ALL-DIGITAL: WHETHER AND HOW TO GET THERE

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Abstract

This year witnesses the first launches of "all-digital networks" by major cable operators. These initiatives can free abundant bandwidth to support hundreds of additional TV channels, faster Internet service and more rapid launches and scaling of advanced video services such as video on-demand and high definition. They also usher in less expensive set-top boxes and other subscriber devices, based only on digital tuning, and have promise for delivering better video quality.

However, the path to the all-digital network does not happen with a simple flip of a switch. Implementation can be quite disruptive to subscribers, as each one will now need to have every one of their television sets and possibly VCRs connected to a digital set-top box (unless these devices are digital cable-ready). This scenario has the potential to become an operational disaster, to say nothing of the imposition many subscribers are likely to feel with specific devices forced everywhere they want to watch television.

Consideration of all-digital cable certainly has merit, but methods and alternatives should also be weighed. There are other emerging techniques for conservation of bandwidth that can be employed before, in parallel with, or instead of going all-digital. And if all-digital is pursued, there are several options to minimize the cost and disruption of achieving it.

THE CASE FOR ALL-DIGITAL

There are three basic drivers most commonly cited by operators as their business motivations for eventually replacing all current programming distributed in analog format with all-digital content. These drivers cumulatively promise to save costs, increase per-subscriber revenues and enhance cable's competitiveness. They are:

1) Bandwidth optimization: Reclaimed analog spectrum will be used by bandwidth-hungry HDTV, VOD, and other advanced video and data services. Analog broadcasting currently occupies more than half of all cable spectrum, so this saving will significantly alleviate the capacity constraints impeding cable operators' abilities to scale up offerings across the full range of these services.

2) Set-top box cost reduction: Removing the analog tuner and conditional access from today's hybrid analog/digital boxes significantly reduces the cost and complexity of the devices. Expanding this concept to today's dual-tuner digital video recorders further expands savings with the elimination of two analog tuners as well as the MPEG-2 encoder chips required to digitally write the analog video to disk.

3) Improved picture quality: Although the level of compression utilized can make the claim dubious, competitive service providers like direct broadcast satellite (DBS) television have used "all-digital"

in marketing campaigns to claim superior quality over cable signals. The quality achieved in digital programming is determined by the quality of the encoder and how much bandwidth is allocated per stream, but converting to all-digital could provide sufficient capacity to in fact make an overall improvement in picture quality, including expanded HDTV carriage. Further, VSB-NTSC analog programming distributed by cable can have poor display quality on large-screen digital televisions, especially noticeable when tuning from digital services to analog services, further reinforcing subscriber perception problems versus DBS.

These drivers are indeed persuasive. Better picture quality would help cable retain and gain subscribers in the churn battle with DBS and other video service alternatives. Likewise, more innovative services available on a bandwidth-optimized plant keeps subscribers interested while driving incremental revenue gains such as on-demand program orders. The lower costs associated with a more efficient plant, as well as with less expensive subscriber devices, also of course contribute to an enhanced bottom line.

But as stated above, with the benefits, all-digital conversion brings challenges as well. In addition to massive churn of subscriber equipment, other current cable analog operations must be considered and transitioned, such as the current multi-billion dollar local advertising insertion practice of cable operators. There is increasing realization in the industry that all-digital conversion must be evolutionary more than revolutionary, and several alternatives can alleviate efforts and expenses.

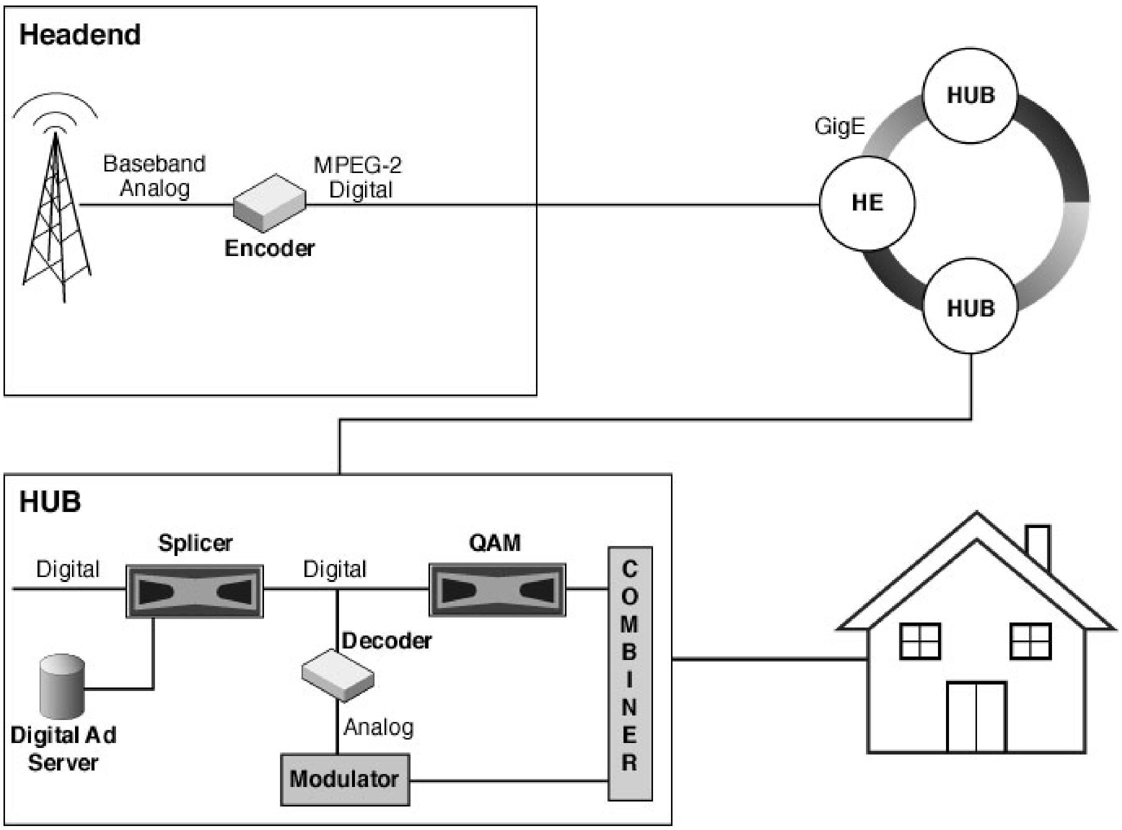
DIGITAL SIMULCAST

Digital simulcast, simply put, is the replication of the analog tier as digital programming. Most systems, especially those upgraded to 750 MHz in the recent years, broadcast at least 80 channels of analog programming (basic and enhanced basic tiers) to their customers. Using advanced RateShaping bit-rate adaptation technology, these programs could be encoded and statistically multiplexed into as few as six 6MHz channels, or within 36 MHz of spectrum. Although having upgraded to 750 MHz does not guarantee that there is sufficient spectrum, especially with the contention of emerging services such as VOD and HDTV, the amount of spectrum required can usually be attained with some bandwidth engineering.

There are several perspectives regarding the optimal topology for digital simulcast programming distribution, from one of pure centralization on a national scale, to a very distributed methodology. In either case, the operator’s primary goal is to replicate the entire analog tier in digital form and utilize broadband transport networks such as Gigabit Ethernet to distribute this programming to the hub or zone level of the network. This transport technology will require that an adaptive switch or router be used to translate some, if not all, of the digital programming from an ASI transport protocol to a unicast IP protocol.

All digital feeds, including the insertable primary network feeds, are delivered to the hubs/zones where they can be received by a statistical multiplexer that supports Gigabit Ethernet input. All incumbent analog ad insertion equipment would need to be replaced or upgraded to support digital program insertion, and the multiplexer would splice the ads into the now-digital programs.

The multiplexer then duplicates all the digital streams that will need to also be distributed as analog programming over the last mile to those customers who only subscribe to the basic or enhanced basic tier, or who have additional televisions with no digital set top box. For each split pair of programming streams, one will be subjected to RateShaping, placed into a multiplex and digitally delivered within QAM-modulated spectrum; the other will be decoded to analog baseband, NTSC-modulated and combined onto the spectrum reserved for the analog tier.



Digital simulcasting allows all-digital conversion while preserving utility of analog customer premises devices by combining both analog and digital versions of basic and expanded basic programming, with transport and splicing performed digitally.

Once simulcasting is implemented, any of the operator's customers that are digital subscribers (and therefore use a digital set-top box or digital cable-ready television) could now receive all of their programming digitally including the digital versions of programming that is broadcasted in analog. They thus no longer require the expense of analog tuning in their set-top boxes and other television devices. Those customers that only subscribe to the basic or enhanced basic tier would continue to receive their programming as they always have, but they can access the digital version of the same programming with a very inexpensive set-top box that only includes a digital tuner. The proposition of improved quality might be sufficiently compelling for a portion of these customers to adopt the use of such a set-top box. As more subscribers access the digital versions of programming, legacy analog devices can be churned out of the system to achieve an effective transition to all-digital over time.

Simulcasting is a viable and controlled path towards the deployment of all-digital cable networks, and also provides the cable operator with ancillary benefits. In fact, some of these benefits are already being seen as sufficient to motivate several cable operators to engage in simulcasting for its own sake, whether or not an all-digital future is ultimately effected.

Simulcasting enables lower cost digital video recorders (DVRs) by eliminating the need for components that support analog programs. With greater familiarity and easier availability through service providers, more North American pay television subscribers are opting to own, and use, a DVR. 25% of all new DBS subscribers now receive a DVR and this has been an area of competitive advantage. But the cable industry has now introduced its DVR offerings, which are being well received. In large part due to the necessity of two analog tuners and two digital tuners to support simultaneously watching and recording either programming tier, and an encoder to digitize and store analog content, the DVRs as provided by traditional cable set-top box vendors are relatively more expensive than those being used by the DBS providers. Some experts in the industry, though, estimate that cable operators could save as much as $100 per set-top box if they, too, could provide a purely digital DVR. Using this potential saving, coupled with a set-top box (sans DVR) that is also purely digital could provide another $50 in savings. This could save millions of dollars in a cable system that has hundreds of thousands of homes passed.

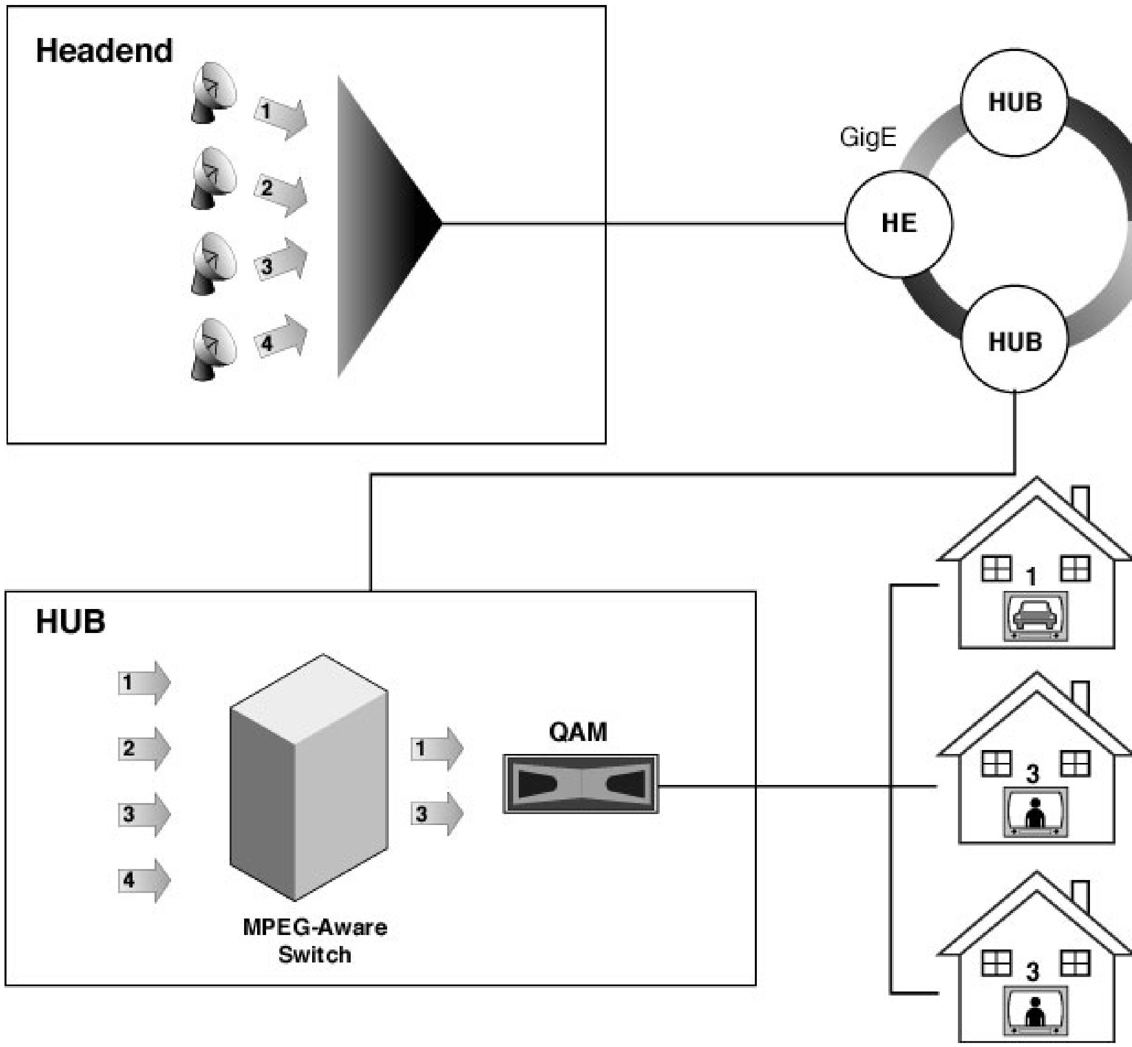
Local cable advertising could also be more profitably operated by simulcasting, regardless of whether all-digital cable is eventually achieved. Cable operators currently derive multi-billion dollar annual revenues from local advertising, almost entirely on analog programming, but have plans for significant growth, as for one thing their stake is a disproportionately small share of all television advertising. Current and emerging digital splicing standards and Gigabit Ethernet transport of content can make the practice easier and more economical, flexible and scalable. All insertable programming can be digital, including analog-sourced content that is encoded in the headend. Once in digital form, programming can be centrally groomed and multiplexed and distributed by Ethernet transport to hub locations that correspond to the zones for insertion. Servers can be situated at those locations, and splice in the zone-specific advertising on receipt of the cue tone in the transported program stream. In simulcasting, at this point an analog copy of the program, with the inserted advertising, would be decoded and NTSC-modulated for plant transmission. There are alternative simulcasting and digital insertion models that can also be considered, and overall, the greater efficiencies of working with digital content for transport, storage and splicing also indicates savings of millions of dollars in a typical cable system.

Simulcasting presents an overall attractive means of gradually converting towards an all-digital cable network. It forestalls the disruption of a singular, massive digital switchover in favor of more gradual means. Ancillary benefits in areas such as DVRs and local advertising can drive economic benefits that make simulcasting worthwhile regardless of whether or when all-digital is eventually attained. Ironically, the goal of an all-digital network is to liberate programming bandwidth consumed in its inefficient broadcast analog form, but the first step of simulcasting begins the process by placing an additional demand on cable spectrum. The primary hurdle is to free sufficient spectrum for both digital and analog versions of basic and advanced basic programming, and several techniques can accomplish this.

SWITCHED BROADCAST

Like all-digital, switched broadcast receives attention as a means of providing more programming and launching more services. Switched broadcast could be an alternative to all-digital, or an aid towards achieving all-digital by freeing up the spectrum required to implement analog-digital simulcasting. Switched broadcast can even play a valuable role in the infrastructure of an all-digital network once it's fully realized.

Switched broadcast combines broadcast techniques of sourcing live programming along with on-demand techniques of distribution. Through a thin client application that can be dynamically downloaded to any digital set-top box, the network detects subscribers' channel selections. Among programs designated to a switched broadcast pool, only those requested from within a node or service group are distributed within it. When a subscriber switches to a locally unwatched program, this is recognized, and a headend-based server dynamically allocates a frequency within the viewer's area will now carry that program, and instructs an MPEG-aware switch and the set-top box of how to transmit and receive this program. If a subscriber switches to a program already being watched in the node or service group, the existing transmission is joined. Once all subscribers in the area tune away from a given program, that program's session can be dynamically discontinued and the bandwidth that was used now becomes available for other switched broadcast sessions. The mechanics of implementing switched broadcast are further explained in the paper *Planning for and Managing the Rollout of Switched Broadcast Services* presented by Time Warner Cable and BigBand Networks at the 2003 SCTE Conference on Emerging Technologies.



Switched broadcast is consistent with all-digital's efficiency objectives, and can facilitate analog-digital simulcasting, by only carrying those digital programs being watched in an area (1 and 3 in the illustration above).

A major cable operator has completed a field trial of switched broadcast on a contained pool of 10 specialized programs. In the analysis of channel requests during this trial, it was determined that the ten programs could have fit in the capacity for seven without suffering any blockage. If they were fit in the capacity for six, then 99% of the time all demand would be met whereas 1% of the time there would be one blocked program out of the six requested, which means that more than 99.8% of all demand would be met. And if enough capacity for 5 programs were provided (i.e. 50% of the number offered), then 94% of the time all requested programs would be provided, and over 99% of all demand would have been met. These specific trial parameters are not a representative sample and the nature of statistics will certainly make the results even better with a larger and more diverse set of programs than the 10 that are were used. Further detail on the results of this trial can be found in the paper *Switched Broadcast: Statistics from the Field* presented by BigBand Networks at the 2003 SCTE Cable-Tec Expo.

The initial results of the limited trial were encouraging enough to warrant larger scale trials with more programming and larger subscriber bases, which are being conducted as this paper is being written. While final analysis is not complete, the statistical indicators are that among the few hundred programs typically digitally broadcast, some subset of the most popular programs, perhaps approximately 100, could be conventionally broadcast and the rest could be most economically provided by including them in a switched broadcast pool. Based on knowledge of subscriber viewing behavior, this programming can most likely be provided at a bandwidth capacity reduction on the order of 50% with virtually no blocking of programs. Furthermore, with switched broadcast, cable operators could dramatically expand the selection of programming they provide to include worldwide international fare, increasingly niche programming topics, live events in sports, performed entertainment, education, professional gatherings and other genres. These are similar benefits to those of all-digital conversion. Switched broadcast could be considered as an alternative or a complement to the all-digital network.

Both carrying programs only in digital form and switching them dynamically so that they only use bandwidth where and when required provides dramatic bandwidth efficiency gains. This derived capacity expansion future-proofs the network for the migration of all programming to higher quality levels including HDTV, and the migration to all on-demand availability.

Confirming the bandwidth gain promise of switched broadcast, the paper *Modeling Switched Broadcast Video Services* presented by Cable Television Laboratories at the 2004 Winter Conference states:

> *Switched broadcast video services can be used to offer many more broadcast programs, using less bandwidth, than traditional broadcast services. A typical 750 MHz cable plant could theoretically offer over a thousand broadcast digital programs to subscribers, compared to a few hundred programs using traditional broadcast.*

The benefits of switched broadcast can be amplified by extending the practice of dynamically allocating bandwidth and associated resources to all services according to subscriber use, not just the digital broadcasting pool. Plant protocols such as 256QAM modulation apply across digital services, so the same modulator and channel that is primarily used for digital broadcast programs at a time when they are popular, such as a weekend afternoon with many live sporting events, could be used primarily for VOD content when that is popular, as in the same day's evening, when subscriber preferences switch to saved entertainment content such as movies, and likewise for interpersonal communications (including video conferencing) or business data services when their traffic demands peak.

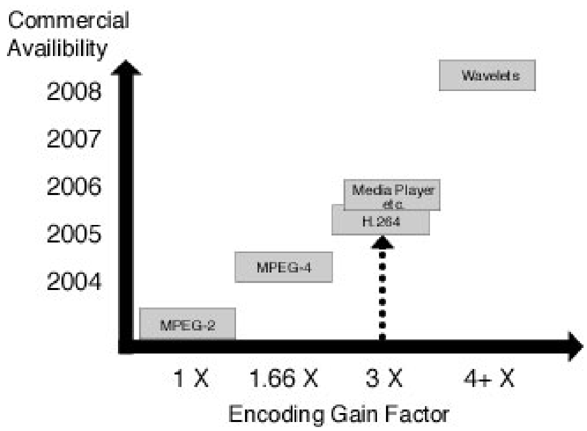
While the long term benefits are enticing, in the near term, switched broadcast can assist in facilitating digital simulcast deployments. The basic and advanced basic programs are most likely too popular to sensibly fit in the switched broadcast pool, but freeing the six channels that may be required to digitally simulcast 80 programs, could be achieved by taking approximately the bottom third of digital programs and switching them. Switched broadcast should conservatively achieve a capacity gain of 50% when applied to such programming, so switching 160 digital programs should provide the bandwidth required to simulcast the 80 programs already carried by analog.

NEXT-GENERATION DIGITAL TECHNIQUES

Other trends in the handling and processing of digital video content are also worthy of consideration for their potential for bandwidth conservation. These can be used to further enhance the efficiencies from switched broadcast and all-digital, and aid in the implementation of digital simulcasting.

RateShaping techniques leverage statistical multiplexing benefits for variable bit rate video programs by observing cumulative bandwidth behavior, and when channel capacity is strained, selectively throttling back allocation to selected programs in order to maintain service while maximizing quality. RateShaping algorithms have progressed to gain 50-100% capacity gains with typical multiplexes of 15 SDTV programs or 3 HDTV programs per 6 MHz channel, or higher, with imperceptible compromise in picture quality if care is taken in selecting appropriate program content type in the multiplexed services. Current developments, including tools for more intelligent assembling of channel groups, should further boost these efficiencies, but at some point algorithmic limits will be reached for RateShaping of MPEG-2 video. An advantage of RateShaping is that it is MPEG-2 compliant, necessitating no changes to headend, plant or customer premises equipment, with algorithmic advances generally achieved by software upgrades to existing grooming and multiplexing equipment.

Further bandwidth efficiency gains beyond RateShaping may be achieved by utilizing different coding formats than today's conventional MPEG-2 video over 256QAM modulation. MPEG-2 now exceeds a decade of useful service and more efficient video encoding techniques are emerging. H.264/MPEG-4 Part 10 promises to enable the carriage of as many as five HDTV programs per channel at constant bit rates, and presumably several more with conversion to variable bit rates and RateShaping practices. However, RateShaping of MPEG-4 encoded programs is unlikely to achieve the extent of bandwidth savings possible with MPEG-2 as MPEG-4's encoding is already highly efficient. Moving to a new video encoding format or transmission format requires replacing digital access equipment, with the corresponding capital expenses. IP encoding and transmission schemes could be simulcast with MPEG-2 (and for some programs analog too if digital simulcast is being used). Switched broadcast architectures could also be applied so that an MPEG-4 stream of a program is only broadcast in an area when an MPEG-4 subscriber requests it, and likewise for other formats. The bandwidth efficiency gains of emerging encoding techniques do provide savings in requirements of equipment such as VOD storage, DVR storage, and transmission equipment, since more programs per channel means more channels per headend device. There are also benefits in extension of broadcast content to more subscriber devices, including PCs, and in abilities to leverage other IP practices such as flexible encryption for open conditional access and XML tags to profile subscribers, services and other entities.



Encoding technique advances promise substantial near-term efficiency gains as all-digital complements or alternatives.

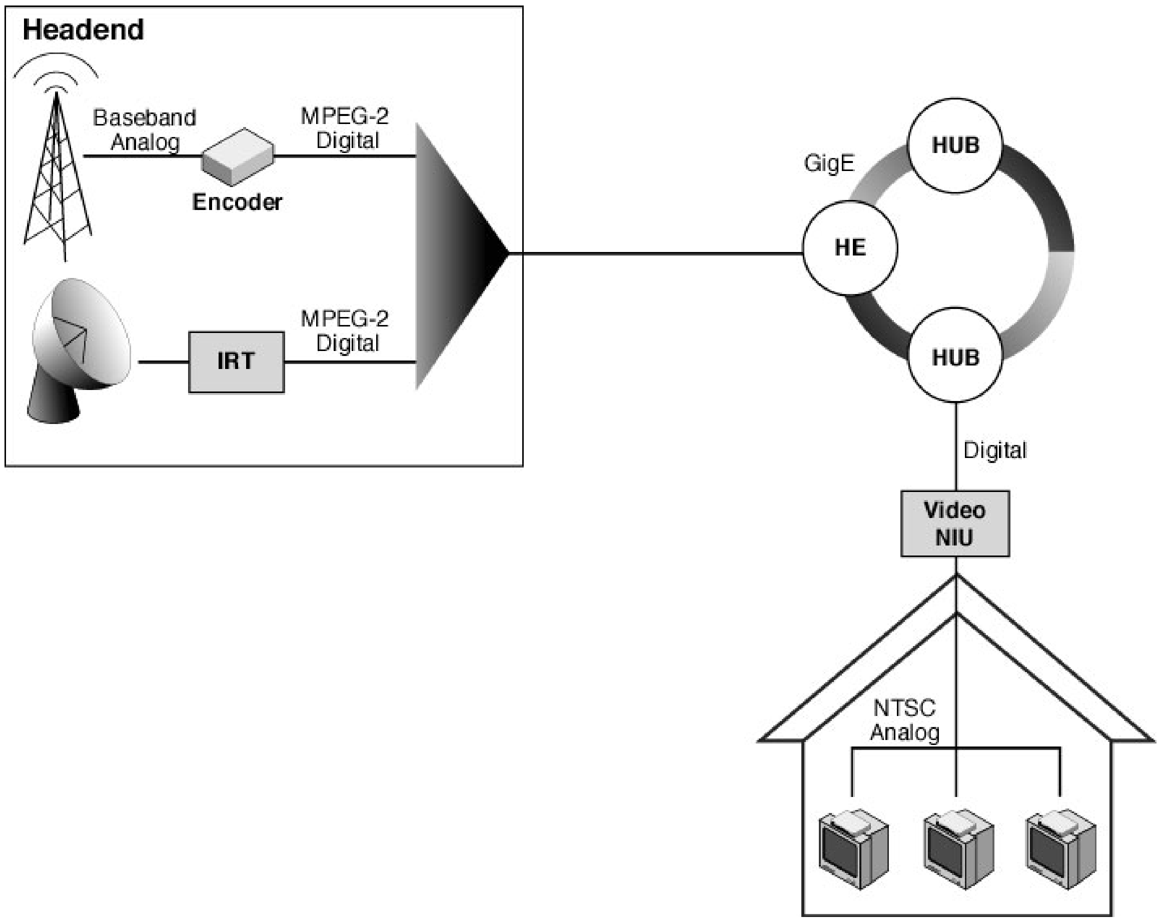
Like MPEG compression, QAM modulation is a practice that will continue to achieve bandwidth efficiencies in succeeding generations. Use of 1024QAM would improve channel capacity for digital content by 25% over 256QAM. Even greater bandwidth efficiencies would be achieved if used in conjunction with advanced encoding such as MPEG-4. Incompatibility with current subscriber equipment would, like advanced encoding, be disruptive but a migration is doable using the switched broadcast stream approach as previously described or through simulcast of formats if spectrum is available during the transition.

Techniques such as MPEG-4 encoding and 1024QAM ultimately dovetail well with other trends related to all-digital to achieve a network of much higher overall capacity with richer functionality available to subscribers. But, like other means to convert to all-digital, these come at some cost and effort, and their merits must be weighed in this light.

CUSTOMER PREMISES DECODING

Eventually an evolution to an all-digital distribution, likely with advanced video encoding, is inevitable. In the nearer term simulcasting may ease the transition and avoid forcing an accelerated conversion of customer premises equipment. At some point, the forced change in the home environment must be confronted. Television receivers tend to have 15 or more years of usage before they are discarded and most cable operators are loath to retire a customer provided STB until well past its depreciated life. Most customer-owned television receivers and VCRs require an analog signal.

Provisioning a digital set-top box for every analog cable client is complicated and expensive. From a cost standpoint, cable operators would prefer to avoid equipping every television in the household with the full functionality of digital tuning, recording, picture-in-picture, interactivity and other features unless the customer finds the added functionality sufficiently compelling to produce incremental revenue. Even the provision of relatively low-cost devices that only perform digital tuning can be prohibitive if several are required for each home. Subscribers can get antagonized as well. From their perspective, a change is being forced on them, perhaps placement of the CPE being incompatible with built-in furniture, and without any perceived increase in the service value proposition – no added services, just the same to that they were already receiving in analog. Some may argue that the digital transition introduces reductions in the quality of service as measured by a metric such as channel-change latency, which is historically slower for digital programming. Offering additional services, such as VOD, and demonstrating improved picture quality of all channels might provide enough benefit to offset at least some of this issue.



Use of a network interface unit to decode digital video preserves existing analog devices within customer premises while allowing for the functionality and bandwidth efficiency gains of all-digital broadcasting and services in the cable facilities and plant.

Alternatively, migration to an all-digital plant with analog homes or at least some analog devices in homes might more economically be achieved if homes have a single point of digital to analog decoding and analog video distribution is effectively maintained just in the home environment. Much like how circuit telephony has been provisioned on cable plants, a video network interface unit (NIU) could be placed at a point of ingress to the home in order to decode programs and distribute internally in analog form. This requires the provisioning of decoding equipment only once per home rather than at every device. The NIU device would need configuration for digital service transparency and to pass the 2-way interactive signals for services such as VOD, high speed data and voice over IP. The concept could be extended to a shared NIU in a multi-dwelling unit, gated community or neighborhood. Such consolidation reduces equipment and maintenance costs. The distribution could be agile across multiple physical methods including wireless to further alleviate expenses.

Decoding digital video at or near customer premises enables the cable operator to use all-digital in order to gain effective capacity at the most constrained part of the network: the coaxial cable distribution plant. Alleviating that environment is the most important accomplishment towards avoidance of the most expensive technique of securing capacity expansion, namely embarking on further rebuilds and upgrades. Securing sufficient bandwidth is much more economical at the destination points of the plant, where decoding to analog can be supported. This practice could deepen penetration of all-digital to the neighborhood, curb, home or device while optimizing economics of subscriber retrofitting and minimizing disruption and annoyance for customers. As more digital televisions migrate into these homes and analog units cease to operate from age, the role of the video NIU becomes redundant, and all-digital the whole way through the network to the client device emerges as an eventuality.

CONCLUSION

Conversion to all-digital enables significant business and competitiveness gains for cable operators, but is on its surface a daunting proposition. Several techniques that leverage characteristics of digital content, described herein, can alleviate the process. Analog-digital simulcasting, switched broadcast, implementation of technical digital video advances, and decoding content at customer premises are all tools for gradual attainment of all-digital without significant service disruption or expense spikes. By implementing several or all of these alternatives, operators can enact an eventual migration towards truly all-digital cable services, from content origination to subscriber consumption, while attaining many of the goal's promised benefits along the way.

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