White Paper

Getting to 200 HD Channels: Meeting & Beating the Cable Bandwidth Challenge

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I. Executive Summary

For the past several years, cable operators have been shaking their heads in dismay at the growing dilemma unfolding before them. Despite the industry's massive investment in hybrid fiber/coax (HFC) plant and equipment over the last decade or so, MSOs are seeing clear evidence that their extensive network upgrades to 750MHz, and even 860MHz, systems have not created enough access capacity to handle all of the new digital services that they wish or need to carry.

Cable technology strategists have reluctantly come to realize that subscriber demand for precious bandwidth, which has been climbing much faster than almost anyone expected, may quite soon far outstrip their ability to meet it. Thanks to a volatile mix of legacy analog channels, digital video networks, HDTV, video-on-demand (VoD), digital video recorders (DVRs), broadcast digital must-carry requirements, and Internet video downloads, among other factors, users will continue to gobble up bandwidth in much greater chunks than previously anticipated. Indeed, if there has been one constant fact over the last several decades, it is that no amount of physical bandwidth has ever proven to be enough. That will likely continue to be the case for the foreseeable future.

Meanwhile, cable rivals such as DirecTV, Dish Network, AT&T, and Verizon are all aggressively expanding their digital video, HD, VoD, DVR, broadband, and other next-generation services. For example, DirecTV now offers 130 national HD channels – far more than any MSO or other multi-channel TV provider. DirecTV also offers local HD channels in 109 markets, covering more than 80 percent of U.S. households. And it plans to offer up to 150 national HD channels by the end of 2008, plus local HD channels in 121 markets, covering more than 88 percent of U.S. homes.

As a result of these forces, cable operators recognize that they must carry even more video and broadband "bandwidth hogs" just to stay competitive in the highly volatile media market. Consider the hotly contested HD space, where some top MSO executives talk about offering as many as 100 or more HD channels per market within the next year. In one of the most ambitious gambits, Comcast is now beefing up its HDTV and VoD programming lineups to offer more than 1,000 "HD choices" to digital subscribers by the close of the year.

To meet such daunting challenges, MSOs are turning to a growing assortment of technologies, tools, and techniques to expand overall capacity and/or use existing bandwidth more efficiently. Specifically, they are exploring analog channel reclamation, fiber node segmentation (a.k.a., node splitting), switched digital video (SDV), 1GHz plant upgrades, MPEG-4 encoding, and improved quadrature amplitude modulation (QAM) to stave off the pending bandwidth crunch. They are also weighing deep-fiber extensions and out-of-band spectrum overlays, among other options.

Fortunately, the big question is not whether cable operators can find enough new capacity to meet these growing bandwidth demands, because this capacity already exists. In fact, the industry's HFC plant is actually quite rich in bandwidth, much of which still lies untapped. In a 1GHz system, for example, each fiber node can support 154 radio frequency (RF) channels, or about 6 Gbit/s of downstream bandwidth. The spectrum just needs to be mined more effectively.

Instead, the big question for cable operators is just how much investment will it take to drill for the surplus bandwidth that is already there. How much capital will be needed to repurpose existing capacity so that all of the desired new digital services can be provided? What combination of new technologies, tools, and techniques makes the most sense for MSOs seeking to deliver improved HD, VoD, DVR, broadband, and other next-generation services to customers?

This white paper attempts to tackle these critical issues by examining the cable industry's growing bandwidth needs. Using a bandwidth optimization model recently developed by Cisco Systems, it examines just how much bandwidth will be required for each emerging service and exactly when that bandwidth will be required. It analyzes several leading techniques for expanding cable HFC plant capacity and/or making greater use of existing capacity, and explores the costs and benefits of two different combined approaches to meet the industry's growing bandwidth challenge.

II. Cable's Challenge: The Brewing Bandwidth Storm

In spite of the cable industry's $110-billion-plus network upgrades over the past dozen years, which were supposed to provide enough fresh bandwidth for many years to come, MSOs find themselves facing another pending capacity crunch as the decade approaches its end. Due to an especially lethal mix of legacy analog channels, digital networks, HDTV programming, VoD offerings, broadcast digital must-carry requirements, Internet video downloads, and time-shifting services, among others, cable subscribers are now consuming bandwidth in much greater amounts than many experts ever anticipated. Plus, it seems as if bandwidth consumption will grow even faster over the next few years.

In this section, we will break down a few of the critical factors contributing to this brewing bandwidth storm. The biggest and most obvious factor is HDTV, which has enjoyed a tremendous surge in consumer interest over the last four years. In its latest forecast issued in July, the Consumer Electronics Association (CEA) projected that electronics makers will ship more than 25.1 million HDTV sets and display monitors to U.S. retail stores in 2008, up from 20.7 million devices in 2007 and 17.3 million units in 2006. The CEA also predicted that HDTV shipments will soar again to a record total of more than 27.7 million sets and monitors in 2009.

Figure 1: Manufacturer Shipments of HDTV Sets to Dealers

YEAR	UNIT SALES	DOLLAR SALES
2003	3.38 million	$6.25 billion
2004	6.09 million	$9.21 billion
2005	8.80 million	$11.55 billion
2006	17.27 million	$18.41 billion
2007	20.72 million	$19.44 billion
2008e	25.10 million	$21.95 billion
2009p	27.75 million	$23.06 billion

Source: Consumer Electronics Association, July 2008

Due to such soaring sales figures, it seems likely that HDTV signals will reach the majority of TV viewers sooner, rather than later. In the most recent surveys, market researchers have found that as many as 50 million American homes, or up to 47 percent of all U.S. households, now have at least one HD set. With many households owning two or more HD sets, the CEA estimates that there are now close to 80 million HD monitors in all U.S. homes, up from 55 million monitors at the close of 2007.

With consumers still snapping up HD-enabled TVs at a robust pace, broadcasters, cable networks, movie studios, sports leagues, and other content providers are increasingly flooding the airwaves with new HD programming. Indeed, the National Cable & Telecommunications Association (NCTA) figures that 77 national cable networks have now gone the HD route, up from just nine networks four years ago. In a prime example, CNN launched its HD channel last fall, joining such cable stalwarts as A&E, Discovery Channel, ESPN, Food Network, HBO, HGTV, MTV, and TNT, along with all of the major broadcast networks.

Many more networks are likely to jump on the HDTV bandwagon over the next year. In a speech earlier in 2008, NCTA president and CEO Kyle McSlarrow cited cable programmers' plans to launch "several dozen more" HD channels by next summer. Plus, local broadcast TV stations, facing a strict mandate from Congress to switch exclusively to digital signals by mid-February 2009, are introducing HD channels in more than 200 markets across the U.S. Under the federal government's rules, all of these channels must be carried by their local cable systems.

Thanks to the soaring popularity of HD, cable operators are now scrambling to bolster their HD lineups substantially. They are also scrambling to respond to intensifying competitive pressure from satellite TV and telco TV providers, which have been aggressively adding new HD channels to differentiate their video offerings from typical cable fare. As noted earlier, DirecTV has especially turned HDTV into a potent marketing weapon against cable, promoting its plans to offer up to 150 national HD channels by the end of 2008 and at least 200 channels in 2009.

Buffeted by these forces, cable operators now talk about offering as many as 100 or more HD channels per market. In fact, at the Cable Show in May 2008, executives from Comcast, Time Warner Cable, Charter Communications, and Cablevision Systems all pledged to add more HD programming to their offerings. In one such move, Comcast is aggressively adding both HDTV linear channels and HD VoD offerings so that it can offer more than 1,000 "HD choices" to digital subscribers by the end of 2008.

The problem with the cable industry's ever-tightening embrace of HD is that carrying dozens of new HD channels will place an increasingly heavier strain on even the most well-endowed cable systems. On average, cable engineers figure that a single HD channel – with its crystal-clear, nearly 3D pictures – uses up to 2 MHz (or about 13 Mbit/s) of network capacity. While this represents only about one third of the spectrum consumed by one analog video channel (6 MHz), it is also about three times the amount of spectrum typically used by a standard definition (SD) video channel (0.6 MHz).

Cisco's bandwidth optimization model shows how the aggressive expansion of HD channels will take its toll on plant capacity over the next few years, provided no mitigating steps are taken. For example, the model projects that a fivefold increase from 30 to 150 MPEG-2 HD channels over the course of one year would require the addition of some 40 6MHz 256-QAM channels.

As subscriber penetration increases over the next few years, that toll will only grow. With more subscribers adopting digital video service, HD tiers, digital voice service, faster data tiers, and dual tuner set-top boxes, it will take progressively more QAM channels to support the additional subscribers within each service group.

In fact, the Cisco bandwidth optimization model calculates that cable systems will need to add 15 percent to 25 percent more QAM channels per service group each year, just to keep up with the anticipated growth of existing services. In the example cited above, instead of needing 40 QAM channels for the planned HD expansion, a cable operator would need to dedicate more like 48 channels to support its growing subscriber base and the introduction of new HD content. Beyond the bandwidth required for new HD programming, a typical provider would likely need to double the number of QAMs in its service groups over a five-year period.

The emergence of VoD as a popular, nearly ubiquitous digital cable product is a prime example of a "growth service" that keeps cutting into cable's precious bandwidth supply. Led by Comcast, Time Warner Cable, and Cox Communications, MSOs have been loading up their cable systems with thousands of on-demand movies, TV shows, sports events, and other offerings to entice new and existing customers alike. Many of these titles are offered for no charge, making them likely to become "highly viewed content." As new content and concurrent viewership within each service group increase, the number of video streams within each service group will also rise, driving the need for more QAM channels.

Indeed, Comcast alone now offers 10,000 VoD titles throughout its markets each month, most of them at no cost to its digital subscribers; other large cable operators are not terribly far behind. Plans call for boosting these numbers even higher as cable executives seek to "monetize" their free VoD programming through targeted advertising projects such as the industry's new Canoe Ventures effort. For example, at the Cable Show in May 2008, MSO leaders stressed the need to make much greater use of their "underutilized" VoD platform and take far greater advantage of on-demand's many financial possibilities.

As the Cisco bandwidth optimization model indicates, VoD services, like HD services, will place an increasingly heavier burden on cable capacity as MSOs add more on-demand programming and viewers tune into more of that programming more often. With overall digital video penetration expected to increase from 57 percent of basic cable homes this year to 65 percent by 2012, the model projects that the number of digital set-top tuners (DSTTs) per subscriber in an average system will climb from 2.8 in 2008 to 3.0 in 2012. At the same time, the bandwidth optimization model predicts that the peak number of concurrent VoD streams per service group will jump from 8 percent today to 12 percent in 2012 – a 50 percent hike, prompting the need for an even greater supply of bandwidth.

Unsurprisingly, HD versions of VoD programming will consume even more bandwidth than either linear HD channels or standard on-demand titles. Bandwidth demands are bound to increase geometrically in the near future, particularly as leading MSOs, such as Comcast, move to offer as many as 1,000 HD choices to digital cable subscribers, with HD-VoD titles accounting for most of these choices.

As the Cisco model shows, the percentage of HD VoD content per service group will more than triple over the five-year life of the model. This means that the HD programming load will grow from about 20 percent of overall VoD content per service group in the first year of the model to approximately 65 percent of the VoD content in the fifth year. As a result, cable operators will need to more than double the number of VoD QAM channels per service group.

Other big bandwidth hogs include DVRs; increasingly popular DVR-lite services such as Time Warner Cable's Start Over product; the network DVR services proposed by Cablevision Systems and other leading MSOs; and the multi-tuner HD-DVRs that cable operators are now beginning to roll out. Indeed, cable technology experts estimate that viewing one HD channel while recording another on a single DVR set-top can consume about 26 Mbit/s of bandwidth – roughly equivalent to two thirds of the bandwidth delivered by one 6MHz channel for a single set-top box or other customer premises device. Multiply that 4MHz figure by the three or more TV sets in the typical U.S. home, and the total then approaches 12 MHz for just this one application type.

Of course, not every TV set or set-top box tuner in a cable service group is ever in use at the same time. But, even assuming that no more than 75 percent of tuners in a given node are active simultaneously even during the heaviest viewing periods, the model still indicates that the typical number of VoD streams per service group could almost triple over five years.

Video downloading from the Internet, also known as over-the-top video, represents yet another swiftly growing bandwidth culprit. Take Google's industry-leading YouTube service, which now downloads more than 4.5 billion videos each month while drawing more than 91 million unique users to its Website, most of them broadband subscribers. Other multimedia-rich Websites – such as Apple's extremely popular iTunes site and heavily trafficked social-networking sites such as MySpace.com and Facebook.com – are generating increasingly heavy usage too, contributing to the growing cable capacity load.

In fact, comScore recently reported that in July 2008 – the latest month for which figures were available – more than 142 million American users watched online video clips. That amounts to 75 percent of all U.S. Internet users. comScore also found that the average online viewer watched nearly four hours of video in July 2008, or almost three videos per day. Overall, Americans viewed more than 11.4 billion videos, for a total duration of 558 million hours, in July 2008.

There is no sign that this growth is slowing. As the latest Cisco Visual Networking Index Forecast predicts, overall Internet video traffic will grow at a compound annual rate of 41 percent between 2007 and 2012. As a result, the study projects that video streams will end up accounting for about half of all Internet traffic by the end of that period, as well as more than half of the new growth. Even more impressively, the study forecasts that video streams will comprise a whopping 87 percent of all consumer IP traffic by 2012.

Figure 2: Consumer IP Traffic 2006-2012 (Petabytes/Month)

YEAR	2006	2007	2008	2009	2010	2011	2012
Web/Data	509	731	1,039	1,396	1,865	2,452	3,253
P2P	1,358	1,764	2,361	3,070	3,857	4,820	5,980
Gaming	91	131	187	252	324	399	490
Video Communications	16	25	37	49	70	103	154
VoIP	23	39	56	72	87	101	114
Internet Video to PC	269	654	1,359	2,064	3,079	4,374	6,069
Internet Video to TV	14	118	332	736	1,405	2,288	3,458

Source: Cisco VNI Forecast 2008

Higher broadband data speeds also threaten to suck up more bandwidth as cable operators seek to match or stay ahead of the blazing data rates offered over new, fiber-rich lines by Verizon, AT&T, and other telco rivals. With several leading U.S. and Canadian MSOs now hiking their highest cable modem downstream rates to 10 Mbit/s, 15 Mbit/s, or higher in response to telco competition, pressure is mounting to devote more than the one 6MHz channel per service group typically dedicated for data use right now. In fact, taking into account the combined effects of higher downstream bitrates, the soaring popularity of Internet video, and growing digital voice penetration, the Cisco model predicts that the number of data QAMs per service group will triple from two to six over the next five years.

This pressure will only increase in the future, as cable operators begin to shift in earnest to the industry's new Docsis 3.0 specification, which allows for virtual bonding of four or more 6MHz channels to deliver even faster data speeds. While this channel-bonding capability will enable the delivery of higher speeds to each broadband user, it will do so by using up more of the overall cable spectrum than usually allocated for high-speed data services today. In a recent study, for example, *Heavy Reading* found that nearly 75 percent of MSOs plan to bond four or more RF channels per service group for downstream data use by 2010 – up dramatically from slightly less than 17 percent of MSOs this year.

As the Cisco bandwidth optimization model illustrates, the pressure will also mount as the cable industry's broadband penetration rate continues to climb. Based on present trends, the model assumes that the cable modem take rate will rise from 35 percent in 2008 to 45 percent in 2012. In turn, that will prompt a 25 percent increase in the number of data QAM channels per service group that are required to support the additional data modems, even without the widespread adoption of Docsis 3.0.

Other young or still-developing cable products also threaten to consume even more bandwidth in the future. The growing list includes such existing or emerging services as real-time gaming, business services, bandwidth-on-demand, home security, video telephony, video over Docsis, and video conferencing, to name just a few. Given these trends, the battle against looming bandwidth shortages may never actually end for cable. Rather, it looks as though cable will constantly have to make more capacity available to keep up with the ever-changing market, satisfy fickle customers, and fend off aggressive competitors.

The load generated by all of these next-generation services will only grow heavier as time passes, because of the increasing popularity of each service. In addition to the projected rising rates for digital video and high-speed data services over the next four years, the Cisco bandwidth optimization model assumes that VoIP penetration will more than double over the five-year period. The model also figures that video over Docsis and business services will steadily increase their take rates.

Even before many of these new services are added, the organic growth of existing cable video and data services alone will produce an enormous burden. The Cisco model figures that these two basic types of cable service will generate approximately a 47 percent increase in narrowcast QAM bandwidth over the next five years. So, unless some significant mitigating steps are taken, cable providers could end up struggling just to support the growth of their existing services.

Figure 3: Rising Consumer Bandwidth Requirements

TYPE OF SERVICE	BANDWIDTH REQUIREMENTS
1 HD Channel	12.9 Mbit/s
1 MPEG-2 SD Channel	3.8 Mbit/s
Web Surfing	5 Mbit/s
Internet Appliances	2 Mbit/s
Gaming	1 Mbit/s
2 Videoconferencing Sessions	2 Mbit/s
1 Phone Conversation	0.1 Mbit/s
Total	**~27 Mbit/s**

Source: Freescale 2007, updated by Cisco Systems 2008

III. Scenario One: 750MHz Broadcast Migration Model

Given such growing bandwidth pressures, it is easy to see why the average cable operator would be tempted to throw up its hands in despair. Fortunately, all is definitely not lost. There are several ways that MSOs can meet these daunting capacity challenges, reconfiguring either 750MHz or 1GHz systems to handle these loads. It is just a question of how much capital and what type of investment it will take to carry out the reconfiguration.

Cisco offers a number of bandwidth optimization and expansion solutions for cable operators. The bandwidth optimization options include such technologies and techniques as MPEG-4, SDV, node segmentation, fiber-deep, and analog spectrum reclamation. At the same time, Cisco offers 1GHz upgrades as a bandwidth expansion solution. The bandwidth optimization model leverages all of these tools. Although they are not part of the model yet, Cisco also plans to provide QAM sharing and cable IPTV variable bitrate (VBR) as bandwidth optimization solutions. In addition, the company intends to introduce a Docsis-based PON (D-PON) product that will offer a fiber-to-the-home (FTTH) delivery system for cable.

Consider a typical 750MHz cable system with an average hub size of slightly more than 34,000 homes passed. In this case, the cable operator has already reached full capacity with its mix of analog video, digital, and data channels. Equipped with enough bandwidth to deliver 112 6MHz channels to its 500-household service groups, the MSO offers 64 analog video channels, 34 digital broadcast channels, 12 VoD and SDV channels, and two narrowcast data channels per service group. The 34-channel digital broadcast lineup includes 10 HD channels, 18 SD channels, and six channels for digital simulcasting of the 64 analog channels. The 12 VoD and SDV channels are split between four channels for narrowcast VoD content and eight channels for SDV.

Using what Cisco terms a "broadcast migration" strategy, the MSO could substantially increase capacity by aggressively employing low-cost, elementary digital terminal adapters (DTAs) to reclaim much of the precious analog spectrum for digital and other uses over the next few years. Under this approach, the cable operator could swiftly deploy the MPEG-2 DTAs to most of its analog customer base in 2009, using today's cable modem "self-install" model to ship the small set-tops to subscribers and encourage them to install the equipment themselves. At least one leading North American MSO is already pursuing this strategy.

As envisioned by the Cisco bandwidth optimization model, rapid, MSO-wide deployment of MPEG-2 DTAs could slash the number of required analog channels by more than 50 percent. So, instead of carrying 64 analog channels, the cable operator would now carry just 25 analog channels by the end of 2009, a huge savings of nearly 40 channels.

With this savings in the bank, the cable provider could then turn around and vastly expand its carriage of broadcast HD channels, increasing its lineup from 30 to a whopping 150 HD broadcast channels in just a year's time and putting it well on its way to its 200 HD channel goal. In the same time frame, the provider could also move 80 channels of SD "long tail" broadcast content to the switched tier, thereby reducing the SD broadcast bandwidth by eight QAM channels while adding three SDV channels to the narrowcast video tier. This introduction of new HD content, coupled with the additional channels required for SD broadcast migration and increased subscriber penetration, would leave one available channel for expansion at the end of year two.

In the next phase of the five-year plan, the cable operator could continue shifting broadcast SD and HD content to the SDV tier to realize even greater bandwidth savings. Besides benefiting from the increased efficiency of SDV, the operator could also introduce a modest amount of MPEG-4 encoding to boost its per-channel efficiency further.

As the Cisco bandwidth optimization model indicates, the provider could steadily shift SD and HD content to the switched tier, moving an additional 30 channels of SD content and 15 channels of HD content. But, even with the added efficiency of MPEG-4 encoding on 5 percent of the SDV

channels, the continued migration of the broadcast video channels and the addition of one data channel would combine to cut overall system capacity by one channel. As a result, there would not be any channels available for expansion by the end of the second phase.

Over the final two years of the broadcast migration approach, the operator could continue this pattern of gradually introducing higher percentages of MPEG-4 encoded channels and moving more of its broadcast HD and SD channels to the SDV tier. By 2012, 40 percent of the total HD and SD content would be encoded using MPEG-4, with 80 percent of the SD content and almost half of the initial 150 HD channels carried in the SDV tier.

During the same time frame, the MSO could then use this freed-up spectrum to launch 50 additional HD channels, support continued subscriber growth, and add two more data channels. And, as **Figure 4** shows, the provider would still be left with two open channels for future use, even after reaching the prized 200 HD channel goal.

Figure 4: 750MHz Broadcast Migration Summary

DOWNSTREAM NETWORK CAPACITY	2008	2009	2010	2011	2012
Downstream Network Bandwidth	750 MHz	750 MHz	750 MHz	750 MHz	750 MHz
Reference Channel Capacity	112	112	112	112	112
HHP per Service Group	500	500	500	500	500
Analog Channels	64	25	25	25	25
Broadcast 256-QAM Channels	34	66	58	50	39
Expanded Commercial Services	0	0	0	0	0
Narrowcast 256-QAM Data Channels	2	3	4	4	6
Narrowcast 256-QAM Video Channels	12	17	25	31	40
Available Channel Capacity	**0**	**1**	**0**	**2**	**2**
UPSTREAM NETWORK CAPACITY	**2008**	**2009**	**2010**	**2011**	**2012**
Upstream Network Capacity	5-42 MHz	5-42 MHz	5-42 MHz	5-42 MHz	5-42 MHz
Reserved Upstream Bandwidth	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz
Expanded Commercial Services Channels	0	0	0	0	0
Upstream Channels	4	4	2	2	2
Available Upstream Spectrum	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**

Source: Cisco

By splitting its node sizes in half and driving fiber deeper into its access network, the cable operator could produce further bandwidth savings, increasing its channel capacity for digital services. Or, with the institution of these 250-household service groups, the provider could free up additional space for HD programming, high-speed data, and other digital services without reclaiming as many analog channels or switching as many digital networks at first. Greater node segmentation would also pave the way for future bandwidth expansion.

How much would this broadcast migration approach to 200 HD channels cost? While the capital costs would vary greatly by MSO, it is safe to say that the deployment of DTAs would generate a sizable portion of the system upgrade expenses. We estimate the DTAs alone, at an assumed price of $40 per device, would account for 25 percent of the overall capex bill. We also estimate that the operator would spend another 35 percent of its budgeted capital on SDV and associated launch costs, and the remaining 40 percent on the required broadcast and narrowcast QAMs.

As the cable operator moved forward with the broadcast migration strategy, additional bandwidth would be needed to support subscriber growth and the introduction of such new services as IPTV or business services. If these new services exceeded available channel capacity, further node segmentation would be required to cut the size of the video service groups. Reducing the video service groups to approximately 250 homes passed would double the narrowcast channel capacity. But this additional capacity would come at a heavy price. In fact, such a "fiber-deep" upgrade to service groups of 250 homes would cost about an extra 25 percent.

In addition to these relatively high capital costs and the need to deploy millions of MPEG-2 DTAs, the operator would have to undertake a capex-intensive "upgrade" cycle over five years. Yet this upgrade cycle would produce virtually no year-over-year increases in available channels. Plus, at the end of the cycle, the cable provider would be left with a 750MHz network that was five years older than before.

IV. Scenario Two: 1GHz On-Demand Model

Instead of staying at the 750MHz level, the typical cable operator could immediately choose to upgrade its systems to 1GHz capacity. Under this scenario, the MSO could expand its bandwidth to 1,000 MHz in the first year of the model's five-year period, absorbing the bulk of the necessary capital expense upfront. At least one leading North American MSO is now pursuing this strategy.

In this case, the cable provider would start the period with a healthy surplus of available channels, thanks to its preemptive system upgrade. With enough bandwidth to deliver 154 6MHz channels to its 500-household service groups, the provider could offer 64 channels of analog video and 37 digital broadcast channels to subscribers while supporting a mix of HD, SD, and data services that closely resembled the mix in the 750MHz model. As the Cisco bandwidth optimization model shows, that would still leave a hefty 45 QAM channels available for future expansion.

Taking further advantage of its 1GHz capacity, the MSO could then add more digital broadcast channels, VoD offerings, and data channels to its lineup without cutting back on its analog video channels. In particular, the provider could use its extra RF capacity to add substantially more HD broadcast networks to its roster, increasing the number of HD broadcast channels from 38 to an impressive 156 in the second phase of the plan. Such a dramatic expansion would put the system well on its way towards reaching the sought-after 200 HD channel goal.

Due to the expansion of HD content and an increase in subscriber penetration, the cable operator's number of unoccupied channels would fall to 10 in 2009 and stay at that relatively low level through 2010, as the Cisco bandwidth optimization model spells out. But then the MSO could begin to produce more channels for future expansion by heavily leveraging its existing VoD infrastructure and introducing MPEG-4 encoding for up to six percent of its burgeoning HD VoD content. As a result, the number of channels available for expansion would start climbing again in 2011, reaching a grand total of 17 channels by the end of 2012.

The MPEG-4 encoding standard can typically squeeze two (SD or HD) channels into the same QAM space now occupied by one MPEG-2 (SD or HD) channel. Because our two models rely on about the same amount of MPEG-4 encoding during the last three years, they yield similar benefits. However, unlike the 750MHz model, the 1GHz network can support the anticipated introduction of new services and subscriber growth without the aid of MPEG-4 encoding.

Thanks to this improved compression ratio, the cable operator could keep boosting the number of SD and HD channels without all that much strain. In fact, by the end of the five-year period, the MSO could easily exceed the 200 HD channel goal, winding up with a grand total of 237 HD channels. The cable provider could also devote more channels for high-speed data services, raising that number to four bonded channels per service group by 2010 and then six bonded channels per service group by 2012. At the same time, the provider could still hike the number of available QAM channels to 16 in 2011 and 17 in 2012, enabling it to end the five-year period with far more available channels than under the 750MHZ broadcast migration option.

In the end, it would seem as if the 1GHz On-Demand approach would cost substantially more than the 750MHz Broadcast Migration approach. But, even though the Cisco model shows that a whopping 75 percent of the total capex costs would be driven by the one-time expense of bandwidth expansion, the 1GHz model would actually cost about the same over the five-year period.

Why? As the model demonstrates, cable operators would end up spending a similar amount of capital on technology upgrades, fiber extensions, and equipment additions to their existing 750MHz plant over the five-year period. Plus, because the 1GHz model leverages both physical plant capacity and the existing VoD infrastructure for a high percentage of the HD broadcast and VoD content, MSOs would not have to pay for the same annual migration of content and waves of SDV upgrades to support growing subscriber demand.

One key capex component that will be especially determinative of the price gap between the two different approaches is the cost of labor. Whenever a cable operator must upgrade or make any other changes to its existing HFC network, labor costs account for a significant portion of the construction bill. Because labor costs almost always rise over time, it behooves MSOs to carry out the upgrades earlier and avoid the inevitably higher expenses of waiting until later. So, in deciding which of these two courses to pursue, cable providers should look carefully at what their labor costs are now and will be in the future.

Another key issue is the level of operational complexity that cable operators can manage and endure. While it may not cost much more to maintain their 750MHz systems, MSOs may find themselves introducing a level of complexity beyond their comfort zone as they leverage such technologies as DTAs, SDV, and MPEG-4 encoding. As a result, a more conservative approach might be to upgrade at least the most hard-pressed systems to 1GHz capacity early on.

Figure 5: 1GHz On-Demand Summary

DOWNSTREAM NETWORK CAPACITY	2008	2009	2010	2011	2012
Downstream Network Bandwidth	1000 MHz	1000 MHz	1000 MHz	1000 MHz	1000 MHz
Reference Channel Capacity	154	154	154	154	154
HHP per Service Group	500	500	500	500	500
Analog Channels	64	64	64	64	64
Broadcast 256-QAM Channels	37	69	65	56	48
Expanded Commercial Services	0	0	0	0	0
Narrowcast 256-QAM Data Channels	2	3	4	4	6
Narrowcast 256-QAM Video Channels	6	8	11	14	19
Available Channel Capacity	**45**	**10**	**10**	**16**	**17**
UPSTREAM NETWORK CAPACITY	**2008**	**2009**	**2010**	**2011**	**2012**
Upstream Network Capacity	5-42 MHz	5-42 MHz	5-42 MHz	5-42 MHz	5-42 MHz
Reserved Upstream Bandwidth	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz
Expanded Commercial Services Channels	0	0	0	0	0
Upstream Channels	4	4	2	2	2
Available Upstream Spectrum	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**	**14.2 MHz**

Source: Cisco

V. Conclusion

As this white paper demonstrates, the situation is far from hopeless for cable operators seeking to vastly expand their HD and other digital service offerings. Although the capacity crunch facing the industry is quite real and will steadily grow in intensity, MSOs have numerous options available for coping with that crunch and staying at least one step ahead of the pending spectrum shortages as well as their chief competitors.

In fact, even today's seemingly bandwidth-constrained 750MHz cable systems can support healthy subscriber growth and service expansion if the right kinds of investments in new technologies, tools, and techniques are made at the right times. The critical questions to answer are which investments to make at what time and at what cost.

The bandwidth optimization model developed by Cisco suggests two different strategies that cable providers can employ to boost their capacity for new video and broadband services over the next five years without breaking the bank or building costly new infrastructure. Using one or both of these strategies, MSOs can increase their HD lineups to 200 channels or more, add more data channels for faster broadband service, make other service improvements, support higher customer take rates, and still have at least a few channels left over to cover their future needs.

Under the first proposed approach, which Cisco calls the 750MHz Broadcast Migration Model, cable operators can achieve their growth objectives through a multi-step process that starts with the deployment of low-cost DTAs. Using these DTAs to reclaim precious analog video spectrum, MSOs can recycle the bulk of their analog channels for more efficient and profitable purposes, especially the vast expansion of their HD tiers. MSOs can then cement and build on these gains by introducing more efficient MPEG-4 encoding, rolling out SDV technology, and/or splitting their node sizes in half, freeing up even more QAM channels for other uses in each service group.

Under the second approach, which Cisco calls the 1GHz On-Demand Model, cable operators can achieve the same objectives by swiftly upgrading their systems to 1GHz capacity. This will allow them to greatly expand their broadcast HD and other new digital offerings, without spending heavily on DTAs and aggressively reclaiming analog spectrum. Cable providers can then cement and build on these gains by leveraging their existing VoD infrastructure and introducing the more efficient MPEG-4 video encoding standard for both SD and HD programming, thereby squeezing more content into the same number of QAM channels.

Both approaches spelled out in this paper offer clear paths for cable operators to reach the promised land of 200 HD channels over the next couple of years. All that is needed now is for cable providers to take a deep breath, commit themselves to one of the two paths, and begin marching resolutely down it.