Opening the Set-Top Box Market

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Many people have contributed to my understanding of this topic and, although they may not be cited here explicitly, they deserve much of the credit for many great ideas. Specifically, I want to thank Lee McKnight and David Tennenhouse of MIT whose ideas have inspired me to think critically about telecommunications technology, policy and economics. This paper is a result of the interactions I have had with them and the researchers associated with the Research Program on Communications Policy including Suzanne Neil, Richard Soloman, David Carver, Paul Bosco, Sharon Gillett, Tom Lee, and Russell Rothstein. I also want to thank Branko Gerovac and Butler Lampson from Digital Equipment Corporation for helping me formulate my ideas on the set-top industry.

While I cannot take credit for many of the ideas presented in this paper, the content represents my own understanding of the subject. Hopefully you will feel that enough interesting issues are addressed in this paper so that you feel, as I do, that more research is needed in this area. I welcome any comments you have. Thank you.

Abstract

As the cable television networks transition from a broadcast-only network, to a high-bandwidth two-way network, the importance and functionality of the set-top box increases. However, developments in the set-top box industry have been restrained by the control the cable companies have over their equipment. Currently, a set-top box includes closed, proprietary technology which prohibits its use on other cable systems' networks.

This paper explores the possibility of abandoning closed, proprietary set-top box standards in favor of open standards. This "opening" of the set-top box is not a trivial matter since it challenges cable companies' concerns about security, quality, etc. The paper includes a policy analysis of the impact the Cable Act of 1984 and 1992 and the implications it had on the set-top box. To help quantify the benefits of open systems for cable television, economic analysis on set-top box costs is included. Finally, the role of the set-top in the emerging National Information Infrastructure (NII) is explored.

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Introduction

The US government is supporting technologies and policies that promote increased connectivity for its citizens to new "information superhighways" and many industries, including cable TV, are in the middle of it. The US cable television industry (a.k.a. CATV for community antenna television) has good reasons for its interest in the National Information Infrastructure (NII) developments because the stakes are high.[2] CATV is also in a good position to be a big player in the development of an NII since cable television has the key to one of the biggest barriers to providing new information services to customers -- access to the local loop. While it may be cheap to install wires or use satellites for long distance data communication, it becomes expensive to wire people's homes for new "bit pipes."[3]

The fiber/coax architecture of the CATV network allows larger data streams of information than conventional copper wire (better known in the industry as unshielded twisted pair or UTP). While companies like Bell Atlantic are demonstrating digital video at approximately 1.5 Mbps, the cable company can realistically send digital video at ten times this rate (approximately Ethernet speeds). Also, it should be noted, that much of the cable and local telephone systems are moving to a more fiber based architecture. While this will allow increased bandwidth for a cable system's bus architecture (everybody shares the information coming over the "backbone"), the phone system still allocates only a fixed bandwidth for each customer -- the bandwidth is there whether you use it or not.

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[2]Vice President Al Gore spoke at an International Telecommunications Union (ITU) conference in March 1994 claiming that a new "global communications infrastructure" could pump hundreds of billions of dollars into the world economy. See "U.S. Calls For Creation of Global Computing Network," Los Angeles Times, March 22, 1994, D3, col. 1.

[3]Reed, 1992.

However, upgrading the current cable networks isn't going to come cheaply. It may cost the CATV industry between $20 and $40 Billion.[4] This cost reflects upgrading much of the current transmission system (which is predominantly analog, one-way traffic over coaxial cable) to a more digital, two-way system.[5] Fortunately for the cable industry, moving to this new architecture allows them to provide Internet access, video-on-demand, (video)telephone service, etc.

Still, notions of openness and connectivity, which has made the Internet grow so rapidly, seem contrary to the CATV model that has developed. CATV has positioned itself as an information provider and not a network provider. The fact that the cable television companies own both the medium and the message (a.k.a. the conduit and the content) is part of cable companies' business to get information to a home. This is dissimilar to the telephone companies' model of owing the cable to get person A to talk to person B, but not owning the data that flows over it. Because of this distinction, the CATV companies are not seen as "common carriers" like the telephone companies are. Common carriers are businesses that must provide a given level of service to all customers -- they cannot discriminate. For example, airlines are considered common carriers along with telephone companies, etc. Therefore, if you own the whole network including the information that flows over it, then you want to protect the network termination devices that sit in your customers home to make sure they don't give the information to another person or get information they didn't pay for. This is why cable companies own their closed, proprietary set-top box.

This simple piece of electronics may prove to be the first big barrier to providing new services to the home. This is not to say that it is the most important barrier and it certainly isn't the only barrier. For example, there would have to be changes in the distribution and headend (source)

[4]Scism, 1993.

[5]Analog signals sent by the cable systems differ from computer networks which use digital signals (1's and 0's). The one-way transmission is similar to the broadcast medium (since both send signals out but don't receive any back from the customer), but it differs greatly from the telephone system which allows symmetric traffic (the consumer sends voice upstream and downstream over the wires).

equipment for there to actually be new services provided over the cable lines. Still the notion that the set-top is owned by the cable system means that cable TV consumers don't have access to the cable system. By allowing people to connect set-tops that they purchase, consumers will get access to the CATV network. This access, in turn, will spur on consumer demands to increase functionality of the set-tops and hence drive the cable industry to offer more services.

Therefore, the question remains: What would the affect be on the CATV industry, and hence the NII, if cable companies were made to make their consumer electronics equipment available for purchase? The model that may emerge may be similar to that of the telephone industry where a customer can buy a telephone from a store and plug it into their jack at home. This motivation has made the set-top box a technology of concern within the multimedia industry and may facilitate the convergence of modes predicted by Pool.[6]

[6]Pool, 1984.

Development of CATV and the Set-Top Box

Cable television has been around for quite some time, but the role of government changes almost quickly as cable TV technology. CATV started as a way for people to share a common antenna between multiple homes and has blossomed into a multi-billion dollar industry. Once someone had the idea of putting their antenna at a better location to receive terrestrial broadcast signals, their neighbors wanted to tap into that resource to get higher quality and/or more programming than they would receive otherwise. The set-top box was not included in this architecture since the CATV system was seen as a way to extend a television's antenna.

From these early beginnings, CATV has grown to penetrate about 60% of American homes. Table 1 outlines the growth of the CATV industry.

Year	Number of Subscribers (in millions)
1955	0.15
1960	0.65
1965	1.275
1970	4.5
1975	9.8
1980	16
1985	32
1990	50

Table 1: Growth of the CATV Market[7]

The set-top was introduced when the CATV signal interfered with a local broadcast signal. For example, the San Diego community started to receive the more popular broadcasts from Los Angeles via a cable system since the broadcast signal was too weak. The CATV architecture that

[7]T&C Factbook, 1994.

emerged included a microwave broadcast from Los Angeles to San Diego and then distribution of the signal to homes via a cable. The idea of re-broadcasting the LA signals caused interference with local broadcasts and facilitated the need for set-top boxes. The television sets that were on the market as cable TV became more popular were only designed to receive TV signals from broadcast channels. Therefore, the television manufacturers weren't concerned about circuits within the TVs that received broadcast signals. These signals actually amplified the signal received by the antenna. However, when a cable system provides the signal, the broadcast signals received by the circuits within the television interfere with the cable signals. This is why cable boxes tune in a channel and send it out on channel 3 or 4 -- an *unused* broadcast channel in the locality.

The set-top became an extension of the CATV network. The development of the set-top wasn't unified like the development of telephones were with AT&T. This is mostly because cable companies are community based and not national like the phone system. Areas like San Diego could develop a cable system, and hence a set-top box, that was totally different than someone who developed a cable system somewhere else in the US. Also, the addition of a set-top to the CATV network increased the cost to subscribers. Therefore a payment system developed where CATV providers purchased the boxes which would work with their system and rent them out to their subscribers on a monthly basis. This model of renting a set-top box designed specifically for a local cable system is still the market model that is followed today.

Even though there were more elements to a CATV system with the re-broadcast of signals, the popularity in areas such as San Diego continued to grow. And, as CATV systems took away viewers from the terrestrial broadcast TV stations, local broadcasters, like San Diego's, got upset. Their voice was heard and it inspired the US government, specifically the Federal Communications Commission (FCC), to get involved with regulation of the CATV industry.

Government gets Involved with CATV, 1965-1980

The FCC put in place a plan in 1965 that would freeze the growth of existing cable facilities hoping that it would silence the complaints of local broadcasters who were loosing their audiences. This plan only seemed to buy the FCC time to investigate this growing medium more closely until they could adopt more detailed regulations. In 1972, the FCC regulations limited the freedom the CATV companies had but no longer said the they couldn't expand.

These facts are not that important to the development of the set-top, but it established a precedent for the FCC to get involved with the affairs of the cable companies. It set the governing structure for cable TV that stayed in place during a time period that CATV significantly penetrated the American marketplace. It divided the roles of the different levels of government (federal, state, and local) and even went so far as to describe the technical standards for equipment and transmission. This last aspect, technical standards, didn't change the structure or functionality of the set-top, it set standards so that CATV equipment wouldn't cause radio frequency interference with other communications equipment.

The growth trends for CATV during this period are important to note. By the end of the 1970's, the number of subscribers in the United States was over 17 million -- about 22 percent of American households.[8] But the biggest boom in the CATV market was still about to happen; spurred on by technologies that were proliferating during the 1970's -- satellite broadcast and reception.

Growth of Extended Services, 1980-1987

The FCC, in 1980, allowed cable operators to import and re-broadcast signals that didn't originate locally.[9] This meant that CATV companies could use video transmitted over satellites

[8]Pool, 1984, p. 155.
[9]FCC Docket 19995.

for programming. Instead of a limited number of over-the-air channels, CATV companies could increase the number of channels it broadcast to include the satellite programs. This feature increased the appeal of cable television and, hence, popularity.

However, the increased number of channels broadcast by the CATV operators also increased the need for the set-top box. Since most televisions were not able to receive the extended variety of channels, the set-top had to de-modulate these signals using radio frequency (RF) tuning and send the signal out on an unused channel as described previously. The other enhancement to the set-top was the inclusion of a descrambler chip. This chip decoded a signal sent over the cable system. This encoding/decoding scheme was used mostly for CATV's premiere services.

In fact, premiere services were a major driving factor to increase the penetration of cable television. By using their satellites, CATV companies were able to receive stations that showed recently-run movie stations like Home Box Office (HBO). Cable companies would then encrypt the premiere channel for re-transmission over its cable system. Then a customer would need a decoder in their set-top box to decode the signal. Whoever got the decoder chip could then be charged a higher subscription rate since they had the advantage of receiving premiere services.

But, as the television engineers started designing television for cable, the televisions started incorporating much of the set-top functionality. Televisions started tuning in channels beyond the usual VHF and UHF bands. Filtering was performed within the television so that there would be no broadcast interference with a cable television input. Not only were televisions labeled "cable ready", but the VCR market was also accommodating tuners that incorporated the set-top functionality as well.

Deregulation of the CATV, 1987-1991

In the midst of the changing set-top box, legislation passed by the US Congress , The Cable Act of 1984 deregulated the CATV industry. This law came into effect in 1987 and reflected the Reagan Administration's stance on getting government out of industry. Then, once regulation was lifted, however, cable companies acted as monopolies and dominated their market. As was predicted, the cable television rates began to rise.

Meanwhile, the cable companies sought to increase the allure of their service by providing services such as pay-per-view. A pay-per-view system can be thought of as being similar to the encryption system that was put in place for services like HBO. However, instead of their being a specific computer chip that descrambles a channel, the computer chip can be programmed remotely by a cable company to descramble a particular program. For example, if a customer wanted to watch "Sleepless in Seattle" at 9pm that night, they would call up their cable company and request that movie. The cable company would then program that person's set-top box to receive that movie by giving them a temporary "key" that unlocks the scrambled channel. With this key, the customer can decode the signal and watch "Sleepless in Seattle" at 9pm, but not at any other time, or for any other movie. This remote programming feature of set-top boxes is known as addressability.

These addressable converters penetrated the market and thwarted any attempt by the television manufacturers to incorporate set-top functionality into the TVs. Although the TV manufacturers were able to work out the proper RF tuning necessary for the advanced televisions, they were unable to include the microprocessor. This component was proprietary technology for the set-top manufacturers and they weren't going to allow television manufacturers to use their encryption system. Another problem is that a television works all over the US, but only a Scientific Atlanta set-top works with Scientific Atlanta headend equipment. The television manufacturers would find it difficult and expensive to design televisions to work on multiple addressable systems.

Therefore, the only way to receive pay-per-view is to rent a set-top from your local CATV company.

On the other hand, there were still advances in television technology that surpassed the set-top advances in the United States. For example, some television tuners were able to receive more than one television signal and display both of them. Figure 1 tries to show this system which is know as picture-in-picture.

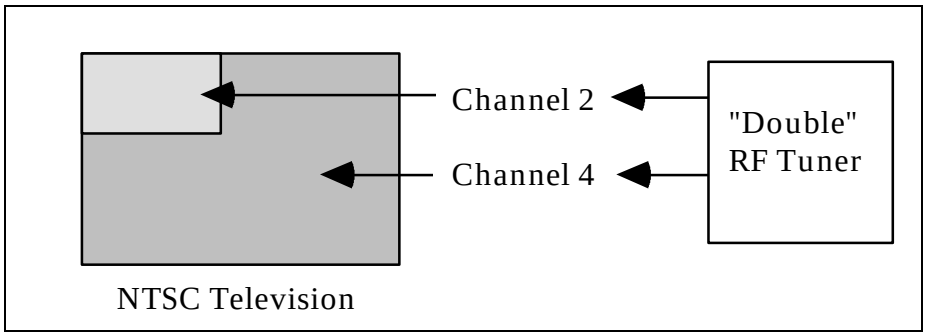

Figure 1: Schematic of Dual Channel Viewing on a TV

This system allows a viewer to preview one channel while viewing another. Once a set-top box is added to the system, the “double” RF tuner only receives the output from the set-top box and not the many channels of the airwaves. Therefore, the introduction of the cable company’s set-top disables this feature of the television. This can be thought of as a non-interoperable architecture.

Consumer dissatisfaction with their cable companies started to grow. They were paying outrageous amounts for cable service since their CATV company had a monopoly. They were also stuck with a set-top box that made such functions on their television as picture-in-picture obsolete. These changes set the stage for government to get involved again.

The Re-Regulation of CATV, 1992 - Present

Cable companies enjoyed a monopoly for a few years until discussion about re-regulation of the cable television industry became very serious. Cable TV became the "bad and ugly" monopoly operator enjoying obscene profits. The Bush Administration stood by the 1984 Act claiming that an unregulated industry was better. It is a little unclear why the administration thought an unregulated cable industry is better as seen by Vice President Dan Quayle's responses to questions on NBC's "Meet the Press":

> Q: Explain in simple terms why the cable companies should not be regulated.
>
> A: O.K. Simple terms, here's the choice. Here's the choice in simple terms. Are you going to try to constrain the price increase through regulation or through genuine competition? Our preference is to do it through genuine competition.
>
> Q: But there isn't genuine competition.
>
> A: That's right. Because you have -- but the cities that grant these things can certainly be more competitive and have more openness if they're --
>
> Q: So your suggestion is that they go out and have two or three different companies wire these communities to get competition?
>
> A: I'm not going to get into the micromanagement of the cable industry.[10]

While Dan Quayle didn't have all the answers, the Bush Administration stood by the 1984 Cable Deregulation Act by vetoing the 1992 Cable Act. However, Congress (which was controlled by the Democrats) overturned the veto. This was the only bill that ever succeeded to be overridden by a Bush veto and it happened just before the 1993 election.[11] Whether or not the bill was passed because of politics or genuine interest in cable television rates doesn't matter as much as the fact that the 1992 Cable Act was now a law.

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[10]Nelson, 1992.

[11]See Clymer, 1992.

The 1992 Act required that cable companies provide levels of service which separated out a basic service tier. This way there was a cheap way for people to get connected to the CATV network without paying for the frills of HBO and the like if they didn't want it. Although this was legislated to achieve a more equitable pricing structure for CATV services, it had an effect on the CATV architecture as well. Because every person's cable needs became very specialized, the need for addressable converters increased. This meant that more cable boxes were introduced in homes and presented the problem of cost and television incompatibilities. This second point was foreseen by the 1992 Cable Act and there was legislation to address this issue.

The Cable Act of 1992 tried to encourage interoperability with television manufacturers. The '92 Cable Act explicitly states:

> Within 1 year after the date of enactment of this section, the [Federal Communications] Commission, in consultation with representatives of the cable industry and the consumer electronic industry, shall report to Congress on means of assuring compatibility between television and video cassette recorders and cable systems, consistent with the need to prevent theft of cable service, so that cable subscribers will be able to enjoy the full benefit of both the programming available on cable systems and the functions available on their televisions and video cassette recorders. Within 180 days after the date of submission of the report required by this subsection, the Commission shall issue such regulations as are necessary to assure such compatibility.[12]

The FCC, however, wasn't able to enforce this Act immediately due to administrative constraints. But, by February of 1994, the FCC started issuing directives to enforce the Cable Act of 1992.[13] The FCC ordered a 7% reduction in cable TV rates. It is unclear how well enforced these laws

[12]This is the exact language from the 1992 Cable TV Consumer Act which adds Section 642A. This is a quote from subsection 1.
[13]Kolbert, 1994.

will be enforced since this task is almost unwieldy.[14] The Commission did offer a report within the allotted time which said that the 1992 Cable Act would be enforced by the FCC.[15]

Besides the '92 Cable Act, changes in cable services may change the role of the set-top once again -- and this time the set-top may need to be "open." One of the changes in cable systems is the movement towards two-way communication. Instead of ordering a pay-per-view movie through your phone lines, cable systems are able to use their coaxial and fiber networks to carry that information upstream. By punching the appropriate keys on your television you may convey the same information to the cable companies that it took a phone call to do before. In order for people to use devices such as touch-screens, the television companies and set-top companies will have to exchange information about their technology and thereby promote interoperability.

The Future of the Set-Top Box

New services, convergence of modes, growth of the Internet, etc. have all been part of the flurry that some call the "Information Superhighway." As was mentioned in the introduction, the cable companies are right in the thick of it because they own high-bandwidth wires in the local loop. So, it is in the interest of CATV companies and other service and network providers to tap into the existing CATV infrastructure so new markets can develop more quickly. As eluded to in the previous section, this cooperation and interconnection to existing infrastructures means interoperability. The Society of Motion Picture and Television Engineers (SMPTE) has defined interoperability to be the following:

> The use of common standard components to serve diverse needs across all affected industries. A digital image architecture should enable the movement of image data across application and industry boundaries without image degradation and with minimum complication. This characteristic is called *interoperability*.[18]

Although SMPTE was defining interoperability specifically for high resolution systems, this definition is quite applicable to interoperability trends in the CATV industry.

The need to use "common standard components" for interoperability hits hard at the set-top box. Proprietary components are not very interoperable since the technology isn't being shared across products. Even if the technology is licensed by the developer of the proprietary technology, licensing fees may prove to be a significant barrier to its success. Therefore, to be more interoperable, the set-top manufacturers need to develop open architectures that allow collaboration and competition in the set-top industry.[19]

The benefit of making the system more open is alluded to in the SMPTE definition as well: "diverse needs across all affected industries." By making interoperable components, the cable system can connect more easily to the Internet and provide existing network services such as electronic mail. It may be technically feasible to phone service, video conferencing, video e-mail, data transfer, etc. as well. This technical ability is supported by proposed legislation in Congress, such as HR3636, which encourages competition and openness in telecommunications. Perhaps one day the phone company will provide TV programs and the cable company will provide telephone service. Certainly the trend seems to indicate that policy makers would like to see this happen.

This paper puts forth the notion of interoperability having three main characteristics:

1. Open Standards
2. Open Access
3. Open Competition

It is very difficult to legislate the third option, open competition, but this paper proposes that by allowing open standards and open access, open competition will result. This argument parallels a point made by Pool, "Universal interconnection implies both adherence to technical standards, without which interconnection can be difficult, and a firm recognition of the right to interconnect."[20]

Currently, the set-top box market has neither open standards nor open access. The open standards question has been addressed in the previous section discussing proprietary technology that prohibits a cable box used with one cable system to be used with another system. A General Instrument set-top is designed to work with GI headend equipment and not Scientific Atlanta equipment. Even provisions in the '92 Cable Act which mandate cooperation between television manufacturers and set-top manufacturers does not constitute a true open architecture since they

[20]Pool, p. 247.

are leaving computer manufacturers et. al. out of the standards setting process. Next, the notion of open access isn't allowed because of non-common carrier status of cable companies. Even though Congress had mandated that cable companies broadcast certain kinds of programs (i.e. local and community access television) this model is far from the open access necessary to facilitate open competition.

Fortunately, businesses have begun to see the importance of open standards and have incorporated openness in their products. For example, General Instrument designed its Digicipher II system to be an open standard which is different than the Digicipher I system, a proprietary technology. In another example, Bell Atlantic is using compression standards set by the Motion Picture Experts Group (MPEG) for its video dialtone trials. Their set-top box for the trial includes the MPEG I decompression chip which decompresses a 1.5 Mbps downstream channel into a regular television channel.

Making the CATV companies into two separate companies, a conduit and content provider, may promote open access in the set-top market. This separation of multimedia services is known as disaggregation.[21] What this may essentially do is create a company that would be similar to the telephone companies by providing a medium to send and receive information. Then, like the telephone company, this conduit provider could be subjected to the same common carrier laws that a local telephone company may be subjected to. The information providers would then be allowed to use the conduit on a common carrier basis. And, since Pool points out that there is no shortage of bandwidth over a cable system, just poor use of the existing bandwidth, we can imagine everyone getting as much information transmitted and/or received over the cable system.

The Fork in the Set-Top Road

[21]McGarty, 1992.

As the set-top becomes open, its functionality comes into question since it can start down the road of elimination or the road of enhancement. This question of home network architecture is currently being debated by many people in the industry. There seemed to be disagreement on the role of the set-top of the future -- whether it should be incorporated into information appliances or whether it should become the "home hub." This role change the set-top is predicted to undergo depends upon whether consumers feel that the set-top services should be increased or decreased. If it is increased, the set-top may look more like a network router at the home (or an information furnace, home hub, etc.). In this case the set-top may connect personal computers, telephones, televisions, etc. to multiple wireline and/or wireless services. The other possibility is more akin to the changes in the close captioning set-top industry -- the functionality of the set-top gets incorporated into the television. The lines industry has drawn are fairly clear on this one -- electronic appliance manufacturers want the set-top to be eliminated while people from the computer industry envision the opposite.[22] Figure 2 demonstrates how these two different views may be represented.

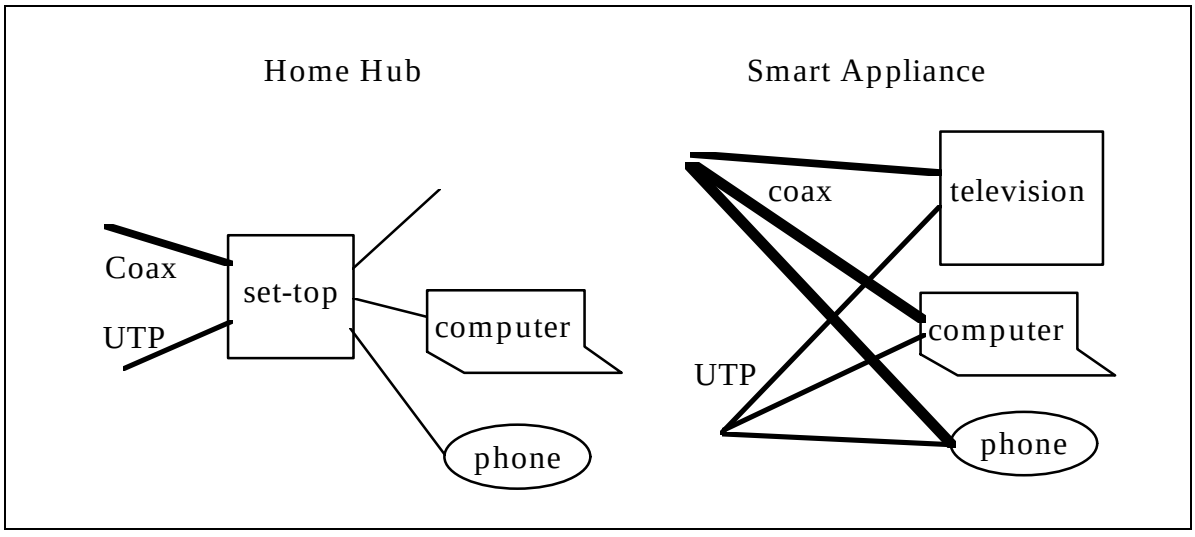

Figure 2: Possible Architectures for the Home Network

[22]This view was presented at the IMA Set-Top Summit by people from the Electronic Industries Association (against the set-top) and people from Kaleida Labs (for the set-top).

The advantage of an interoperable system is that both of these architectures may develop and still work with each other. It would be up to consumers to decide which architecture best meets their needs and their pocketbooks. Although this debate is currently being argued, it is beyond the scope of this paper to predict which of these two architectures will dominate the market.

Local Loop Considerations

Physically, the CATV companies have a much different local loop architecture than the telephone companies and that may not change even with disaggregation. Figure 3 demonstrates this point.

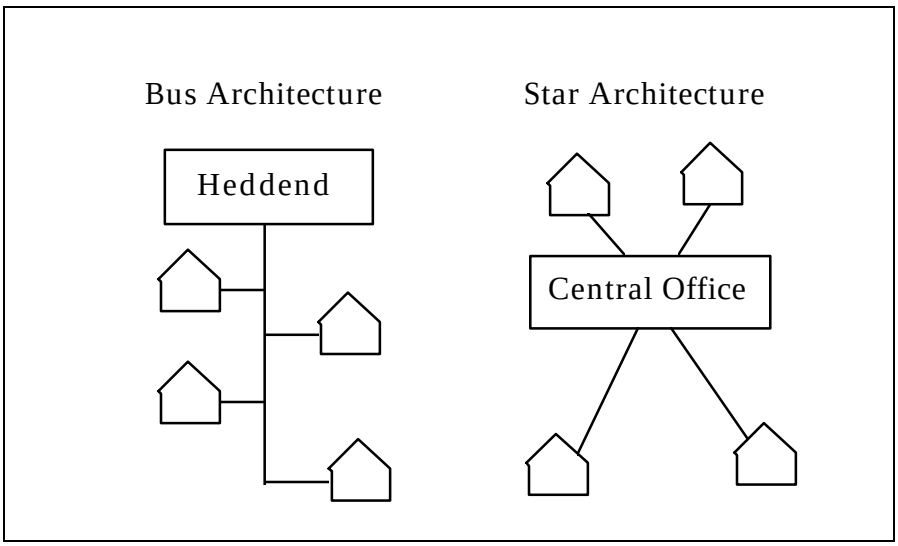

Figure 3: Differences in Local Loop Architectures

By sharing a bus architecture, the cable companies provide a medium similar to Ethernet. There is no allocated portion of the backbone for a particular home's use. Rather, if you are not using the bandwidth, someone else can. That makes the bus configuration very extensible since adding more people to the network doesn't change the bandwidth of the bus, however it may be necessary to change the power of the signals over the backbone since more people will be sharing the signal. In contrast, the phone company's star architecture allocates a fixed amount of bandwidth whether you're using it or not. It is likely that fiber optics and coaxial cables are used with multiplexing in the local phone system to share a wire, but that bandwidth is allocated for a

consumer whether or not they are using their phone. This hinders the extensibility of the phone system architecture since new electronics and possibly wires are needed all the way to the central office in order for another user to connect to the system. This is in contrast to the cable bus architecture where it takes electronics added up to the bus connection.

Because the cable system is a shared medium, it is a major concern that people will receive signals that are not intended for them. This is already a major concern in the computer networking field where data transmissions meant for a particular user were intercepted by another user. If, for example, the information flowing over the network is a key to a pay-per-view program, a cable company is going to be very upset that it is losing revenue on someone who "stole" a movie from them. The phone architecture doesn't have this problem since the phone company only sends information downstream that they know is yours. It is possible to tap into someone else's phone system and spy on their data they are receiving or transmitting, but the data switching to determine what a user sends and receives is done at the phone company's central office. In contrast with that model, the "switching" that occurs for CATV subscribers occurs in the set-top box. By giving the user the "switch" it is argued that illegal information will be taken from the bus -- information that wasn't intended for that consumer. This concern of network security is the biggest reason why people don't want to set open standards for a set-top box.

Network Security

Currently, CATV network security is a problem and cable companies are arguing that it will only get worse if the set-top box market becomes open. In his article about why set-tops should not become interoperable, Krauss says that, "Set-top interoperability might mean a single standardized scrambling method for the entire country -- far too risky as a target for pirates."[23] What is interesting about this argument is that a national encryption scheme is in place for satellite encryption, a system that isn't being targeted by video pirates. Rather, it is the cable television

[23]Krauss, 1994.

market that has multiple encryption standards that is being seized by the black market of decoder chips.

Cable TV security is handled by owning the set-top box and the keys that unlock the encrypted signals. If a specific hard-wired computer chip is used to decrypt the signal, it is quite possible that the chip exists on the black market and is being sold. When this chip is put into your set-top, it will be undetectable by the cable company. However, when this system included addressable converters, it is very easy to make sure that the system stays secure. By updating the encryption and decryption methods regularly, you can thwart efforts by people to steal keys. Then, by knowing who has the authorized boxes, you can make sure that they are the only ones that have the keys. If, in the event that someone has an unauthorized set-top box connected to your cable network, you can disable it right from the headend.

For example, a cable company can send out a signal to all "legal" set-tops telling them to "ignore the next message I send you." The illegal set-tops have no way of understanding this message. Then, the next message sent by the headend tells them to "go into standby mode," in other words, stop working. Perhaps one of the best parts of this scheme is that many people who own the black-market set-tops will call their cable company and complain that they are no longer receiving their cable service. The cable company can then apologize, get their address to send out a service person, and send out the police instead.

This is not to say that this is the best future for security is addressable converters and the police, rather the notion of regularly updated keys distributed regularly through the medium will prevent piracy (the addressable converter model minus the police). This system is very similar to a satellite security system. Use of the Videocipher system allows people to receive satellite transmissions if they have received the proper keys. Satellite set-tops are not leased by satellite

companies, they are purchased in stores like Radio Shack. Most importantly, as was pointed out earlier, the satellite set-top encryption/decryption system is more secure than the cable TV model.

Perhaps one of the biggest reasons why the cable model developed differently than the satellite model is the scope of the system. Cable companies were seen a local, community services. The satellite system was national, even international in scope. Because of this, the cable companies could actually own the entire transmission and electronics connected to the CATV system. The satellite system was too large, and the information was owned by too many people for one person to own the whole system. What developed was a more interoperable, open system.

Radio Frequency Interference

Another concern the cable companies have with opening the set-top is that the set-tops will send signal transmissions upstream an unlicensed frequencies that will interfere with other communication devices. Krauss points out that a subscriber "could actually create a mini-broadcast station" by connecting a poorly designed set-top and this could, in turn, create "serious safety concerns if cable signals leak into aeronautical channels."[24] This indeed is a problem, and one that has been addressed before.

Krauss' argument sounds very similar to the argument given by the phone company when they allowed only their telephones for the phone system. This matter was resolved by numerous cases the most famous of which is *AT&T vs. Carterfone* which was decided in 1968.[25] The Carterfone system was a radio communication service that then connected to the existing telephone network. AT&T argued that such a system would degrade the integrity of the phone system. It was decided that any service was allowed to connect with the existing telephone network as long as the interconnection point meet the technical standards set by AT&T.

[24]Krauss, 1994.
[25]See FCC Dockets 16942 and 17073.

This decision for the telephone company doesn't apply to cable companies exactly, but a precedent has been set for interconnection to happen even though incorrect interconnection would degrade the system. The first reason that the Carterfone decision doesn't apply is because the cable companies are not common carriers. The possibility of the disaggregation of the cable company to be a common carrier is discussed previously and, if it happens, will counter this argument. The other reason that stands out is the difference in the network traffic and architecture. Since the cable system uses a bus system where the bandwidth is shared among users, it is possible to foul up traffic that doesn't belong to you. Even with these two differences, it is possible to set technical standards with confront these differences. For example, the router market for computer networks has developed for efficient queuing, routing, collision detection, etc. The lessons learned from an open Internet market can be applied to the CATV system to ensure there will be no RF interference.

Economics of an Open Set-Top

What may be the most interesting part about opening the set-top market is what will happen to the set-top market itself if it become open. What would this market look like? There would be no set-top rental charge on your cable bill each month. Instead, you would walk into a department store and there would be a few different models of cable boxes to select from right next to shelf of televisions. The next television you bought would be "addressable ready" so you wouldn't even need a set-top box to receive programs like pay-per-view. If you moved to a new location, you could take your existing set-top box with you, plug it in (if there is an existing drop already), call up your cable company, and within a day you would have exactly the kind of video service you want. There would be no need to send someone to your house and "install" a cable box to your television. In the future, you could buy special set-top boxes to connect your computer to the Internet, tune in multiple channels so you could use your picture-in-picture television. This is all technically possible -- it is only the policy that is holding up this model.

The biggest economic question is how much is this box going to cost? Maybe a good place to start is a current addressable set-top box. Table 2 outlines the eight major components to a set-top box and their associated marginal cost of production.

Component	Cost
Power Supply	$5
RF Tuner	$20
RF Output	$1
Remote Control	$2
Decoder Chip	$1
Casing	$3
LED Display	$1
Touch Pad	$1
Total	**$34**

Table 2: Estimate of the Cost of an Addressable Set-Top Box

This estimate coincides fairly well with an aggregate estimated cost of $40.[26] This cost estimate differs greatly from the actual price paid by cable companies of $100 for a new addressable converter and between $80 and $90 for a refurbished one.[27] This then means that there is over a factor of two with the mark-up of the set-top box. Similarly, in the television market, the mark-up is about 1.8.[28] That's fairly close, but certainly not the cost savings you may imagine. After all, the cable companies are buying in bulk from set-top box manufacturers so they avoid the retail mark-up and retail costs. Even if a $100 sale price could be explained, it is difficult to determine why consumers pay $300 for the same set-top box.[29]

[26]Branko Gerovac, Digital Equipment Corporation, op. cit.

[27]Nina Briggs, Contak Inc. Contak is in the business of refurbishing set-top boxes and then they sell them to cable companies. Nina pointed out that they are very careful only to sell them to cable companies since it would be against their policy and, hence, ruin their reputation to sell to cable customers.

[28]Jeffrey Hart, University of Indiana, author of "Consumer Electronics," 1992, op. cit.

[29]MD Electronics, 1994 catalog. The item for sale is a Jerrold (General Instrument) DPV-7. This is a "vanilla" addressable set-top box.

If there was some open standards set for the set-top box market, the complexity and cost of the set-tops would fall greatly. According to Randy Ostler of Texas Instruments, standardization of set-top functionality would allow computer chip manufacturers to integrate all of the RF tuning, decoding, memory, and microprocessor functions on one chip.[30] This would allow for tremendous savings in cost since the price of that chip would approach a few dollars just as many complex chips have done in the past. This is a result from a phenomenon known as Moore's Law which states that the performance per dollar of electronics doubles every 18 months.

As argued earlier in the paper, there would also be increased functionality of the set-top boxes in the market. For example, the future of high definition television (HDTV) may rely on the cable networks to penetrate the market. By creating an interoperable HDTV standard, there will be cost advantages with the set-top box market. Table 3 outlines this point.

Year	Interoperable Set-Top	Non-Interoperable Set-Top
1995	$309	$225
1997	$128	$147
1999	$74	$111
2001	$52	$94
2003	$37	$77
2005	$31	$70
2007	$26	$66
2009	$24	$63

Table 3: Cost of Interoperable vs. Non-Interoperable Set-Top Boxes[31]

Table 3 shows that an interoperable set-top may cost more initially, but the cost advantage is realized only after two years. Jacobson's argument stems from the fact that interoperable

[30]This is from his presentation given at the IMA Set-Top Summit, April 1994, Arlington, VA.
[31]Jacobson, 1993, Appendix A.

components can be shared across technologies thereby having advantages of economies of scale and scope.

No matter which direction the set-top box takes, there will be advantages to making the technology interoperable. The notion of an enhanced set-top box will increase the number of units sold since the set-top box will have more market appeal. As more units are sold, the price decreases due to economies of scale and greater competition facilitated by open standards and open access. If the set-top box gets incorporated into televisions, for example, thereby eliminating the need for set-tops, components such as the power supply, tuner, remote, etc. no longer have to be redundant components and will give consumers a cost savings.

Conclusion

The convergence in the telecommunications industry is putting a squeeze on the highly closed and proprietary set-top box. In order to fit into the interoperable model of the NII, the set-top box will have to communicate and interconnect with different networks and different electronic devices. It must leave the CATV paradigm behind in favor of an interoperable one. This push isn't coming only from the policy makers in Washington, however. Business models of interconnection and new services are making typically closed companies, like General Instrument, open up.

In order for a fully interoperable set-top to be introduced, however, open standards and open access must be ensured. Although cable systems developed in a very decentralized fashion, new reregulation by the government (namely the '92 Cable Act) has established new national policies that create a more unified infrastructure. This movement may facilitate common standards between cable companies and lead to possible disaggregation of the cable market. Other policies which allow competition to provide video services in the local loop, such as video-on-demand from the telephone company, may mean more direct competition for cable companies. Hence, rate regulation that was reintroduced in the '92 Cable Act may be lifted so that competition will help keep prices low. Perhaps Dan Quayle wasn't so far off. After all, services such as direct broadcast satellite (DBS) and video over the Internet (via MBONE broadcasts) may provide non-traditional CATV services.

These open standards and open access may not be such a bad thing for the CATV industry as expected. Security problems that are feared can be alleviated by adoption of open standards like General Instrument's Digicipher II system and a decryption key distribution like the satellite system. The radio frequency problems that may be expected can be eliminated by making sure exact and open specifications are agreed upon by the different people interested in making set-top

boxes. However, there is one area that openness will definitely hurt the cable television companies -- control over the information.

By promoting open standards and open access, open competition can dominate and the consumer will be the winner. One benefit may be that the price of set-top boxes fall. Another benefit may be the introduction of the "home hub" which will allow the home network architecture to develop. And, more services, such as Internet access, may develop. Opening the set-top unlocks the key to better prices and more services so to encourage the development of the NII.

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