COMPREHENSIVE TESTING FOR CLOSED CAPTIONING IN VIDEO CPE

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Abstract

Closed Captioning is a key element of the technologies which increase accessibility for MVPD customers. Over the years it has been a struggle to validate that the elements of the MVPD video pipeline correctly handle the Closed Captions included in the video stream. In the last 3 years, Comcast has made an extremely focused effort to construct a comprehensive framework for the validation of CC handling in the Video Delivery Network with initial emphasis on its video CPE (DTAs and STBs).

PROGRAM OVERVIEW

Comcast is taking a number of steps to improve the accessibility of its products. On the operational side, this effort includes:

- Implementation of a national network-wide effort to monitor all video streams for Closed Captioning (CC) impairments
- Upgrading of all guide programs to improve the ease of access to and use of accessibility features
- Rigorous testing of CC performance on its Video Customer Premise Equipment (VCPE)

This paper will focus on the engineering behind the VCPE test effort.

CC Testing on Comcast VCPE

In mid 2011 Comcast began an effort to improve the video and operational performance of its Video Customer Premise Equipment (VCPE). The first functional area selected was Closed Captioning (CC) performance.

The goal was to eliminate CC issues in video CPE in our video production network. The scope includes all associated programs: Cavalry (DTAs), legacy STBs and the X1 Platform. The target timeframe was the releases planned for deployment in 2013.

This effort would require participation across all software/firmware providers for each product:

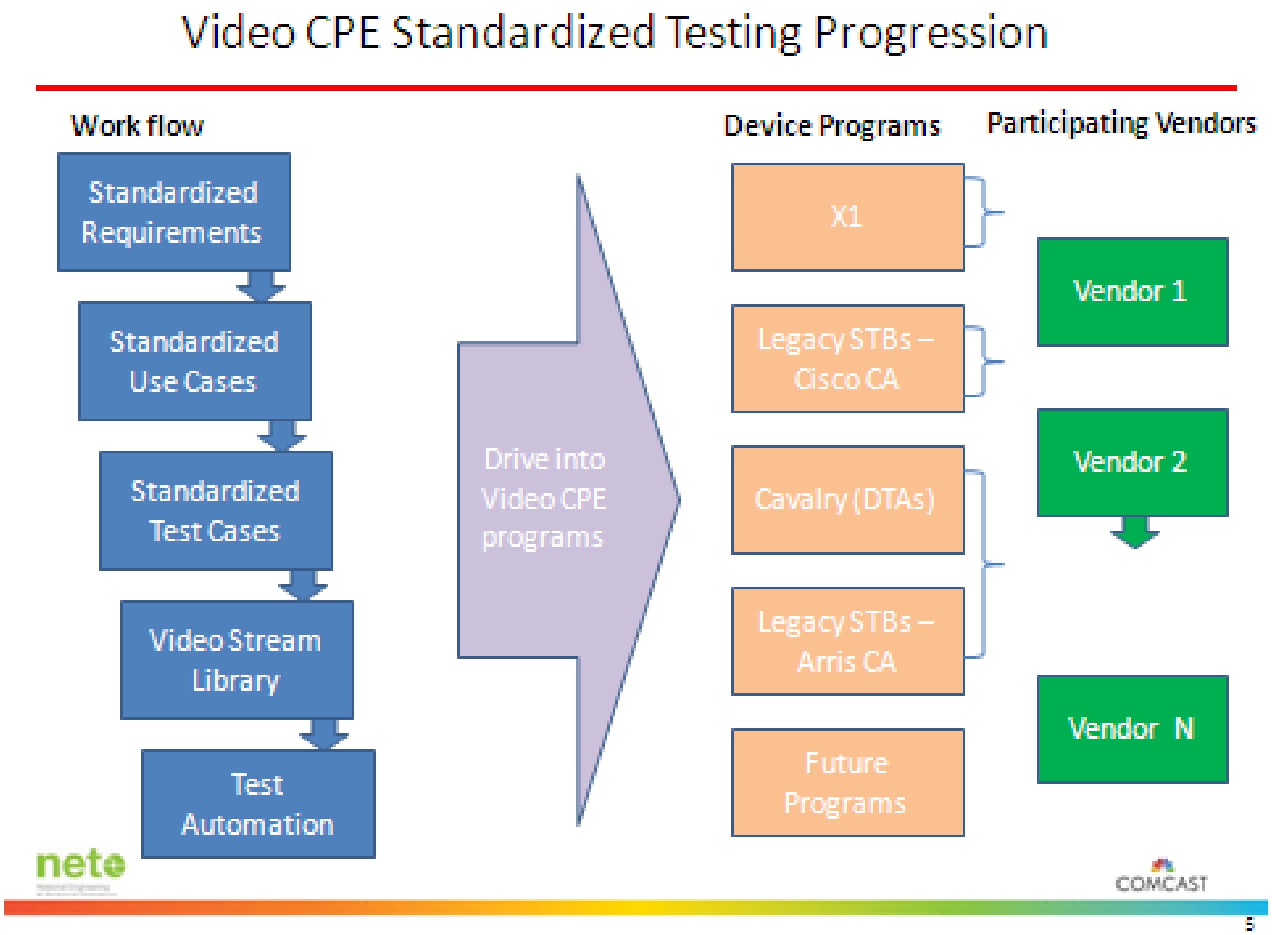
- External vendors for DTA and STB firmware
- Partner guide development/test teams
- Comcast guide development/test teams
- Comcast program teams (devices and guides)

TEST DEVELOPMENT PROGRESSION

The intent was to engineer our way out of the uneven performance of the past. From requirements to test cases. The key elements of this effort:

- Requirements analysis – what are the products supposed to do?
- Use cases – at a high level what functions must be validated?
- Test cases – exactly what steps are needed to execute on the use cases?
- Video Stream Library – testing by hopping around the live channel map was inadequate. We needed a set of streams to comprehensively exercise CC functionality in the Comcast video streaming environment – these predefined streams permit reproducible manual and/or automated testing
- Automated testing – it quickly became obvious that manual testing was an inefficient use of time and test resources.

The test development process flow is depicted on the following page.



REQUIREMENTS: CLOSED CAPTION

The foundation of the CC requirement for VCPE consists of the CEA-608 and CEA-708 specifications. In addition to passing CC data through to the SD video outputs in the VBI, the CC data must be rendered on the graphics overlay plane on all HD outputs.

Early HD STBs initially based their requirements on the profile defined by the FCC Report and Order FCC 00-259 for DTV receivers. Subsequent to that order, FCC Report and Order, FCC 12-9 governing, among other matters, enhanced closed captioning went into effect on 01/01/2014, requiring additional settings, presentation modes, and caption preview capability.

As part of its renewed focus on accessibility, Comcast made the decision to extend these requirements to older devices not formally covered by the new order. Each of our VCPE guide programs and device families was evaluated against these more stringent requirements and then any required feature development and/or defect repair was added to the plan for the target releases.

TEST STANDARDIZATION

In the past, VCPE testing was designed and implemented in guide oriented silos. Testing focused primarily on the guides and since the guides were unique per VCPE family, the testing per family was developed in isolation, often independently of any pre-existing test plans/cases and with varying degrees of comprehensiveness when measured against the requirements.

Prior to this effort, test cases were developed directly from a myriad of requirements. The test cases were then executed on the independent guide/VCPE families. This resulted in test duplication and inconsistencies among the various families. To address this, development of use cases was prioritized and formalized to streamline the process. Test cases were derived from the use cases which were *then* applied to the guide/VCPE families

After collecting the requirements, they were coalesced into use cases derived from each specific requirement. These use cases, generic and device-independent, became the master requirements for the test engineers.

For example, CC use cases are very similar across the various VCPE. They pertain to 708, 608, and SCTE20 pass through. The CC functionality is then normalized across pertinent orthogonal test planes such as EAS, video formats, DVR, parental control, PPV, etc. The intent is to ensure that CC functions correctly across each plane.

The use cases shielded the test engineer from the burden of organizing the scattered requirements. Test engineers could now focus on what they did best -- write test cases. The use cases describe the test environment, provide a high level description of the functional sequence of events and conclude with a description of the expected outcomes.

The next phase in the standardization process was to develop a set of generic test cases from each uses case. Usually multiple test cases can be traced back to each use case. Like the use cases, the generic test cases would also span the device families. They would be the test case superset from which device/guide specific subsets could be drawn. The generic test cases break the use cases down into individual test steps. The individual test steps are described at a high enough level to be independent of guides and guide key sequences and yet generic enough to be readily applied to the actual guide/device pairings.

The final step in the test standardization process was to create the test cases specific to each device family, taking into considerations the guide-specific displays, menus, and menu navigation.

The test standardization process permits consistent in-depth comprehensive test coverage across all VCPE families. Starting with the actual requirements and generating cases avoids the trap of testing to a guide or a device and not to the real requirement. The use cases can also be readily prioritized for varying levels of test coverage depth per development program phase. And lastly, of course, this structure provides an excellent basis for test automation.

VIDEO STREAM LIBRARY

A necessary complement to the development of rigorous use/test cases is an environment in which those cases can be executed repeatedly and consistently. Thus a comprehensive stream library is required.

In the past, live feeds were used for testing audio, video, and closed captions. Although live feeds have their merits particularly with regards to replicating plant conditions and a production environment, the feeds do not lend themselves to repeatability and consistency. This is not to say that live feeds should not be used, but rather they should supplement the library.

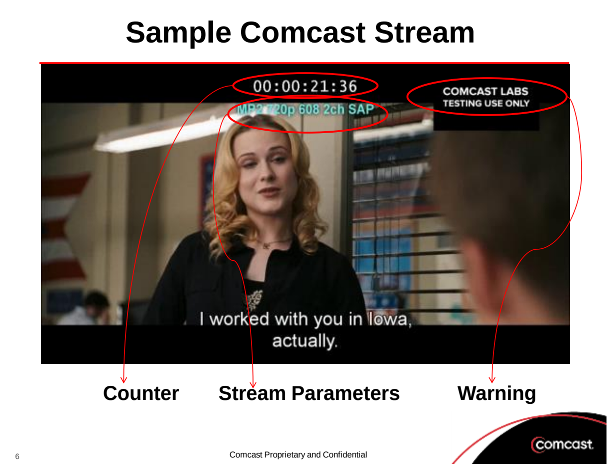
A video stream library significantly improves efficiency. It can be time consuming and challenging, if not impossible, to search through channels and locate content with specific features such as close captions for CEA-708 only, CEA-708 with CEA-608, CEA-608 only, and SCTE20. Just as importantly, having content with precise and known captions is imperative in ensuring that no captions are dropped. In addition, having known content with prescribed features such as video format (1080i30, 720p60, 480i30) and audio format (AC3 stereo, AC3 5.1) permits verification of captions in the varied stream environment of the device. A video stream library is fundamental to a deterministic test environment.

Just as important as having comprehensive feature-laden content, the encoders used to create the streams are vital to the test system. By creating streams which use production equipment and production encoding profiles, the streams can quickly confirm that VCPE has no issues with production configured encoders. The production streams should be created for both linear and VOD applications using the encoders and profiles specific to the delivery vehicle. Once again, bit rates, GOP structure, video formats, and audio formats are all designated and known.

Stream generation and capture are important components of our custom Comcast video stream library. However, purchased streams provide a valuable supplemental capability. Comcast has purchased streams from Sarnoff Labs which offer the ability to drill down deep into CC functionality. Streams are available which thoroughly exercise MPEG syntax, video formats, audio formats, and CEA-708 CC functionality. It is worth noting that these purchased streams only focus on one function at a time where the Comcast-generated streams incorporate the varied functionality already present in the real cable distribution plant.

Our Comcast video stream library is the fundamental enabler for our test standardization strategy. The video stream library provides the consistency and repeatability required for a rigorous standardized test process. Our feature rich Comcast streams offer tremendous efficiency as they are used to simultaneously exercise multiple functions permitting simultaneous test execution.

Probably the most important aspect of our stream library is that it enables test automation. Without them, an automated test process would be impossible or at best impractical.



TEST AUTOMATION

Closed Caption test automation development could now begin with the three necessary building blocks: use cases and test cases from the standardization effort; and video streams from the video stream library. Assessing CC compliance in all the applicable video environments within the Comcast footprint and across the variety of VCPE devices in an automated method became the primary automation goal. Manual testing is not a feasible solution, due to the numerous permutations associated with 25+ device models, multiple guide releases, and the large number of streams.

The CC automation breaks down into two primary areas defined by the streams: testing against all required video formats and configurations using the 10-minute Comcast streams and testing implementation compliance against CEA-608 and CEA-708 CC specifications with the Sarnoff stream library. The Comcast stream testing suite addresses topics including audio splicing, video splicing, CC transitions between types, resolution changes, video encryption, delivery type (VOD, PPV, trick-play, live), and encoding type (MPEG2, MPEG4). Sarnoff stream based testing validates the CEA-608 and CEA-708 protocol specific functionality including fonts, colors, location, timing, scrolling and data rates.

Automating the testing posed several hurdles. The largest issue was finding an automation tool that had an HD capture solution able to handle the high frame rate updates of the streams and also able to analyze the results in a reasonable amount of time. The second obstacle was creating and routing the multitude of required video configurations for the Comcast streams to the applicable boxes within the Comcast test environment. The content had to be provided in encrypted and unencrypted forms on both controller types, DAC and DNCS and across different device types (DOCSIS STB, legacy STB and DTA). Additionally all the streams needed to be ingested into the VOD systems and guide data generated to allow for VOD and DVR functionality.

The automation solution also is required to automatically select a video to stream and to receive the video with all the permutations of settings needed for the test. To accomplish this, a pool of video streamers was established in which each is addressable and available for reservation by the automation tool. Each streamer can play any of the appropriate video files from the stream library. The selected IP video stream is routed to the edge devices for the appropriate test systems. The edge devices (both Cisco and Arris systems) then replicate the video, and insert unencrypted and encrypted copies into the channel lineup. The automation tool then tunes to the appropriate channel to get the proper test configuration. In addition, the system is configured with mock guide data and all videos are ingested into the VOD system giving the automation a way to replicate VOD, DVR and trick-play functionality.

Test tool selection

Several test tools were investigated; each being tested against a representative set of streams. The selected tool, Witbe QOE Robots, demonstrated the required HD capture capabilities, a modular approach to test development, satisfactory OCR performance and a reporting solution that could be integrated with Comcast's existing test framework. The tool selection also aligned with automation efforts in other parts of the company so that we could share resources and best practices as necessary.

Test design

Reusability and portability were driven into the test design from the beginning. With over 25 different device models to be tested and the multitude of different resolutions, guides and other test parameters, the test block architecture was required to be very configurable and reusable. Using a reusable automation test block system combined with test configuration files, the test architecture is able to reuse a majority of test blocks between test permutations. This reduces the amount of work necessary to change any test. Small configuration changes allow for scripting to cover large populations of tests.

We also had to account for the minor differences in CC implementation among the various implementations of the CEA-608 and CEA-708 specification. The specification has some ambiguity about locations and performance that the test results must account for. Allowances had to be made in the verification of timing, position and fonts. This was accomplished by creating device specific configurations or creating search parameters in the applicable algorithms able to accommodate variation -- i.e. fuzzy location searches and timing variances. This flexibility allowed tests to adjust dynamically without having to be modified for each device.

The general flow of the automated closed captioning test is:

1) Validate device health
2) Set relevant guide settings (CC, fonts, menus, resolution)
3) Start video play-out from streamer
4) Tune to appropriate channel
5) Validate stream video matches expected
6) Validate CC
7) At end of test, undo guide settings as appropriate

Each Comcast stream has an associated test data file that the automation utilizes for validation. Inside the file is a listing of caption text, the number of times each caption should appear and where on the screen it should be rendered. The automation script will synchronize the video to the test data and then commence validating all of the captions within the ten minute sequence. Validation of each closed caption is done via OCR. Using the defined appearance time from the configuration file the script will search within a configurable time window for up to three simultaneous captions. The best OCR result within the window is used for the result. After completion of the sequence, the automation will compute a pass or fail for the test and create an output file that has all the expected and detected results. A nominal ten minute test stream sequence contains about 300 closed captions.

The Sarnoff stream based test cases are designed to validate the functionality of the CEA-608 and CEA-708 CC specifications. Therefore a different rigor is applied to the testing. The Sarnoff streams are designed for efficient specification compliance by a knowledgeable person observing the video output of the device. The video is highly dynamic and covers many features simultaneously.

The test blocks use image comparison to compare known good images against set top output to verify that fonts, colors, location, timing and presentation are all correct. Depending on the test requirement, the automation will compare one or multiple images simultaneously on the screen. Simultaneous image compare allows us to verify that frames are timed correctly to the video time source. Due to the high change rate of video and closed captioning, testing of the Sarnoff streams can take several iterations through a video loop to complete a single program descriptor.

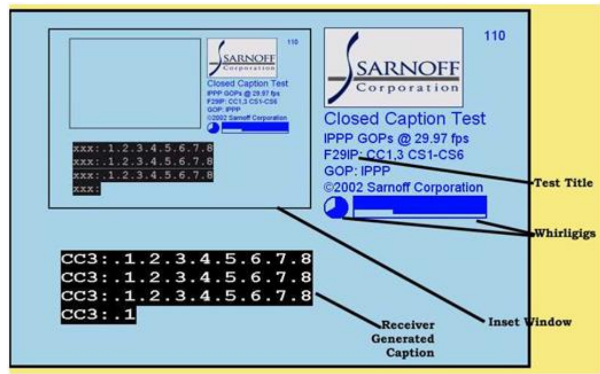
Test Development

Test development is run just like a typical Comcast agile software development project. Teams are on a two week scrum schedule. Tests scripts are kept in source control and are run through integration/ingest cycles as part of the release process.

After completion of the initial phase of automation we have several lessons learned from the difficulties encountered.

- OCR has inherent repeatability issues - to reduce the number of false positives & negatives a large population of tests must be used.
- Rendering across device families may appear the same to the human eye, but automation is subject to small variations in timing and location.
- Compliance to a specification that was not rigorously enforced initially can lead to many defects when testing first occurs

Automated Testing - Comcast Stream



Automated Testing - Sarnoff stream

VENDOR PARTICIPATION

The final step in implementing this program was to drive the automated standardized testing upstream into our CPE vendor community (both internal and external). The benefits are significant:

- Earlier detection leads to less costly defect repair (the engineers are still "on the job" and have immediate access to reproducible defects)
- Earlier detection leads to a shortened elapsed time (reduced repetition of the development cycle phases)
- Drive cost out of the formal Comcast test process

As did we, our vendors quickly realized the need to automate this testing. Some vendors chose to "port" our tests and scripts to their automation systems. Others chose to adopt the same tools and hence take advantage of the work we had done and gladly shared. Either way, this automated testing has been migrated back up the pipeline.

CONCLUSION AND FORWARD LOOK

Comcast has instituted and organized a thorough Closed Captioning test suite comprised of use cases, test cases and a comprehensive video stream library. By automating the testing of Closed Captioning using carefully selected tools and an integrated framework, we hope to eliminate VCPE induced flaws in the presentation of CC services to our customers.

This framework and test catalog is in a continuous improvement mode, expanding and fine tuning the test methods, test stream library and testing scope to incorporate new and improved technologies as they become available. Future areas of expansion include new video services such as:

- IP streams
- MPEG4 HD
- HEVC encoding
- Transition/spliced streams
- Descriptive Video Services (for enhanced accessibility) automation

Beyond addressing the expansion of video stream variety, areas that Comcast may apply the benefits of this rigorously engineered framework and technology include:

- Future Comcast Video CPE
- Customer owned, operated, and maintained devices
- Centralized Video Delivery Network elements (encoders, ad-slicers, etc.)
- End-to-end testing of all elements in the video delivery network

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