NARROWCAST SERVICES – UNIFYING ARCHITECTURES

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Abstract

Cable advertising is a primary source of revenue for the cable industry. It is a massive successful industry by its own right. The ability to target an advertisement to a subset of the cable plant or "ad zone" is one of the key attributes that differentiates cable's advertising capability from that of the national broadcasters. These uniquely zoned advertisements are now more valuable as they are targeted to their intended recipients and narrowly broadcast to a subset of the cable plant to reach the recipients.

High Speed Data (HSD) is another highly successful cable service that cable deployed over 10 years ago and is still experiencing strong growth. On a wide scale, Cable's HSD offering is leading the competition with 8Mbps and 10 Mbps HSD offering.

Closely tied to the HSD service is the Voice Over Internet Protocol (VOIP) phone service. This relatively new service has quickly become another mission critical offering for the cable operator representing new sources of growth and income.

There is little doubt that Video On Demand (VOD) is a success. According to the industry press, across the industry, VOD revenues have grown to over a billion dollars of revenue for the cable industry per year. VOD is widely deployed across all major markets and is the cornerstone of the digital offering.

One of the next generation key technologies to unlock Cable's bandwidth potential is the delivery of television through the Switched Digital Video (SDV) infrastructure. Broadcasting the select programs from the digital tier through SDV is projected to save 50 percent of the bandwidth required when compared to broadcasting through normal mechanisms.

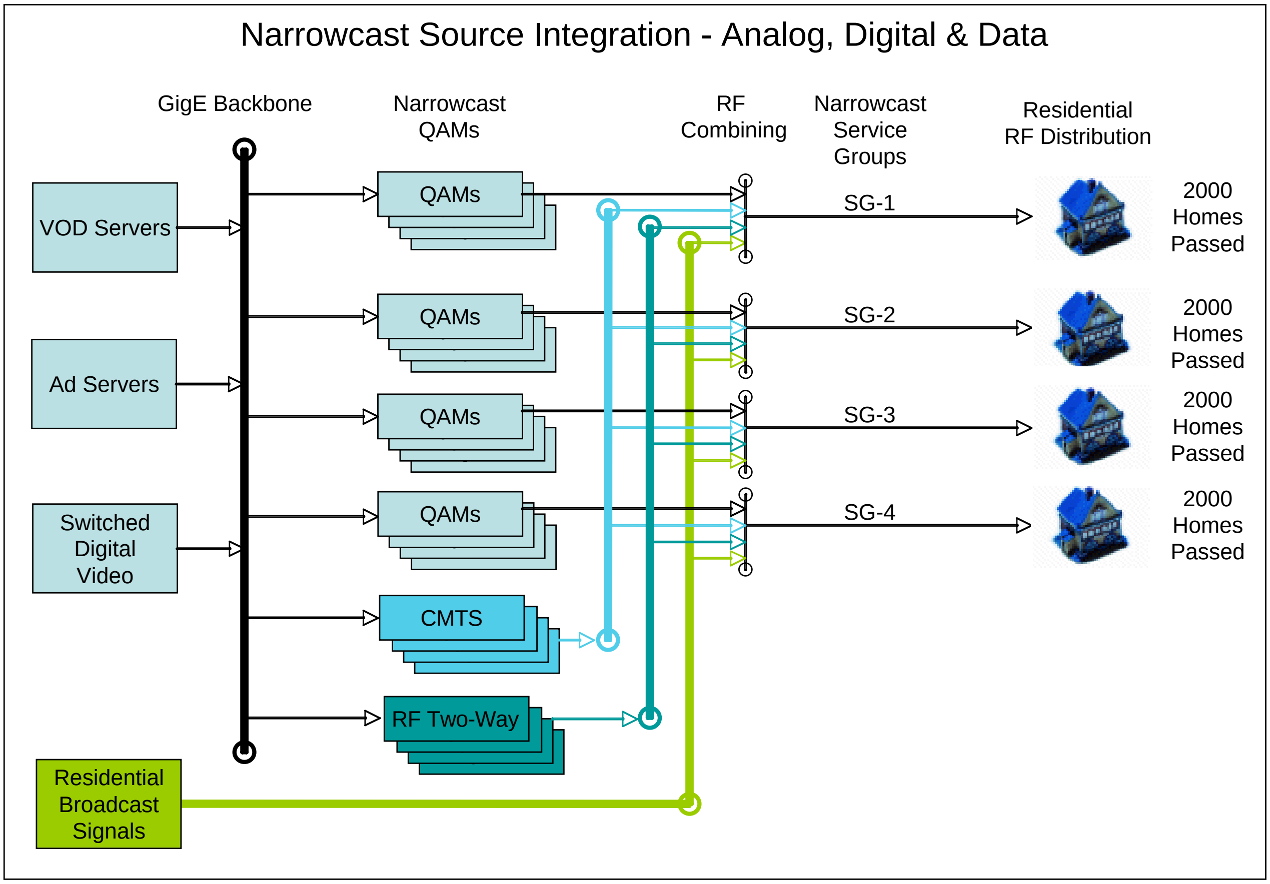
Narrowcast Bandwidth is the primary technology infrastructure that forms the foundation to allow cable to deliver the aforementioned services of the triple play; Voice, Video and Data. The Narrowcast Bandwidth is native to the cable platform, is one of cable's primary differentiators and serves as a springboard on which next generation services are launched. Cable's current successes can be traced back to investing in the Hybrid Fiber Coax (HFC) architectures. Cable's future success will be built upon the extension of the HFC network, the Narrowcast. It is key to building cable's sustainable network and is cable's primary tool to address competition.

This paper seeks to provide context for the Narrowcast - its origins, growth, future and importance to cable's future.

Defining "Narrowcast"

First, a few terms need to be defined to clarify their use in this paper.

Broadcasting is the transmission of programs or signals to the entire cable plant. That is to say, source signals (analog video, digital video or data) are modulated onto a frequency where it is broadcast across the cable plant unmolested or uninterrupted to the entirety of end users. Cable was built on that capability to transmit signals to the entire plant and it will always continue to broadcast.



Narrowcasting is the narrow "broadcasting" of source signals (analog video, digital video or data) to a subset of the cable plant and not indiscriminately to the plant on the whole.

In this manner, end users will receive unique source material based on their geographic location within the plant. This is accomplished by inserting unique or targeted source and modulating it onto a RF frequency that only serves a small subset of the cable plant. These Narrowcast modulators deliver unique RF channels (bandwidth) and thus unique sources to a subset of the cable homes.

It needs to be acknowledged that there is, in fact, both a Forward Narrowcast and a Return Narrowcast, but to avoid too much complexity in the discussion, this paper will focus on the forward Narrowcast.

A Narrowcast Service Group is the subset of subscribers within a cable plant that is served by a unique set of source signals (analog video, digital video or data).

A **Channel** is defined as a single 6 MHz frequency slot, whereas a **Program** is defined a single video source. To put it into perspective, an analog source would occupy an entire 6 MHz channel as a single program stream, whereas a digital program stream may be only one of ten programs on a channel. A **Stream** is the transport of a program across a channel at defined bandwidth. In the context of this paper, streams can be analog, VOD and SDV.

Understanding the Architecture

Cable systems were originally constructed as purely broadcast networks using cascading amplifiers in series to distribute the broadcast signals to the entire cable footprint. This architecture was interdependent and was as much an art as a science to keep the distribution network in “balance” across all the amplifiers within the network.

The figure above represents the basic constructs of the Narrowcast architecture. Modern Hybrid Fiber Coax (HFC) architectures were introduced to compensate for the limitation and complexity of managing series of cascading amplifiers. The reference architecture was based on roughly 500 homes per node and 4 nodes or 2000 homes per laser.

As part of this transformation, real-time two-way Radio Frequency (RF) communication was introduced to lay in the foundation for advanced services. Narrowcasting of the two-way RF communications addressed the problem of trying to communicate to a very large population of Set-Top-Boxes (STBs) by breaking the down the cable plant into subsections. The two-way RF communication equipment would narrowcast on the same frequency, but due to plant isolation they would not interfere with each other. In that way, the same narrowcast frequency could be “re-used” by each sub-plant. To put this into well-known context, the Narrowcast communication technologies that provide the two-way RF communications are Scientific Atlanta’s Quadrature Phase Shift Key (QPSK) modulators and demodulators and the Motorola’s Out of Band Modulator (OM) and Return Path Demodulator (RPD).

This basic technique of plant segmentation and spectrum re-use for creation of Narrowcast Bandwidth serves as the foundation for all of all the following services:

- Two-way RF Communications
- Advertising Zoning
- High Speed Data
- Voice Over Internet Protocol
- Video On Demand/Start Over
- Switched Digital Video

Each service type may serve a unique subset of the cable plant. Thus, within a given cable plant there could be an almost infinite number of different service groups based on service types. This is complex enough in the abstract but in the plant, this represents countless numbers of physical devices, wires, combiners and splitters located across a large geographic area (and this is just the forward path).

Traffic Modeling Narrowcast Services

Traffic modeling is the exercise in estimating the simultaneous use of limited resources by a given number of users. In context of cable’s Narrowcast services it is the estimation of the amount of bandwidth at peak required per service type to deliver that service.

In cable’s context:

Two-way RF Communications – it is the number of STBs that can be attached to a given QPSK Mod/Demod without having too many collisions that would make communication impossible.

Advertising Zoning – is the exception. Although it is a Narrowcast service it is multicast to all users within a zone with guaranteed non-contested bandwidth and, therefore, is not bound by a traffic model constraint.

High Speed Data – it is the modeling of the number of cable modems that can attach to a
CMTS port and provide the required bits/second service performance.

Voice Over Internet Protocol Phone Service – it is the number of simultaneous phone calls that can be made at a given moment in time.

Video On Demand/StartOver - it is the number of simultaneous VOD sessions that can support at a given moment in time.

Switched Digital Video – it is the number of simultaneous switched television programs that users can be watching at a given moment in time.

When analyzing the various traffic models of the different narrowcast services, it is important to note the key differentiator of service type, and that is the Quality of Service (QoS) requirement. All video services such a VOD and SDV require near perfect QoS delivery, where as with data services like two-way RF communication and data DOCSIS services they have built-in mechanisms to overcome delivery issues such as collisions, dropped packets, burst or sporadic packet delivery and out-of-order packet delivery. Streaming video delivery does not have any of these mechanisms. If a video packet is dropped, arrives out-of-order, is improperly spliced into the main stream or is not properly paced in its delivery, a video artifact will be seen by the end user. Video delivery is all about QoS.

The exception to that statement is VOIP telephone service. With the introduction of VOIP, the data side of the network had to address this new QoS requirement. VOIP is the first DOCSIS service to really demand QoS. Not to overly understate the importance of VOIP QoS but it is by magnitudes less demanding than video QoS. A phone call requires 128Kbps/sec versus 3.75Mbps for Standard Definition (SD) VOD sessions. Network architectures are being adjusted to compensate for this new QoS requirement on the data-networking infrastructure.

Besides QoS, there is another important concept to take into account when performing traffic modeling on Narrowcast services; blocking. Blocking is the term used to describe denial of service due to contention of resource. The familiar analogy is the busy signal associated with trying to make a call on Mother's Day when everybody else is trying to do the same. There are not enough resources to fulfill everyone's request at the same time.

Either due to the QoS requirement for both VOD and VOIP each service is guaranteed its full bandwidth requirement for that session or the session/call is denied or blocked in its entirety. This is unlike "best effort" delivery of data services.

For each service type, there may be an acceptable level of blocking. The Service Level Agreement for VOIP phones service and SDV services may require them to be non-blocking where as VOD may be considered a blocking service.

The basic traffic model analysis example will be performed on video service due to the QoS requirement of video.

<u>Video Narrowcast Modeling</u>

Video Narrowcast utilization is based on three key factors, the number of subscribers, the available bandwidth (i.e. streams both SD and HD) and peak simultaneous utilization. In the examples only SD content is used to model for simplicity.

VOD & Narrowcast

Originally, the narrowcast for VOD was built to a 6% peak streaming utilization of digital households. Four RF channels were allocated with each channel supporting 10 VOD streams per QAM 256 for 40 streams per 666 Digital Households.

The basic math:
500 Homes per node
4 nodes per VOD Service Group
2000 Homes Passed per VOD Service Group
Digital Penetration 33% (Digital Households)
4 QAMs (256) @ Payload of 37.5 Mbps
10 VOD streams per QAM at 3.75Mbps

2000 HP * 0.33 Digital = 666 Digital Homes
4 QAMs/SG * 10 streams=40 streams/SG

40 streams/SG / 666 Digital Homes = .06
or 6%

Therefore, the 40 available streams are to be shared across the 666 Digital Homes within the VOD Narrowcast Service Group.

VOD is considered a blocking service where at peak utilization some requests are accepted to be blocked denying service. Additionally, VOD is a uni-cast narrowcast service. This means there is a one to one relationship between narrowcast bandwidth use and user.

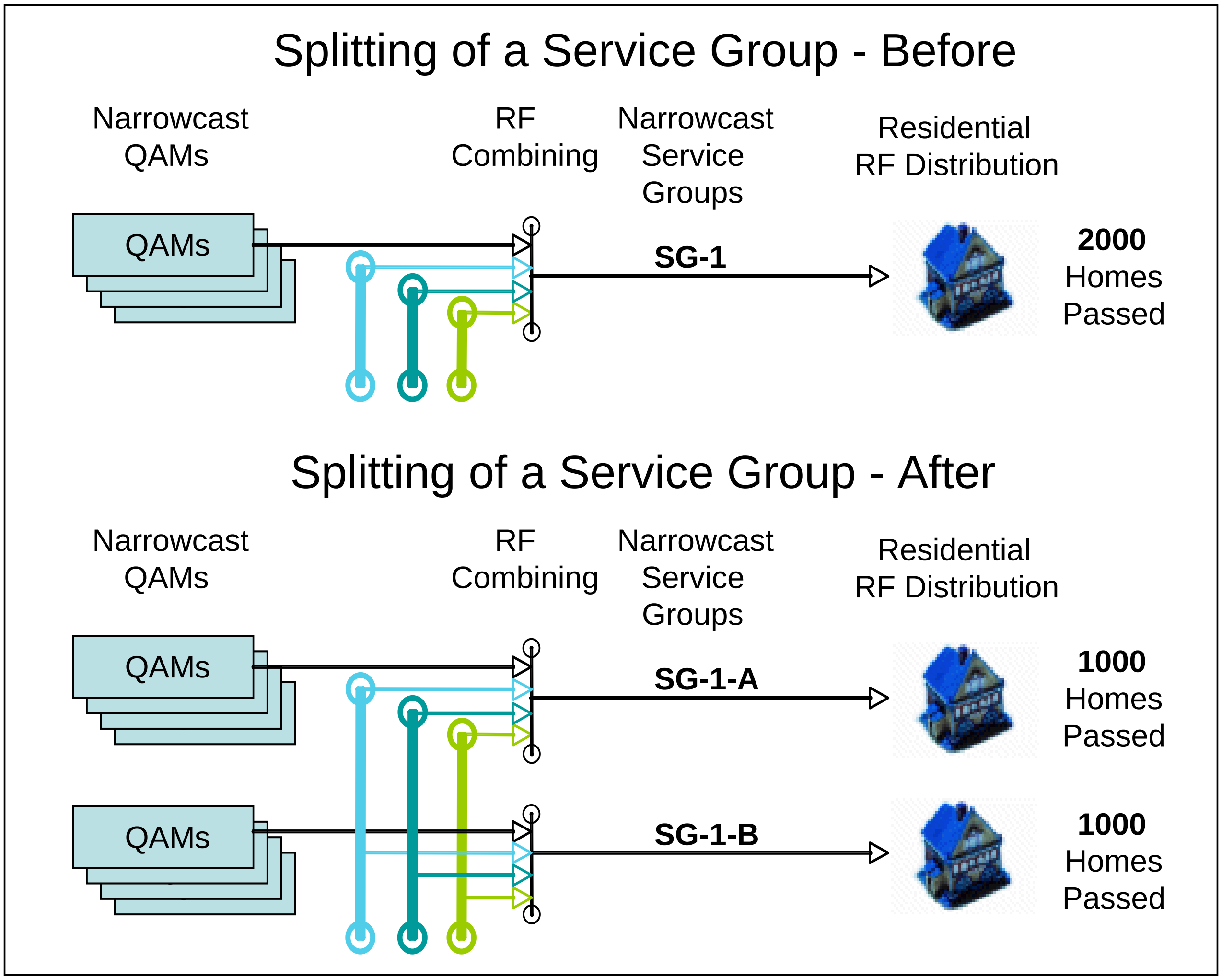
As mentioned at the beginning of this paper VOD is a huge success and with that success, careful management of the Narrowcast Bandwidth is critical to avoid block and denial of services. There are few major factors contributing to high use of VOD.

On the system today there is more compelling content, the digital penetration has increased by ten percentage points to around 45%, and markets have launched High Definition VOD (HDVOD) that uses 15 Mbps instead of the SD rate of 3.75 Mbps. However, the biggest contributor to increase usage of the VOD Narrowcast is the StartOver service.

StartOver is an advanced VOD technology that utilizes the existing VOD and Narrowcast infrastructure. Start Over enables the time shifting of live television without the need for upgrades to customer premises equipment. Time-shifted television allows subscribers to re-start and begin watching their favorite broadcast TV program during any point in the broadcast window. Unlike traditional on-demand services that have license windows measured in days or weeks, the Start Over content is only available to start a session within the actual broadcast window of the particular content.

With the launch of the StartOver service stream utilization within the narrowcast of service group has seen a 50% increase in utilization of the narrowcast bandwidth.

Success is a high-class problem to solve and cable is well equipped to address contention within the VOD Narrowcast. The optimum technique to address contention within the narrowcast is to increase the number of channels per narrowcast service group. But this requires additional bandwidth that is typically not available. Therefore the primary tool at their disposal is what is termed “splitting” the VOD Service to “manufacture” enough bandwidth to support the ever-increasing demand.



Manufacturing Bandwidth

In the previous example where the VOD service group consisted of:

500 Homes per node
4 nodes per VOD Service Group
2000 Homes Passed per VOD Service Group

To split a service group the number of nodes defined in the service group are halved thus a split service group now consists of:

500 Homes per node
2 nodes per VOD Service Group
1000 Homes Passed per VOD Service Group
Digital Penetration 33% (Digital Households)

The VOD math - holding Digital Penetration constant:
1000 HP * 0.33 Digital = 333 Digital Homes
4 QAMs/SG * 10 streams=40 streams/SG

40 streams/SG / 333 Digital Homes = .12 or 12%

The VOD math - adjusting Digital Penetration to 45%:
1000 HP * 0.45 Digital = 450 Digital Homes
4 QAMs/SG * 10 streams=40 streams/SG

40 streams/SG / 450 Digital Homes = .089 or 8.9%

The drawing above illustrates the basic concept of splitting of the service group.
By splitting the SG-1 service group into SG-1-A and SG-1-B the affect was to increase the peak simultaneous streaming capacity from 6 % to 12% and even when including the increased Digital Penetration of 45% the peak streaming capacity worked out to roughly 9%, an increase of 3% per service group from before the split of the original service group.

Real work must be performed in a coordinated manner in the RF plant to make a Service Group split occur without impacting the customer. On the physical level within the cable plant to accomplish a Service Group split, new QAMs are require to be:

- Installed
- Configured IP & Controller
- Wired into the combining and distribution network (forward and reverse)
- RF balanced into the plant
- All the STBs on that original service group must be notified that belong to the "new" service group
- Tested

This work represents a manageable amount of work for the cable system and they have become very adept at managing the service group split to a science.

This is the same basic technique used to address contention across any of the Narrowcast Services. Regardless of the service VOD, HSD or VOIP service group splitting has become an organic response to address the changing demographics encompassed within the cable footprint. Diligent monitoring of the various contention thresholds per service and an appropriate response to provide additional narrowcast bandwidth is all that is required to ensure optimum performance. This is why the term "manufacturing" bandwidth is a truism within the cable industry.

<u>Switched Digital Video & Narrowcast</u>

SDV works off the basic premise that not all digital programs are being watched in a given service area at the same time, so why broadcast them, why not narrowcast them just like a VOD stream.

SDV can be thought as of moving the STB tuner out of the STB and placing it just in front of the narrowcast SDV QAMs. To provision these SDV Narrowcast QAMs, the digital programs are multicast onto the transport ring and when a client "tunes" a multicast join occurs on the edge device and the signal is routed through the narrowcast QAM for distribution to the STB.

When studying the narrowcast modeling for SDV the basis for modeling was changed from Digital Households to STB tuners. This was done to accommodate devices that can have multiple tuners per device like DVRs. Where each tuner could be tuned to a different signal source at the same time. For every 250 to 500 STB tuners (DVR STBs have 2 tuners), a SDV narrowcast service group is created across the entire cable footprint.

The SDV math (more factors):
500 Homes per node
2 nodes per SDV Service Group
Digital Penetration 28.6%
Target size of 500 tuners per SDV SG
Boxes Per Home =1.4 average
Tuners Per Box = 1.3 average
8 QAMs (256) @ Payload of 37.5 Mbps
10 SDV streams per QAM at 3.75Mbps

1000HP *0.268 D*1.4STBs/H*1.3 T/B = 520 Tuners per SDV SG
8 QAMs/SG * 10 streams=80 streams/SG

80 streams/SG / 526 Tuners per SDV SG = 0.154 or 15.4%

Therefore, the 80 unique programs are available to be viewed simultaneous across the 520 digital tuners within the SDV Narrowcast Service Group.

The SDV service is considered a non-blocking service where contention is not allowed and must always be available. To borrow an adage from the telcos, POTs (Plain Old Telephone) now represents Plain Old Television and SDV must provide that same seamless service that the customers expect. SDV differs from StarOver/VOD service, as it is a multicast narrowcast service, meaning that there is a one-to-many relationship between narrow bandwidth use and user. That is to say, within the narrowcast more than one user can tune into the SDV narrowcast stream and watch the same program.

SDV is a unique service as it highly dependent on content placed into the SDV tier. Content is the primary factor in determining the utilization of the service and the required bandwidth. For SDV, the number of programs put into the SDV tier will determine the exact amount of bandwidth required to support the number of streams. If there are only 80 services in the SDV tier then there is no possible contention, it is just an expensive broadcast/narrowcast network. SDV becomes much more interesting when it is oversubscribed with content.

If SDV contention is based on tuner math and not Digital Homes, then VOD contention should be normalized to that same basis.

Re-calculating VOD Math based on tuners:

- 1000 Homes per node
- 2 nodes per VOD Service Group
- Digital Penetration 45% (Digital Households)
- Boxes Per Home = 1.8
- Tuners Per Box = 1 (DVRs can only order one movie at a time)
- 4 QAMs (256) @ Payload of 37.5 Mbps
- 10 SDV streams per QAM at 3.75Mbps

1000 HP *0.268 D*1.7STBs/H*1T/B = 400 Tuners per VOD SG
4 QAMs/SG * 10 streams=40 streams/SG

40 streams/SG / 400 Tuners per VOD SG = 0.099 or about 10%

It is interesting to note that when basing VOD math on Digital Homes we have a contention rate of 8.9% but when it is normalized to tuner math is around 10% for exactly the same service contention level. So it seems that SDV and VOD should be able so share the same physical Narrowcast downstream infrastructure even though running in separate Narrowcast Bandwidth

Going forward, traffic modeling should be calculated using tuner math to normalize the analysis across narrowcast services.

Unifying the Architecture

A couple of questions need to be asked when architecting a unified narrowcast architecture Voice, Video and Data.

Does it make sense to have one Narrowcast for all services sharing the same downstream infrastructure physical layer or are there many?

Can the narrowcast services share the narrowcast bandwidth?

When all services are normalized to tuner math, either QAM tuners or DOCISIS tuners, the math and traffic analysis becomes an even more interesting exercise in “And & Or “ math and understand the peak trending of services.

A single QAM tuner can either be tuned to a broadcast stream OR to a VOD stream OR to a SDV stream OR turned off. A QAM tuner cannot tune to multiple services at the same time. Therefore, it is easily conceived that for services targeted at QAM tuners the services can coexist and interoperate quite well within the same shared Narrowcast. OR math dictates that is just a series of tradeoffs. Therefore, when the bandwidth for QAM tuner Narrowcast services are shared or pooled together there are economies of sharing.

Current DOCSIS tuners only tune to one frequency at time. With DOCSIS 3.0 and channel bonding the DOCSIS tuners can tune wideband frequencies but as they are tuning discrete frequencies at any one point in time they can be considered bound by OR math when operating in a shared bandwidth pool just like they are today. Typically a single 6 MHz narrowcast channel is allocated for HSD and VOIP phone service across the cable plant.

Today in the residential market, the coexistence complexity arises when looking at the peaks of QAM tuner services and DOCSIS tuner services. While each service type may be bound by OR math when viewed together the two services actually peak at or very close to the same time and are thus actually bound by AND math. Thus, the total load between a QAM tuner and a DOCSIS tuner is cumulative. There are not economies of scale to share the bandwidth between the two tuner service types.

In the near future, when cable has more greatly penetrated into the commercial market with its HSD offering there will be some advantages in sharing the bandwidth between video and HSD narrowcast services. This will be because video narrowcast services under-utilize narrowcast bandwidth during the daytime and that excess capacity could be switched over for commercial HSD use during the day and then back to residential video narrowcast services in the evening.

<u>Combined Narrowcast Services</u>

There are two key technologies that are missing to truly unify the Narrowcast Services, the Global Session Resource Manager (GSRM) and the Business Rules Engine (BRE).

The Global Session Resource Manager (GSRM) is the unifying manager of all the source signal and bandwidth resources. The GSRM negotiates and arbitrates between all services and all requests. It is the key bandwidth allocation mechanism; employing bandwidth optimization algorithms to ensure that efficiencies are realized across the utilization of bandwidth across all narrowcast services.

The fact that the GSRM will be able to share the narrowcast bandwidth will allow for greater bandwidth usage efficiencies across the combined services and is predicted to require less total bandwidth for the same blocking factor for any given service. Efficiency is the key to performance.

The Business Rules Engine is the “uber” Policy Manger for all narrowcast services.

It is the tool that determines how to “sell” the narrowcast bandwidth for how much, to whom and prioritizes services and customers. It “plugs” into the GSRM and is not so much an engineering tool as a business tool. It will allow the cable business to optimize its service, its services and its revenues.

Along with the adoption of the GSRM and BRE a holistic approach must be taken into account when architecting the Narrowcast design. The physical layer of the Narrowcast cannot just be thought of in an abstract way without really identifying with the physical infrastructure of the headend, hubsite, laser, node and customer's home. This is purely a practical operational model concern. If the wiring of the various narrowcast services becomes too complicated to manage and the sheer number of service groups, types of service groups, QAMs combining and distribution networks the field personnel will not be able to support it. Although not detailed in this paper, remember to not forget the complexity of the reverse path traffic modeling and its physical combining and splitting network which is almost equal to the forward path.

Case Study – The Exponential Growth

The growth of services dependent on the video Narrowcast has dynamically increased the total number of streams that are "cast" into the cable plant; either broadcast or narrowcast.

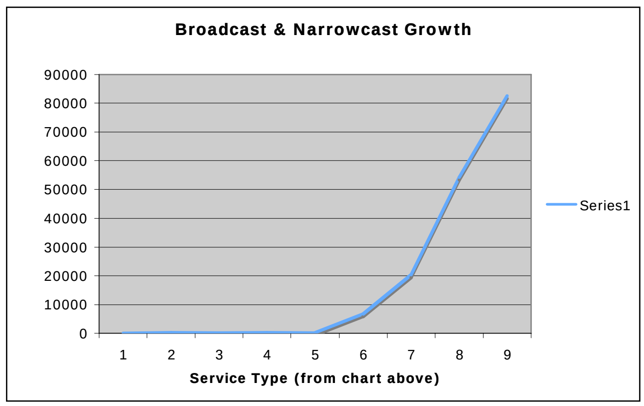
As cable technology advanced in steps from 300MHz, 450MHz, 550MHz, 750MHz, 860MHz and now to 1 GHz and at the same time transitioned from an analog broadcast network, digital broadcast network, HSD narrowcast, VOD narrowcast, VOIP narrowcast and finally to SDV narrowcast networks the number of channels, programs and streams offered in cable system has grown tremendously.

For example in a medium size market:

	Service	Service Groups	Ōcast 6-MHz Channels	Streams Per Channel	Total ŅcastÓ Streams	Cumulative Streams
1	**Analog**	1	78	1	78	**78**
2	**Digital**	1	25	12	300	**378**
3	**Ad Zones**	4	Same as above	68	272	**650**
4	**HSD**	338	1	Best Effort	338	**988**
5	**VOIP**	200	Same as above	QoS	200	**1,188**
6	**VOD**	170	4	10	6,800	**7,988**
7	**StartOver**	508	Same as above	10	20,320	**28,308**
8	**SDV**	678	8	10	52,400	**82,548**

The way to interpret the chart above is by culminating the growth of each service stream load and adding it to the next tier of service.

Graphing this culminating growth across services creates a graph that looks like:



Therefore, for the medium size market running all services, the cable system went from broadcasting of a few dozen analog streams to managing over 80,000 streams across their cable footprint within the last 15 years.

In the case study, the Narrowcasts for SDV and VOD have an equal number of service groups at 675 and can therefore share the same physical downstream wiring, combining and distribution path. However, the number narrowcast service groups for HSD/VOIP has a total of 538 services groups and is not in parity with SDV/VOD and thus cannot share the same physical downstream narrowcast wiring. The questions arise in this real-life example:

To simplify the implementation and operational model, does it make sense to increase the number of HDS service groups by 137 to bring it into parity with SDV and VOD so that all services can share the same downstream narrowcast wiring?

Is the peak demand for HSD going to naturally to follow the peak demand for VOD and SDV?

Is it cost justifiable, practical?

Conclusion – It is One Network

Narrowcast services are pervasive within the cable infrastructure and they form some of the most revenue generating services offered by the cable company. Voice, Video and Data all share the same common cable network but unique Narrowcast Bandwidth.

To fully license this advantage of the Narrowcast Bandwidth, each service should not be looked at discreetly as a unique isolated and separate narrowcast service but in the whole across all service and the cable plant infrastructure.

The emerging and maturing Global Session Resource and Business Rules Engine will unlock the true economies of sharing narrowcast bandwidth within and between HSD and Video services.

The Narrowcast Services will continue to evolve and new yet to be developed and deployed services will guarantee cable's future success.