Capacity Planning with Advanced Services

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This article will investigate the effects of system penetration rates on the sizing of serving areas and nodes. In today's robust environment, defining appropriate serving areas requires careful consideration. Multiple services are competing for the same forward and return path spectrum. Now, network quality and performance reliability are as important as the breadth of services offered.

With a system consisting of a 5-40 MHz return bandwidth and a 52-750 MHz forward bandwidth, downstream broadcast services reside in the 52-550 MHz passband with the remaining 200 MHz reserved for digital services. The system's analog broadcast services consist of analog non-encrypted services (basic), analog encrypted premium services (HBO, Showtime, etc.) and analog pay-per-view services. The digital broadcast services include digital audio programming, along with encrypted digitally compressed video programming. For this study, broadcast video's compression ratio was 4:1. Table 1 provides the number of channels for each of these broadcast services.

BROADCAST SERVICES		
Service	**Analog or Digital**	**Quantity of channels**
Non-encrypted	Analog	45
Encrypted	Analog	15
Digital Audio	Digital	30
Digital services (4:1 compression)	Digital	10
	Total Broadcast Channels	73

Table 1: Broadcast Channel Loading

Several different services, such as interactive video, cable modems and Hybrid Fiber Coax (HFC) telephony, make up the interactive services. These services vary according to the system and subscriber demographics.

Interactive video compression rates vary depending on video content. Three interactive video services were used at the following compression ratios:

Sports-on-demand @ 4:1 compression

Movies-on-demand @ 8:1 compression

School-on-demand @ 6:1 compression

Cable modem equipment utilized a two-way RF system with 64 QAM modulation in the downstream direction and QPSK modulation in the upstream

direction. Data rates for the downstream and upstream paths were 27 Mb/s and 1.7 Mb/s, respectively.

The HFC telephony equipment used in this investigation was symmetrical in nature and required a 50 kHz bandwidth for both downstream and upstream transmissions.

After determining the services, the next step is to compute the bandwidth per user for each of these services. Tables 2 and 3 present the required bandwidth per user for each of the services in the downstream and upstream signal paths. Broadcast services are delivered to every subscriber, while interactive services are delivered only to those who request them. The required bandwidth for interactive downstream services is determined by the compression ratio (for the on-demand services), modulation scheme (for cable modem) and the bandwidth needed to operate the HFC telephony equipment. Upstream signals are based on the carrier size for the different applications (300 kHz for addressable information, 200 kHz for on-demand services, etc.). The figures shown in Tables 2 and 3 were used in this testing.

DOWNSTREAM BANDWIDTH PER HOME SERVED (MHz)			
Service	**Bandwidth per service**	**Number of channels**	**Total bandwidth required (MHz)**
Non-encrypted (broadcast)	6	45	270
Encrypted (broadcast)	6	15	90
Digital Audio (broadcast)	0.6	30	18
Digital services (broadcast)	6	10	60
Total broadcast services			**438**
Sports-on-demand	1.5	1	1.5
Movies-on-demand	0.75	1	0.75
School-on-demand	1	1	1
Cable Modem	1	1	1
HFC Telephony	0.05	1	0.05
Total interactive services			**4.3**
Total Broadcast Services			**443**

Table 2: Downstream Bandwidth Requirements

UPSTREAM BANDWIDTH PER HOME SERVED (MHz)			
Service	**Bandwidth per service**	**Number of channels**	**Total bandwidth required**
Non-encrypted (broadcast)	0	1	0
Encrypted (broadcast)	0.300	1	0.300
Digital Audio (broadcast)	0	1	0
Digital Services (broadcast)	0.300	1	0.300
Total broadcast services			**.600**
Sports-on-demand	0.200	1	0.200
Movies-on-demand	0.200	1	0.200
School-on-demand	0.200	1	0.200
Cable Modem	0.200	1	0.200
HFC Telephony	0.05	1	0.05
Total interactive services			**0.850**
Total Broadcast Services			**1.450**

Table 3: Upstream Bandwidth Requirements

Once the bandwidth requirements are established, the penetration rates of these services must be determined. Two main penetration rates were used to identify appropriate node sizing: system penetration and interactive services penetration. System penetration is defined as the percentage of subscribers in the number of homes passed by the cable system. Interactive services penetration refers to the percentage of subscribers that will subscribe to interactive services. Simultaneous use of interactive services also must be taken into account when determining the proper number of homes passed for a node serving area. This parameter is often the limiting factor for the serving area size.

According to the 1995 “FCC Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming Second Annual Report" (released December 10, 1995), approximately 65% of the homes passed are basic cable subscribers. This number was assumed to be accurate and was held constant in the calculations for node sizing.

Interactive service penetration rates and simultaneous use rates are not well defined, because these services are just beginning to emerge. Operators must track this information carefully to obtain data for traffic studies, which will help to plan the network.

Example 1 shows how these percentages work. A 1000 homes passed node was multiplied by the 65% penetration rate to obtain the number of cable subscribers. Subscriber count was then multiplied by the 50% interactive service penetration rate to calculate the number of interactive service subscribers within the node. This number was then multiplied by the 25% simultaneous use rate to determine the estimated number of simultaneous interactive services users.

Example 1:

(1000 homes passed) x (.65) = 650 cable subscribers

(650 subscribers) x (.50) = 325 interactive services subscribers

(325 interactive subscribers) x (.25) = 81 simultaneous users

Calculating the node size

To calculate the node size, the calculation in Example 1 was used with two changes. First, the bandwidth available in both the downstream and upstream was used. Available bandwidth limits the number of simultaneous users possible in the network, driving down the number of homes passed per node. Secondly, the number of homes passed per node was calculated from the number of simultaneous users. This calculation came from doing the math in reverse order, using the number of simultaneous users as the given.

Using the system bandwidth information shown earlier, the available bandwidth in the downstream direction is 698 MHz. Both broadcast and interactive services use this bandwidth. Available upstream bandwidth is limited to 35 MHz, assuming that the entire 5-40 bandpass is useable.

The maximum number of simultaneous users can be calculated by using the bandwidth requirement for each service. The number of users depends on the bandwidth available in both the downstream and upstream paths. The lower of these numbers is the limiting factor for node sizing. The number of interactive subscribers is calculated using the number of simultaneous users. Once the number of interactive subscribers is known, the total number of cable subscribers is calculated using the interactive service penetration rate. Example 2 illustrates similar calculations used in the study, keeping the following penetration rates constant.

System penetration	65%
Interactive services penetration	50%
Estimated simultaneous use	25%
Downstream interactive bandwidth available (after broadcast services usage)	260 MHz
Upstream interactive bandwidth available (after broadcast services usage)	34.4 MHz

Example 2:

Simultaneous users possible (downstream) = (698-438) / 4.3 = 60 users

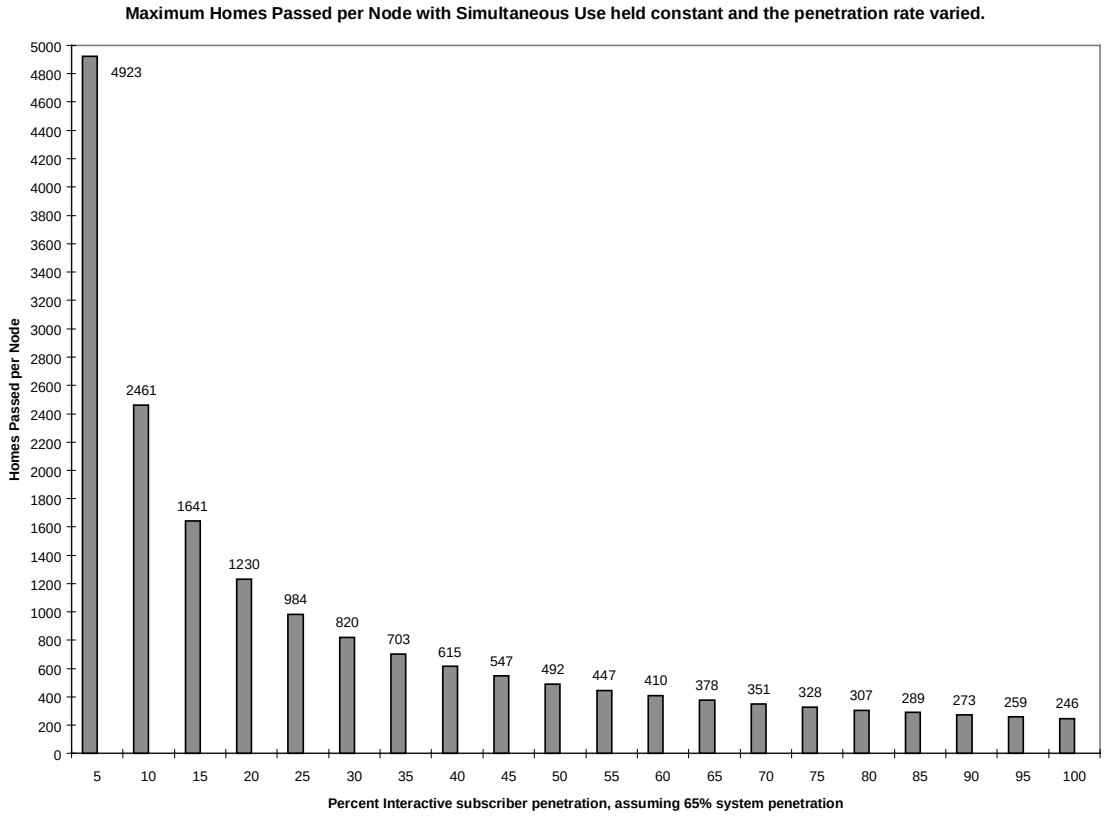
Simultaneous users possible (upstream) = (35-0.6) / 0.850 = 40 users

Interactive services subscribers = 40 / 0.25 = 160 interactive subscribers

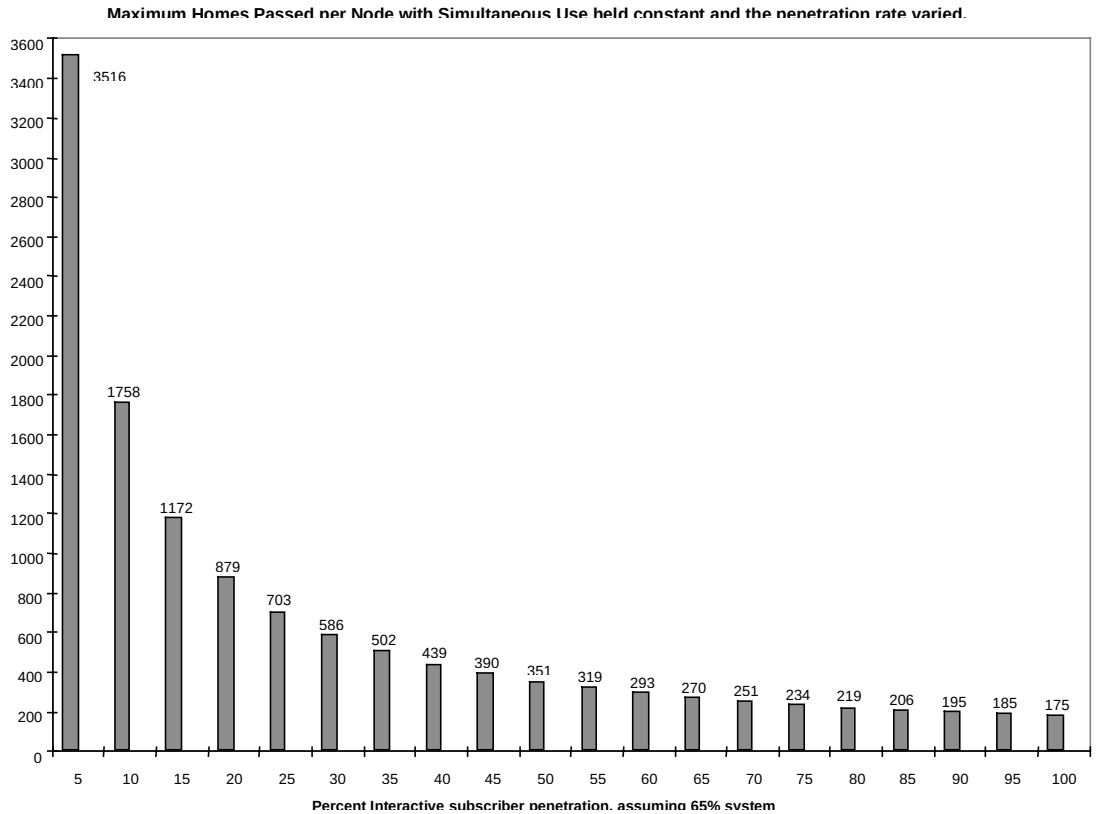
Cable subscribers = 160 / 0.50 = 320 cable subscribers

Homes passed = 320 / 0.65 = 492 homes passed per node

Both interactive penetration and simultaneous use affect node sizing. These parameters must be estimated realistically to size the node properly. To illustrate this point, Graph 1 shows the homes passed per node, holding simultaneous use at 25% and varying the interactive penetration rate. Graph 2 illustrates the maximum number of homes passed per node with simultaneous use held at 35% and a varying interactive penetration rate.



Graph 1: Simultaneous Use Held at 25%, Interactive Penetration Varied



Graph 2: Simultaneous Use Held at 35%, Interactive Penetration Varied

As seen in these graphs, the relationship between increasing interactive penetration rates and the resultant node size is disproportional. If the interactive penetration is held constant and the simultaneous use is increased, greater proportions result. For example, a system designed with 1000 homes passed nodes and an interactive subscriber rate of 15% supports little simultaneous use if the penetration rate increases available bandwidth. The solution is to migrate to a smaller node size when the penetration rate starts to increase. The scenarios presented have been limited by the upstream system's bandwidth. However, systems with high analog loading (77 channels) plus digital broadcast channels may become limited by downstream bandwidth as well.

Migration strategies for the network must be carefully planned. Selection of downsizable architecture is crucial in this planning process. Also, conducting detailed traffic studies about these services when they are first offered in the network is crucial. By observing the growth rates of these services, a more accurate estimate can be employed for planning node sizes and migration strategies. If demand for these services increases rapidly, technological innovations such as advanced modulation schemes and frequency upconversion may not become available quickly enough. If a flexible architecture is not implemented, system operators may risk additional headaches and expenses by trying to retrofit non-migratable architectures.

Taking the time to estimate interactive services' penetrations and performing a few calculations enables system operators to reach a starting point for node sizing. The point at which the node bandwidth can no longer support the users of the services can be determined by plotting curves based on different percentages. Using this information, system operators can smoothly transition the network to support the ever-expanding list of network services.