TRANSMISSION OF TELEVISION CONTENT VIA INTERNET: AN ANALYSIS AND PRACTICAL EVALUATION

Aleksandër BIBERAJ and Elson AGASTRA
Faculty of Information Technology, Polytechnic University of Tirana, Albania
Eni HAXHIRAJ and Ardit SKËNDULI
Technical Department, Digitalb, Albania

ABSTRACT

The transmission of television content via internet, otherwise known over the top television (OTT) has expanded the television audience by reaching individuals who want to see their favourite content without a predetermined timetable or in a lot of different devices. It is an innovative technology, which is being used increasingly from OTT service providers that have started their activity in the recent years as well as traditional broadcast companies, which are adapting to the market requests. Although it is an important part of the industry, there is an insufficient amount of information regarding its technology and operation. In addition, this information is often unclear and unorganized. This paper gives a complete view of the OTT TV systems, including the technical challenges, transmission protocols and infrastructure. This explanation is provided using a 'demo' OTT Live platform with one channel and several clients. Building this system, revealed a lot of difficulties related to the creation of an OTT platform, which brings a lot of benefits to the service providers and users. However, there are a lot of aspects that can be improved through proper research like transmission latency, which is considerable due to the long path, which the content follows before reaching the client application, advertisement inclusion in a suitable way and maintaining a good quality of experience for each viewer in every device to ensure the longevity of the OTT television service.
Keywords**:** over the top, television, live, transcoder, origin server, packager, CDN

1. INTRODUCTION

Over the top television is defined as the transmission of television content through the internet infrastructure and protocols. The last decade marked the introduction and development of this new technology, but in the first decade of the 2000s, television and the internet were completely separated from each other. It was only in 2010 that OTT TV started to attract the attention of viewers and the media companies, considering Netflix's history of success and the technological advances which allowed television content to be viewed in a lot of different electronic devices (Lotz 2018). Over the top television has been successful in the distribution of live content and video on demand. One of the main reasons for this success has to do with the possibility to view the content in every device that has an internet connection such as smartphones, tablets, smart TVs etc. Given the role that internet has in people's everyday life, OTT TV is now accessible for most of the world's population and has attracted new audiences which were not satisfied with the traditional terrestrial, satellite or cable television (Blanc 2017; Sadana and Sharma 2021). However, OTT TV is still considered as a novelty in television industry. and as a result, there is little information regarding its technology, operation, and architecture. Also, this information can sometimes be unclear and difficult to understand. This fact brings the necessity for a detailed analysis of over-the-top TV service, which is the purpose of this paper (Taylor 2019). The following sections explain the full architecture of an OTT system as well as the new streaming protocols and technical aspects of the system. This explanation is accompanied with a demo platform, which is built to study more closely the constituent parts of it and to monitor all the content processing that is made before it is published on the internet and distributed to the client. The last section of the paper gives the conclusions and highlights the innovative aspects of over-the-top television and the challenges that it faces in order to achieve the same performance as broadcast TV.

2. VIDEO STREAMING PROTOCOLS

Protocols are often described as a set of rules that enable a successful communication and data transmission, but video streaming protocols have several characteristics related to their specific application, because most of the video content is not created for streaming purposes. This means that first it is necessary to convert the video into a suitable format. This includes breaking it up in small chunks, which are transmitted sequentially and are played the moment they are received. This is the core functionality of video streaming protocols, but they are more complex, because they usually use adaptive bitrate delivery. This technology is implemented by transcoding video content with multiple profiles, which means that the same content is transcoded with different resolution and bitrate. The Internet connection of different people does not have the same speed and even the connection of a specific user changes in time depending on circumstances. For this reason, OTT TV protocols offer different profiles of the same content, and the client application evaluates the Internet connection at the moment of viewing and chooses the profile that is more suitable for the specific client, so every user gets the best quality that he can support. Some protocols focus on different aspects of the streaming process such as the latency or content encryption, but there are three most popular and used protocols HLS, MPEG-DASH and Microsoft Smooth Streaming. HLS was originally designed exclusively for Apple devices, but nowadays it is supported by a lot of devices and browsers, and it is in fact the most used streaming protocol. It ensures a good quality of video with low cost and high security. MPEG-DASH or Dynamic Adaptive Streaming over HTTP is a streaming protocol, which was developed by MPEG (Moving Pictures Expert Group), with the purpose of creating an alternative to Apple HLS. The crucial difference between these protocols is their ownership. Also, HLS supports only some specific video and audio formats whereas MPEG-DASH operates with all formats. Microsoft Smooth Streaming is a streaming protocol, like two protocols explained above, but unlike them, Smooth Streaming uses CPU usage as an indicator in choosing the right profile. This new indicator is specifically useful in mobile devices such as smartphones or tablets (Barz and Bassett 2016).

3. OTT TV PLATFORMS' ARCHITECTURE

OTT TV services use the internet network to distribute live or on demand video content to viewers. Although they use Internet attributes for the data transmission, there is a need for some specific processing steps in order for the content to be suitable for distribution to the client. The full architecture of an OTT platform is given in the Figure 1. Firstly, all television content (Live Streaming, Video on Demand) goes through the transcoder, which changes different characteristics so that this content is in the required format. Transcoding is the process that ensures adaptive bitrate delivery. The next step in an OTT platform is the packager that breaks up the content in fragments or chunks and creates the manifest files, both of which are published in the origin server, which is the server responsible for processing client requests and serving the content to the client application (Blanc 2017). However, an OTT platform with only one origin server that communicates with all the clients would not be efficient, because this server would become a one point of failure. In an effort to avoid this problem and also to improve the quality of viewing, OTT TV uses Content Delivery Networks, that are a group of servers placed in different geographical locations (Oliveira *et al*., 2018). These servers save the content in their memory so that when a client sends a request, it can be served to him directly from the closest server. After the CDN, the request is delivered to the client application, which is the software that has built the request for the content and when it receives this content is responsible for decoding and playing it. This is the transmission chain, in which the content goes through, but there are two other important systems that complete the whole OTT platform which are the DRM and the Middleware. Digital Rights Management or DRM is a system that ensures that a specific content is available only for authorized clients and it does this through encryption, which actually happens in the packager, but it is the DRM system that authenticates the client and distributes the encryption and decryption keys towards the packager and the client application respectively. The middleware is a very important software for the operation of an OTT service with many clients and many channels because it manages the whole system. The middleware gives the client the opportunity to view his requested channel without the need for knowledge regarding manifest files and URLs. It guaranties a successful communication between all the components of the platform, which are designed by different vendors, and it communicates constantly with CRM (Customer Relationship Management) to exchange information about billing and information about the clients and their rights so that together with the DRM, they ensure that the OTT service is received only by authorized clients.

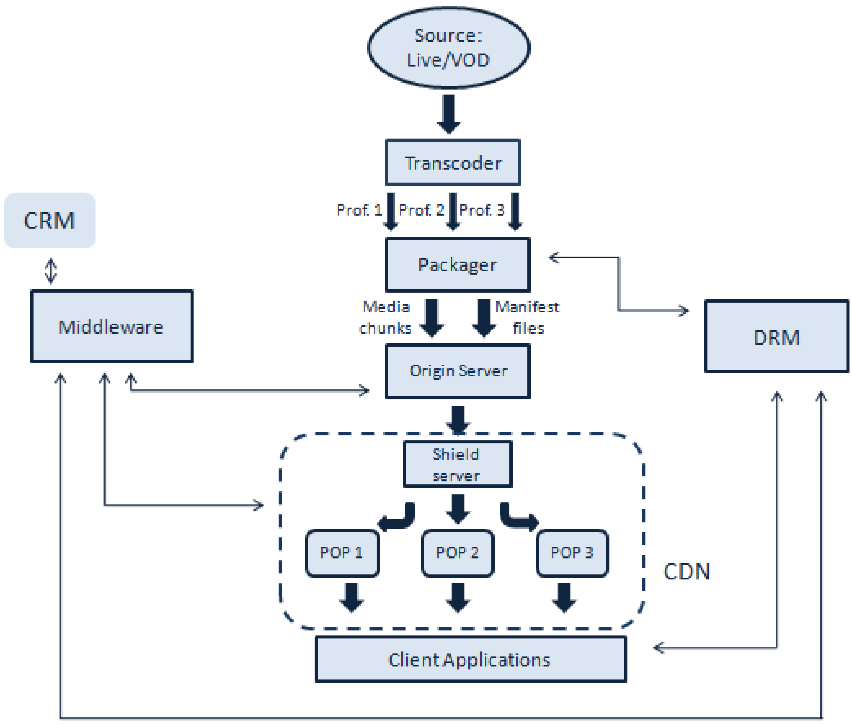

Fig. 9: Architecture of an OTT TV platform.

Transcoding

Transcoding is the process of transforming the media content in a different format to ensure that it is suitable for platforms and applications with different requests. Two of the most important components of transcoding are trans-sizing and trans-rating. Trans-sizing is the change of the video size which includes not only the place that this video occupies in the hardware memory, but also the resolution. Trans-rating is a similar process, but it has to do with the bitrate. It is necessary as the process that enables adaptive bitrate delivery.

Packaging

As aforementioned said, once the transcoding process is done, the content is transformed into a specific format, but an application responsible for playing the video requires more information than what can be included in an individual media file such as available resolutions and bitrates, available audio and video formats, audio languages, subtitles, and advertisement insertion points. HLS and MPEG-DASH protocols put all these information in a single file called a manifest file. In the HLS protocol this file is called a Master Playlist, which includes the bandwidth, resolution, and coding format for each profile and the URL where this format can be found. Media Presentation Descriptions give the same information in the MPEG-DASH protocol, but it is slightly more organized since it arranges media profiles into Adaption Sets. In an OTT TV platform, the packager does two essential services. It fragments the content in chunks, and it prepares the manifest file, as it is explained above.

Origin Server

An origin server is a computer with the main responsibility of processing and answering the clients' Internet requests. It can be the only part of the OTT platform responsible for delivering the content to an Internet entity such as a website as long as the traffic does not exceed the server's capabilities and short delay is not a priority. The physical distance between the origin server and the client increases the latency and as a result it increases the loading time of an Internet source. Using a Content Delivery Network (CDN) is the current solution for reducing round trip time and the number of requests that are handled by the origin server.

Content Delivery Network

A Content Delivery Network can be defined as a server platform located in strategic positions with the goal of decreasing the physical distance between a client and the server that responds to him. Usually, a CDN has three kinds of servers: the origin server, the shield, which is a server that protects the origin from overloading with requests and the points of presence (POP). Once a request arrives, the shield subsequently checks the local memory and if the information is not found, the requests go to the origin. The third kind of servers which is the most common in a CDN is POP, which is a cache server located far from the origin. These POPs answer the clients request with the version of content that they have in their cache memory. If one POP does not find the requested files it searches them in other POPs of the network and only when content is unavailable or not updated, the client request goes to the origin server (Aljumaily 2016; Al-Abbasi Aggarwal *et al*., 2019) A Content Delivery Network has a lot of advantages such as availability, scalability, security, and a better performance for the platform (Held 2011; Zolfaghari *et al*., 2020).

4. BUILDING A DEMO OTT LIVE PLATFORM

Description of the demo platform building process

The following paragraph describes every step in the process of creating a demo version of a Live OTT platform, which is a small platform with one live channel, that does not include all the parts of the infrastructure but is very helpful in completing the OTT view and presenting a practical demonstration of the information explained previously. It also gives more insight into the whole processing flow of the signal and all the files that are created for specific needs.

The input signal of this platform is an IP stream that is generated based on DVB-T2 standard, which means that it is adapted for traditional terrestrial broadcast. According to the DVB-T2 standard the television signal is transmitted as an MPEG transport stream, which encapsulates several elementary streams, with different PIDs (Program Identifier) for different elements of the signal such as video, audio, subtitles etc. As it is mentioned earlier the OTT transmission requires TV signals with different characteristics that are suitable for the streaming protocols of the Internet. Therefore, after passing through the processing components of the demo platform, the output signal is presented as a set of files, whose type depends on the file-based protocol used for transmission such as HLS, MPEG-DASH, MSS etc. Each of these files contains the video, audio and metadata components of the signal. In the OTT platform each of these files is considered as a “chunk”, whose duration can be configured in the packager. However, for a specific time length we expect to have more than one file, considering the use of adaptive bitrate streaming, which means the same part of the TV content will be represented as different files with different bitrates and resolution. The necessary information regarding these files, their characteristics and order is included in the manifest file. In the final step of the demo platform, the player of the client app will request the proper files depending on the client device screen resolution, network connectivity capacity and will play the content as a continuous stream.

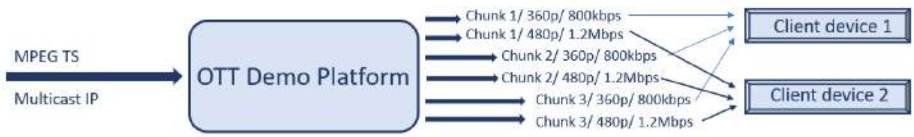

Fig. 10: Input and output signal of the OTT demo platform

In the demo platform, the two most important components are the transcoder and the packager, which are implemented together with the origin server. Although every part of the OTT architecture has a role in ensuring a good operation and quality of experience for the viewer, these two parts are crucial for the transmission. They enable the distribution of content via the Internet, while other components like DRM, CDN or Middleware offer services that facilitate the management and avoid problems that may rise in a platform with more content and more clients. Regarding the client application, the software chosen is VLC, which is an application that can be installed in every client’s equipment.

Hardware equipment

In the creation of the demo OTT Live platform, there was a need for several computers and hardware equipment. First, it was used an Edge Probe Nano monitoring DVB-T/T2 signal equipment (TestTree 2020), which serves as a receiver of the terrestrial signal. It receives a DVB-T2 stream, chooses a specific channel and streams it in a multicast IP address. This multicast stream is captured by the transcoder, which is the HERO Live transcoder from Media Excel (MediaExcel 2021). This software is installed in a standard datacentre server running over a virtualized platform. The next device is a standard desktop computer with installed Ubuntu Server 21.04 operating system. This computer contains the Unified Streaming origin server (Unified 2021). A standard network and management computers are connected in a LAN (Local Area Network) for management purposes. Each build platform is accessed by the management computer either from their respective web interface, or from the PuTTy ssh client and WinSCP FTP client. In the same network, a standard computer is also used as OTT client with VLC application installed. Another client equipment used is an Android Box, which is connected to a TV and allows the installation of the VLC application. A switch is used to connect all of the mentioned equipment with each other in a small local network. OTT is the transmission of the signal via the Internet, but taking into consideration the fact that the Internet is a very large network, using a small local network would not bring any difference.

Demonstration of the demo OTT platform

The following pictures demonstrate and explain the creation of the OTT Live platform. Figure 3 shows the web management interface of the HERO Transcoder, which has the option of configuring different groups of transcoders along with every channel, which has only one input and have one or more output. That means that different profiles can be created for the same content to enable the adaptive bitrate transmission. The channel configuration also includes pre-processing, logo overlay and video and audio pre-set for every output, as in the Figure 4 depicted.

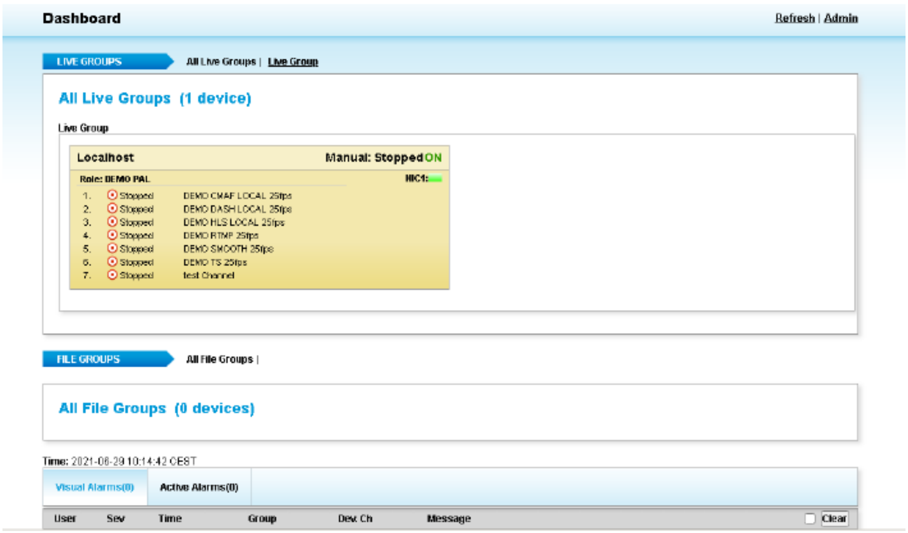

Fig. 3: The transcoder web management interface

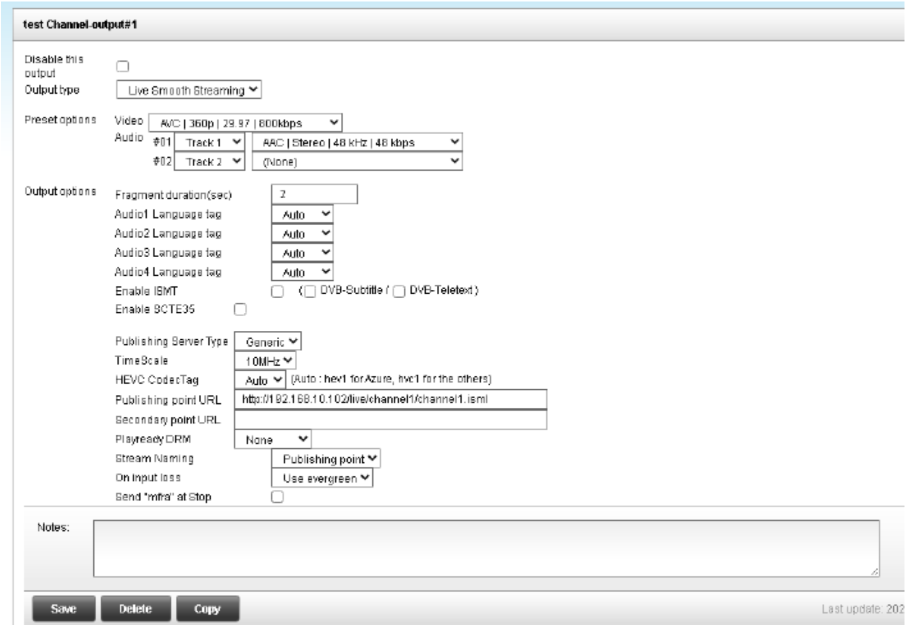

Fig. 4: The channel configuration in the transcoder.

As aforementioned said, the packager and origin server used in this platform in the Unified Streaming origin, which is installed in a computer that also contains the Apache software. This is an open-source software that enables the creation of several web servers in a single physical machine. A web server is called a virtual host in Apache, and it is set up by editing its configuration file. After configuring the web server, the next step is the creation of the publishing points, which are the folders, where the transcoder posts the content. In this platform, the transcoder and the origin server communicate through the Microsoft Smooth Streaming protocol, therefore the publishing point is created by writing the server manifest file (.isml). The script, executed to create the publishing point is shown in figure 5, while figure 6 shows the manifest file.

```
#/bin/bash

FOLDER="/var/www/html/live/demoservice"

MANIFEST="$FOLDER/demoservice.isml"

echo $FOLDER

mkdir -m 777 -p $FOLDER

mp4split --license-key=/var/www/usp-license.key -o $MANIFEST \
--archiving=true \
--archive_segment_length=3600 \
--dvr_window_length=120 \
--archive_length=86400 \
--restart_on_encoder_reconnect \
--hls.client_manifest_version=4 \

chmod 666 $MANIFEST

sudo chown -R www-data:www-data $FOLDER
```

Fig. 5: The executable script for creating the publishing point

```
channel1.isml
<?xml version='1.0" encoding="utf-8"?>
<!-- Created with Unified Streaming Platform (version=1.10.28-22802) -->
<smil xmlns='http://www.w3.org/2001/SMIL20/Language">
  <head>
    <meta name="clientManifestRelativePath" content='channel1.ismc" />
    <meta name="creator' content="Unified Streaming Platform (USP)" />
    <meta name="lookahead_fragments" content='2" />
    <meta name="dvr_window_length" content='120" />
    <meta name="archive_segment_length" content="3600" />
    <meta name="archiving' content="true" />
    <meta name="archive_length' content="86400" />
    <meta name="restart_on_encoder_reconnect" content='true' />
    <meta name="fixed_gop' content="48/25' />
    <meta name="hls_client_manifest_version' content="4" />
    <meta name="hls_no_multiplex' content="true" />
  </head>
  <body>
    <switch>
    </switch>
  </body>
</smil>
```

Fig. 6: The manifest file (.isml) in the origin server.

Once the channel and its respective publishing point is created, the OTT distribution can begin. Figure 7 depicts the monitoring of the channel in the transcoder, while the state of the publishing point folder in the origin server, which now contains the manifest file (.isml) and the chunks for every profile of the channel (.ismv) is in the Figure 8 depicted.

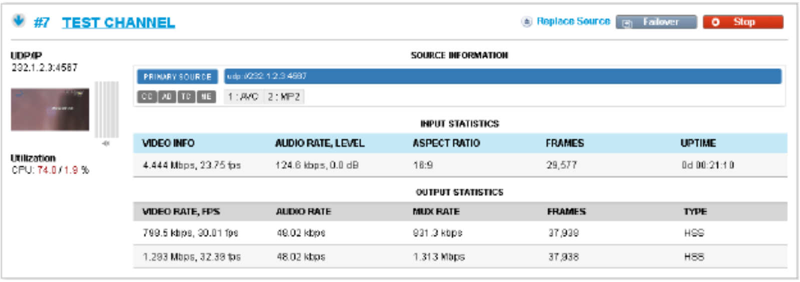

Fig. 7: Monitoring the channel after it is started.

It can be seen that since the moment the channel is started in the transcoder, in the publishing point there are two chunks created at the same time. As expected, there are two files with the same content, but with different resolution and bitrate.

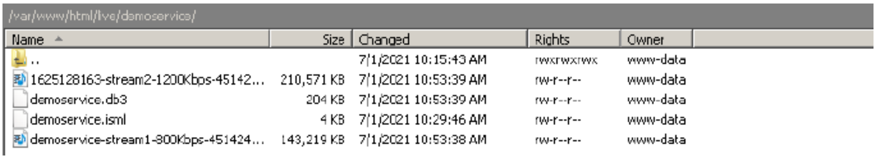

Fig. 8: The publishing point directory during the transmission.

The demo platform, configured with only two profiles, is sufficient to test the OTT transmission's capabilities and adaptiveness to the available resources of several clients. Table 1 shows the chosen profile of several client devices that differ regarding their screen resolution and the available bandwidth of their internet connection. In this experiment, the available bandwidth of the client devices has been controlled, so that the behaviour of the built OTT platform can be monitored, on presenting the right profile to each client that offers the best user experience with the available resources.

Table 6: OTT Profile chosen based on the client devices' screen resolution and available bandwidth

Client device	**Available bandwidth**	**Chosen profile**
Mobile phone	1024 kbps	360p / 800kbps
Mobile phone	2048 kbps	360p / 800kbps
Desktop computer	1024 kbps	360p / 800kbps
Desktop computer	2048 kbps	480p / 1200kbps
Android TV	1024 kbps	360p / 800kbps
Android TV	2048 kbps	480p / 1200kbps

Table 1 reports that the mobile phone, which is a device with a small screen resolution, chooses the 360p/800kbps profile even when the connection bandwidth can support the higher profile. The player of the device does not choose the highest profile available which is the 480p/1200kbps, because the screen resolution of the mobile phone does not support it and it would not bring any significant benefit to the user experience.

It clear that for the desktop computer and Android TV, which have a higher resolution and are considered as ‘big screens’, the player chooses the highest profile offered by the OTT platform that is permitted by the available bandwidth. In this case, when the available bandwidth is higher than 1200 kbps, the platform choses the 480p/1200kbps profile. When the Internet connection speed is reduced, it does not allow for the TV content to be streamed continuously from the platform to the client using the previous profile. As a result of that, the player chooses the next available profile (with a lower resolution and bitrate) so that the content can be transmitted without any error or missing packet, that would appear as an artifact in the video and would degrade the user experience. This ability to adapt to the client devices and their properties, ensured by the adaptive bitrate transcoding and packaging, is dynamic. This means that the connection of each client is monitored continuously so that the player automatically switches to different profiles when the network conditions change, and the best user experience is offered to all the clients.

Figure 9 shows the content played in the client software, which in this case is installed in a laptop. As explained previously, the computer screen is considered as a ‘big screen’; therefore, the player of the client application chooses the higher profile, which is 480 pixels and 1.2 Mbps. Once the creating the demo version of a live OTT TV platform is created, the television signal starts to be played in the chosen client devices, and its profile is adapting to the capabilities of each device, which means that the demo platform is complete and the distribution of the content through the internet has been achieved.

Fig. 9: The VLC software playing the content

6. CONCLUSIONS

Over the top television is the transmission of television content through the Internet. In OTT TV, the viewer has to require the content in order for it to be transmitted. As an industry, the OTT television has developed a lot in the last 10 years, but it still faces many challenges, which have to be solved so that more audiences can be reached. OTT service providers have to analyse and offer flexibility in payment methods, marketing and advertisement inclusion. Moreover, the transmission latency is a performance parameter that appears to be not as good as in traditional TV due to the nature of the OTT protocols, that separate the content in chunks. This parameter needs to be improved, by using suitable algorithms, chunk duration and the exact moment when the video starts to be played (Bjelica *et al.*, 2015; Latkoski *et al.*, 2016). The process of building a demo OTT platform showcased two major factors that contribute to the growing popularity of the OTT TV nowadays, which are the low cost and relative simplicity in creating an OTT platform, considering that is built on top of existing Internet infrastructure. Moreover, the demo version emphasized all the system components and their functions, which require further research in order to be developed so that a good quality of experience can be ensured for every client, despite his equipment, internet connection or the content he is watching (Goldstein *et al.*, 2020). The build platform allows to monitor and test different video streaming profiles (different resolution and bandwidth) and different CDNs. These tests can be performed not only for the stream profiles as in this experiment, but also for more profiles and several channels with different type of content. The testing results can help to evaluate and fix bottleneck problems or any other obstacles that may appear during streaming when the number of clients grows.

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