Operationalize Going All Digital

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I. Introduction

Over the past several years the cable operator's competition has dramatically increased. This includes competition from DirectTV, Dish Network, Verizon, AT&T, and many others. The response to this intense competition requires increased HD services and DOCSIS® bandwidth to meet this competitive challenge. There are several options to reclaim analog bandwidth; this paper will consider a strategy to reclaim bandwidth based on the Comcast experience of transitioning to an "All Digital" network. It will examine areas of interest in each of the stages of transitioning to an "All Digital" network. The four areas of interest will be:

- Goals – this section will include a description of the primary goals for the transition stages.
- Technology – this section will discuss the technology used to accomplish those goals.
- Technical Challenges – this section will describe challenges that are encountered as part of the transition to an "All Digital" network.
- Operational Impact – this section will review the impact to both customer operations and technical operations.

II. Definitions and Acronyms

Acronyms

ADS	All Digital Simulcast
AMOL	Automated Measurement of Lineups
ATSC	Advanced Television Standards Committee
CBR	Constant Bit Rate
CAE	Customer Account Executive
CE	Consumer Electronics
CPE	Customer premises equipment
CVT	Code Version Table
DTA	Digital Transport Adapter
EMM	Entitlement Management Message
HD	High Definition
IP	Internet protocol
IVR	Interactive voice response
mDTA	MDU Digital Transport Adapter
MDU	Multi-Dwelling Unit
PID	Package Identifier
PSIP	Program and System Information Protocol
QAM	Quadtrature Amplitude Modulation
RF	Radio Frequency
SCTE	Society of Cable Telecommunications Engineers
SD	Standard Definition

SOA	Service Oriented Architecture
UDCP	Unidirectional Cable-ready Product
VBI	Vertical Blanking Interval
VBR	Variable Bit Rate

Definitions

Digital Devices – A Digital Device is a digital set-top, CableCARD™ Host, or DTA.

Digital Only Set-top / Host – This is a Digital Device that ONLY has digital tuners. It can only receive content in a digital format. It also has both upstream and downstream communications as well as a guide and other applications. This device is different from a DTA in the respect that a DTA is not interactive nor does it have a guide.

Interactive Digital Devices – An Interactive Digital Device is a digital set-top or CableCARD Host that has both upstream and downstream communications with the headend. This definition specifically does not include DTAs and UDCPs which are one-way devices.

III. Comcast Case Study Overview

In mid-2003, Comcast started a project to transition to an "All-Digital" network. Internal to Comcast this project was known as the "All Digital Simulcast" (ADS). The goal of this project was to digitally simulcast all analog services to enable the purchase of Interactive Digital Devices that would not require an analog tuner. The ADS project ran from 2004 to 2008 upgrading Comcast's infrastructure to the ADS architecture. The scope of this project was quite extensive leading to significant changes in the Comcast video and ad-insertion infrastructures.

The primary goals of the ADS project were to:

- Reclaim bandwidth
- Enable lower cost Interactive Digital Devices by not requiring analog tuners and associated complexity
- Improve Picture Quality
- Allow Comcast to add new product tiers that leverage 100% digital and the low-cost digital only devices at various price points
- Place VOD in front of more subscribers
- Improve company image and customer satisfaction
- Reduce theft of service
- Use standards based solutions where possible

In late 2007, Comcast kicked off another project, code named "Project Cavalry," to pick-up where the ADS project had left off. It had the primary goal of reclaiming the bandwidth allocated to analog expanded basic services. This project needed to solve the problems of creating a low-cost digital device for additional outlets and creating a solution for MDUs, bulk, and commercial accounts in the transition to an "All Digital" network.

The primary goals of Project Cavalry are to:

- Reclaim bandwidth for new services (Figure 1)
- Create a low cost CPE device that meets regulatory requirements and enables self-installs
- Create a device to convert digital services to analog for MDUs and bulk accounts
- Fully automate the order and activate process via Comcast.com and IVR
- Enable self install success rate of greater than 70%

In this paper, we will consider both Comcast projects as part of the transition to the "All Digital" network as both phases are essential to make the transition to an "All Digital" network.

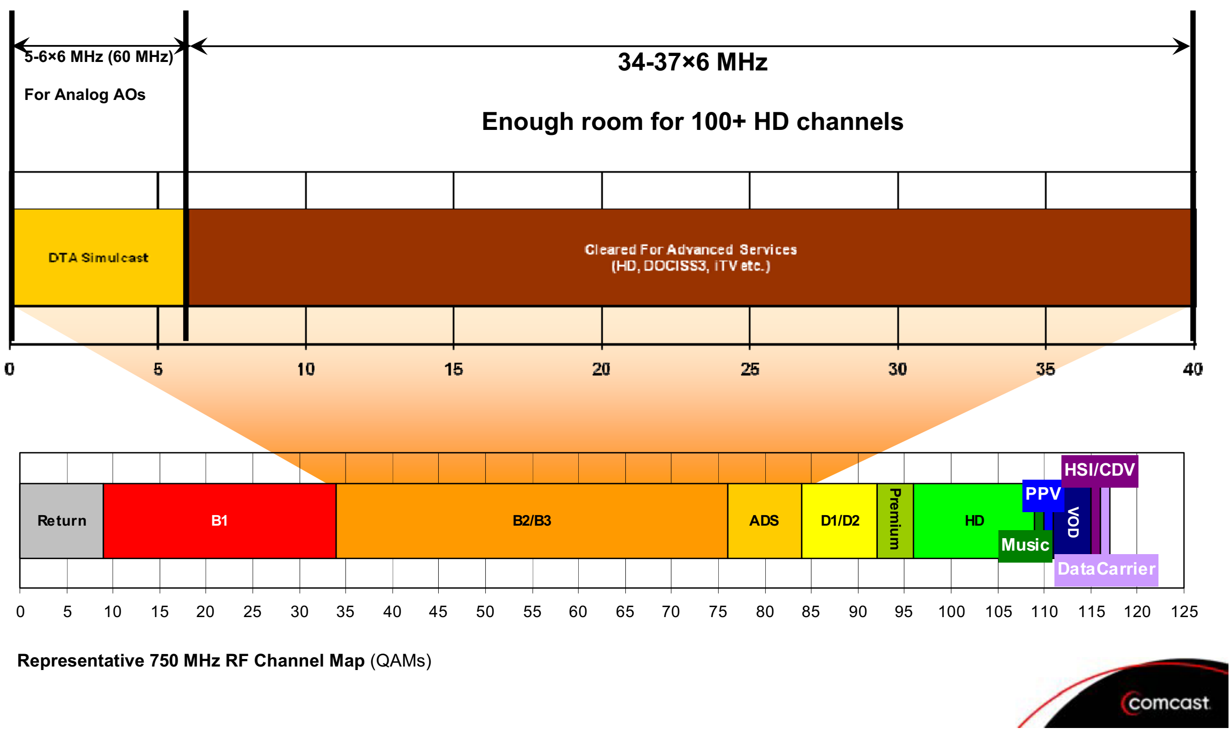


Figure 1 – Cable Spectrum

IV. What does an "All Digital Network" really mean?

The term "All Digital" network has many definitions depending on the context of the conversation. This is the result of there being a continuum of options from simulcasting all content in digital to removing all analog carries from the plant. The "All Digital" network transition will be examined in four phases of an "All Digital" network. For the first three phases, the technical and operational impacts of these phases will be examined.

All Digital Phase 1 - Digital Simulcast: In the first phase of transition, all of the content that is found in analog (basic and expanded basic tiers of services) will be simulcast in digital.

All Digital Phase 2 - CPE Distribution: For the second phase of transition, the cable operator needs to deploy digital devices (set-tops, hosts, DTAs, and mDTAs) onto all outlets that have a service level of expanded basic or higher. This includes outlets for subscribers, bulk accounts, MDUs, and commercial accounts.

All Digital Phase 3 – Expanded Basic Analog Reclamation: Once "All Digital Phase 2" is complete, the cable operator can reclaim bandwidth associated with expanded basic services. This is a very significant accomplishment as it represents 250-300 MHz of bandwidth – as much bandwidth as a rebuild on the physical plant from a 550 MHz plant to a 860 MHz plant at only a fraction of the cost of a rebuild!

All Digital Phase 4 - Basic Analog Reclamation: This is the final phase of going to an "All Digital" network that an operator may choose. In this phase, all analog services are removed from the plant leaving only digital services.

Each cable operator will need to decide how far it will progress down the "All Digital" network continuum towards the "All Digital Phase 4," and how long it will dwell at each stage of the process.

V. All Digital Phase 1 - Digital Simulcast

A. Overview

The "All Digital Phase 1 – Digital Simulcast" is the first step in migrating to an "All Digital" network. The main goal of this phase is make the changes to carry digital copies of all content that is currently only carried in analog. In a typical plant, this content falls into two service packages: Basic and Expanded Basic. This content can be also be broken down further into several classes of content based on source and technical characteristics:

Over-the-Air Broadcast – These are services that are broadcast by the local broadcaster. These are typically associated with national networks like ABC, Fox, NBC, CBS, Univision, and others. These services are part of the Basic package. The carriage of these services are managed either under must-carry or retransmission consent agreements. These services have recently undergone their own transition to digital as mandated by the FCC, which introduced new challenges especially with bitrates, Captions, and PSIP. In addition, most cable plants must continue carrying these channels in analog and SD digital, which presents challenges with down conversion and aspect ratio. It's important to note that the format of the source from broadcasters (excluding several small broadcasters that have obtained an analog waiver and most low-power and translator stations) is already digital, and can be either SD or HD. The cable operator must coordinate with the broadcaster to assure the proper technology is in place to avoid any issues. This also includes conversion of Closed Captioning formats, and other ancillary data such as TVGuide+ data.

Characteristic		**Comments**
Service Tier	Basic	
# per channel line up	5-20	Varies considerably by market
# per market	5-50	
Source	Off-air, Direct Fiber	
Ad Insertion	No	
Picture Quality	Poor - High	Depends on service, source, and service encoding (SD or HD)
Source Content Type	Digital	
Blackout Requirements	No	
Encrypted (on cable plant)	No	

Public, Educational, and Governmental Access (PEG) – These are services that cable operators carry as part of agreements with local franchise authorities. These services are part of the Basic package. These services are usually very limited in their geographical distribution and are for only very specific franchise areas. However, there are typically many of these services in a large market that covers many franchise areas. In one example within Comcast, there were over 800 PEG channels in a large metro market. The other challenge with these services is the quality of the video content can be very poor and require pre-processing before digital encoding can occur.

Characteristic		**Comments**
Service Tier	Basic	
# per channel line up	1-5	Varies considerably by market
# per market	5 to several hundred	
Source	Tape Decks	
Ad Insertion	No	
Picture Quality	Poor - Medium	Depends on service and source
Source Content Type	Analog	Needs to be encoded and typically at the edge of the network
Blackout Requirements	No	
Encrypted (on cable plant)	No	

Ad Inserted Channels – These channels are services where cable operators insert ads as part of the ad sales business line. These services typically include ESPN, TNT, TBS, and others. In many markets there are many ad zones which requires ad insertion at the edge of the network as part of the ad zone.

Characteristic		Comments
Service Tier	Expanded Basic	
# per channel line up	35-55	
# per market	35-55	
Source	Satellite feeds	
Ad Insertion	Yes	
Picture Quality	High	
Source Content Type	Analog or Digital	These feeds must carry SCTE-35 for ad insertion signaling
Blackout Requirements	Yes	
Encrypted (on cable plant)	Yes	

Non-Ad Inserted Services – These services are carried in analog, are national feeds, are usually part of the expanded basic service tier, but typically do not have ads inserted. An example of this type of service is C-SPAN.

Characteristic		Comments
Service Tier	Basic or Expanded Basic	
# per channel line up	2-10	
# per market	2-10	
Source	Satellite feeds	
Ad Insertion	No	
Picture Quality	Medium - High	
Source Content Type	Analog or Digital	
Blackout Requirements	No	
Encrypted (on cable plant)	Yes	(Typically)

B. Digital Simulcast - The Goals

In this phase of the all digital conversion, the requirement is to simulcast all analog services into digital feeds. Once this is complete, the market can begin to use "Digital Only" devices. These are digital hosts and set-tops that only have a digital tuner. The cost savings of digital only devices can be significant especially for large markets. Also, this step is required to enable the market to support DTAs which are digital only devices. Another advantage of the transition to all digital transmission is improved picture quality.

C. *Digital Simulcast - The Technology*

1. Headend and Hub Infrastructure

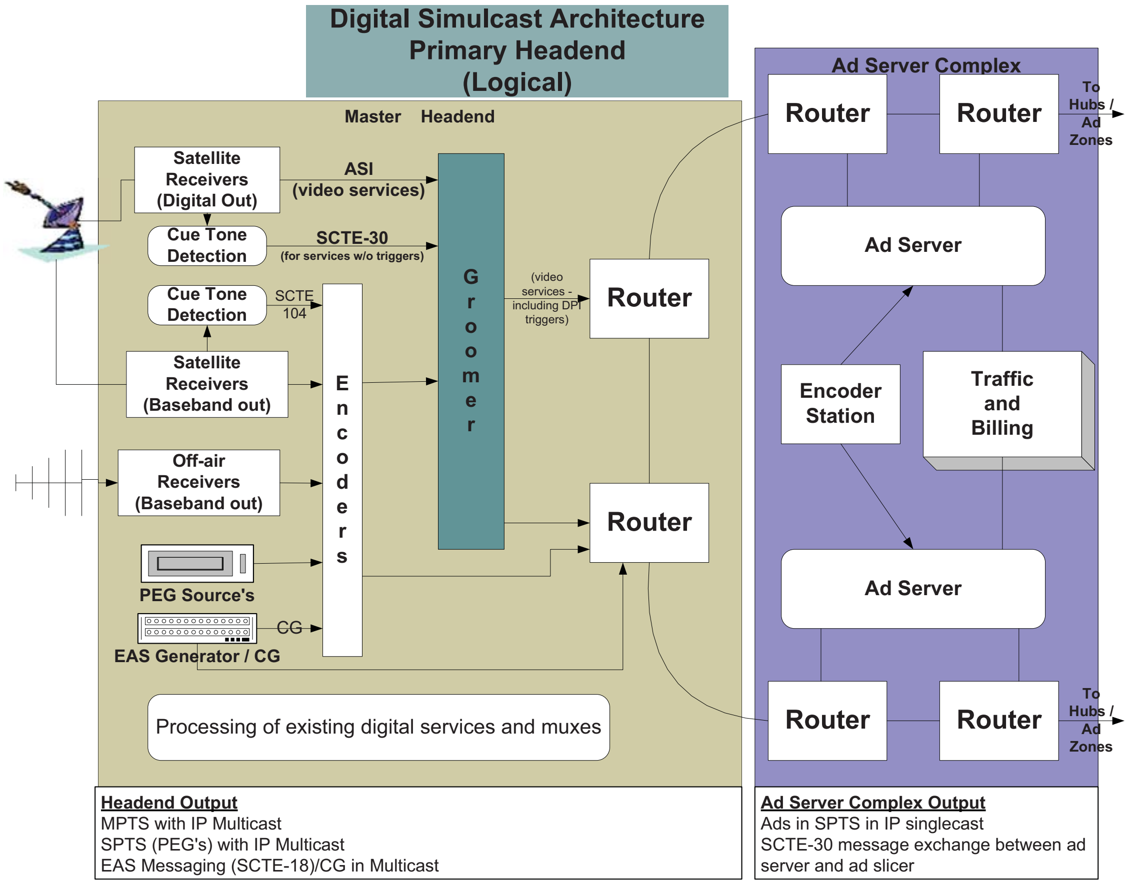


Figure 2 – Headend / Ad Server Infrastructure

Of primary importance in the ADS architecture is the headend, hub, and transport architectures. In the headend, the cable operator will first need to examine which video sources need to be digitally encoded. For content that arrives in analog, the content will need to be digitally encoded. Typically the content that will need to be encoded in the headend will be off-air broadcasters, PEG channels local to that headend, and expanded basic content. In the Comcast example, most of the expanded basic content was digitally encoded at the Comcast Media Center (CMC) and transported into the market either via satellite or over the Comcast IP backbone.

Creating a quality digital multiplex is a combination of good engineering and lots of video quality analysis. Deciding on the composition of the digital multiplex needs to take several characteristics into account including:

- Video complexity
- Content type – sports, talking heads, movies, etc
- Film versus video
- Ad-insertion requirements
- Encryption requirements

The results of this analysis should be used to assemble a digital multiplex that achieves the desired video quality for all services in the digital multiples. Before putting the digital multiplex on the plant, it should be carefully monitored over the course of several days for video quality issues as the video complexity does vary over the day. If the digital multiplex passes the video quality monitoring, then the multiplex can be added to the cable plant.

For sources that arrive in a digital format, they will need to be added to a digital multiplex through a video groomer. Similar analysis and quality monitoring need to be done for composing a digital multiplex.

As digital multiplexes are planned, the cable operator will need to take into account any requirements for PEG channel that will be inserted at the edge. If PEG channels are to be added at the edge of the network (either through a statistical multiplexer, groomer, or directly in the QAM), bandwidth will need to allocated in the digital multiplex.

Also, for any service that is to have ads inserted SCTE-35 signaling must be part of the digital feed. If the SCTE-35 signaling is not present, then the cable operator will need to convert the analog cue tones to SCTE-35.

Another issue to be considered is blackout requirements. Several of the services in expanded basic have blackout requirements. Blackout requirements limit distribution of sports programming to select geographical areas (direct marketing areas or DMAs) determined by the programmer. If a cable operator is serving sports programming across more than one DMA, it may be necessary to carry a copy of the sports programming for each DMA served and groom the appropriate sports programming at the edge of the network based on the DMA for that area of the plant. This allows the cable operator to create the best fit of sports programming distribution while enforcing blackout requirements.

As part of the Comcast conversion to the "All Digital" network, Comcast started to use an IP network for the distribution of video. This approach has allowed Comcast to carry data for all lines of business over the same IP infrastructure resulting in capital and operational cost savings.

The final part of the ADS architecture is the changes made in the hub/ad zone. The first change was the delivery of both video content and ads over the IP distribution network.

The second change was driven by a fundamental decision to do all ad insertion in the digital domain and retire the existing analog ad insertion infrastructure. As part of the transition to the "All Digital" network, the cable operator needs to choose between:

- Single Digital Ad Insertion Infrastructure – This choice will require the existing analog ad infrastructure to be retired. However, for each service that will continue to be carried in analog on the plant, the service will need to be converted back to analog after the ad insertion in the ad zone. This requires the cable operator to acquire the MPEG to NTSC equipment for each analog service in each ad zone.
- Dual Ad Insertion – In this choice, the cable operator will continue to do ad insertion in parallel to the ad insertion done in the digital copy of the services. This requires significant re-configuration of the ad insertion infrastructure and the operational tools to measure and manage ad insertion in both the analog and digital domains.

Comcast chose to implement the single digital ad insertion infrastructure with conversion back to analog. This decision was primarily driven by the desire to keep the on-going operations as simple as possible.

The hub/ad zone is also the logical location to encode and multiplex PEG channels that are required for the franchise areas serviced by that hub. For the PEG channel to be properly multiplexed at the hub, the digital multiplex needs to have an appropriate allocation of bandwidth reserved for the edge insertion of the PEG service.

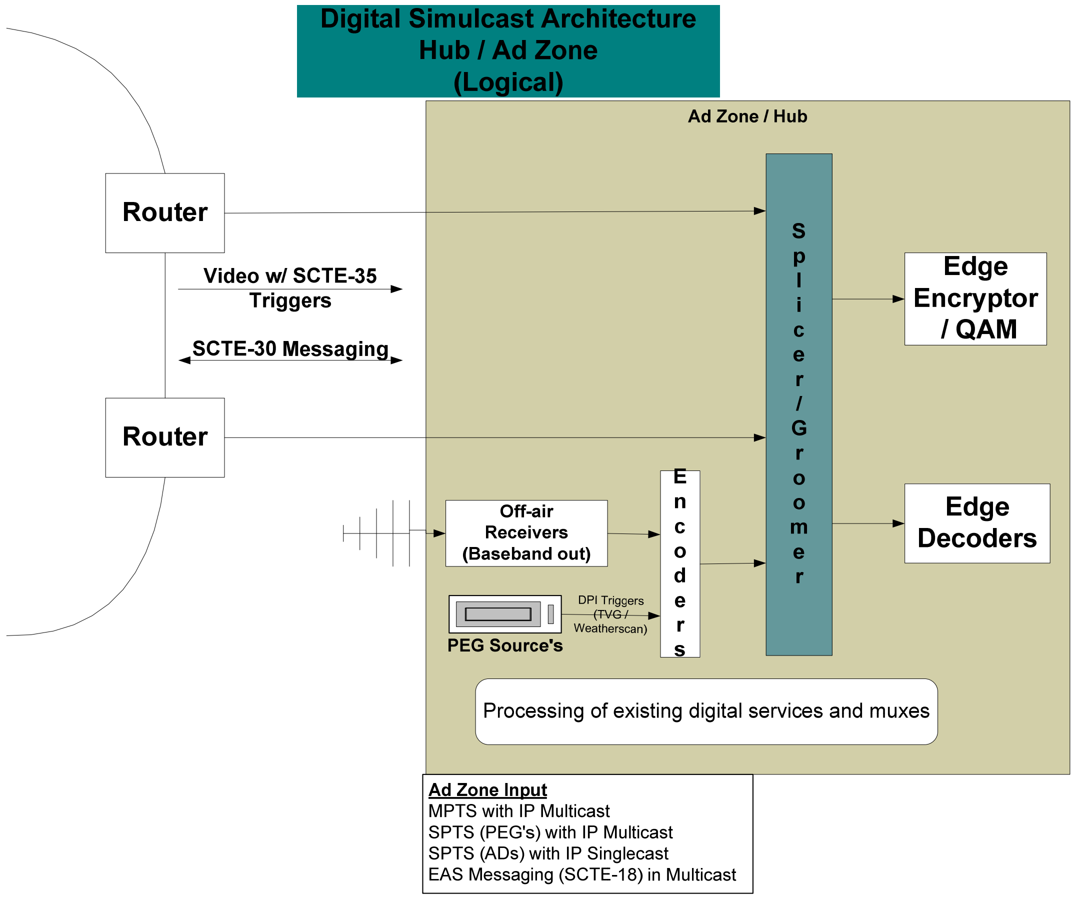


Figure 3 – Hub / Ad Zone

2. Ad Insertion Infrastructure

Another challenge to be faced is the conversion to a fully digital ad insertion system. The digital ad insertion consists of several processes that need to be modified to work properly in this phase of the "All Digital" network. The ad insertion system includes the ad encoding process, the ad signaling process, and ad insertion process.

The first area to consider is the ad encoding process. Prior to today's digital simulcast activities, ads were encoded in digital, but the encoding rate was in the 5-8 Mbps range which is much too high to be inserted into the digital multiplex. Older ad encoders need to be swapped with ad encoders that digitally encode video at the standard VOD 3.75 Mbps rate. Using this encoding rate will allow ads to be easily inserted into a properly configured digital multiplex.

The next area of the ad insertion infrastructure to be considered is the ad signal processing. In an analog ad insertion system, there are cue tones that signal the ad insertion system to insert an ad. In the digital domain, this function is performed by the SCTE-35 signaling. In the planning process of converting a system to "All Digital" network, all of the services that will have ad insertion will need to be verified to have SCTE-35 cue tones. Any services that do not provide the cue tones will need to have equipment added to convert the analog cue tone to the digital SCTE-35 signaling.

The final area to consider is the insertion of ads in the digital domain. First is the composition of the digital multiplex that contains services which are ad inserted. In creating the multiplex, the overall composition of the multiplex needs to take into account the number of services that may have ads simultaneously inserted. Typically a digital multiplex consist of a group of services that are combined by the encoding system creating a VBR (Variable Bit Rate) multiplex. Since ads use CBR encoding, the ad insertion equipment needs to groom the CBR video feed into the VBR multiplex. Without careful planning the capacity of the digital multiplex may be exceeded with significant impact to picture quality. A final consideration is the billing reconciliation process for Ad insertion. Specifically, there can only be one Ad insertion point per channel, per ad zone. This requires that the service (post Ad Insert) be converted back to analog to retain the analog tier. A digital *and* analog copy of the service is then combined onto the plant assuring a common Ad, and insertion point.

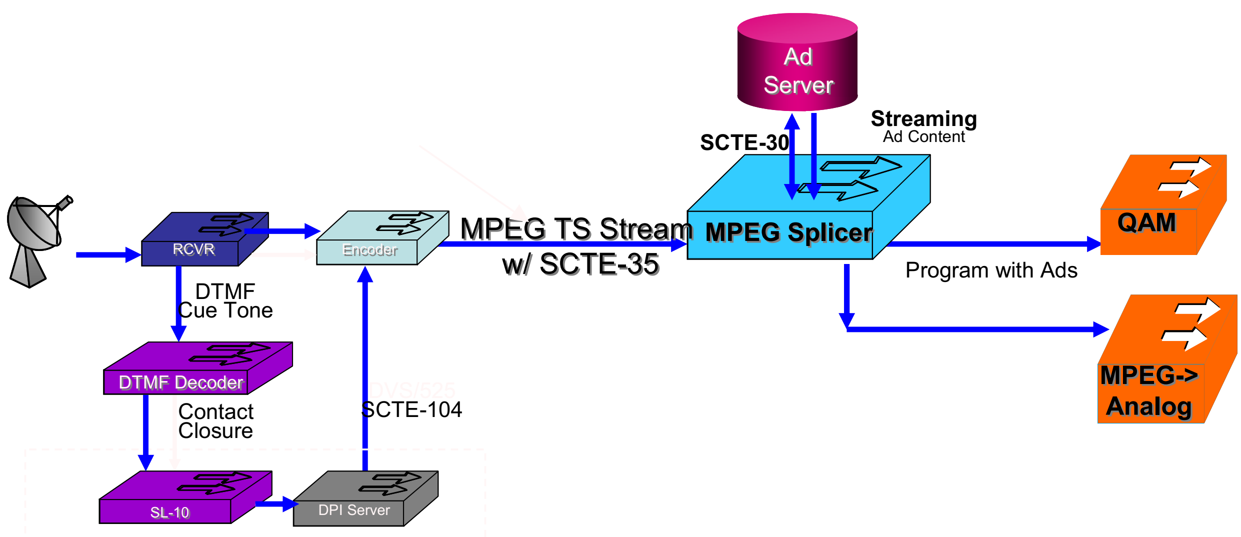


Figure 4 – Ad Insertion Infrastructure

D. Digital Simulcast – The Technical Challenges

1. PEGs

Another challenge that will need to be faced in the All Digital Phase 1 - Digital Simulcast is the placement and encoding of PEG channels. Most of the digital encoding and digital multiplex creation happens at a primary headend. However, given the geographical nature of PEG channels, usually they will need to be encoded and inserted at the edge of the network. Several options exist to solve this problem. If the PEG channel is to be inserted at a site that already is doing ad insertion, the digital multiplex can have bandwidth allocated and the ad splicer can be used to groom the PEG channel into a digital multiplex. Another approach is to allocate a static amount of bandwidth back at the point the digital multiplex is created. Then encode the PEG channel using Constant Bit Rate (CBR) encoding. At each edge of the network, the PEG channel can be inserted by the edge QAM using only statistical multiplexing.

Another problem with PEG channels is the video quality. Many of these channels are played back off of VCRs or other low quality sources. It may be necessary to work with the provider of the PEG channel to do video pre-processing to correct for jitter, black level, and other baseband video issues before encoding the video source. Without this video processing, the PEG channel may not be stable enough to be digitally encoded.

2. DTV Transition

The DTV transition as mandated by the FCC introduced several new challenges especially with the requirement for most cable plants to continue carrying these channels in analog. Some of the more interesting challenges centered around PSIP (Program and System Information Protocol) metadata and ATSC Captions on SD channels.

Down conversion to analog with 4:3 aspect (Letterbox vs. Center Cut), and managing bandwidth for several versions of the same channel (HD, SD, and Analog) were also challenges that MSOs had to work through.

3. Vertical Blanking Interval (VBI) Data Services

Cable operators are under contractual and regulatory obligations to carry various types of VBI services and pass these through to consumer electronics devices. However, as a market converts to an “All Digital” network there are technical considerations that affect closed captioning, V-Chip data, Nielsen AMOL data, and Gemstar/VCR+ data.

In the analog video signal, closed captioning data resides in the vertical blanking interval (VBI) at line 21. In a digital video system, the closed captioning data is encoded according to two separate standards: SCTE-20 and SCTE-21. SCTE-20 is supported by many cable digital set-tops while SCTE-21 is primarily a standard implemented by CE devices and newer digital set-tops. In the digital system, the digital set-top or leased host converts the SCTE-20 or SCTE-21 into the required CEA-608 closed caption signaling to feed to a CE device. However, there are a large number of legacy set-tops that only support the SCTE-20 standard. To support this legacy base, digital encoders need to be configured to simultaneously output both SCTE-20 and SCTE-21 to ensure all legacy devices, hosts, and CE equipment can display closed captioning properly. Local broadcasters are bound by ATSC regulations, which require only Advanced Closed Captions (CEA-708), while carriage of CEA-608 captions is only recommended. Care must be taken when coordinating with the local broadcaster to either assure CEA-608 captions are present or the cable operator must apply technology to convert 708 to 608 captions to assure backwards compatibility with legacy STBs.

DTV standard-definition channels are encoded and delivered to cable systems with ONLY SCTE 21 (ATSC) captions, causing legacy set-tops to potentially lose captions during the transition. In this case, captions had to be transcoded with MPEG2 multiplexing equipment in order to (re)create SCTE 20 + 21

The next area to be considered is Nielsen AMOL data. For many years, the Nielsen AMOL data has been the primary method of tagging channels for Nielsen rating measurement. All legacy set-tops have the ability to pass through Nielsen AMOL data when the input is an analog channel. However, up until the past two years legacy devices could not recreate the Nielsen AMOL VBI waveform as there was no published standard. To solve this problem the SCTE-127 standard was created. Another approach that has been applied by Nielsen is the use of sub-audible tones (NAVE II) to convey the information needed by Nielsen devices. When a headend converts to an All Digital Phase 1 - Digital Simulcast network, the market needs to decide how to process the Nielsen data. This will entail either relying on SCTE-127 and newer digital devices or the Nielsen sub-audible tones.

Another VBI signal that some operators may have an obligation to carry is the Gemstar / VCR+ data feed for CE devices (not the TVGI data feed for leased devices). This feed is used to deliver the Gemstar guide present on many CE devices. The Gemstar / VCR+ VBI signal had the same issue as the Nielsen AMOL data. The Gemstar / VCR+ VBI data will be passed through by legacy devices only when the input to the legacy device is an analog channel. However, when the input service is digital, legacy set-top devices do not support the recreation of the Gemstar / VCR+ VBI waveform. There was no standard to carry the encoded data in the digital stream. The Gemstar / VCR+ data is also covered by the SCTE-127 specification. The first method for solving this problem is to leave one analog channel that carries the Gemstar / VCR+ in the digital channel map. The CE devices that require Gemstar / VCR+ data will find this channel and use it as the source of data. The second option is to encode the Gemstar / VCR+ data using SCTE-127, and when subscribers have configurations requiring Gemstar / VCR+ data, the cable operator can provide a SCTE-127 enabled digital device.

Emergency Alert System (EAS) – The emergency alert system is an important part of the service provided by cable operators and is a regulatory requirement. EAS has been implemented in several ways in the analog headend. Prior to All Digital Phase 1 - Digital Simulcast, all digital services were encrypted requiring a subscriber to have a Digital Device or CableCARD. All EAS requirements for digital services were taken care of by the Digital Device or CableCARD. As All Digital Phase 1 - Digital Simulcast is implemented, the cable operator has anywhere between 20 to 40 services that are unencrypted and therefore do not necessarily have a cable operator provided Digital Device. The cable operator can either implement slate switching in the video network or insert SCTE-18 in all unencrypted services. It is important that a cable operator consult with their regulatory team as they implement EAS in the All Digital Phase 1 - Digital Simulcast Network

Multi-Dwelling Units (MDU) – On the other side of the cable plant, the cable operator transitioning to an All Digital Phase 1 - Digital Simulcast network will need to decide its approach to MDU monitoring requirements. A common service provided to MDU owners by the cable operator is analog channels dedicated to internal security cameras in a MDU. The output of these cameras is combined into the MDU analog cable plant providing the tenants access to monitoring cameras. When the cable operator starts to deploy digital only devices in the MDU, the cable operator will need to work with the MDU owner to encode the MDU security video feeds and output them onto a QAM to be combined into the cable plant on the MDU's premises. Also, the digital device will need to have the new digital video feeds included in the channel maps for that MDU.

E. Digital Simulcast – The Operational Impact

1. Transition to Digital Simulcast

Once all of the new All Digital Phase 1 - Digital Simulcast multiplexes are in place on the plant and all of the changes to the ad insertion infrastructure are in place, the final change is to configure all of the existing digital set-tops and host channel maps to point at the new digital multiplexes. This will be the most customer impacting step, so it is important that there is a well thought-out operational plan.

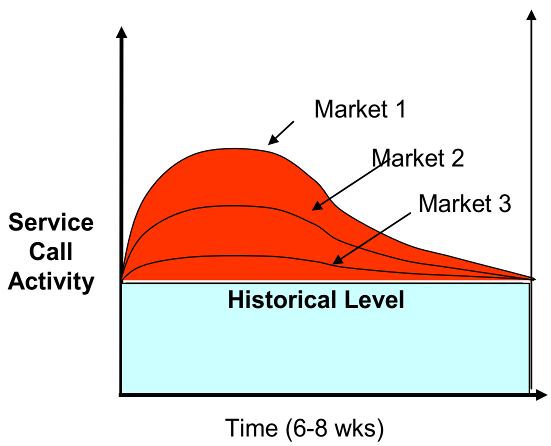
The approach used in the Comcast ADS project was to convert blocks of channels in the channel map from analog services to digital services. This conversion was done in several blocks of channels over a week starting with the programs with lower viewership. After each channel map change, there will be a settling out period. During this period the cable operator will see a spike in customer calls due to pre-existing technical problems that weren't visible in the analog world. Customer service and technical operations will need to be appropriately staffed for each channel map change. The cable operator will continue this process over the period of several days in doing channel map changes and handling customer calls.

2. Customer Issues

Based on the Comcast experience of going to an All Digital Phase 1 - Digital Simulcast network, the cable operator will typically see issues with F-Connectors, splitters, and other in-home wiring issues. Once these issues are addressed, the customer calls will return to previous levels.

There are several characteristics of the cable system which will predict the level of service calls associated with a transition to a full Digital Simulcast line up. These include:

- Re-use of frequencies for new digital multiplexes
- Cable Plant Upgrade vintage
- Signal to Noise Ratio
- HSD Penetration
- Current use of 256 QAM
- Non-responding set-tops
- Two-way operational maturity
- Quality / Age of drops
- VOD error rate



Low Impact	Service Impact Predictors	High Impact
All re-used or adjacent	**Re-use of frequencies**	All unused
> 2 years	**Upgrade Vintage**	New
> 32dB	**Signal to Noise Ratio**	<32dB
High	**HSD Penetration**	Low
High	**Current use of 256 QAM**	Low
Low	**Non-responding STBs**	High
Established	**2- way ops culture**	Growing
High	**Quality/age of Drops**	Low
Low	**VOD error rate**	High

Increased probability of calls →

Most issues are inside the home and can not be avoided

Figure 5 – Digital Simulcast - Operational Impact

VI. All Digital Phases 2 and 3 - CPE Distribution with Analog Reclamation

A. Overview

The next phase of the transition to an "All Digital" network is the step to prepare the market to start to reclaim the analog bandwidth. The goal of this phase is to deploy digital devices on *each* and *every* outlet for all subscribers who receive Expanded Basic and then reclaim the analog bandwidth. This will require a very well coordinated effort to identify, contact, install, and activate each subscriber with a digital device. Additionally, headend equipment is required to be upgraded to support the new DTA configuration. Optionally, other back-office systems for handling device ordering, automation and troubleshooting can be implemented to help with the CPE deployment. In this section, several examples will be drawn from the Comcast "Project Cavalry."

B. CPE Distribution – The Goals

In Comcast's Project Cavalry, there were several goals that were laid out to make the project successful. These goals include:

> **Create a low-cost and simple CPE device** – The first goal was to create a low-cost CPE device. Some of the initial analysis showed that Comcast would require around 20M digital devices to deploy to additional outlets (AO) to complete Project Cavalry, so it was essential that the cost of the CPE device be as low as possible. Also, it was important that the CPE device be as simple as possible to enable a successful self-install program. The solution is a DTA, which is a low cost and very simple digital device.
>
> **Create a Multi-Dwelling Unit (MDU) solution** – One of the challenges of converting all of the expanded basic services to digital and reclaiming the bandwidth is supporting MDUs, bulk, and commercial accounts. These include some MDUs where Digital Device deployments are prohibited due to contractual arrangements. It also includes some bulk and commercial accounts where it is impractical or prohibitively expense to deploy digital devices. To service these types of accounts, it was necessary to build a mDTA. A mDTA receives digital services and converts these to analog channels to be combined into the MDU cable plant.
>
> **Mimic the analog experience –** A primary goal is to mimic the analog experience to minimize customer disruption, while preparing to offer new digital services.
>
> **Fully automate the order and activation processes** – To make the transition as easy and cost effective as possible, one of the goals was to automate the device order process such that a subscriber can order as many DTAs as necessary for their household.

The second automation goal was to enable subscribers to activate services just as soon as they hook up the device. When the subscriber calls in, the DTA is added to the account and provisioning messages are sent to configure it for services on that control system and network. DTAs typically start providing subscribed audio and video services within three minutes of activation.

Support a self-install success rate of greater than 70% - The last goal was to sustain a self-install success rate of greater than 70%. In this program, there is a very unique opportunity where the cable operator is deploying devices into existing homes where service is already present and working. This allows the cable operator to depend on a self-install approach to a much greater extent than it has in the past. This greatly helps reduce the overall costs associated with a program that touches each subscriber without rolling a truck.

The operator is going to interact with two categories of subscribers. The first category is subscribers who already have a digital device on their primary outlet, but have additional outlets that only have analog devices (analog only set-top or TV). The second category is Expanded Basic subscribers with no leased digital devices. The good news is that the cable operator already knows these subscribers and cable is already in place for these outlets. As part of the Project Calvary initiative at Comcast, a self-install program was created and 80% of all distribution of digital devices is done via self-install.

Create a Service Offering that would encourage the subscriber to switch to digital – The service offering is an important component of determining the success of this phase of going all digital. The cable operator will need to decide the device offering and fee structure they will offer. In the case of the Comcast Project Cavalry the following service offering is provided to Comcast subscribers:

- Free upgrade to digital for Expanded Basic customers (1 Interactive device (DCH/DCT/Explorer) + up to 2 DTAs now part of new Standard Cable-Digital package that replaces Expanded Basic)
- Provide existing digital customers with up to 2 DTAs at no additional charge
- Additional DTAs $1.99/mo

C. CPE Distribution – The Cable Operator Process

The cable operator will need to develop project milestones in order to reach full DTA deployments. The project resources and schedule for reaching full deployment includes parallel efforts to prepare the business and technology. The following is a brief outline of steps to reach the analog reclamation phase.

Step 1 Create project plan, resource plan, scope and goals.
Step 2 Create technology roadmap, architecture and requirements.
Step 3 Create a business model and subscriber marketing plan.

Step 4 Create business relationships necessary to engage in both DTA acquisitions and network upgrades.

Step 5 Work with selected vendors for DTA models and network upgrades, through the test and trial process to ensure the technology meets requirements and expectations.

Step 6 Upgrade the network to support DTAs and mDTAs

- In-band infrastructure for DTAs
  - Channel map planning
  - PID planning
  - Code download support with a DSM-CC
  - EAS routing
- Control System upgrades
  - Motorola DAC and SEM upgrades
  - Cisco DNCS / DTACS QAM upgrades
- Billing Configuration
  - New device type
  - New rate codes
  - Performance optimization / port balancing

Step 7 Optional upgrade the back office infrastructure to support automated order and activation of DTA devices.

Step 8 Create infrastructure to support fulfillment of self-install kits and the supporting processes.

Step 9 Plan with warehouse, technician training and customer service for DTA support.

Step 10 Create a roll-out plan that works with each targeted system, market, region or deployment area.

Step 11a Deploy Interactive Digital Devices (DCH, DCT, Explorers) and DTAs

Step 11b Work with MDU, bulk, and commercial accounts to deploy DTAs or mDTAs

Step 12 Provide digital services, remove analog services, reclaim bandwidth.

D. CPE Distribution – The End-to-End Technology

The DTA end-to-end architecture for Comcast includes all interfaces to the subscriber through the network to the DTA device in the subscriber home as illustrated by the following the logical architecture figure.

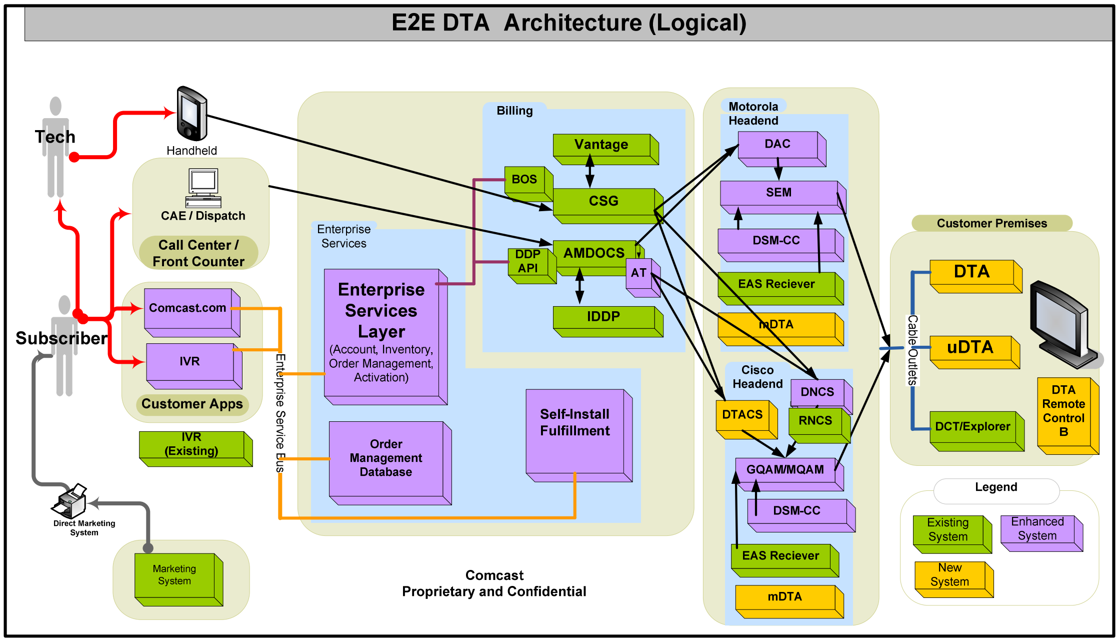


Figure 6 – End to End Architecture for Project Cavalry

The subscriber is offered the opportunity to order Interactive Digital Devices and DTAs to continue services on the new Comcast digital network through the marketing materials. When the subscriber orders DTAs and/or Interactive Digital Devices, they select an ordering process through Comcast.com, the IVR or a CAE. The order is placed with a customer selected self-installation or scheduled for a professional installation process. Optionally, the customer may pick up DTAs and Interactive Digital Devices at a local front counter to fulfill their order. The order is made available through the billing system and the enterprise services order management system. If the self-installation process is selected, the customer is drop shipped devices to their door typically within one week.

Upon receipt of ordered devices, either the subscriber follows the self-installation instructions or the professional installer/technician activates the devices for service. The activation process is simplified for the self-installation process by either dialing the IVR or using the web interface. The subscriber identification process is automated and the customer selects the device serial number to request activation. Typically the devices are activated and the subscriber can receive subscribed services within three minutes for DTA devices. Interactive Digital Devices may take longer to provision.

If the subscriber does run into any issues with self-installation, CAEs and professional installers are available to assist as necessary.

The DTA was designed as a simple adapter that does not require staging in the cable operator warehouse. When the DTA powers up and operates, it automatically listens for configuration messaging and for any code download necessary to fulfill the latest required adapter patch.

After the activation process, subscriber services from the headend to the DTA and Interactive Digital Devices operate within business-as-usual constructs, at least from the customer perspective.

Comcast designed the end-to-end project Calvary infrastructure to meet our objectives and have tested and successfully launched most of the functionality as of the writing of this paper. Some pieces are coming in subsequent phases of the project to complete a full featured network end-to-end.

1. Back Office Infrastructure

Each component within the DTA back office infrastructure was not only designed to meet the goals of launching initial digital services using DTAs, but was also designed to support the digital experience for the next ten years and beyond. Investments for creating a solid foundation for automated device ordering, self-installation and activation enable many types of devices to follow the same model in the future. Automation is deemed an absolute necessity for Comcast due to the scale of device deployments and customer interaction to achieve an all digital network, especially given the three year timeline to upgrade all systems and subscribers.

Comcast.com – The Comcast.com web site was updated for subscribers who prefer a visual interface over the Internet to order and activate devices. A URL with simple instructions is included in the ordering and activation materials for their use. This interface hooks into the new Comcast enterprise services to support DTA.

IVR – A new IVR was created for subscribers who prefer an auditory interface to order and activate devices. A phone number with simple instructions is included in the ordering and activation materials for their use. This interface hooks into the new Comcast enterprise services to support DTA.

CAE, Professional Installer and Front Counter – Project Calvary continues to support our subscriber relationship in the typical cable operator business-as-usual (BAU) scenarios. It is a necessity to provide BAU for subscribers who are uncomfortable attempting a self order and installation process.

Enterprise Services Layer – The Comcast enterprise services layer was originally added to support other projects inside of Comcast, but has greatly expanded to support the DTA automated order and activation processes. This layer was introduced to support an evolving architecture embraced by Comcast to provide a highly adaptable environment for infrastructure support services over time. This is a critical foundational piece for Comcast's current and future back office needs. The enterprise services are designed to better manage inventory, support customer processes such as order and activation as well as provide new ways for transactions to move across the Comcast network without traversing and complicating legacy systems. This new layer will continue to evolve for some years to come to support additional products and services for Comcast.

Order Management – Generally considered part of the enterprise services layer, the order management database is the heart of the automated process. This order management database ensures the enterprise services and the transactions which interface with the billing system have good data while providing a new management tool for orders, activations, inventory and device lifecycle issues.

Self-Install Kit (SIK) Fulfillment – The fulfillment process for SIK includes development of a management system for this process. It takes input from the Order Management system to ship devices to specific subscriber accounts. Additionally, the SIK fulfillment process tracks shipments and closes orders upon device activation which is considered as confirmation of receipt of device shipment.

Billing System – The billing system interfaces have not changed to support DTA. The billing system supports new equipment types and rate codes for the program. Additional port and interface preparation and load balancing is accounted for in the billing system work.

2. DTA Headend In-band Infrastructure

Since the DTA only has one in-band tuner, all communications must use in-band signaling. For each digital multiplex that will carry basic or expanded basic content, the multiplex is required to have appropriate PID 0, PID 1, Network PID with SCTE-65 and CVT, EMM with DTA configuration messages and PSIP PID with EAS messaging. Also, one multiplex on the plant will need to be configured to carry the DTA code objects.

The DTA in-band data consists of the following categories:

System Information – This data is carried on the network PID and consists of channel map, system time, and other data as defined in the SCTE-65 standard.
Emergency Alert Signaling – Emergency alert information is carried in the PSIP PID using the SCTE-18 standard.
DTA Control Messages – The DTA control messages are sent in the EMM stream and include configuration messages and reset messages.
CVT Messages – The code download signaling used by the DTA is the CVT message, as defined by OpenCable CDL2.
Code Object Carousel – The DTA code download is carried in a DSM-CC carousel, as defined by OpenCable CDL2.

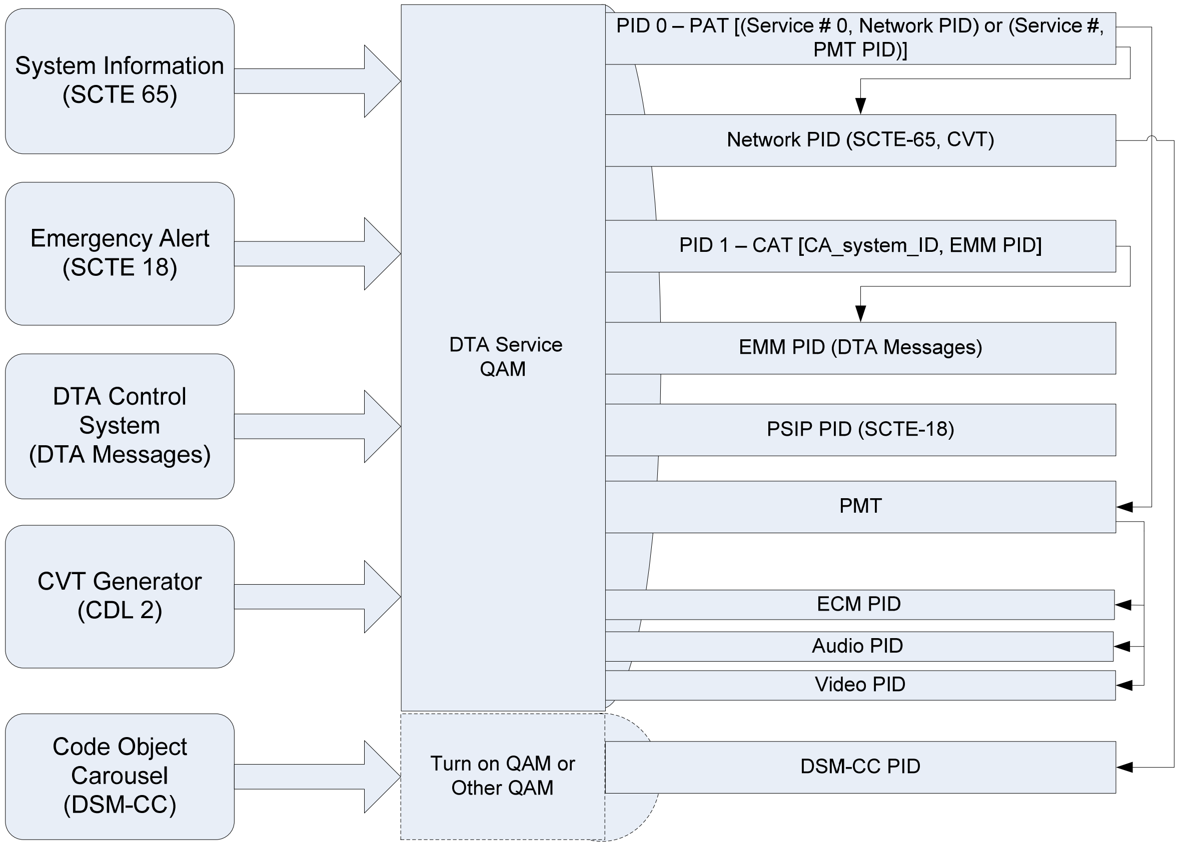


Figure 7 – DTA In-band Signaling

In order to fulfill the designed in-band signaling requirements, updates are made to network controllers (DACs and DNCS + DTACS) and edge QAM / SEM devices. Additional upgrades include new key servers to support DTA content protection.

Control System

Network Controllers – The Motorola DAC and Cisco DNCS/DTACS network controllers upgrades have been specifically designed to support a common messaging protocol to configure DTA devices. Additionally, other changes for DTA include channel map configurations and CVT formation/routing.

SEM and QAM – The Cisco QAMs and Motorola SEMs need updated firmware and configuration to support the new PID muxing plan, DTA content protection and multicast routing.

DSM-CC – In order to provide code objects delivered over the in-band, updated DSM-CC servers are used to provide code objects on a specified PID available to DTAs through the instructions in the CVT. A channel map may include supplemental code download information in the case of CVT formation without frequency tuning information. The DSM-CC may include CVT information forwarded to the network controller for inclusion on the Network PID.

3. DTA Features

As part of the effort to get to the "All-Digital" network, a new device has been created to address the need for a low cost digital-to-analog adapter, which is named the Digital Transport Adapter or DTA. This device is being provided by several CPE manufacturers.

The DTA has the following characteristics:

- Low-cost, customer device intended to be used on additional outlets
- Intended for display on analog-only devices
- Single RF Input, MPEG-2/SD
- Single RF Output (channel 3 / 4)
- No Multi-Stream CableCARD (MSCC)
- Small device form factor
- Better digital signal sensitivity (better than current Digital Devices)
- One-way device
- Simplified remote control

The DTA has been designed to match the typical analog TV experience. It has been designed to receive broadcast, PEG, and expanded basic. For security, it employs a Content Protection System (CPS) that is built to be compatible with existing Motorola DCII and Cisco PowerKey systems. There are several things that DTA is *not* designed to support:

- No Premium Channels
- No Interactive services (VOD, SDV, etc)
- No Electronic Program Guide or Applications
- No Out-of-band
- No Two-way Connectivity

The DTA has been designed to include the following behaviors:

- Automatically detect network type (Motorola or Cisco)
- Defined modes of behavior that includes knowing it has valid code, a valid DTA QAM, activation for service and configuration, code download, EAS processing, audio and video processing requirements.
- Continually listen for and perform code upgrades
- Continually listen for and process configuration messages
- LED blink patterns to assign visual diagnostics with associated modes
- Diagnostics
- Customer facing messages displayed to the attached TV
- Defined remote control commands specific to DTA
- DTA is always on, the remote control powers on and off the TV upon remote control set-up.
- Agreed upon serial number and unit identifier numbering and format.

Some unique items for DTA include, providing updated onscreen messaging to the subscribers TV with a simple network controller configuration as well as providing a simple to use remote control interface.

To date, Comcast has two waves of DTA products. The first generation is based on early hardware that is suitable for deployments on Motorola networks. The second generation is hardware suitable for deployments on both Cisco and Motorola networks – this product is termed Universal DTA (uDTA). Each time the uDTA powers up, it determines which network type it is on prior to proceeding with other functions in order to ensure appropriate functionality and behaviors for that network.

The following are pictures of one DTA design and the remote control.

Figure 8 – DTA Remote and DTA

4. DTA Self-Install Kit

The self-install kit has been a big win for Comcast since the success rate of subscribers installing their own equipment has been more than expected. The self-install kit was designed with significant usability testing to support the creation of the packaging, instructions and components. Providing a simple 1-2-3 step process for customers to follow along with making the DTA as simple as possible in combination with the automated activation process has made the customer transition to digital an easy experience.

Figure 9 – DTA Self-Install Kit

5. Multi-Dwelling Unit Digital Transport Adapter (mDTA)

One of the primary issues to be dealt with in a transition to an "All-Digital" network is the approach to MDU, bulk, and commercial accounts. These accounts fall into several classifications including apartments, condominiums, businesses, business campuses, restaurants, hospices, hospitals, hotels, schools, prisons, and federal or state buildings. In some cases, it is not advisable to deploy digital devices either due to cost, practical concerns, or contractual prohibitions. This leads to the need to have a device that can convert the incoming QAM signals to a block of analog channels while preserving the current digital offerings.

The Mutli-Dwelling Unit Digital Transport Adapter (mDTA) was created to solve the problem of converting a large number of digital services back to the analog domain. These analog channels are then combined onto the cable plant in that location below 552 MHz leaving the spectrum above 552 MHz unaltered to pass thorough the digital services, high speed data, and voice services. The mDTA has the following characteristics:

Inputs
- Single coaxial input (Port 1 in Figure 10)
- 3 wide-band tuners (48 MHz per tuner)

Processing
- 16 QAMs

Outputs
- Up to 80 NTSC RF channels (54-552 MHz)
- Coaxial output with regenerated analog RF channels (Port 2 in Figure 10)
- Coaxial output with pass-through of cable plant (Port 3 in Figure 10)

The physical environment for the mDTA is considered to be a hostile environment. It can be deployed either outside, maintenance closets, or basements without proper air handling. The mDTA has been designed to handle these difficult conditions.

- Node enclosure with one coax input and two coax outputs, plus 3 aux inputs
  - Supports the insertion of premium and local origination channels

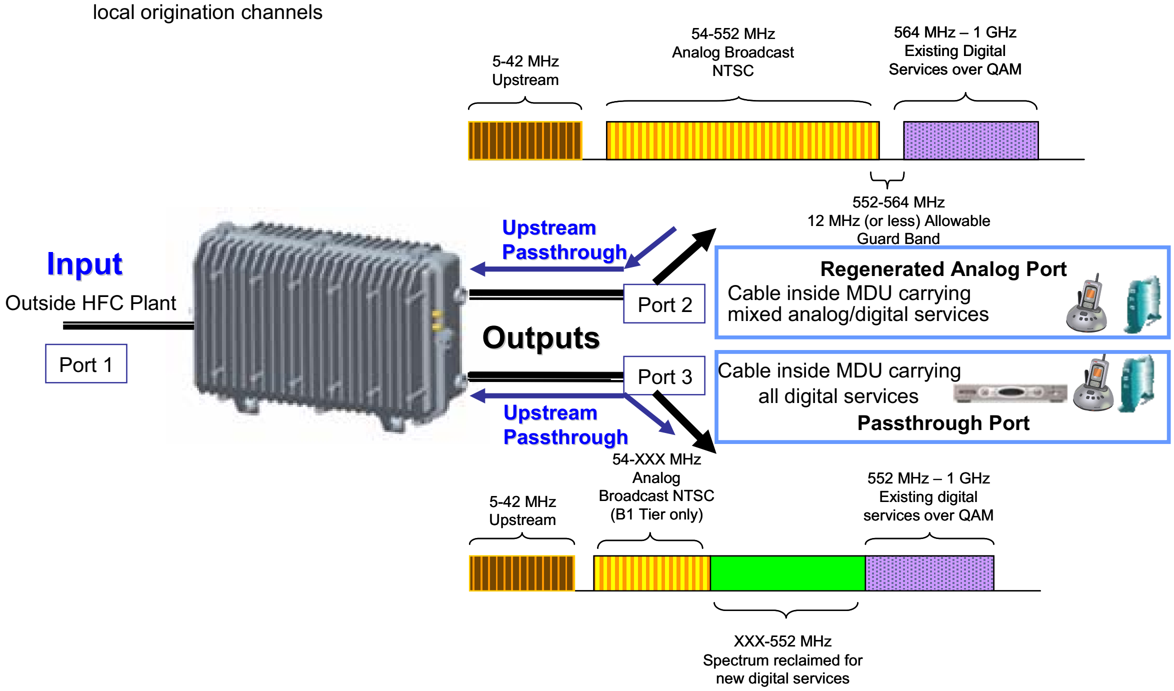


Figure 10 – mDTA

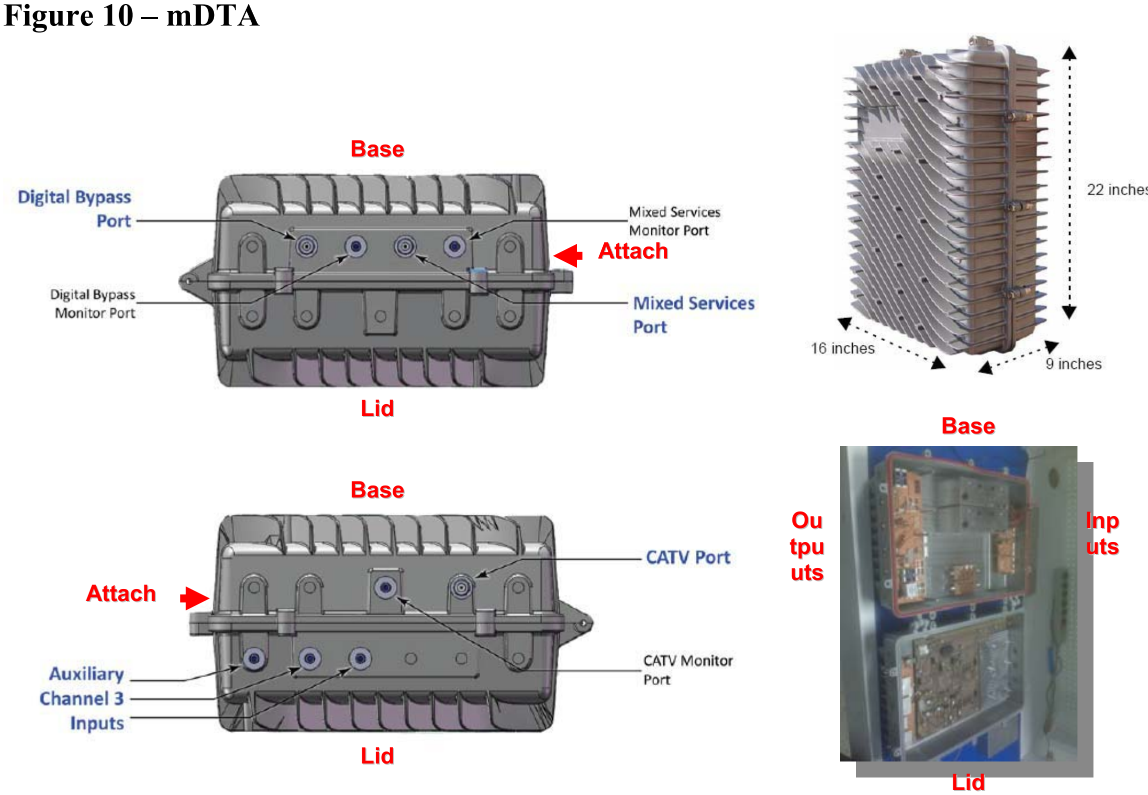


Figure 11 – mDTA – Physical Characteristics

E. CPE Distribution – The Operational Impact

In this section, the operational steps and impacts of moving to an "All-Digital" network are considered. The message to customers, the steps of converting subscribers, and the issues involved in converting MDU, bulk, and commercial accounts will be examined.

1. The Customer Message

The first topic to be considered is the customer message. The customer message needs to be memorable, a directive, and must be communicated with ease. In the Comcast example, the message is:

"Click or Call, Install, That's All"

It was chosen for its clear and concise message. It is a call to action. It also helps to communicate the desired communication paths of Comcast.com and call into the Comcast IVR. The primary goal of IVR and Comcast.com design was to create a smooth and seamless customer experience.

2. The Customer Interface

In the Comcast example, the primary interfaces for the subscriber are Comcast.com, IVR, and CAEs. There are four steps that a subscriber goes through in their upgrade. These are:

- **Offer** – The first step in this process is to identify eligible subscribers and send them material that explains their offer and gives them a unique identifier. At that point the subscriber can either log onto Comcast.com or call into the IVR. After the subscriber is authenticated, they are presented with an offer on their status as a current digital subscriber or an expanded basic subscriber.
- **Order** – The subscriber selects a number of Interactive Digital Devices (0 or 1) and number of DTAs (0-3). This order is placed to the SIK fulfillment system and the equipment is shipped to the subscriber.
- **Activate** – When the equipment arrives, the SIK kit has instructions on the installation process. The SIK instructions instruct the subscriber to either call the IVR phone number or log onto Comcast.com. Once identified by the system, the subscriber's equipment is activated by adding it to their account and sending instructions to the billing system to activate their equipment.
- **Troubleshooting** – If the customer is having trouble activating the equipment the IVR has basic troubleshooting logic which uses "DTA Blink" patterns to help identify where in the process the customer's equipment is stuck. At any time, the subscriber can be transferred to a CAE. On Comcast.com, there are also troubleshooting procedures and FAQs to help the customer through the process.

For a customer logged into Comcast.com, he or she may transfer to a chat agent at anytime.

Each of the Comcast systems has been optimized to quickly identify the subscriber and respond based on where they are in the offer, order, activate, and troubleshooting process. For Project Cavalry, there was a new CAE team that was put together and trained specifically to help in this process. Also, in the DTAs there is a cable operator phone number that is displayed by the DTA as it comes onto the network. This phone number is configured to be primary number the subscriber calls. If the customer has been identified as a subscriber that qualifies for the DTA offer, then the customer is routed to the IVR where the DTA offer is made.

3. Steps to Analog Reclamation

In the process of converting a market to the "All Digital" network, there are several phases the market will pass through.

Operational Phase	Customer Impact	Results
Pre-launch	None In this phase all of the system upgrades need to be accomplished.	The market is prepared to start the transition to the "All Digital" network
Marination	All customer contacts should result in DTA installations.	Increase penetration of Interactive Digital Devices and DTAs due to business as usual activities.
Call to Action	All Expanded Basic subscribers are offered Interactive Digital devices for primary outlets and DTAs for additional outlets. All current digital subscribers are offered DTAs for additional outlets.	1st wave of subscribers calling in to order and activate new digital devices
Urgent – Call to Action	Continue marketing message	
Last Chance – Call to Action	Continue marketing message	Increase digital penetration to greater than 90% for expanded basic subscribers
Analog Channel Cut #1	Half of the expanded basic analog services are removed from the plant starting with those with lowest viewership.	Increased customer requests for DTA offer MDU, Bulk, and Commercial upgrades must be complete
Clean Up	Subscriber realizes analog	Increased digital penetration

Operational Phase	Customer Impact	Results
	services are missing and places call to cable operator.	
Analog Channel Cut #2	All the analog expanded basic services are removed from the plant leaving only Basic analog service on plant	Increased customer requests for DTA offer
Final Clean Up	Final wave of subscriber calls	
Launch new services	Additional HD services, DOCSIS 3.0, and iTV services.	Clear message to subscriber that their cable operator is providing additional quality services

4. MDU, Bulk, and Commercial Accounts

Among of the most complicated issues to be faced in the transition to the "All Digital" network are the choices related to MDUs, bulk, and commercial accounts. The primary choice is whether DTAs or mDTAs be deployed into a particular MDU, bulk, or commercial account. Each of these accounts will need to be individually assessed. There are several factors that need to be taken into account to determine which approach is best. These factors include:

Contract – The first area of consideration is the contractual agreement with the building or business owner. Sometimes there are terms that limit the deployment of individual devices onto that account due to safety, tenant, or cost concerns.
Building Wiring – Commercial building can either have home run wiring or loop through. The type of wiring will influence the type of services that can be offered in the building when a mDTA is installed.
Service Offering – There are several different types of billing arrangements with bulk accounts. Some arrangements prevent individual tenants from upgrading to additional services and others do allow the subscriber to purchase higher tiers of services from the cable operator including high-speed data and voice.
DOCSIS and Voice Channel Allocation - If the DOCSIS channel used for HSD services or voice services is below 554 MHz, then the DOCSIS channel will not be passed through the mDTA. This would prevent voice or HSD services from being present in a building where the mDTA is being used to regenerate the analog spectrum. In this case, it may be better to either install digital devices or move the DOCSIS carrier to a channel above 554 MHz.
Number of subscribers – The number of subscribers in the MDU should be taken into account. If the number of subscribers is low, it may be more cost effective to deploy digital devices to all tenants rather than install a mDTA.
Physical Layout – In the case of large hospital, business, or educational campuses, there may be many buildings with multiple points of entry. This may require either a significant number of mDTAs to service the entire campus or the deployment of many DTAs. The cost of each approach should be considered.

Co-located DTAs – In the case of hospital rooms and other care facilities where DTAs are deployed, the cable operator may have the situation where there are multiple DTAs in a single room. It may be necessary to purchase DTAs that can be configured for separate remote controls to allow multiple DTAs in a single room.

5. mDTA Impact on Channel Allocations

As discussed previously, the mDTA has three wide band tuners of 48 MHz apiece. It also can only process a total of 16 digital multiplexes. This places restrictions on how services in basic and expanded basic can be spread across the cable spectrum and allocated in digital multiplexes. The rules are:

- All PEG, Off-air, and expanded basic services must be contained in no more than 16 individual multiplexes
- All PEG, off-air, and expanded basic services must be located in 3 groups of 48 MHz

6. QAM to QAM

Another area of concern to the cable operator is the servicing of hotels and other hospitality accounts. An ever increasing number of hotels are upgrading their in-room program offering to digital. This creates the need to decrypt digital services on the cable operator plant, re-encrypt with content protection for the hotel, and combine into the hotel cable plant. A new device is being specified that will perform these functions to fulfill the needs of hotel operators.

VII. Conclusions

The process of converting from a hybrid analog/digital network to an "All Digital" network is a complex and time consuming project requiring close coordination between engineering, operations, and marketing. The transition can take the period of a few months to several years to complete. Regardless of the challenges of the transition to "All-Digital," the payback of reclaiming significant bandwidth to launch new services to subscriber is essential for the cable operator to remain competitive and profitable.