CATV BANDWIDTH ASSESSMENT
(A PRACTICAL APPROACH TO SYSTEM DESIGN)

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Abstract

The multitude of upcoming franchise renewals, the resulting need for many cable television system re-builds, and the recent onslaught of evolving technologies, are provoking much discussion among CATV personnel regarding the amount of bandwidth that should be built into cable systems. Many industry leaders are touting 1GHz as the bandwidth of choice, while others are concerned that even 1GHz will not be enough bandwidth to support the incredible amount of services that the future Cable TV operator will want to provide.

Current development of spectrum-saving technologies such as video compression and signal multiplexing, however, may eliminate the need for such an enormous bandwidth. In fact, when utilized in conjunction with an appropriate architecture, 550MHz and 750MHz systems will provide ample capacity, both today and in the future, for the delivery of a wide range of conventional and interactive services.

BANDWIDTH ASSESSMENT

Relative to a system re-build (or new build), there are at least two major technical questions that must be answered:

1. At what bandwidth should the system be designed?
2. What type of architecture should be employed?

When searching for the best answers to these questions, it is easy to be confused by the many factors which play a part in the decision-making process, (e.g., company economics, preparation for future CATV services, product availability, etc.). Since most of the industry discussion relating to system bandwidth is centered around future CATV services, (e.g., telephony-over-cable, video on demand, etc.), it is probably most practical to begin an analysis by taking a closer look at those services.

It is important to understand the types of CATV services that will be available and the amount of bandwidth that each service will demand. Also, because the provisioning of certain services is dependent upon the use of an appropriate system architecture, it is important to understand which types of architectures are conducive to providing particular types of services.

Since a picture is worth a thousand words, Figure 1 (on the following page) will form a good basis for discussion relative to the two questions above.

Bandwidth Segmentation

FORWARD ONLY		
Off Air	60 MHz	10 channels
Satellite Basic	252 MHz	42 channels
Pay Channels (*HBO*, etc.)	42 MHz	7 channels
Analog PPV	18 MHz	3 channels
Near Video On Demand	90 MHz	120 channels
Local Access, Local Origination	18 MHz	3 channels
SUBTOTAL	**480 MHz**	**185 channels**
Digital Music Service	18 MHz	
INTERACTIVE (Forward/Reverse)		
Customer Sig./Status Monitor	6 MHz	
Telephone Service	36 MHz	
Personal Computer Networking	24 MHz	
GRAND TOTAL	**564 MHz**	

FIGURE 1

While the number of channels allotted for each service will vary from system to system, the purpose of this chart is to provide the foundation for a well-informed decision.

Listed in Figure 1 are various services that will be provided by CATV operators, both in the present and in the future. The chart is *not* intended to represent exact bandwidth segmentation for every cable system in the country. Instead, it is intended to be a source of information for those who are concerned with the demand that certain services will place on system bandwidth.

Following are explanations regarding some of the services listed...

Near Video on Demand

Near Video On Demand will allow subscribers to choose from a list of movies, with each movie beginning approximately every 15-30 minutes (or at whatever interval the operator chooses). Generally, because N.V.O.D. is channel-intensive, it makes best sense to employ this service in conjunction with video compression technology. Assuming a compression ratio of 8:1 (a reasonable assumption for movie services) 90MHz can be used to provide the following:

Assuming two-hour movies...

- Each of ten (10) movies can begin every fifteen (15) minutes (80 channels required), and...
- Each of ten (10) movies can begin every thirty (30) minutes (40 channels required).

That's a total of twenty (20) movies in all; each being shown with a relatively small interval of time between successive starts (15-30 minutes). As technology advances and compression ratios increase, more movies can be added with less time between successive starts.

The mathematics here are quite simple. A movie that lasts two hours will utilize eight (8) channels if it is to be shown every fifteen minutes. This results from the fact that there are eight (8) fifteen-minute intervals in a two-hour period. Similarly, if the same movie will be shown every thirty minutes, it will require four (4) channels as there are four (4) thirty-minute intervals in a two-hour period.

The 90MHz of bandwidth can be divided up in many different ways depending on the number of movies to be shown and the intervals between successive starts (e.g., assuming two-hour movies and 8:1 compression, using 120 channels, each of twenty (20) movies can begin every twenty minutes).

What about Video On Demand (as opposed to Near Video on Demand)? While video on demand is certainly a service that will be provided by the CATV operator, video on demand is not so much bandwidth intensive as it is dependent on an appropriate system architecture (one that segments the system by limiting the number of homes per fiber node) and the addition of intelligent headend and subscriber equipment. The headend equipment will be capable of delivering a single movie to a particular subscriber as needed and may incorporate some form of *less-than-real-time* delivery (e.g., forward & store). It is expected that a 2,000-household fiber node will require approximately twenty-four (24) channels dedicated to V.O.D., assuming 60% of the homes passed by cable take basic service and 25% of those subscribe to V.O.D. with a peak usage rate of eight percent. Assuming 4:1 compression, for example, these 24 channels would occupy only 36MHz of bandwidth.

Depending on the compression scheme used, the subscriber demand, and the number of channels available to the operator for the service, many scenarios can be envisioned related to the provisioning of V.O.D. In any case, it can be expected that Video On Demand will require considerably less bandwidth than the 90MHz shown in Figure 1; thereby freeing a portion of the spectrum for use by other services.

It is assumed here that most systems will not find the need to provide a full slate of N.V.O.D. programming <u>and</u> a full slate of V.O.D. programming. Delivery of one service or the other would be most appropriate.

<u>Telephone Service</u>

Telephone service may include a Personal Communications Service (PCS) or may be a standard telephony-over-cable service. In either case, the following will serve to explain some of the applicable math:

Regarding standard telephony-over-cable, one (1) 6MHz channel in each direction (upstream & downstream) will be capable of supporting approximately 375 voice users. Assuming a telephony penetration of 25%, these two channels can serve a 1500-home node (1500 x 25% = 375). Two (2) channels in each direction will support approximately 850 voice users. Assuming 2,000 homes-per-node, these four channels (2 in each direction) will support a penetration rate of about 43%. The 36 MHz in the above chart will support approximately 1,380 voice users. In a 2,000-home node, that equates to a telephony penetration of nearly 70%. *The above numbers relating to voice users per channel are based on a Grade of Service equal to P.01. This equates to a call-blocking probability of less than 1% during the busiest hour of the busiest season (BHBS).*

It is signal multiplexing that allows such a large number of users to use such a small amount of spectrum. The bandwidth requirements for a personal communications service will be similar to those spelled out above for standard telephony-over-cable. As time marches on, and multiplexing and compression technologies improve, it can be expected that these services will require even less bandwidth.

Personal Computer Networking

This particular category covers a wide range of potential services related to data transfer (as with a standard modem). One related scenario might include linking schools together via the cable network to provide a *distance learning* environment. In this way, for example, a local grade school could tap into the library of a local high school or college. Another scenario may include the private, point-to-point interconnection of business users via the cable network.

Products are available today which allow for Ethernet- (IEEE-802.3) type data transfer over standard cable television plant. Current technology allows for a digital bit rate of approximately 10Mb/s to be placed within one (1) 6MHz channel on the cable network. The number of channels required for a particular service will be dependent upon the number of users on the network and the amount of delay time that is acceptable to the users. Overloading the network with users (and therefore data) will result in data congestion. This congestion results in slower transfer of data. Enough bandwidth will have to be provided to accommodate the number of users and their demands on network speed.

Presently, two (2) 6MHz channels (one in each direction) will allow for full, two-way 10Mb/s data transfer; allowing approximately twenty to thirty (20-30) users to share the network without severe delay times. The 24MHz in the chart above will allow for approximately twice that number. The majority of cable operators will likely find most of their success (related to this category) in dealing with point-to-point connections such as schools and businesses as described above. In these scenarios, 24MHz should be plenty of bandwidth to provide for a host of options relating to personal computer networking. Again, as technology advances, the bandwidth requirements related to the provisioning of this service will relax.

Digital Music

The 18MHz allows for approximately thirty (30) channels of commercial-free stereo audio programming to be delivered to the customer. The 18MHz can generally be segregated into smaller portions and be placed in the *roll-off* or FM portions of the spectrum, making it very bandwidth-efficient. The programming consists of a wide variety of music including jazz, rock, country, classical, etc. This technology (known by the trade names *DMX*, *DCR*, etc.) is already being successfully used by many cable operators around the country.

There are those who will argue that the above chart (Figure 1) fails to account for other services that may develop five to ten years from now, and therefore cannot be used to properly assess bandwidth requirements. Figure 2 below serves as a counterpoint to that argument.

Bandwidth Segmentation

(large-scale use of compression)

[shaded] = **compressed 4:1**
(N.V.O.D. = 8:1)

FORWARD ONLY

Off Air, L.O., Access	84 MHz	14 channels
Satellite Basic	**72 MHz**	**48 channels**
Pay Channels (*HBO*, etc.)	**11 MHz**	**7 channels**
Pay-Per-View	**5 MHz**	**3 channels**
Near Video On Demand	**90 MHz**	**120 channels**
SUBTOTAL	**262 MHz**	**192 channels**
Digital Music Service	18 MHz	

INTERACTIVE (Forward/Reverse)

Customer Sig./Status Monitor	6 MHz
Telephone Service	36 MHz
Personal Computer Networking	24 MHz
GRAND TOTAL	**346 MHz**

FIGURE 2

There are two simultaneous evolutions taking place in the CATV industry:

1. The number and types of potential CATV services are increasing and expanding.

2. Technologies for limiting the bandwidth requirements associated with those services are also progressing.

As technology continues to advance, the use of video compression and other spectrum-saving techniques such as multiplexing will increase. It can be expected that most satellite and pay channels will eventually be compressed, yielding an incredible amount of bandwidth that can be used for other services.

Practical Economics

Before getting caught up in too many arguments about future services, it is worthwhile to take a look at some factors of economics. Relative to system design, and applicable to almost all cable systems, are the following arguments:

1. Any system planned at less than 550MHz is impractical. With all of the recent advancements in electronics, a 550MHz build can be done more cost effectively than a 450MHz build. In fact, according to most sources, 450MHz is a thing of the past.

2. As discussed earlier, in order to be prepared to provide the many future CATV services that will be available, a system design which specifies 2,000 (or fewer) homes per fiber node is most desirable. Fortunately, with the cost of fiber-optic equipment dropping, and the availability of a new generation of specially-designed amplifiers and cable, it has been shown that, in most cases, a Fiber-to-the-Service Area design serving 2,000-home nodes can be implemented at a lower cost than a conventional trunk & feeder design.

If the CATV engineer follows the above logic and agrees that a 550MHz Fiber-to-the-Service Area design is the most practical starting point for today's re-builds, a decision then needs to be made regarding the possibility of incorporating a bandwidth greater than 550MHz. There are three (3) possibilities to consider for design:

1. Build the system at 550MHz with no regard to future bandwidth expansion.

2. Build the system at 550MHz, using proper amplifier spacing and an ample amount of fiber to accommodate easy expansion to a higher bandwidth.

3. Forego the 550MHz design by immediately building a system with a greater bandwidth.

Which is the right thing to do? The best answer to this question will be dependent upon the cable company's economic factors and whether or not the operator feels that he/she will desire to be a provider of such services as telephony-over-cable, distance learning, etc. Community demographics may play as important a role as any in regards to this decision.

In any case, a few points should be kept in mind...

1. As Figures 1 & 2 suggest, 1GHz is more bandwidth than most cable operators need to be concerned with. If a system is to be designed with consideration to a capacity of more than 550MHz, then 750MHz is an appropriate bandwidth to aim for. In Figure 1, the amount of bandwidth between 564MHz and 750MHz can be used for services such as High Definition Television (HDTV), which will require one (1) 6MHz channel per compressed HDTV channel. This extra bandwidth (up to 750MHz) can also be used for various digital data services that the CATV operator may want to provide.

2. A system designed at 550MHz without a true *footprint* for expansion to 750MHz can still be expanded to that higher frequency at some later date. The downside, however is that the operator will pay a huge premium for extra fiber, construction, and high-gain actives as compared with the operator who originally designed the system with future expansion in mind.

3. A system that is designed at 550MHz with the proper spacing and amount of fiber to allow for an easy upgrade to 750MHz will cost approximately 10% more for the initial build. However, expansion from 550MHz to 750MHz will be relatively painless.

CONCLUSIONS

With the advent of such services as V.O.D. and telephony-over-cable, and the continuing development of compression and multiplexing technologies, limiting the number of homes per fiber node is at least as important as (if not *more* important than) increasing system bandwidth.

Relative to system design, decision-makers can regard a 550MHz, Fiber-to-the-Service Area (2,000, or fewer, homes per node) architecture as a starting point for deliberation. From there, the most important decision is whether or not to consider 750MHz. If 750MHz is considered, the operator can either build a 550MHz system that is spaced for 750MHz or the operator can build a 750MHz system in the first place (which will cost about 10% more than a 550MHz system spaced for 750MHz). This decision must take into account both company finances and community demographics. For operators building a system today, it is important to keep the following in mind:

1. Depending on the number of channels currently being used for conventional programming services, and taking into account local demographics, many system operators will find that there is no need to plan for a system capacity beyond 550MHz. Many systems will be able to provide a full slate of conventional as well as interactive programming within that 550MHz.

2. If the operator knows that he/she will want to expand to 750MHz at some point during the life of the system, it may be more economical to build at 750MHz in the first place. Otherwise, the operator pays for a full set of 550MHz electronics now, and has to scrap the entire lot for 750MHz gear in a few years. In a case such as this, an immediate 750MHz build will actually end up being less expensive than the 550MHz build. *While this point may sound obvious, it is often overlooked.*

A 1GHz architecture may make sense for those systems involved in pioneering the development of new technologies, but 1GHz is far too impractical for the overwhelming majority of cable systems. The cost premium for the 1GHz system cannot be readily justified. (In fact, in most cases it is currently more economical to build a dual 550MHz plant than it is to build a single 1GHz plant). Today's cable operators will find much reward, both now and in the future, in limiting their current bandwidth planning to no greater than 550/750MHz.