bandwidth to send and receive data. For the Zenith HomeWorks modem, the baud efficiency is 1:3, meaning that for every 3 cycles, 1 bit of information can be extracted. The Zenith modem is rated as having a maximum data rate of 500 Kbps.

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