Analysis of the Technologies enabling the broadcast convergence

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***Abstract*— This paper analyses the technology change and its impact on the broadcast sector. Different elements of the television ecosystem, such as access technologies, platforms and end-user device technologies, has been reviewed and their evolution discussed, including Internet Protocol Television and Over The Top applications. Moreover, the potential interelation between traditional broadcasters and new mobile access technologies has been pointed out in a convergence scenario. Television, therefore, has stopped being a media exclusively managed by the broadcasters, which must adapt to new technologies in order to keep the leads. The key role played by the spectrum regulatory framework is also stressed. The paper concludes that the evolution and integration of technologies, with the arrival of new technologies which allow the convergence of networks and services, is transforming the industry and the actors´ relationships. In fact, it is required to use the technology to reach a wider audience from different platforms in an integrative manner.**

Keywords - broadcast; television; access technologies; devices; platform;convergence

I. INTRODUCTION

The broadcast sector lives on a continuous reconfiguration and integration. Television broadcasters must integrate new technologies in order to keep the leads when the emergence of new platforms, that allow to watch any content at any time, have promoted the development of new innovative business models. These technological changes has altered the economical balance of this sector, strongly impacted the whole economy of the 21st century and provoking relevant societal transformations.

Currently, there is an increasing interdependence between the companies involved in the entertainment sector and the firms related to the delivery and processing of information [1] and also a move that translates the added value of communication services from basic services into the level of transport to services at the application level [2]. In this complete reconfiguration for the XXI century, the broadcast sector is in a critical moment in all aspects:

- Technological changes: from traditional platforms to new ways of broadcasting content, such as connected TVs, IPTV, Over the Top services, etc
- Integration and consolidation movement among the actors: telecom operators, producers and media.
- Different ways of consuming contents: the behavior of the consumer has evolved along with the industry.
- Drastic changes in the regulatory framework, in the assignment of a critical resource as it is the radio-electric spectrum.
- The proper dynamism of the sector allows testing new business models on financial formulas previously unknown.

Therefore, the main objectives of this article are analyzing the current situation of the broadcast sector and getting a holistic view of the whole ecosystem and understanding its dynamics and its strategies for the future. The main changes in technology and their evolution applied to television and main access technologies and platforms will be shown; improvements in mobile broadband networks and devices will be also analyzed as they represent new possibilities for television broadcasting and have created a total new separated subsector.

II. TECHNOLOGY EVOLUTION TOWARDS THE INTEGRATION

This section analyzes the evolution of technology related to broadcast transmissions, traditionally based on fixed solutions. It is worth noting that technology is constantly evolving since cinema and television services were born, and it is reflected in the structure of the media industry and its consumers. Technological changes have been the key in the transformation of the sector:

- New systems and access technologies: new "broadcast" systems over optical fiber, broadband mobile or IP protocols based solutions.
- New devices: for example, cell phones or tablets, which have a complete di□erent market than traditional broadcast systems.
- Digitization of the communications: new standards and platforms.

The convergence of those main areas of changes, which are interrelated, makes possible new platforms, over the Internet and the multi-platform services and, as a consequence, new ways of accessing media communications from multiple devices, from anywhere, at any time.

Furthermore, there has been an initial restlessness with respect to the future of the sector and a certain resistance against the obvious changes, caused by the fear or the uncertainty of the traditional stakeholders that have seen how new players have come into the broadcast market.

A. Television Services and Access Technologies

Broadcast services can be provided over several access technologies. The main fixed access technologies are radio broadcasting, used by the Digital Terrestrial Television (DTT) and the Satellite Digital TV broadcasting services; and wired technologies used by the Cable TV and IPTV and OTT TV, IP based access services. In addition, mobile broadband networks have evolved to new generations and technologies like 4G and the upcoming 5G networks, which should support television broadcasting. 5G, the re-structuring of the spectrum and the possible convergence between mobile networks and TV broadcasting are still under definition. The improvements on the mobile broadband networks, which also support voice and data services, evoke to inevitable changes on the fixed television networks. To illustrate the access technologies evolution [3] shows a wide overview of the access networks; moreover, technologies performance and their adequacy to provide different services, including television, and networks convergenceis stated.

This multi-technology scenario makes easier the content consumption through multiple devices. It is possible to watch TV anywhere at any time. So, as technology has changed, so has the consumer [4]. While DTT keeps a descendant trend, satellite TV and IPTV and OTT are highly increasing their share of the market [5].

Digital terrestrial television (DDT)

In Digital Terrestrial Television radio is the access medium. The digitalized television signal is transmitted on an Ultra High Frequency (UHF) band through terrestrial waves. In most of the countries around the world, the standard is the Digital Video Broadcasting - Terrestrial, DVB-T [6], which shows the expansion of DVB-T and other standards such as the Advanced Television Systems Committee (ATSC), the Digital Terrestrial Multimedia Broadcast (DTMB) or the Integrated Services Digital Broadcasting (ISDB) worldwide. Therefore, DTT is fragmented in several standards. To solve this difference, the Future of Broadcast Television initiative (FOBTV) was created by global broadcasters to define a common future generation of broadcast systems [11]. Comprehensive overviews of the terrestrial broadcasting systems from the points of view oftechnology and standards are provided by L. Dai [8], and C. Ong [9] respectively.

DVB-T uses Coded Orthogonal Frequency Division Multiplexing (COFDM) modulation. It has evolved to a new standard, the DVB-T2 that allows, for example, the transmission of 4K resolution content with better stability and without significant losses. 4K resolution refers to horizontal resolution on the order of 4,000 pixels and vertical resolution on the order of 2,000 pixels. That is feasible because of a higher degree of compression and a more efficient use of the spectrum.

Satellite digital television broadcasting

Satellite Digital Television allows broadcasting via radio TV signals, previously transmitted from a distribution center to the satellite, to a specific area of coverage on the earth.

The main standard for this kind of transmission is the Digital Video Broadcasting - Satellite (DVB-S), and its second version DVB-S2 [10]. It introduces channel codification techniques to protect and to adapt the signals to the characteristics of the channel. Attenuation is the main problem that satellite channels face due to the long distances the signals have to travel. Both DVB-S and DVB-S2 use Quadrature Phase Shift Keying (QPSK) modulation. DVB-S2 is a 30 % more efficient than the previous standard release by using improved codification techniques to maximize the resources of the satellites. Its implementation coincided with the introduction of High Definition TV and H.264 (MPEG-4 AVC), a video compression standard which is the most commonly used format for distribution. This gives the possibility to use the channel for both, domestic and professional services with high quality performances. Furthermore, satellite technology is evolving to serve higher throughput and power to cope with, among others, new high definition requirements [11].

Cable TV (Hybrid Fiber-Coaxial)

Cable digital TV transmits TV digital signal services over Hybrid fiber-coaxial (HFC) networks. Cable TV operators usually provide convergent services, such as telephone, Internet access, and radio and television, over the HFC network; this was denoted as "triple play". The most widely used standard for Digital TV over Cable is the Digital Video Broadcasting - Cable (DVB-C) [12]. This standard uses

Quadrature Amplitude Modulation (QAM), giving strength to the signal against noise and interferences. The main problem of this technology is that the access is done through coaxial cable, and that makes its deployment and implementation expensive and hard to provide coverage to new areas. The DVB-C2 release allows bitrates up to 97Mbits/s and 110.8Mbits/s per channel with 4K video transmissions.

Internet Protocol Television and Over The Top

Internet Protocol Television (IPTV) and Over The Top (OTT) provide multimedia content over broadband connections using IP network protocols. Digital Subscriber Loop (DSL) over cooper pair, such as VDSL (Very High speed DSL) and optical fiber, such Fiber to the Home (FTTH) or to the Build (FFTB), are the main broadband access technologies which support IPTV and OTT [13].

IPTV services were developed by the telecom operators in order to offer real convergent services over their managed networks: telephone, data and television (triple play), to compete against cable operators.

The increase of bandwidth in the networks has paved the way to new services providers, such as, OTT broadcast providers, which delivery television services over open Internet. In fact, nowadays the user can access with enough capacity and reliability to perceive a good quality of experience (QoE) to any online multimedia content. Moreover, these technologies support on demand service, live content service and a high degree of interactivity natively.

New Mobile Access Technologies

The expansion of new mobile access technologies is, as mentioned before, the main reason for the digital dividends; while the mobile market keeps growing, the fight between both operators and broadcasters that use the spectrum is still far from ended. As mobile TV broadcasting will play an important role in the future of Television, the 3rd Generation Partnership Project (3GPP), which standardizes the current and future mobile systems, defined evolved Multimedia Broadcast and Multicast Service (eMBMS) to improve the broadcast efficiency. In addition, there are some other initiatives for future broadcast networks such as combining the infrastructure of both television broadcasters and mobile operators or defining DVB and 3GPP standards to converge broadcast service, however it will be difficult to achieve a consensus [14].

Meanwhile, the fourth generation of mobile communication systems, 4G, is still a far dream to most users, but it is becoming more and more common and accessible. Manufactures and operators are doing their best to spread the 4G connection as wide as possible; however 4G download speed seems to be not enough for the future demand and for what the broadcast future of the industry looks alike, with a lot more high quality video streaming and fast big data transmissions. That is one of the reasons why the new fifth generation networks, 5G, are under definition. In fact, there is a general view related to the traffic volume forecast in 5G networks, it will be 1000 times the today´s networks traffic. However, the objective of the 5G is not only multiplying the speed of the connection but also improving its quality by increasing the number of terminals that can access the network simultaneously through the same antenna and by decreasing the latency, the total sum of delays in a transmission from end to end inside a network. It has been established a calendar for 5G networks, from its standardization to its deployment.

B. Devices

In the previous section, main access technologies and systems for television transmissions were explained. This section analyzes the main devices for television consumption and their evolution. Society is currently on a period of hybrid consumption model that combines traditional broadcasting with the Internet streaming. The gap between traditional television consumption, which used to be the main daily activity for most end-users, and internet television consumption, is decreasing day by day. The technology evolution of the television set is part of this process, [15].

Making the television able to connect to the Internet has become a usual characteristic in the market.The lack of new high-tech/high quality content, e.g. 4K/8K or High Dynamic Range (HDR) video broadcasted through traditional platforms is one of its drivers. A Smart TV is a television set which offers the possibility to be connected to the Internet via Wi-Fi or cable and install operating systems, that is usually provided by the manufacturer [16], for using dedicated applications for television, besides the traditional possibilities of playing content from several sources (USB, HDMI, Coax, etc.). It merges in one final device the possibilities of live or VoD content and stored video for the user to decide. Smart TVs include an electronic guide to easy access to a multimedia content catalog available through the Internet.

The trend is to have bigger and bigger televisions; screens of 30-40 inches feel small nowadays. Screens' definition has evolved from HD to Full HD 1080i, the most common image format for television nowadays: 1.920px x 1.080px, and then to 4K: 4096px x 2160px, although in most cases it is called Ultra High Definition (UHD) and it is 3840px x 2160px. This means more than 8 million pixels in the screen, and consequently, 4 times more detail than in a Full HD screen; it is called to be the next standard image format in the future.

Super Ultra High Definition (SUHD) does not improve the 4K resolution, because that remains 3840px x 2160px but it does improve the image quality, thanks to quantum dots. The quantum dots are nano-glasses that can produce light when you give power to them. They can be added on top of the LED back-light of a TV, filtering it and creating more

natural colors. SUHD TV sets promise 2.5 more brightness in models from 44 inches to 88 inches, with curved screens and SUHD technology. Even though this technology seems to be the technology of the future it is still not accessible to most consumers, mainly because its cost and lack of content [17].

High Dynamic Range (HDR) technology expands the color range when capturing the video, obtaining darker blacks and brighter whites (high level of contrast). The final goal is to get pictures more similar to real life.In order to play HDR video in a television set, it generates a wider range of brightness than a traditional LED TV (that uses conventional gamma curve and a bit depth of 8bits/sample) thanks to precise attenuation of the back-light [18]. Televisions with this technology use complex algorithms to analyze each photogram and dynamically control the brightness of each area. This technology needs to be combined with other high-tech ones, like 4K or SUHD and has started to be available for mobile phones and tablets.

Increasing the video resolution from Full HD 1080i to 4K implies multiplying by almost four the information carried in each photogram, and therefore considerably increasing the bandwidth needed for a stable connection. One of the problems that the consumer can face is the insufficient or limited speed in the final connection that makes more than just necessary the implementation of new codecs at system level to respond to new high quality content broadcasting. Finally, High Efficiency Video Coding (HECV) or H265 is the evolution of H264/MPEG-4 Advanced Video Coding (AVC), the industry standard used for recording, compressing and distributing video. Some of the big Internet video content providers, such as Netflix, are currently using it. Outside this format, Google has developed the VP9 open source video codec, used for their 4K YouTube Video Streaming and Chrome browser. VP9 codec seems to other a decrease in size of 63 % in comparison with the H.264 standard for a 1080p sample (24 pps), lowering the video bit rate from 8.2 Mbps down to 3 Mbps. Google is pursuing the goal of radically reduce 4K bandwidth with VP10 to half of VP9 and a quarter of H.264, (Fingas, 2015). Both VP9 and H.265 codecs have been developed with the support of some the main big television manufactures.

C. Emergent platforms

As it has been mentioned before, television services are nowadays forwarding to a mode of use in which the user can practically choose and control what to see and when to do it: absolute control of a media center with the convergence of several television technologies. The new emergent TV services follow mainly the pay per view or subscription models. The content is offered in exchange of a monthly rate that can vary depending on the service. Its business model is a bit different from the others due to the fact that with the basic monthly rate the user receives a service with standard definition content; but with a more expensive rate, high definition content is available, and in addition, the platform gives the opportunity to share the account between two different users.

Internet Protocol Television and Over The Top Television Platforms

Internet Protocol Television (IPTV, although is not a protocol itself) uses, as mentioned before, broadband connections over IP protocols in order to broadcast multimedia content through an owned and dedicated telecom operator`s network. It is one of the most popular subscription services for television. In the television industry, OTT services refer to Value-Added Services (VAS) that are provided over the Internet without the involvement of this network operator controlling the distribution.

The main differentiating factor between both IPTV and OTT with other technologies is the interactivity: most of the services are on demand (Video on Demand, VoD), and the final consumer can choose the content to watch at any time. In the end, what is most important is that the consumer has switched to an active role in the digital age [20]. However, the technology behind both IPTV and OTT TV platforms allows the integration of TV and others communication services easily.

IPTV platforms provide linear or broadcast television, video on demand and shift-TV among other services. These solutions are usually based on client-server architecture. The service delivery and the video on demand platforms are the core servers which handle the linear TV and VoD services. The service delivery platform plays the role of media center portal to provide content when it receives a user request. The TV channels and VoD contents are delivered as IP encoded flux of data (streams); linear channels and live events are transported as multicast (connection point to multipoint) from the TV head-end to the users, video on demand is distributed through a content delivery network to the video servers next to the users, and it is transported as unicast stream (connection point to point) from those videoservers to the users. The client is placed at the final destination in the home set-top-box, it decodes and decrypts IP streams (TV or VoD content), and it is in charge of displaying it on the TV and handling the user interface.The European Telecommunications Standards Institute (ETSI) covers the standardization of the critical elements of the IPTV ecosystem.

On the other hand, the OTT TV is mainly possible thanks to Content Delivery Networks (CDN), which are networks of proxy servers globally distributed. The goal is to provide a high quality and high performance unicast streaming service to multiple end-users. In the CDN servers a copy of the original content is stored and geographically distributed next to its potential consumers. This improves the quality of service, reducing important problems like latency (end-to-end delay), transmission errors, and congestion or transmission losses and therefore it means an approximation to a quality of service (QoS).

When IPTV has been mentioned before, it referred to conventional Internet Protocol TV, which is usually offered by different telecom operators and thus transmitted through a dedicated own network. OTT platforms do not require expensive investments, infrastructures or spectrum bands and they are not controlled under the regulatory framework of the network owner. This services have become an important threat for traditional broadcasters because they fight for the same audiences offering the same or better contents without a deployment of infrastructure or own network.

Due to the common confusion between IPTV and OTT TV in table 1 there is a comparison table between both of them:

TABLE 1. OVER THE TOP VS. INTERNET PROTOCOL TV

Category	OTT	IPTV
Content delivery	• Point-to-point in private connections over Internet public network.	• Dedicated network owned by the operators.
QoS	• Besteffortconditions.	• High quality, reliablenetwork.
Delivery protocol	• HTTP/TCP evolving towards adaptive technologies such as HTTP Live Streaming (HLS, developed by Apple) or Smooth Streaming (MS) and HTTP Dynamic Streaming (HDS by Adobe).	• Uses Transport Stream; RTP (Real Time Protocol) over UDP.
Distribution	• Unicast (HTTP) and Simulated Multicast (UDP/TCP).	• Multicast.
Category service	• Complementary.	• At the same level of main services, like Satellite/Cable/Terrestrial TV services.
Major platform players	• Online Video Platforms (OVP).	• Mainly Telecom Service Providers and IPTV platform vendors like Ericsson or Cisco Inc.
Example	• YouTube, Netflix, Amazon, etc.	• AT&T U-Verse, China Telecom, France Telecom, Movistar, etc.
Cons	• Low QoS, less live content, unicast model.	• Expensive, enormous investments in infrastructure and bandwidth.
Pros	• Low cost, easy platforms and transparent to the user.	• High quality of service and content.

Both IPTV and OTT TV mean a turning point in the television sector; both have changed the broadcast industry and the market. With this scenario, there are five main different players in the sector, with clear positions: DTT, Satellite TV, Cable TV, IPTV, and OTT TV.

Television, therefore, has stopped being a media exclusively owned by the broadcasters. New television providers such as the IPTV platforms China Telecom, Verizon, AT&T or the emergent OTT TV services like Google, Amazon or Netflix have become direct competitors to traditional services. Connected TVs and other new technologies for television (described before) make easier the access to the Internet through the screen of the TV, and hence bring closer new broadcast contents to the consumer. It is not a question of the future, it is already a reality: the industry and the market have changed.

III. FUTURE RESEARCH AND CONCLUSIONS

The broadcast sector has been analyzed in a comprehensive manner, showing the big impact of the technological evolution and integration in its configuration. Relevant phenomena of this industry´s evolution have been identified, but further research is required to delve in the industrial and economic impact of the observed changes from this introductory study of technology. The main future areas of research and final remarks are mainly related to the following aspects:

- The evolution and integration of technologies is reconfiguring the industry and the actor´s relationships. Further analysis of their dynamics is required to understand the impact in the development of this industry

- The spectrum points to an unstoppable change in the next future, so the best strategy that a player can take is the adaptation to changes in all aspects. It is required to use the technology to arrive to a wider audience from different platforms in an integrative manner, and also to study and understand the consumers to give them what they expect and to fight in the market to bigger players with innovative products, such as social TV, interaction, adaptive catalogue and offers, better quality, etc.

- With the new technologies, which allow the convergence of networks and services, the sector lives on a continuous reconfiguration, building a new scenario where the consumer has all possibilities to access to any content from any kind of platform: anycast service. Moreover, next step seems to be future broadcast networks such as combining the infrastructure of both television broadcasters and mobile operators or defining DVB and 3GPP standards to converge broadcast service.

Finally, it is important to remark that the new platforms have revolutionized the value chain of the sector by playing several roles of the value chain simultaneously: producer, aggregator and distributor. The publicity incomes are switching to digital platforms and the audiences and demand of the new digital players steady increase. Based on what has been previously exposed, the broadcast sector should adopt a clear consumer centric approach. This interesting phenomenon paves avenues for future sectorial researches.

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