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Components of a cloud-based solution for sign language accessibility: the España Directo use case.

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Abstract: *Embedding sign language as a PiP (picture in picture) is one of the most common accessibility techniques used in television to make the content accessible for all. Specific technical equipment on premise is required to its production and broadcast distribution. Hybrid technology, like HbbTV, can be used for a more convenient sign language production exploiting the television capabilities to reproduce the sign language embedded in a web streaming. Traditional equipment can be changed for more suitable and cheap equipment using web technologies in cloud. This article elaborates the cloud solution for sign language accessibility service built for España Directo, a television program broadcasted in the first channel of RTVE, the Spanish National Broadcaster.*

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I. Introduction

Accessibility is the capability of a system, product or content to be accessible to persons with disabilities [1]. To achieve a full accessibility depends among others on the device and its technical capabilities. In broadcast production, accessibility is implemented providing a second sign language image embedded in the broadcast signal, the inclusion of the content's audio-description and finally adding the audio subtitling to the emission. These three techniques allow people listen, watch or read an audiovisual content.

TV production is expensive, as is the sign language video production in this context. The cost is usually related to the equipment needed to produce the sign language video, its coordination, its injection into the broadcast and finally its distribution. It usually requires the acquisition of expensive technical equipment.

TV sets have become smarter: the devices include a set of broadband features based on HTTP [2] (Hypertext Transfer Protocol) like HLS, DASH or the hybrid standard HbbTV (see section II). This ecosystem provides new means to create complementary services for the broadcast emission using the broadband features. There thus emerges the cross-media production, where programs in linear broadcast use these technologies to create interactivity with users in the television, integrate social media activity around the program or the episodes, or create complementary services using second screen applications ([3], [4]).

In this context, the usage of web technologies would reduce the sign language production costs providing a better experience for people with disabilities. This reduction would help to disseminate the sign language alternative upon the transmission schedule.

To verify such premise, a use case was launched based on a daily-basis program broadcasted in La1[1]. The program chosen is España Directo, scheduled from 19:30 to 20:30, from Monday to Friday. The use case tends to determine the technical elements needed for live sign language production upon a live broadcast emission using HbbTV technologies. It is also relevant to evaluate if its costs are convenient in terms of money, resources and scalability. The result of our use case is the launching of the sign language service via HbbTV for the España Directo emissions. It was launched the 14th of May of 2018 and it will be online, at least for the next six months.

The main contribution of this article is the architecture created for the use case. All the technical elements used for the video contribution, its coordination and its distribution have been identified and described. Intentionally, the machines to compute and coordinate the signal have been deployed using a cloud solution; in this case AWS (Amazon Web Services)[2].

[1]La1 is the main television channel broadcasted by CRTVE (Corporación Radio Televisión Española), http://www.rtve.es/corporacion for more details.
[2]https://aws.amazon.com

As per the costs, the technical solution is based on cloud concepts, except the translator to sign language. Thus, the costs of the solution are based on the real user consumption, instead of a fixed payment per emission, like in broadcast solutions. We conclude that a broadband-broadcast solution is more cost effective, the time to be implemented is shorter than in the broadcast environment and the risks associated to the investments are minimum.

Additionally, the broadband solution enriched the user experience in two ways. For the majority of the users, the sign language is displayed after clicking the green button. Therefore, the broadcast signal does not require a PiP (Picture in Picture) occupying a portion of the screen. For deaf and hard of hearing people, the accessible alternative can be displayed in a more suitable way. As it can be seen, the experience can be fit to the user.

This article is structured as follows: first of all we introduce the technology background in section II. Then, section III introduces the use case and the conceptual problem. Next, section IV discusses the technical solution while the results are presented in section V. Finally, next steps and future work are in section VI.

II. Technical background

The purpose of this work is focused on the usage of web technologies applied to the production of hybrid solutions and services to be consumed in the television. This section elaborates from two approaches.

The first one, described in the first subsection, introduces the European hybrid standard. This technology enables the interlinking between broadcast and broadband services. This link is essential for our use case, since sign language is applied to the current emission in a broadcast channel. Then the coordination between live broadcast and its complementary broadband service becomes extremely important. In our case, the coordination of the program emission and its sign language translation is a must. In this context, some issues to be considered are the channel identification or the time-stamping.

The second subsection covers the second approach and it focuses on the live video pipeline. Two sub processes are described: video contribution and video distribution. The article discusses web video technologies applied to each one of them. A special attention is paid to interoperability issues across the different television platforms, and its potential practical relevance to implement the solution.

A. Hybrid Broadcast Broadband Television

HbbTV is a global initiative that aims to harmonizing the broadcast and broadband delivery of entertainment services to consumers through connected TVs, set-top boxes and multiscreen devices [5]. For that end, an ETSI specification was developed to provide interactive in connected TV.

From a web developer point of view, HbbTV allows the injection of a web page into a device that supports the standard. To that end, the standard sets that the URL (Unified Resource Locator) [2] address to provide a service in the device is encapsulated in the MPEG2-TS (MPEG-2 Transport Stream) broadcasted through the DTT (Digital Terrestrial Television) network (see subsection II), signaled in the meta-data section as an application [6] (see figure 1).

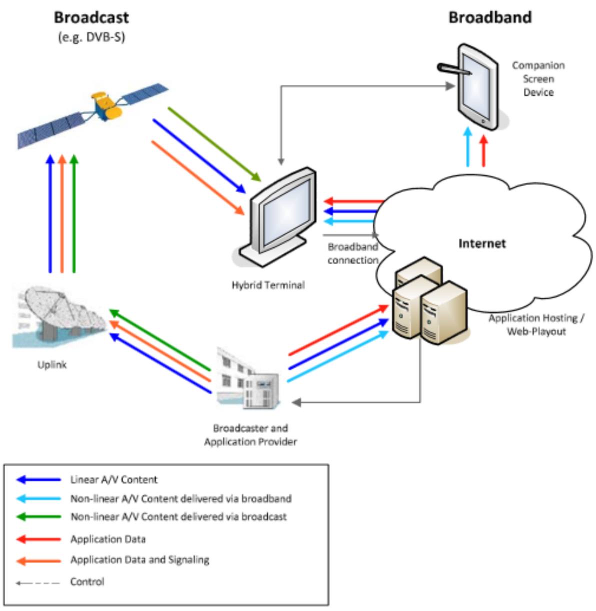

Figure no 1: HbbTV Schema

If a device is compliant with the standard, when a channel is tuned in, the embedded page is loaded in a web engine and suddenly, the web page is rendered in the device and the interactivity developed in the web page is launched. Among others, it allows to handle the remote control or the injection of video, audio, podcasts, or others.

Each HbbTV standard version sets the minimum HTML capabilities available that are implemented in the devices. Depending on the HbbTV version, a page must follow the CE-HTML [7] specification (HbbTV version 1.1) or follow the HTML5 specification (HbbTV version 1.5 or higher)[5]. Regarding video formats, only MPEG2-TS (Transport Streams) are available for version 1.1. However, in version1.5 MPEG-DASH streaming is available for live and on demand. And, although it is not in the standard, the majority of 1.5compatible devices are able to reproduce HLS streaming (seethe next section).

B. *Streaming protocols*

In general, live production is based on three different processes linked like a pipe. The first process is the video contribution, involving all the tasks and technologies needed to incorporate live video into the pipeline. Next, the video editing, where the live is enriched with other meta-data, mixed with other videos, etc. Finally, the video distribution process is in charge of serving the video enriched to the final users. Each process requires its own techniques, methods, protocols and technologies. This subsection elaborates web streaming protocols and its potential contribution to the use case implementation, specially applied to the contribution and distribution processes.

Video distribution is usually based on two models: broadcast and broadband distribution[3]. Each model has benefits and drawbacks. In broadcast, a signal is sent by one transmitter and can reach million people. All receivers receive the same signal usually at the same time, which can imply a lack of personalization. But in web or broadband distribution a client-server connection is created for each user and then scalability becomes more complex. In this case this distribution model could enable a higher consumer personalization and customization improving the user experience.

As per costs, broadcasting is more expensive and it costs are fixed since it does not depend on the number of users that tune in the channel or signal, while broadband or web technologies are cheaper and usually based on user's consumption, which implies that more active users, more cost.

1) Live video distribution

In Spain, video broadcast is signaled through the Digital Terrestrial Television (DTT) network. The signal is received by TV (television) sets when the user tunes in a channel. The video is coded in the signal using the MPEG-2 Transport Stream specification [6] (hereinafter MPEG2-TS). MPEG2-TS is the protocol used in broadcast systems such as DVB or IPTV. Transport Stream specifies a container format encapsulating packetized elementary streams, with error correction and synchronization pattern features for maintaining transmission integrity when the communication channel carrying the stream is degraded [6]. Although the MPEG2-TS standard was originally created for video broadcast, it can be distributed using HTTP. It is especially relevant for legacy televisions, those compliant with HbbTV 1.1, since it is the only technology available in that televisions for a web-based live distribution. So, MPEG2-TS is used in our use case for broadcast distribution using the DTT network and broadband distribution through the Internet.

The usage of MPEG2-TS is poorly scalable in the web domain. Two additional protocols where created in the web domain to reach a higher performance: MPEG-DASH (MPEG Dynamic Adaptive Streaming over HTTP) [8] and HLS (HTTP Live Streaming) [9]. They both are based on video segmentation. *They work by breaking the overall stream into a sequence of small HTTP-based file downloads, each download loading one short chunk of an overall potentially unbounded transport stream. As the stream is played, the client may select from a number of different alternate streams containing the same material encoded at a variety of data rates, allowing the streaming session to adapt to the available data rate. At the start of the streaming session, HLS downloads an extended M3U play-list containing the meta-data for the various substreams that are available* [10].

Apple specified HLS in 2009 and it has become a standard de facto in web domain. It is used in web, mobiles, tablets, etc., regardless the operating system. But its adoption is partial in the television domain. It is not fully supported by TV manufacturers, but it is widely implemented and available in the television firmwares.

MPEG-DASH, in turn, was adopted as the live video protocol from the HbbTV 1.5 specification in 2012. It is an opened standard, and it is widely supported by television manufacturers, but with limitations. Some interoperability issues happen depending on the manufacturer and even on the brand or TV serial, due to different standard implementations.

[3]In this article we use the terms broadband and web distribution as synonyms.

An effective distribution to reach all the televisions in the market requires the usage of the three protocols mentioned:

1. MPEG2-TS for HbbTV 1.1 or higher over HTTP.
2. MPEG-DASH for HbbTV 1.5 or higher.
3. HLS where supported.

2) Live video contribution

In the television domain, the video contribution process implies the techniques, processes, formats, protocols and so on, needed to incorporate video into the video production pipeline. There are many ways to push video into the pipeline. Some of them imply raw video uploading to the system. But for live and for the purpose of this work, the live contribution is made using web streaming [11].

There are a bunch of protocols in the market for this purpose, but currently, RTMP (Real Time Messaging Protocol)[12] is the most current for the Internet. It is used to produce live video streaming in services like Facebook, Instagram or Youtube. It is also available to create a web streaming in almost all the devices in the market: from mobiles to tables, and even in small cameras. RTMP has become a standard de facto for streaming contribution in the web domain.

Basically, RTMP is a TCP-based protocol that maintains persistent connections and allows low latency communication. To deliver streams smoothly and transmit as much information as possible, it splits streams into fragments, and their size is negotiated dynamically between the client and server. RTMP encapsulates MP3 or AAC audio and flash video multimedia streams.

RTMP architecture follows a classical client-server architecture where the RTMP provider is the client and it is in charge of the generation of the segments that are pushed to the RTMP server. The latter is in charge of saving and pushing segments into the pipeline. The link between client and server is created through the entry point, an URL provided to the client and read for the server. RMTP URLs resemble to *rtmp://ip:port/stream_name*.

III. Use case

CRTVE, as the national broadcaster in Spain, has the legal obligation to meet a high degree of accessibility in its broadcast channels. In this domain, accessibility for digital television is based on three techniques: enriching content with audio-description, subtitling and sign language.

Accessibility for digital television is hard to be implemented in the 100% of the programming grid both technically and economically. As an example, and in case of sign language, figure2 shows the technical solution required to create a sign language signal in a live broadcast. The program audio is sent to the sign interpreter. Then, a camera catches the translation and the images are injected in a mixer. This hardware includes the sign language as a PiP (picture in picture image) embedded into the live program video. These images are sent to the broadcast emitter, and finally it is broadcasted through DTT network.

The main technical costs in the solution shown in figure 2 are the mixer, the cameras and the injection. That costs do not depend on the number of receivers, and it is fixed: CRTVE will pay the same amount in a program basis.

As per translation, the interpreter and all the elements used for this signal production are currently on CRTVE premises, due to technical limitations.

Given the complexities described above, the legislator sets a compliance threshold that CRTVE must overcome. The current legislation sets the obligation of at least ten hours per channel in a weekly-basis.

But the accessibility is a real concerning in CRTVE, since it is one of the pillars of the public service that CRTVE offers to the society. Given the complexities and costs of the traditional broadcast solution and our compromise for accessibility, other mechanisms are explored to increase our offering of content and services available for everyone in the digital television.

In this context, the España Directo use case emerge as an innovation action for the purpose of harnessing of web technologies in digital television, with the aim to increase accessibility and the compliance of the legal obligations.

For this action we chose a daily-basis program, España Directo, and we contacted to the Center for the Standardization of Spanish Sign Language (CNLSE)[4] to provide the interpreters on their premises for a six-month project.

[4]http://www.cnlse.es

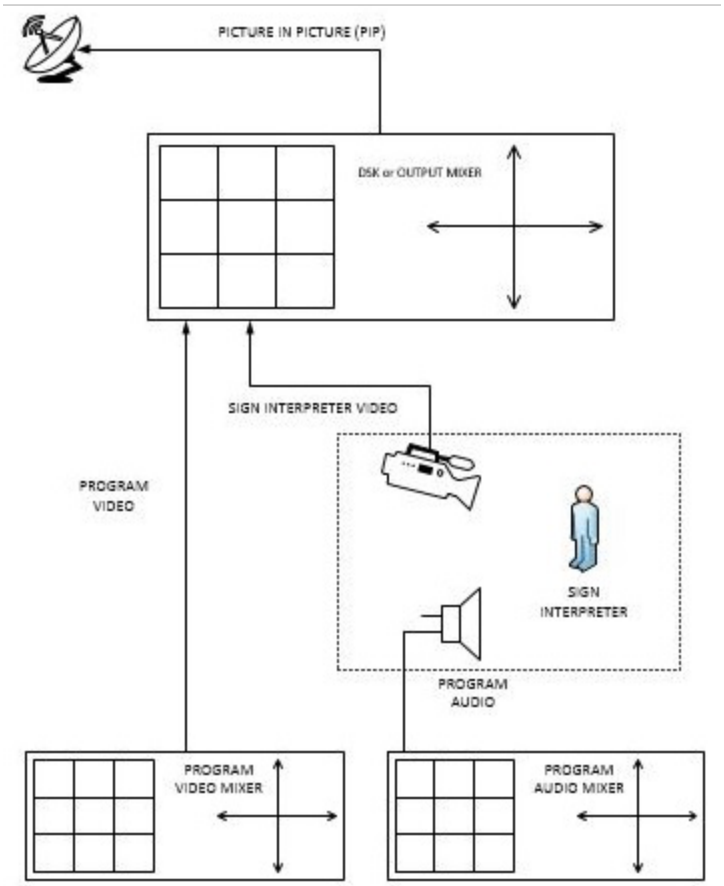

Figure no 2: Technical Broadcast Sign Language Schema

Functionally, the use case works as follow: a user tunes inLa1, the channel where España Directo is usually broadcasted. A disclaimer indicating the presence of a sign language alternative must appear only if the program is live. Then, when the user clicks a button, the green one, the current live emission changes, and a PiP with the sign language appears. Finally, when the program ends, the disclaimer must disappear.

Additionally, there are some additional requirements defined for the use case:

- The solution must use cloud infrastructure when possible.
- CNLSE is in charge of creating the sign language on their premises. It is a big difference from the broadcast live production where the interpreter is on CRTVE premises.
- CNLSE only have to provide is a space with a television, a camera and HTTP connectivity. The camera chosen is an JVC that cost less than three thousand euros, far away the costs of a professional one, but it gives good enough video quality for a sign language production.
- CRTVE produces and distributes the broadcast program live as well as the sign language embedded as a PiP into the program video.
- CRTVE is in charge of mixing videos and bringing quality of service.
- The solution should aim to reach as many of televisions as possible. Interoperability issues must be taken into account.

The next section elaborates the solution developed according to the use case presented.

IV. Technical solution

In the previous section, the use case and its context were introduced. The project aims to use web technology to provide accessibility for the digital television. The use case is focused on the provision of an alternative live video that embeds the sign language that corresponds to the channel the user is watching. But this alternative signal, from the users perspective, must be coordinated with what they see in the television. There are only two technical options currently available: using Smart TV technologies or a hybrid broadcast-broadband technology.

The first option, developing Smart TV applications, poses interoperability issues, since there is not a standard to develop an application for all the television brands and platforms. For instance, a Smart TV application developed for Samsung must be developed under the Tizen ecosystem, while the development for LG only requires the usage of HTML5.

As per hybrid technology, there is an European standard to create solutions based on web technology for digital television (see subsection II-A). HbbTV enables the usage of web techniques in compliant televisions and, what is more important, allows interactivity and the creation of complementary on-line services related to the tuned channel. This interactivity can be used to enrich broadcast channels with social media activity, additional information related to the content or other services related to what the user is watching which is our use case. As a conclusion, our use case is founded on the usage of HbbTV and the different components will use its capabilities to create an accessible experience.

CRTVE technical solution does not require a change in the video pipeline (see section II). It defines specific components applied to the different sub processes. In the following, the components are introduced within the process where they are applied.

1) The broadcast emission

The implementation of the hybrid solution based on HbbTV requires the inclusion of an URL into the MPEG2-TS (see section II) that is broadcasted through the DTT network. The MPEG2-TS standard defines a meta-data section to indicate the presence of an HbbTV application. Therefore, our case requires the development of a web page to take control of the television to provide the accessible experience. This web page is hosted in the www.rtve.es domain and must be added to the channel broadcasted. The page is launched only if the television is compliant with the HbbTV standard and it is connected to the Internet. The developer must take into consideration the HbbTV version of the device and adjust the developments to the device capabilities.

2) The video contribution

The video contribution process implies the processes and technologies to add video into the production pipeline. In our use case, this process takes the live program that is being broadcasted to generate the video with the interpreter's translation.

The generation of the signal language requires the live program to be translated. The translator must watch and listen the live program. Take in mind that the translator is not in CRTVE premises, so, there are only two feasible options to receive the live program: watching the broadcast signal in a television or receiving an Internet streaming with the broadcast content.

From our perspective, it is more efficient the first option for an issue of latency. Broadcast signal is available faster than its corresponding web streaming due to trans-coding and re-encapsulation delays. Currently, the delay in the CRTVE production environment is around seven seconds between the broadcast emission and its corresponding streaming. It means that the same scene happens seven seconds before in the television that in the Internet.

Figure 3 shows the different components used in the video contribution process. First of all, it is required a television in the translator's room. The translator receives the broadcast channel tuned in and then translates from Spanish to sign language, while a camera is capturing the gestures and expressions. The camera installed in the CNLSE premises is a JVC with a cost of around 2.000 euros. It can capture video with a high quality, up to 50 Mbps and with a 720p resolution. These qualities are good enough for the purpose of our use case, and even for broadcast live production.

But there is an additional feature that makes the camera chosen excellent for our purpose. It can connect to Internet using an Ethernet connection, allowing stability in the connection and a fixed delay in the video uploading.

The camera acts as the RTMP provider, pushing the segments to the RTMP server (see section II-B) using an entry point provided. This entry point is published in AWS using the Node-Media-Server[5] package, a RTMP server implementation based on NodeJS[6]. The RTMP server adds the video received into the pipeline for its following processing.

[5]https://github.com/illuspas/Node-Media-Server
[6]https://nodejs.org

3) Video Editing: mixing the signals

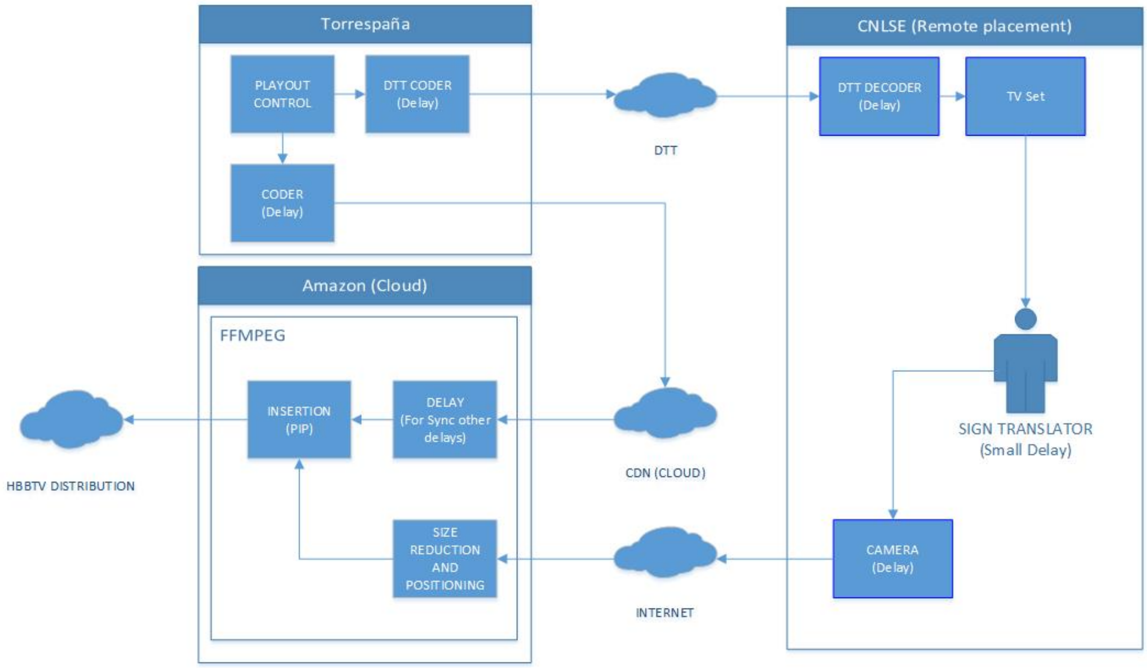

Figure no 3: Broadband video distribution schema

Current HbbTV devices (at least the majority of televisions in the market) can only decode a video regardless the input source. Thus, they cannot mix a broadcast signal with a broadband one due to hardware limitations. Therefore, two images only can be shown together in the television if one is embedded in the other one like a PiP. For sake of interoperability, our use case requires the program emission and the sign language signal to be combined in one video. To that end, this video mixing must take into consideration the delay between the two signals.

In the previous subsection the generation of the sign language stream was explained. It is available for mixing like a RTMP stream and it is mixed with another RTMP stream containing the live program emission. This second stream and the broadcast emission were generated at the same time, but while one is pushed into the Internet, the other is sent to the broadcasting system (see figure 3). It allows setting a fixed delay between the two signals. It is simple to estimate the sign language time needed for encoding, and as the connection is stable, the total delay between the program and the sign language RTMP streams can be foreseen.

Once the streams are available in a platform, and the delays are known, the streams are combined in AWS. For that purpose, the ffmpeg [13] command is used following the next specification:

- Live program must fill the screen, as happen in broadcast emissions.
- Sign language must appear as a PiP.
- They both are RTMP streams.
- Live program must be delayed for sign language coordination.
- The result must be portable to HLS, MPEG-DASH and MPEG2- TS

To fulfill the previous requirements, a solution based on the ffmpeg command was implemented. It can capture the two streams and it can generate the required stream as an RTMP. Below, we attach a sample command generated by the service once the delay was calculated.

```
ffmpeg -re -thread_queue_size 2048 -itsoffset 0  -i "<\_live\_rtmp>" -y -itsoffset 0
-i "\_sign\_language\_rtmp"  -filter_complex "[1:v]fifo,scale=w=iw/2:
h=ih/2[video2s];[0:v]fifo[video1s]; [video1s][video2s]overlay=main_w-overlay_w
-10:main_h-overlay_h-10[salida];[0:a:0] afifo[asalida]" -map [salida] -c:v libx264
-refs 2 -profile:v high -level 4.1 -preset fast -b:v 2500k -r 25 -pix_fmt yuv420p -g 25
 -sc_threshold 0 -map [asalida]  -acodecaac -b:a 96000 -ac 2 -ar 48000
-movflags +frag_keyframe -f flv  -y "<\_rtmp\_url\_to\_transcoder>"
```

Intentionally for sake of security, the real URLs are hidden since they are referred to the CRTVE real systems. The command generates a RTMP stream that is injected in the CRTVE transcoder, a service based on the Cires21 technology that is in charge of demultiplexing from a single RTMP stream to multiple formats and qualities. In this case HLS, MPEG-DASH and MPEG2-TS. This topic is discussed in the next subsection.

4) Distributing the mixed signal

Interoperability is one of the most relevant issues when distributing video for HbbTV. Live distribution in televisions over HbbTV is very fragmented and it depends on the HbbTV version (see section II-B).

To succeed, the RTMP stream with the program and the sign language must be transcoded to the formats HLS, MPEG-DASH and MPEG2-TS. To this end, CRTVE built a solution based on a proprietary solution developed by the companyCires21, the Cires21 LMS. It converts in real time from a RTMP stream to as many qualities and formats as needed. The product generates first of all the manifest files for HLS and MPEG-DASH with the different qualities specified on them. Then, when segments are generated, in case of HLS and MPEG-DASH, they are pushed to a CDN (Content Delivery Network) for its distribution and the manifest is updated.

For MPEG2-TS, CRTVE uses a specialized service for its distribution over the Internet. The company CINFO provides the service and it creates as many servers as client's requests received for the stream. Then, CINFO acts as a CDN in case of MPEG2-TS.

Figure 4 depicts the elements that conform the video distribution infrastructure described above.

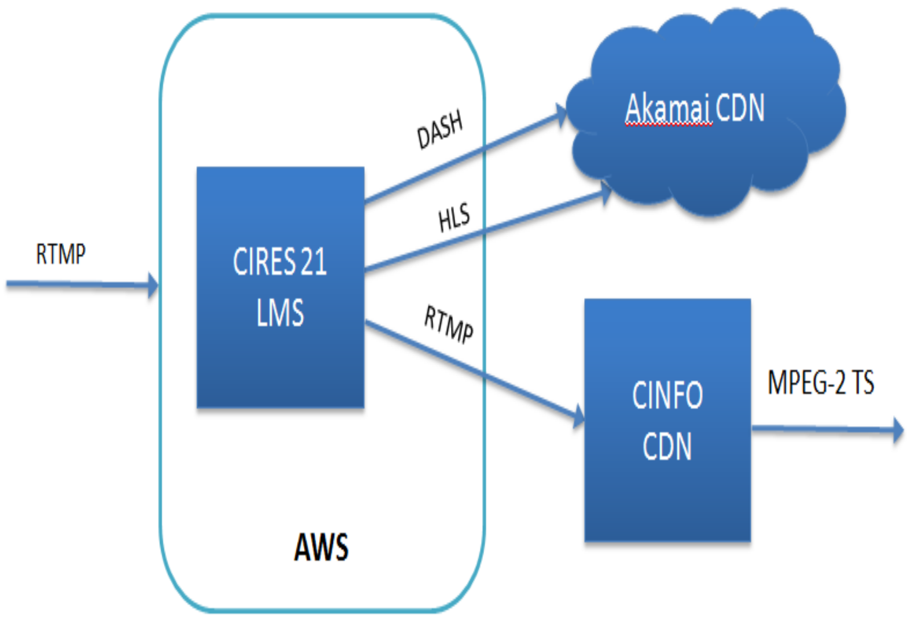

Figure no 4: Video transcoding and distribution schema

As per qualities and codecs, table I shows the codification parameters used in the streaming live. These parameters are the same for HLS, DASH and MPEG2-TS.

Table no 1: Video/audio Output Specification

Video	Codec	Profile	Level	Bitrate	FPS	Resolution
	H.264	High	4.1	2.500 Kbps	25	1024x576

Audio	Codec	Bitrate	Channels	Frequency
	H.264	96 Kbps	2	48.000 Hz

The next section elaborates the solution in the client side, as well as some pictures caught from the television.

V. The use case in live and results

The above sub sections describe the video solution implemented by CRTVE for the España Directo use case. The web page injected in the digital television must work with the program schedule as follows: when the user tunes in the channel (figure 5(a)) after a few seconds a disclaimer appears indicating the presence of an HbbTV application (figure 5(b)). Then, if the program España Directo is live and after a few seconds, a second disclaimer appears indicating that the alternative sign language experience is available (figure 5(c)). The green button disclaimer only appears when the program España Directo is live managing the channel schedule in the client side. Finally, if the user clicks the green button, the video with the embedded sign language as a PiP is shown in the television (figure 5(d)).

a) Channel Tune in

b) Red button disclaimer

c) Green button disclaimer

d) Green button clicked

Figure no 5: Use case screen shots

Figure 5 shows the full sequence that happens in the client from the channel tunes in to the final sign language consumption. It is important to highlight that once the channel is tuned in, all the process is handled by the web page signaled in the MPEG2-TS as defined in the HbbTV standard. So, the disclaimers workflow as well as the actions triggered by clicking in the remote control are analyzed and processed using Javascript.

The decision-making of the video to be shown is done in the client side based on the device user-agent [2]. This meta-data is used to determine the HbbTV version and the television brand. Thus, HLS or MPEG-Dash is injected depending on the television capabilities. For that purpose, CRTVE maintains a list with the video formats supported for every television brand. Otherwise, if the HbbTV version is lesser than 1.5 and HLS or MPEG-DASH are not available for one device, theMPEG2-TS is injected for a sake of interoperability.

Finally, the service was launched the 14th of May. The first week, more than 2.700 unique users consumed the sign language, with an average video consumption of 20 minutes.

Regarding costs, the solution implemented in this article has a very minimum cost compared to the traditional sign language approach. Platform setting costs around 2.400 euros, including the Internet connectivity and the camera. Once the signal in contributed into the pipeline, everything happens in Amazon, and the costs depend on the number of users that consumes the live. According to our contracts, 50.000 users consuming completely the one-hour program by streaming costs less than200 euros per hour emitted. As it can be seen, given such costs, this sign language solution removes technological barriers to create cost effective accessibility solutions in television. It also makes the translation services cheaper since it is provided at the provider premises. It makes the provision of this kind of services more convenient and effective, applying the solution to new programs is very quickly, and finally, the cost model is based on real consumption, so it does not require major investments, which minimize the risk.

VI. Conclusions and future work

Broadcasters and content providers must adapt its processes and cost models to the new reality. Technology is evolving very quickly, and now, web technologies can be used to support complementary services around the traditional broadcast emission. Emerging, but mature technologies like HbbTV can enrich the emissions with new services more personalized, and cheaper, based on web technologies. The use case discussed in this article shows one example of these new opportunities and services that can be provide using hybrid technologies.

This article shows the different components required for the production and distribution of a signal language solution in the television associated to one program. All the components are based on current and mature web technologies, like ffmpeg or HTML5 and can be implemented and offered like services in cloud.

Our next step is including this service to more programs due to scalability in terms of costs, scalability and time to market.

Additionally, we are currently working in other services to improve the accessibility in the digital television provided in a more cost effective way. Developing these new services are critical to improve our audience expectations and enhance the social compromise that a public company like RTVE must fulfil.

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