D R A F T

Audiovisual media services and 5G

White paper

The purpose of this paper is to facilitate an informed discussion on the 5G challenges in the domain of audiovisual media services as perceived by the members of the community. The views expressed in this document are the amalgamated opinions of the contributors and may not be considered as representing the views of any individual organisation.

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Executive summary

Audiovisual (AV) media services aim to inform, educate, and entertain the members of the audience. They are as much cultural as they are economic services. Their growing importance for societies, democracy, in particular ensuring freedom of information, diversity of opinion and media pluralism, education, and culture justifies the application of specific rules to these services.

User demand for content is the main driver for AV media services and the technology is one of the key enablers. 5G may have a potential to substantially enhance the user experience and positively impact the audiovisual media value chain, including content production, distribution, and the user environment, provided that it successfully addresses the future needs of all stakeholders in the value chain.

For the most part, AV media services belong to a traffic category that is commonly referred to as '*video*'. However, not all video content qualifies to be considered AV media service. AV media services are subject to sector specific regulation and require a service provider to assume a certain degree of editorial responsibility. Many kinds of video content do not have these attributes and, therefore, are not considered to be AV media services (e.g. videoconferences, tele-surveillance, video games).

Quality drives demand. In order to create a compelling user experience, AV media service providers seek to deliver the content wherever and whenever the users expect to receive it. They also need to accommodate the user's choice of device. The user expectations on choice, quality, and convenience will continue to increase for the foreseeable future.

Delivery options for AV media services

There are two principal ways for the AV media services providers to reach the audiences: the broadcast networks and the Internet which relies on broadband infrastructure. Broadcast networks are optimised for the distribution of linear services to very large audiences. They have a near-universal coverage and allow both a free-to-air and a controlled access to services. However, broadcast networks are not inherently adapted for the delivery of on-demand services. Nonetheless, there are innovative caching approaches that allow broadcast networks to facilitate certain type of on-demand access to AV media services.

Broadband networks enable two different approaches, a '*managed lane'* such as IPTV and a '*best-effort lane'* where services are delivered over the open Internet (e.g. over-the-top, or OTT). In managed networks quality of service can be assured whereas the best-effort networks in most cases provide adequate quality but sometimes experience capacity and quality issues, especially when the number of concurrent users is high.

IPTV is based on a similar business model as the traditional cable TV and is used to provide linear TV services and certain types of on-demand services. The Internet-based distribution provides much more flexibility and is characterised by substantially lower entry barriers, fast-paced evolution of technologies and services, and a variety of business practices. It is the primary distribution mechanism for on-demand AV media services.

No single delivery option is capable of meeting all service requirements and reaching all users in all situations.

Serving the evolving needs of the audience

The way in which we watch audiovisual content continues to evolve. On-demand viewing is steadily growing with an accelerating pace while linear broadcast remains the most important way of watching TV. At present, traditional broadcast delivery networks serve around 95% of the total viewing. The rest is delivered online.

Audience behaviour is changing but this change is not fast. Some users have adopted new habits and use the Internet and mobile media while others prefer to carry on watching and listening to traditional channels. In reality, most users combine both the new and the old ways in a manner that suits them best. As the AV media service providers, both commercial and Public Service Media (PSM), seek to serve all segments of the audience they need to continue to use both the broadcast infrastructure and the Internet in parallel, ideally in a combined manner to deliver a seamless experience to the end user.

In the future, the Internet may become as important for AV media services as the purpose-built broadcast infrastructure networks are today. AV media service providers recognise this and strive to make their content and services '*Internet-ready*'. It is equally important that regulators, policymakers, and the industry consider what steps need to be taken to ensure that the network infrastructure, both broadcast and broadband, is progressively made ready for the new media paradigm, i.e. capable of supporting both the evolving content production workflows and a large-scale distribution of AV media services.

The impact on the distribution networks

AV media services tend to generate a very large amount of data traffic. As the users become accustomed to high quality they expect it on all distribution networks and this is already placing increased capacity and quality demands on the network infrastructure. The arrival of new services such as UHDTV and even more capable user devices will further drive the capacity requirements. At the same time the users' willingness to pay may not substantially increase. The challenge is to find a sustainable way of meeting the future AV distribution requirements within these constrains.

While all AV technologies and digital networks continue to evolve, broadband and broadcast technology developments have traditionally followed separate paths and aim to meet different requirements. Nonetheless, today's broadcast and broadband networks are highly complementary and there is an increasing degree of commonality between them, in particular with regard to the core technologies, the range of AV media services they seek to support, and the target audiences. However, their seamless integration remains a challenge, while a better mutual awareness and cooperation would be highly desirable.

Hybrid solutions such as HbbTV are becoming technically available where traditional broadcast distribution is combined with the Internet in order to respond to the demand for advanced AV media services and the enhanced user experience.

Furthermore, a complementary nature of broadcast and broadband technologies opens the possibility for their closer integration in the future.

5G as a key differentiator for AV media services

5G has a potential to overcome the limitations of the existing technologies, enable better utilisation of network infrastructures, and unlock the potential for new and innovative businesses. Several areas have been identified where 5G development efforts need to take into account the AV media service requirements:

- Support for the innovative content production workflows
- Support for the distribution of AV media services over 5G networks
- Interoperability between 5G and the existing AV distribution networks that continue to evolve
- Audience data collection and analytics

Furthermore, there is a growing recognition within the AV media industry that the stakeholders across the value chain need to work together in order to find sustainable delivery mechanisms that will be able to meet the future needs of consumers, content producers, service providers, and network operators, as well as the regulatory requirements.

As the 5G developments enter the standardisation stage there may be an opportunity to align the respective 3GPP and DVB roadmaps as regard their work on the technologies for AV media services. Interoperability and technological harmonisation would further promote content and service diversity, portability, and access for the users.

In the short to medium term the 5G initiative could be a vehicle towards a cooperative use of broadcast and broadband infrastructures in order to leverage on their respective strengths while optimising the investments and the use of the existing resources. This alone could result in new business opportunities and partnerships.

In the long term 5G could provide a unifying framework for technical evolution of different AV distribution networks and foster their technological convergence. This would help to reduce market fragmentation and the impact of the legacy situation which might hinder the transition to 5G.

Audiovisual content and services have been amongst the key drivers of the take-up of fast and superfast broadband and of the adoption of new consumer technologies. They could play a similar role in the adoption of 5G. This would require the 5G ecosystem to support a virtuous circle between content creation, demand for new services and applications, technological developments, and the infrastructure developments.

Provision of AV media services is subject to regulation in a number of different areas and the regulatory regime continues to evolve in order to keep pace with technological and market developments. Technological neutrality is a fundamental principle of the EU legislation and it is assumed that the relevant regulation for the AV media services will also apply in the 5G context.

Success of 5G in the AV market will strongly depend on its ability to align the incentives of the stakeholders across the value chain. In doing so, it will be important to strike a balance between market players' legitimate commercial interests and the policy objectives aiming at promoting general interests and the public value.

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Introduction

The viewers and listeners have an unprecedented choice of audiovisual (AV) services and ways to access them. This influences their habits, preferences, and expectations. AV media service providers are making use of new technologies and are offering a wide range of content and services but are also confronted with a changing market environment and increased competition. The regulators are looking to update the relevant regulation in order to keep up with the accelerating technological and market developments and with the evolving audience behaviour.

The audiovisual sector has not been in the focus of the ongoing discussion on 5G. Nonetheless, it is one of the sectors adapting to the profound changes resulting from greater connectivity and connected consumers. In addition, the AV sector has a particular role as a key driver of the uptake of fast and superfast broadband, adoption of new technologies, and the demand for mobile data. Indeed, access to AV media services is one of the main reasons for the audiences adopting new communication technologies, including mobile.

For the most part, AV media services belong to a traffic category that is commonly referred to as '*video*'. However, not all video content qualifies to be considered AV media service. AV media services are subject to sector specific regulation and require a service provider to assume a certain degree of editorial responsibility. Many kinds of video content do not have these attributes and, therefore, are not considered to be AV media services (e.g. videoconferences, tele-surveillance, video games).

There are two principal ways for the AV media services providers to reach the audiences: broadcast networks and the Internet.

The current broadcast distribution networks have a number of characteristics which have benefitted AV media service providers as well as audiences, such as:

- Widespread network availability and a high level of reliability and resilience
- Guaranteed quality of service
- Technically and cost-efficient delivery option for the providers; affordable access for the users
- Direct, unmediated relationship with audiences
- Service and technical innovation
- Support for a virtuous circle of free-to-air delivery and investments in the original content

At the same time, IP-based broadband technologies have brought about new distribution possibilities with great potential for the audiovisual sector. They allow both a managed delivery within a given network (e.g. IPTV) and a best-effort delivery over the open Internet. Managed IP networks operate on the basis of a business model that is similar to the traditional cable-TV model and provide linear TV services and certain types of on-demand services.

The key feature of the best-effort networks is that they enable access to the Internet which has facilitated entirely new distribution approaches (e.g. OTT) characterised by substantially lower entry barriers, scalability, and a fast-paced evolution of technologies, services, and business models. This is one of the primary distribution mechanisms for on-demand AV media services. The other one is the managed distribution environment such as IPTV.

The two models, the broadcast (including IPTV[1]) and the Internet-based delivery, continue to evolve in parallel and it is likely that they will coexist for a long time.[2] AV media service providers will need to continue to use both channels as they strive to serve both those who have adopted new habits and use the Internet and mobile media as well as those who want to carry on watching and listening in a traditional way. In reality, most users combine the new and the old ways in a manner that suits them best.

5G could provide a great opportunity for the AV media sector to unlock new creative potential and reinvent the content and service portfolios, including long and short-form content, live and on-demand. It could open up the possibility of new formats and new immersive ways of telling stories, facilitate curation, recommendations, and personalisation of services, all delivered to where the audience is.

[1] While IPTV is based on IP multicast technology the prevailing business model is similar to that of the traditional cable TV. IPTV is provided over the same infrastructure as the Internet access services. However, IPTV is neither an Internet-based service nor does it allow the users to access the Internet. This is why IPTV is considered together with the traditional broadcast networks, such as terrestrial, satellite, and cable.

[2] It is also worth noting that there are many examples where broadcast and OTT distribution are successfully combined, although it remains unclear whether or not any particular model will prevail on the market.

As AV media service providers, including both commercial and Public Service Media (PSM), make their services 'Internet-ready', it is important that regulators, policymakers, and the industry consider what steps need to be taken to ensure that the network infrastructure is progressively made 'AV-ready', i.e. capable of supporting both the evolving content production workflows and a large-scale distribution of AV media services.

The 5G ecosystem should be designed to maximise the benefits for European citizens and the European cultural and creative industries of which the audiovisual sector is an integral part[3].

In doing so, 5G should support the European and national audiovisual policies as articulated in the Audiovisual Media Services Directive:

- Ensuring a level playing field for existing and emerging audiovisual media services;
- Strengthening the single European market and guaranteed conditions of fair competition;
- Strengthening the competitiveness of the European audiovisual industry and promoting European audiovisual content;
- Protecting and empowering consumers (audiences), in particular minors and people with a visual or hearing disability;
- Contributing to the support of cultural and linguistic diversity and heritage in Europe;
- Safeguarding media pluralism, freedom of expression and information.

The regulatory regime needs to keep pace with technological and market developments, and seek to mitigate the risks associated with the transition to Internet-first delivery strategies. In particular, these risks include:

- The increasing gatekeeping power of the vertically integrated, converged operators. There is a tension between the commercial incentives of these companies and the public policy objectives which underpin the current European regulatory audiovisual media landscape;
- Transfer of value in favour of Internet audiovisual platforms that act as intermediaries between the AV media service providers and the audience, thereby undermining the existing models of funding for original European content;
- Increasing delivery costs for the AV media service providers (see also section 1.3.2 below)
- Public service media content could be increasingly left without adequate guarantees to secure its widespread availability, prominence, and quality of delivery. PSM providers could be forced to divert investments in content to pay for carriage.

Since the market for AV media services remains dynamic and innovative, it may eventually overcome some of the current policy and technical challenges. Nevertheless, public policy has an important role to play and some issues are likely to require coordinated action from policy makers, regulators, and industry.

[3] According to a recent study jointly presented by the CISAC the UNESCO, Cultural and Creative Industries' (CCI) revenues exceed those of telecom services and employ more people than the car industry of Europe, Japan and the USA combined. In Europe, CCI generates $709b revenues and employs 7.7 million people. The study concludes that, in the digital market, policy makers need to address the transfer of value currently taking place in favour of Internet intermediaries and ensure that creators and the creative industries are paid fairly for the exploitation of their works. For further information see http://www.worldcreative.org/.

1. Socio-economic drivers of AV media services

There has never been more audiovisual content available and consumed than there is today. This huge popularity of media is not new. Storytelling has always been essential to our social interaction and culture. As viewers and listeners we derive value from content and the way we experience it. We expect the AV media services to inform, educate, and entertain us whether we are actively engaging or passively exposing ourselves to their influence. Technology is a key enabler but never a substitute for the narrative.

Audiovisual works encompass particular values, identity and meanings that very often go beyond their strictly commercial value. They play a central role in democratic societies, informing citizens, shaping public opinion and offering a window to the world.

There is a very large variety of AV content available to the users, in particular on-line. However, not all AV content offers fall into the category of AV media *services*.

1.1 AV media services and their development

It is generally accepted that AV media services share some common characteristics, such as:

- Audiovisual elements are used with the purpose to provide programmes to the general public.
- The function of the programmes is to inform, entertain, or educate.
- The provider of AV media services can be identified as a natural or legal person.
- The service provider has editorial responsibility for the AV content.
- AV media services are normally subject to content regulation.

Examples of AV media services include linear TV, but also on-demand, time shifted, hybrid, interactive, and personalised services, multi-screen and multi-view services, and cross-platform services. Different services allow different levels of user engagement and interaction, and may be tailored to different segments of the audience, user context, or a particular distribution mechanism.

A lot of innovation is happening in the domain of service development and it is likely that new kinds of AV media services will emerge in the future.

The following examples also use audiovisual content but do not share the above mentioned characteristics and hence are not considered to be AV media services:

- User generated content
- Online games
- Teleconferences
- Personal communication
- Video surveillance

The term *'video'* is often used to describe a particular type of traffic carried on electronic communications networks, as distinguished from *data, voice,* or other types of traffic. Both the AV media services and the above examples of other AV content belong to category 'video'.

The focus of this document is on AV media services. They comprise a broad range of content and the business models that facilitate user's access to the content.

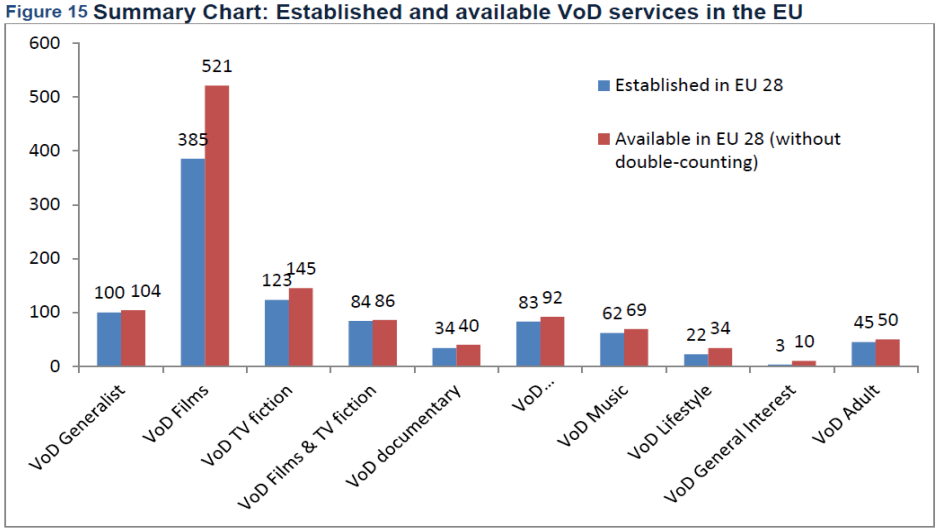
AV media services are developing along the three main dimensions: increasing choice, better quality, and convenience. Convenience is sometimes described as '*anytime, anywhere, on any device*'.

Technological advances are the key enablers of these developments. The other determining factors include business and regulatory considerations.

1.1.1 Increasing choice of content and services

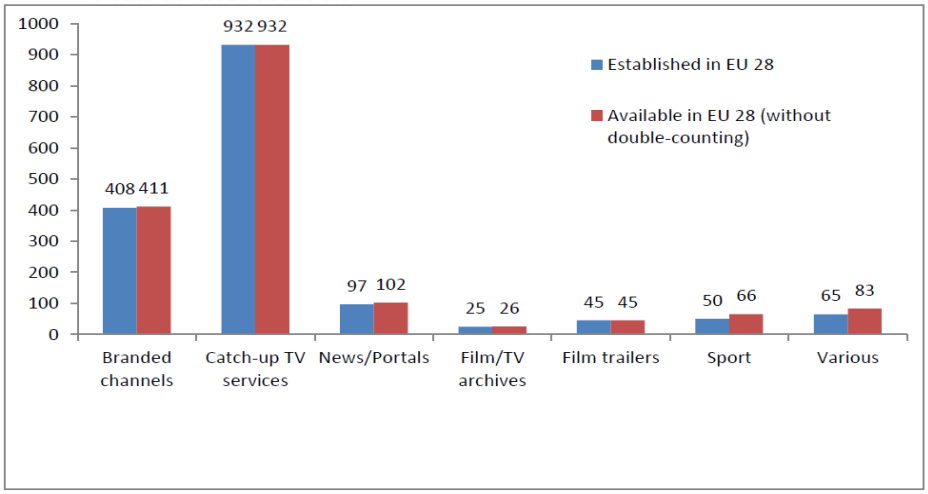
According to the European Audiovisual Observatory, more than 11000 TV channels are available in Europe, although not all of them can be viewed in all countries. Furthermore, 1161 VoD services and 1665 other on-demand audiovisual services were available in the EU at the end of 2014. The number of both linear and on-demand services continues to grow.

Figure 15 **Summary Chart: Established and available VoD services in the EU**



Source: MAVISE/OBS

Figure 16 **Summary Chart: Established and available other on-demand audio-visual services in the EU**



Source: MAVISE/OBS

As the amount of AV content and number of services continues to increase, in particular on-demand, content discovery is becoming an issue for many users. Therefore, personalised and curated services, and recommendations are becoming integral elements of the service.

1.1.2. Increasing technical quality

TV picture quality is defined by a set of technical parameters such as:

- spatial resolution (the number of pixels in a picture)
- temporal resolution (the number of picture frames per second)
- colour gamut (the range of colours that can be displayed)
- dynamic range (the span between minimum and maximum brightness)

These parameters, and their combinations, are standardised in order to ensure interoperability. The picture formats that indicate progressively higher quality on TV sets are SDTV, HDTV, and UHDTV.

For on-line distribution a number of different picture formats are used that are adapted to the throughput available on broadband connections and the capabilities of connected devices. They may represent lower or similar quality to the above mentioned TV formats.

There is a general trend towards a higher picture quality on all services and all devices. Better quality leads to higher user engagement and increases the value of the content. This is the AV media service providers seek to deliver as high quality as possible, despite the growing associated costs and the issues related to network capacity, be it on broadcast network or on the Internet.

1.1.3. Growing on-demand consumption (‘*any time’*)

Linear TV was and still is the dominant AV media service. The main characteristic of a linear service is that the programmes can be watched at the time of broadcast. In the past, the only alternatives to linear TV were AV content on physical media (e.g. DVD) and the recorded content on personal video recorders (PVR).

As the broadband networks became capable of delivering AV media services with sufficient quality, they also enabled the provision of time-shifted and on-demand services. There are also examples where on-demand consumption is enabled by pre-positioning of the popular content on user devices via broadcast networks (e.g. MultiChoice in South Africa, Canal Plus in France). As a consequence, access to the AV content is now possible also outside the linear broadcast schedule. Nonetheless, linear viewing remains a dominant way of watching while on-demand is largely additive but growing.

The corresponding audience trends are discussed in section 1.2 below.

1.1.4. Lowering constraints for physical access to the content (‘*anywhere*’)

With the proliferation of portable user devices and the growing capabilities of distribution infrastructure, notably wireless broadband but also digital terrestrial TV, viewers have a possibility to access the AV media services not only in their living room on the stationary TV set but also in other parts of the home, and even on the move.

AV media services, both linear and non-linear, are mainly used at home. On the move the users will most likely opt for pre-loaded content or short form on-demand content. Delivery of linear TV services to the viewers on the move remains a challenge with existing infrastructure and technology.

One effect of lowering the physical constraints for access to AV content is the user expectation for service continuity as they move across different devices and environments.

1.1.5. Expanding range of consumer devices (‘*on any device’*)

In the past, audiovisual media services were only available on dedicated TV receivers which were in most cases stationary.

Today, viewers have at their disposal an increasing range of devices. Whilst the large stationary TV set remains the central point and preferred for AV media consumption in the home, other devices such as personal computers, smartphones and tablets are also used to access AV media services. The range of devices is further expanded by many different streaming devices, including game consoles, that can be connected to the TV set.

It is important to note that different devices are used for different purposes. Given a choice, consumers use different devices for different types of content and in different situations. For example, long form content such as films or live sport is most likely to be watched on a big screen, while smartphones and tablets are a preferred device category for short video clips.

1.2 Audience trends

The growing capabilities of user devices coupled with an increasing choice of high quality content and services continues to drive user expectations, in particular in terms of quality, choice, convenience, and cost.

Whilst audience behaviour can be characterised in a number of ways, it seems appropriate to consider those aspects that bear upon the network infrastructure, in particular:

- The type of service and the time spent with different services
- The type of user devices (e.g. stationary TV set, personal computer, smartphone or tablet)
- The user context in which the service is consumed (e.g. in the home or on the move, indoors or outdoors)

1.2.1 The choice of service and the viewing time

Viewing time is highly correlated with the data volumes to be transferred from the AV media service providers to the users and this directly impacts the requirements on the network infrastructure. Whilst statistical data on user behaviour is abundant, a complete picture remains elusive primarily because of incompatible measurement methodologies across different AV delivery platforms, services, and devices.

IHS Technology provides the following information based on their own market research[4]:

Cross-platform viewing times provide an insight into the changing behaviours of viewers around the world. IHS tracks the total viewing of France, Spain, Germany, Italy, the United Kingdom and the United States. By combining viewing time data from linear television, PVR (personal video recorder) time-shifting, pay TV video-on-demand services and over-the-top (OTT) content IHS is able to provide a holistic view of how video consumption habits are changing in response to the emergence of new media in these key markets.

- *In 2014 television content, linear and time-shifted viewing equated to 96% of all video consumption in IHS' six sample markets.*

  Despite a decline in linear TV consumption, it remains prominent in each of the monitored markets, equating to an average of 88% of total viewing time and reaching as high as 94% of viewing in some markets.

  Across the six markets there is a general trend towards a reduction in linear viewing, however it is worth noting that these reductions are nominal, between 1% and 2% annually.

- *PVR viewing is the most popular non-linear method of viewing TV content, representing more than 50% of all non-linear consumption in 2014. Although in 2014 time-shifting slipped 1.6% in terms of overall viewing time, it remained at an average of 6% of the total.*

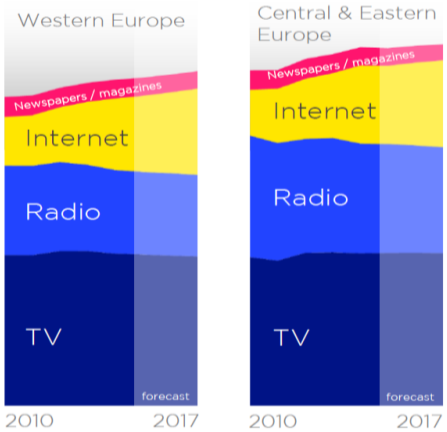
- *Pay TV VoD services offer a range of experiences depending on the availability of set-top box (STB) connectivity. … In 2013 and 2014, pay TV VoD viewing grew 1% year-on-year. However, pay TV VoD only represents 13% of non-linear viewing and 1.7% of total viewing in 2014.*

- *In 2014 OTT viewing time increased by 4.2% across the six markets with online short form content continuing to lead the field with a 2.6% share of total viewing time across the countries. … Short form content is particularly popular with younger audiences, figures from YouTube's Multichannel Networks (MCN) indicating the most active demographic being aged 14-24 years old*

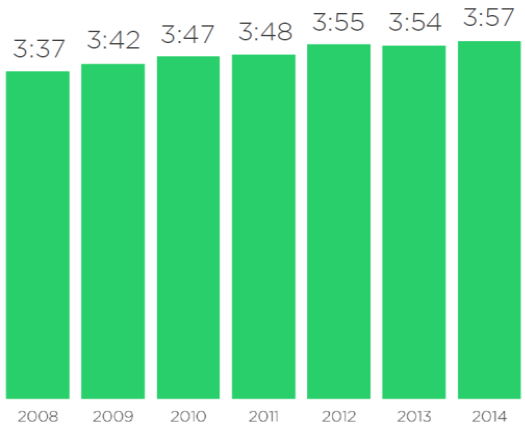
  Online long form content in 2014 on average constituted 2% of viewing time (or 13% of non-linear viewing). In the US, where this behaviour is at its peak, viewing share only reached 3% of average daily viewing.

In addition, several key trends can be observed:

The total time spent on media is increasing while the average TV viewing time remains stable



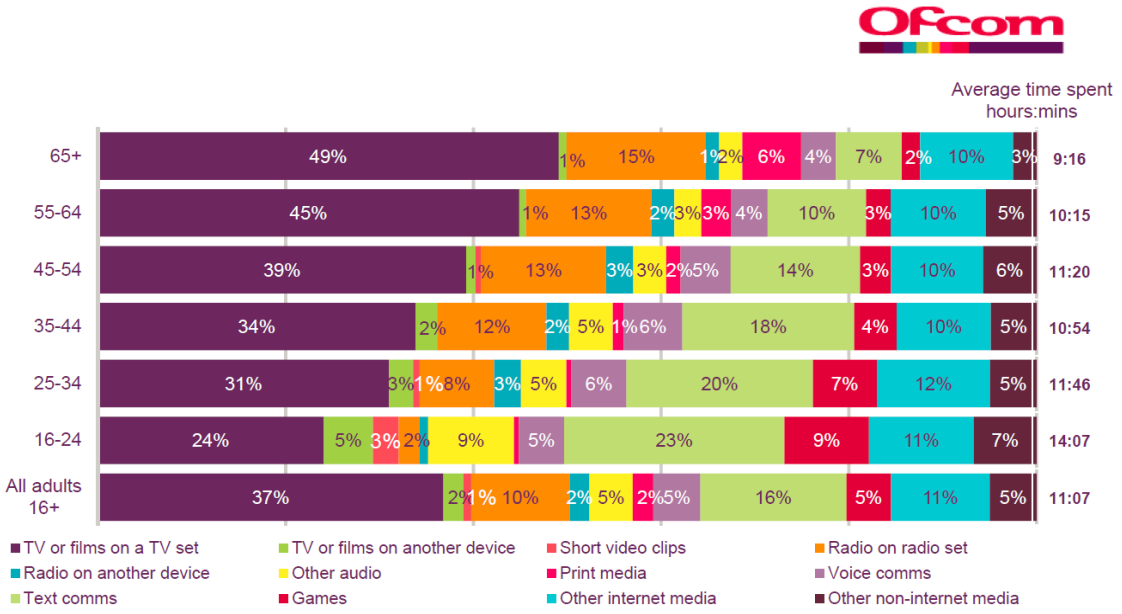
Media Consumption Time 2010-2017
Source: ZenithOptimedia,
Media Consumption Forecasts 2015



Daily TV viewing time per individual in Europe (hh:mm)
Source: *Eurodata TV Worldwide,*
based on 43 European markets

[4] WIPO Standing Committee on Copyright and Related Rights, 30th Session, Doc. SCCRR/30/5, *Current Market and Technology Trends in the Broadcasting Sector*, prepared by IHS Technology, http://www.wipo.int/edocs/mdocs/copyright/en/sccr_30/sccr_30_5.pdf

The 'traditional TV' continues to represent the lion's share of total viewing



Proportion of media and communications time, by age
Source: Ofcom (UK) Digital Day 7 day diary, 2014

However, the total viewing time should not be used as a sole measure of the importance of a particular type of media service to the users.

Furthermore, there is a fundamental issue of audience metrics which is not consistent across different networks, devices, and content formats. For example, TV viewing is typically quantified by the number of viewers (live, or within a one or three-day window) whereas online video is measured in views (which are accumulated over time).

Nonetheless, the total viewing time is a meaningful measure for assessing the capacity requirements on distribution infrastructure.[5]

Personalisation

AV media services are increasingly tailored to the preferences of individual members of the audience, rather than as mass media where the same content was provided to the whole often large audience. Personalisation is possible when AV media services are delivered on-line[6] and is facilitated by several key factors such as:

- the possibility to gather large amounts of data about individual viewing behaviour and preferences
- sophisticated data analytics algorithms and recommendations systems
- advanced user interfaces
- uptake of personal user devices such as personal computers, smartphones, and tablets

Personalisation generally improves the user satisfaction and increases the value of the content. At the same time it leads to audience fragmentation and requires technological innovation and novel market approaches.

[5] For example, YouTube claims over one billion unique users and more than six billion hours of viewing per month. In comparison, in Europe about 2 billion hours of TV are watched every day. This amounts to around 60 billion hours of TV viewing per month in Europe alone.

At the same time, YouTube is the application that generates the largest amount of Internet traffic both in peak periods (around 20%) and during the entire day. For further data on the Internet traffic see *Global Internet Phenomena Report: Asia-Pacific and Europe*, September 2015, https://www.sandvine.com/trends/global-internet-phenomena/

[6] To a certain degree, broadcast networks also allow for the content to be tailored for some particular segment of the audience (e.g. local news, local advertising) and there is ongoing work to improve these capabilities.

'Binge' viewing

With the growing popularity of video on demand services a new kind of viewing behaviour emerged where a viewer consumes a large amount of related content (e.g. several episodes of a drama series or movie sequels) back-to-back in a single sitting. This way of viewing was termed 'binge viewing' or 'bingeing'.

Some content, such as fiction drama, is more suitable for binge viewing then other (e.g. news, sport, or interactive programming). This type of viewing behaviour has been correlated with the adoption of streaming VoD services such as Netflix.

Short-form vs. long-form content

Traditional TV programming is largely based a long-form format with most programmes of about 30 minutes or an hour duration. Online content comes in much greater variety, including both long-form content (e.g. films, TV series, or documentaries) and short-form clips typically lasting 10 minutes or less.

Most viewers watch both long-form and short-form programmes. It appears that from the viewer's perspective long-form and short-form content are distinct, non substitutive propositions that suit different needs and are often watched at different times of the day and on different devices.[7]

A useful compilation of market data that illustrates behaviour of young audiences in relation to AV media services is available on http://www.worldtelevisionday.com/facts-and-figures/. These age groups are of particular interests for AV media service providers and the advertisers.[8]

One of the main challenges in studying audience behaviour is the lack of consistent metrics for the viewing across different networks, devices, and services.

It can be concluded that the strong adoption of on-demand AV media services in the recent years has been largely complementary to the linear TV viewing with little sign of substitution. However, the online distribution of AV content and services has a significant negative impact on the market of physical media (e.g. DVD, Blu-ray and printed media).

The total viewing time continues to increase, in part as a result of simultaneous use of multiple services and devices (multi-tasking). A substantial portion of the time spent with AV content, in particular with younger age groups, is dedicated to user generated content and other forms of video content that do not fall in the category of AV media services.

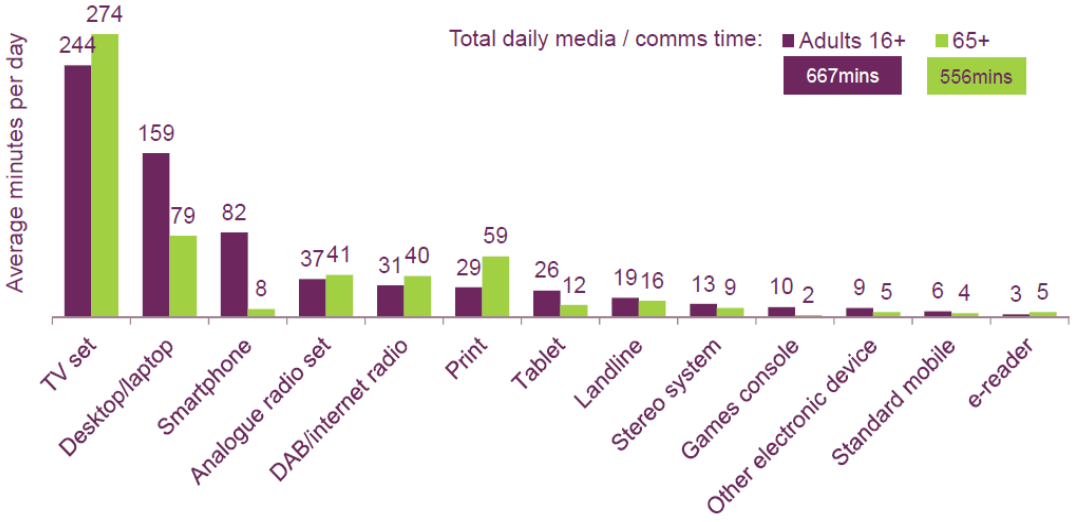
1.2.2 The choice of user devices

AV media services are mainly accessed via a TV set, although for non-linear services other devices are equally important. However, as the users normally prefer a device that provides the highest available quality without compromising on convenience, viewing of on-demand content on the main TV set is significant and growing. This is facilitated in particular by various streaming devices (e.g. Roku, Apple TV, Amazon Fire TC, Google Chromecast, game consoles), home gateways and set-top boxes.

The following figures come from the Ofcom's (UK) study on audience behaviour in 2014 and are representative of the UK population.

[7] For further discussion of the long-form versus short-form format see Deloitte: *Television's business model, Fit for a digital world*, http://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/ibc-2014.html

[8] Young generations are often the early adopters of new services, technologies, and behaviour. Their behaviour is sometimes seen as an indicator of changes in usage patterns that may eventually spread into other age groups. Furthermore, young adults often have a sizable disposable income.



Average daily total device time (in minutes), including simultaneous activity
Source: Ofcom (UK) Digital Day 7 day diary, 2014

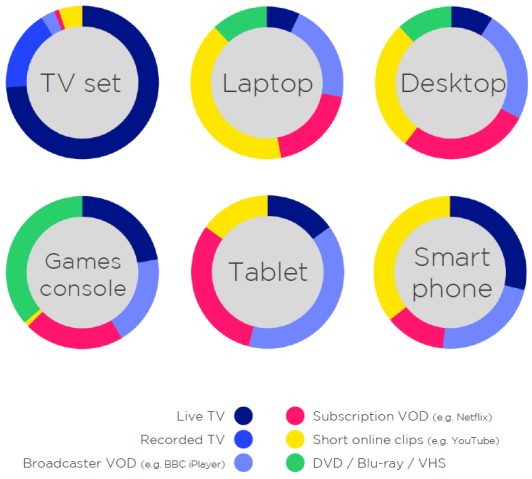
The above figure is consistent with the recent findings in the USA by Nielsen, which stated[9]:

The popular industry narrative of fragmented video viewing often features visions of viewers migrating away from the television and connecting with content alone in their bedrooms, basements and man caves.

With a steady flow of viewing options being brought to market and a nearly 20% year-over-year increase in digital video growth among U.S. adults, it's not hard to understand why this line of thinking plays out.

However, TV remains a mainstay as the primary screen for viewing long form video content. And connected devices, spurred by streaming video, have consumers connected in a familiar spot: the living room!'

Whilst the TV set remains the main device in particular for watching the long-form content, a number of other user devices are increasingly important for access to AV media services.



Proportion of watching activities, by device, UK, adults 16+

Note that the total time spent is not equal on all devices (see also the previous chart)

Source: Ofcom (UK) Digital Day 7 day diary, 2014

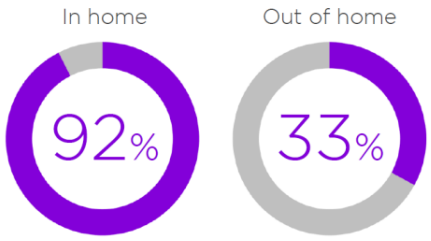
[9] http://www.nielsen.com/us/en/insights/news/2015/friends-with-benefits-tv-connected-devices-bring-consumers-together.html

1.2.3 The user context

Most viewing of AV media services occurs indoors, in particular at home. Whilst this is more pronounced for linear TV services, it is equally true for on-demand services, as illustrated on the following charts:

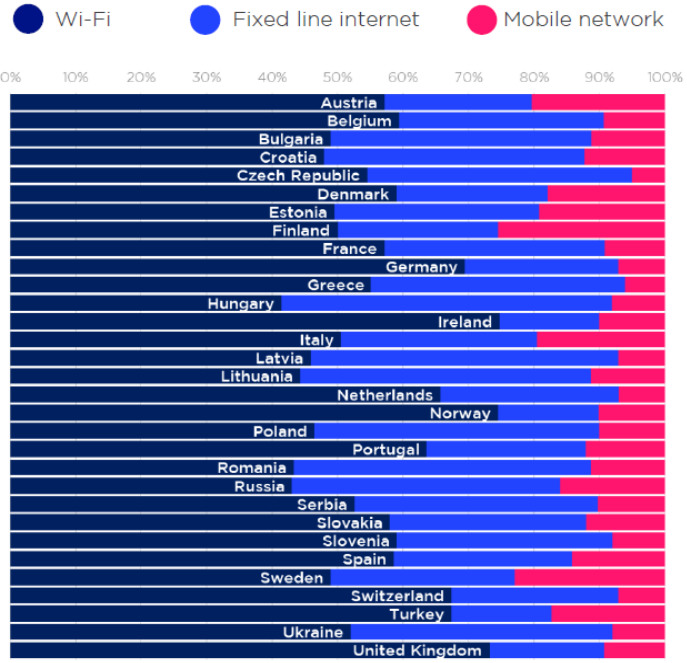
Watching location for online video
In % of online video users 16+, based on past week

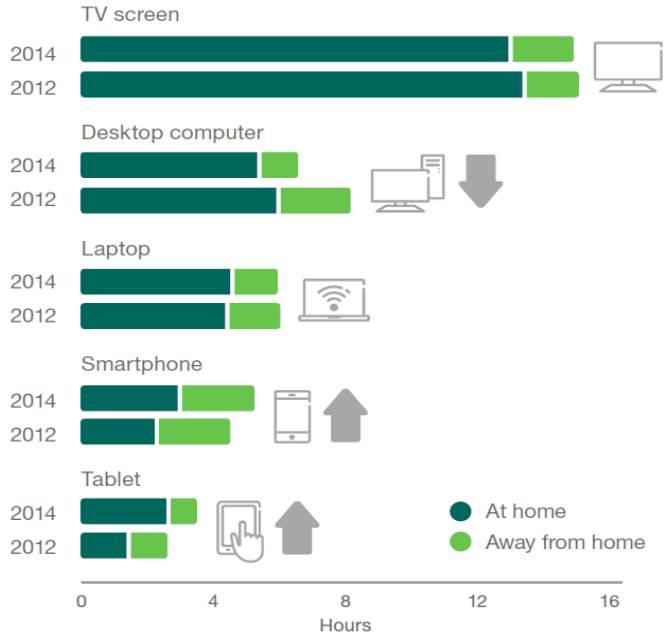
Source:
The Consumer Barometer Survey 2014/2015,
TNS Infratest on behalf of Google



Connection used for online video based on last session

Source:
The Consumer Barometer Survey 2014/2015,
TNS Infratest on behalf of Google





Average hours spent watching video on each device per week
(those who have and use each device to watch video)
Base: 9 markets, people aged 16-59

Source: Ericsson ConsumerLab
TV and media 2014

Furthermore, the following should be noted with regard to audience behaviour:

- Although viewer behaviour is changing, it is important to remember that this change is taking place slowly, with the majority of viewing still going to linear broadcast TV. There is also a wide variation in people's viewing behaviour.
- Some viewers and listeners simultaneously engage with another device while following the programme. This parallel activity could be browsing the web or social media and is often related to the current programme[10].
- Linear viewing and listening should be distinguished from broadcasting. Whilst the former represents a particular, albeit prevailing, type of audience behaviour, the latter is a delivery method that utilises certain technologies. Traditionally, viewing behaviour has been tightly coupled with an underlying delivery method because of technological and economic necessity, but this may not be so in the future. Broadcast distribution will remain important as an efficient way of delivering AV media services, and possibly other type of services. However, user preferences and viewing habits will increasingly be independent of the distribution method.
- Linear radio and TV show strong resilience even in those markets that offer a rich choice of on-demand AV media services and benefit from a well developed broadband infrastructure. One possible explanation is that linear services successfully respond to certain social and psychological needs of the audiences that cannot be satisfied by on-demand services.
- User expectations and user experience have to do with quality, choice, convenience, and costs of the service. All else being equal users will always prefer higher quality, wider choice, lower costs, and more convenience, which together contribute to the user experience. Better user experience leads to higher engagement and loyalty to the brand or service. This is why service providers seek to deliver the best user experience they can. The challenge is to do so in a sustainable way.

1.3 The market of AV media services

The roles of market players in the audiovisual markets can be broadly categorised as follows:

- ***Content producers*** develop original AV material which can in principle be distributed across any distribution channel, whether analogue or digital networks, or on physical media. Most of the content provided by means of AV media services is professionally produced, although a substantial amount of online video content is produced by the users (i.e. user-generated-content).
- ***Service providers*** undertake to bring the content to the users. They use a variety of market approaches and that differ in their focus and the manner in which revenues are generated. The most common approaches are:
    - Aggregating the content licensed from producers in order to store, package, and offer it to the users in a form of AV media services. This approach is often adopted by VoD providers.
    - Provision of a multi-sided outlet that facilitates interaction between content and service providers, users, and advertisers. An operator of such an outlet provides the means (e.g. servers, storage, software applications, user interface) for AV content providers to make their content available to the viewers. As the users engage with the AV media services, the outlet operator collects the audience data and monetizes it by offering services to the advertisers. A number of Internet-based companies have successfully established such a multi-sided market model. Some of them have grown very fast in the recent years and now act as intermediaries between the content providers, the advertisers, and the audiences on a global scale.
    - Provision of an AV media service on the basis of the own content. This approach is used by many traditional broadcasters, although they usually combine the content produced in-house with that acquired from other producers. The increasing importance of on-line distribution has prompted some content owners, such as sport organisations, to explore the possibility of providing their content directly to the viewers, i.e. without going through intermediaries such as content aggregators.
- ***Distribution infrastructure operators***
    - *Network operators* provide a physical connection between the playout servers and the users. This can be via a broadcast network (i.e. satellites, terrestrial, cable) or a telecommunications network (wired or wireless). A particular class of network operators are CDN operators[11]
    - *Cloud infrastructure operators* provide storage and computing resources

[10] The term 'social TV' describes the simultaneous use of TV and social media which reinforce each other as the viewers communicate in real time about the content they are watching.

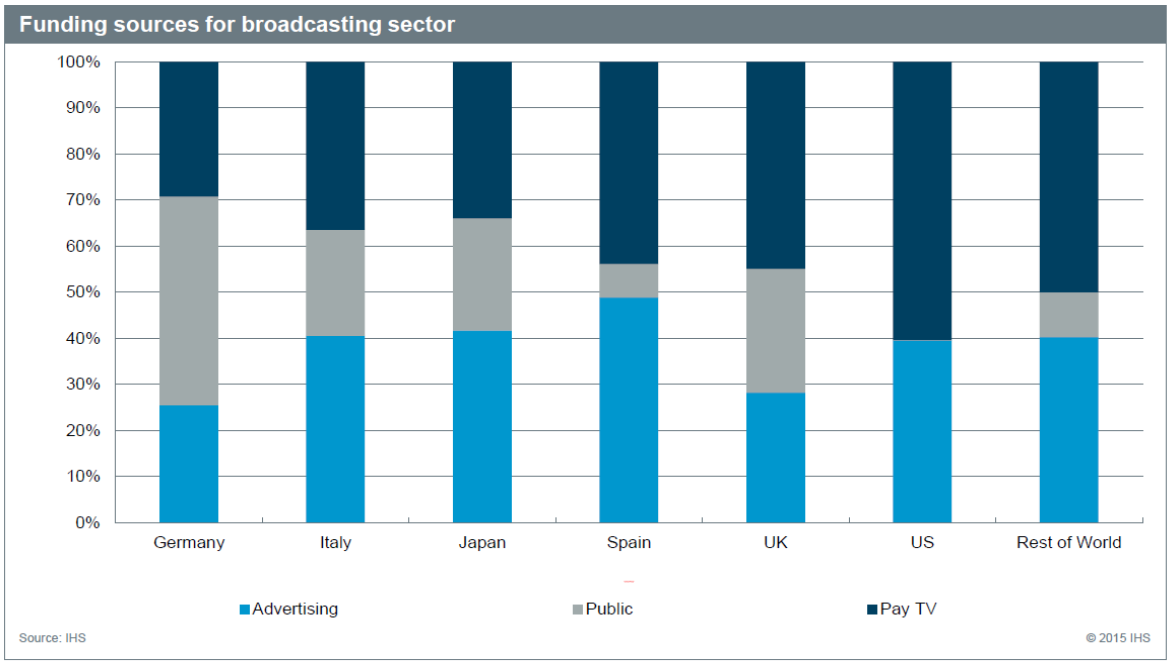
[11] Content Delivery Networks (CDNs) are described in section 4.2.2. below.

- ***Equipment manufacturers*** design and produce the network equipment and the end-user devices that enable access to AV media services.
- ***Advertisers***
- ***Supporting services*** such as programme guides, search, recommendations tools, data analytics services, hosting, and transcoding are the essential elements in most of the business built on AV media services.

The above mentioned categories should be understood as generic functions within a value chain, rather than distinct roles assigned to individual actors. In reality, market players compete within each of these categories and many of them, in particular the large vertically integrated companies, are active across multiple categories.

Co-ordination and cooperation across the whole value chain are necessary in such domains as technical standards, protection of content rights, and implementation of specific regulatory requirements (e.g. protection of minors).

The market for AV media services is characterised by a mixed economy in which companies generate revenues from three major sources: advertising, subscription fees, and public revenues. The main competitors to broadcasters are the specialist online VoD providers (e.g. Netflix), large global Internet companies (e.g. Google), vertically integrated telecommunication operators, and large equipment manufacturers (e.g. Apple, Samsung).



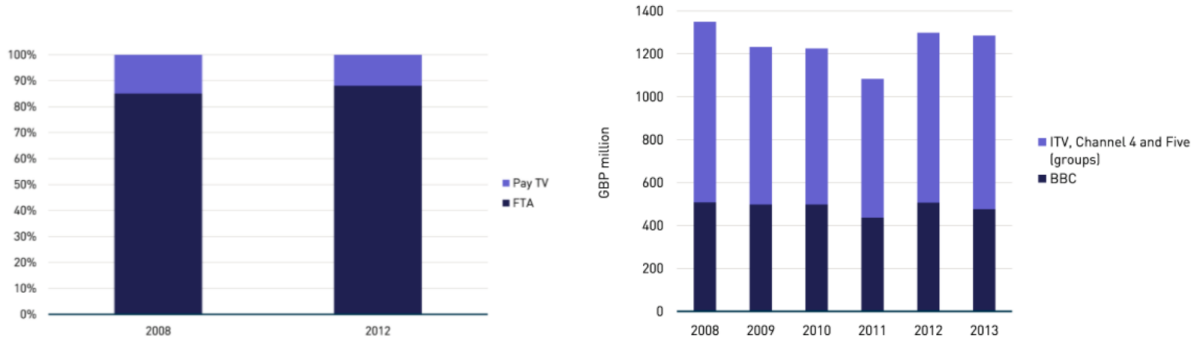
Funding sources for broadcasting sector **(**Source: IHS)

Broadcasters funded by advertising and public revenues are typically free-to-air (FTA), aiming to transmit to the widest possible audience in their markets. The advertising-funded commercial broadcasters seek to attract mass audiences or those of the most interest to advertisers. Publicly funded broadcasters are also subject to a set of legal obligations, defined in their remit, to produce specific types of content and deliver it to everyone free of charge.

A different market situation has historically developed in different parts of the world. For example, in the US, the dominant national players are pay-TV operators and FTA broadcasters which mainly operate in local metropolitan areas. While publicly funded television exists in the US in the form of the PBS network, it has a much more marginal presence in the broadcasting market than is the case in Europe, where many public broadcasters have retained their status as market leaders, at least in the free-to-air market.

European FTA broadcasters normally serve national markets but also provide regional and local programming. Furthermore, the European audiovisual model has enabled coexistence between public service and commercial broadcasters as well as sustainable funding for the original TV content.

According to a study by Analysys Mason[12], FTA services command the largest viewing share while FTA broadcasters provide up to 80% or more of the funding of the original European TV content.



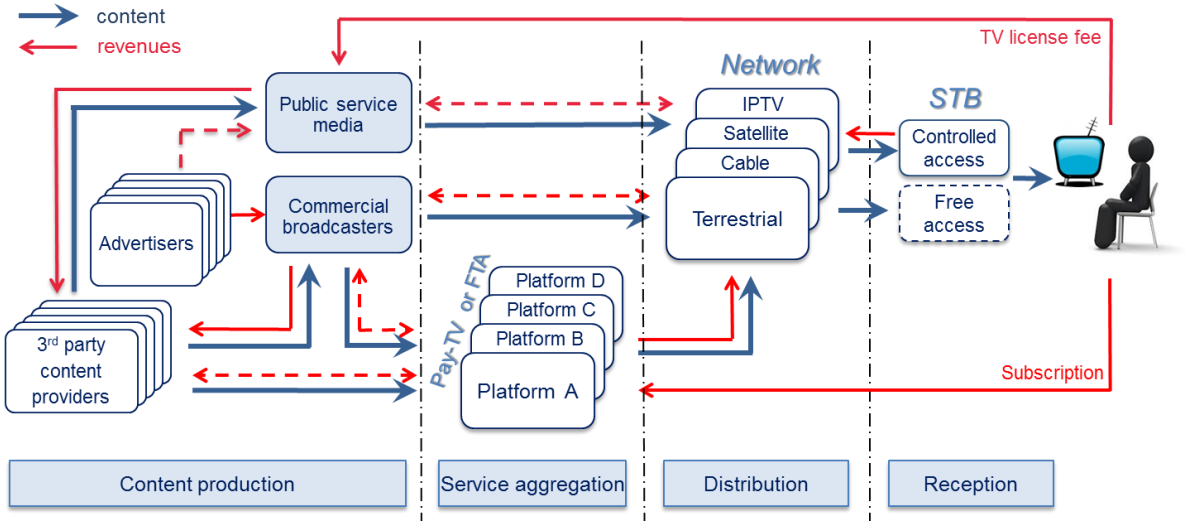
Investments in original audiovisual production in France and UK (Source: Analysys Mason)

Pay TV, in general, continues to grow, although the pricing and penetration varies considerably between different countries. While FTA broadcasters remain the main investors in the original content, pay-TV providers are increasingly investing in some specific types of content, in particular first-run movies and sport, seeking to obtain exclusive rights.

1.3.1 The broadcast distribution model

Broadcasting is also known as a *'one-to-many'* distribution method, designed to carry signals to all users simultaneously. Broadcast networks are uncontested in providing linear radio and TV services, given their ability to serve very large audiences with high quality of service at low cost.

The main strengths of the broadcast model come from the universal availability of services (due to large network coverage), high penetration of the receiving equipment (every household in Europe is equipped for access to at least one broadcast network), the cost efficiency, and a predictable quality of service at the user's end.



The broadcast distribution model

[12] *'FTA still attracts a viewing share of around 80% in Europe, even in countries with pay-TV penetration of more than 50% (like the UK), or even over 80% (like the Netherlands or Denmark). The majority of programmes broadcast on the main FTA channels are original productions, which may be commissioned as independent productions: the main FTA groups in the UK account for 80% of the value of independent UK production commissioning. The situation is similar elsewhere in the EU, arguably as a result of comparable audiovisual histories and policies imposing content obligations on FTA channels. In France, for example, the FTA channels (mainly France Televisions, TF1 and M6 groups) account for more than 85% of the investment in original French production.'*
Source: Analysys Mason: *The sustainability of funding for original TV content in Europe is at risk,* January 2015, http://www.analysysmason.com/About-Us/News/Insight/TV-content-in-Europe-Jan2015

Many aspects of broadcast distribution (e.g. provision of service, transmission, allocation of multiplex capacity) are regulated, although the rules that govern them may vary from one country to another.

The choice of TV channels on broadcast networks is relatively static although this is somewhat balanced by a large number of available channels. For further information on content offer see section 1.1.1 above.

Most users have a choice between free access and controlled access to TV services, although the service offer is generally not the same in both cases. Free access is provided to public service media (PSM) services and, often, to the advertising funded commercial TV. Controlled access is usually associated with some sort of payment to the provider (e.g. subscription).

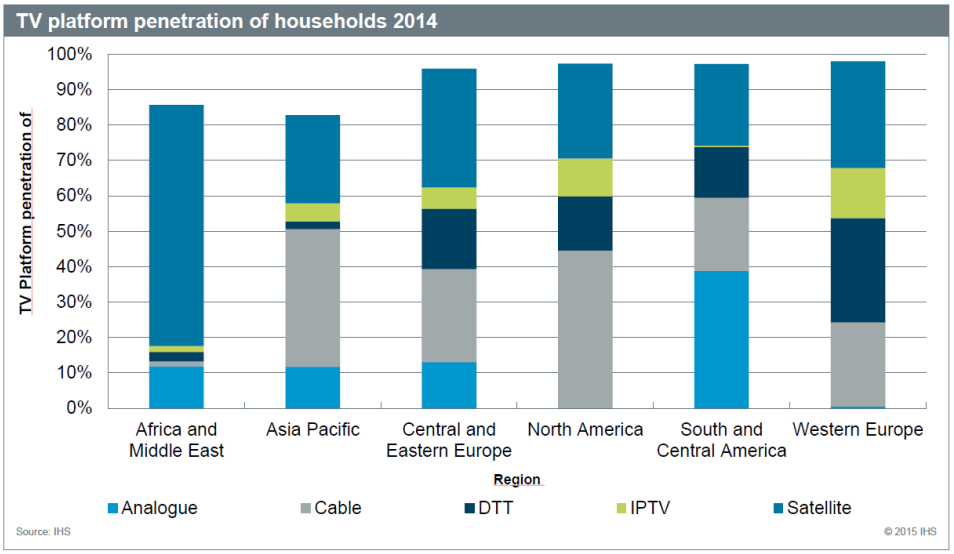
IPTV networks

IPTV networks utilise the IP-multicast technology to deliver linear TV services to multiple users simultaneously. Although IPTV is delivered over the same broadband infrastructure as the Internet services, it shall not be confused with the distribution of AV media services over the open Internet. IPTV is neither an Internet-based service nor does it allow the users to access the Internet.

Instead, IPTV belongs to the category of '*specialised*' or '*managed*' services where a network operator sets aside certain capacity for particular services and actively ensures that the QoS requirements are fulfilled. Managed services are usually subject to special arrangements between a network operator and a service provider.

The prevailing IPTV business model is similar to that of the traditional cable TV where linear TV channels are grouped together and provided, e.g. as thematic packages on a subscription basis. It is also common for IPTV providers to offer a transactional VoD service alongside linear TV channels. IPTV is typically available only to the subscribers of a particular network operator, either as a stand-alone service or, more commonly, as part of triple-play or quadruple-play bundles.

The broadcast model that applies to terrestrial, satellite, and cable networks is also applicable to IPTV as far as linear TV distribution is concerned. Competition between terrestrial, cable, satellite, and IPTV providers is strong but the penetration of different TV platforms varies significantly between different countries and regions.



TV Platform penetration of households 2014 **(**Source: IHS)

1.3.2 Online distribution of AV media services

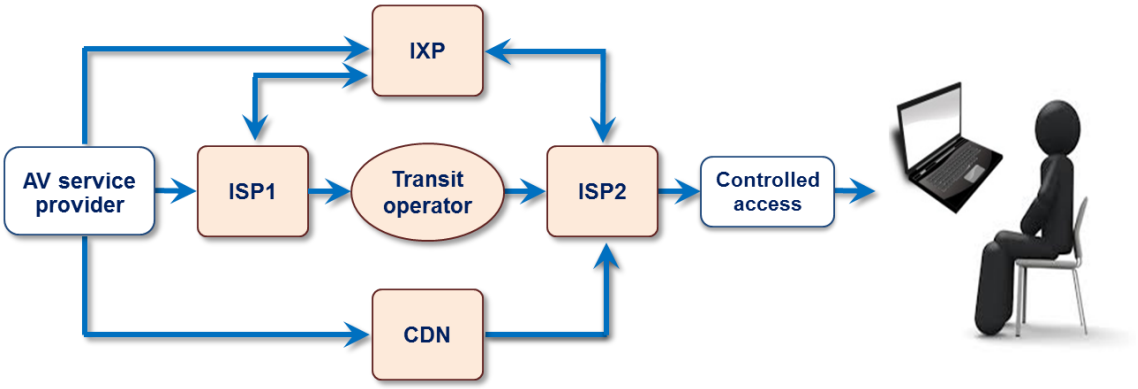
Online delivery is the key enabler of on-demand AV media services which are primarily delivered over the open Internet to a range of user devices, including personal computers, smartphones, tablets, connected TV sets as well as various streaming devices that can be connected to a TV set. Many of these services are specialised for a particular type of content or target niche audiences.

The Internet is a more complex and dynamic environment than that of traditional broadcasting or IPTV. Whilst the main parts of the audiovisual value chain (content production, service aggregation, distribution, and reception) are the same as in the above described broadcast model, the main market players, business models, and the underlying technologies are different.

The prevailing on-line distribution approach is 'over-the-top' (OTT) where the AV media service providers do not own or control the distribution network infrastructure[13] and usually do not have any formal relationship with network operators. Instead, they make their services available on the open Internet and they are distributed to the users on a best-effort basis along with all other online services. The OTT model enables AV media service providers to address potentially large, indeed global, audiences without high upfront investments.

With respect to network infrastructure, the AV media service providers essentially have three possibilities to distribute their services online:

- Commercial arrangements with Internet service providers (ISP)
- Peering, e.g. direct connection to the Internet Exchange Point (IXP)
- Employing a Content Delivery Network (CDN)



Interconnection arrangements make it possible to use any of the three possibilities and reach all connected users. In reality, an AV media service provider would often use multiple ISPs and CDN providers, while direct peering with ISPs is less common.

Apart from AV media service providers, many different parties seek to 'own the viewer' including content aggregators, Internet outlet operators, ISPs, and consumer equipment manufacturers.

On-line content offer

The choice of online content is very large. Most established broadcasters, both FTA and pay-TV, now also offer on-line services as a complement to linear services. The 'catch-up' services provided by national broadcasters, both public and commercial, are amongst the most popular online AV media services.

Furthermore, telecom operators usually also offer AV media services (e.g. IPTV and VoD) which are often 'bundled' together with voice and data connectivity.

In addition, there is a large and growing number of 'pure' online AV media service providers. The most successful ones, such as Netflix, YouTube, Spotify, or Amazon, have adopted new and highly focussed business models that can scale up quickly and globally. This enables them to compete with the traditional broadcasters for audience attention and advertising funds.

The Internet has provided great new opportunities for the established AV providers to repurpose their content and make it easily available to the audiences. It has also allowed a large number of new entrants to enter the market. Some of them have achieved a global presence and have been successful in capturing a significant share of the value in their respective markets.

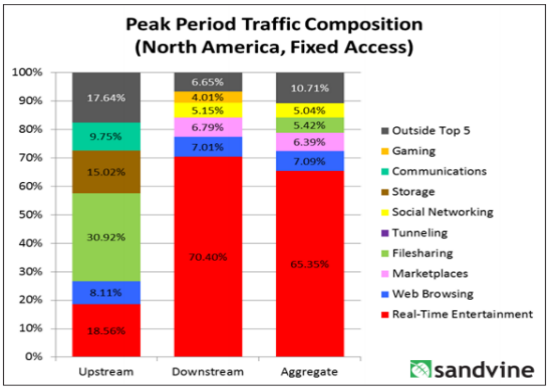
Nevertheless, most of the provisionally produced online content still comes from the established providers, such as the film industry and broadcasters, which are also the main sources of content on the traditional broadcast networks. The amount of the originally produced content by the 'pure' OTT providers has been relatively modest in comparison. This is particularly valid for the original European content[14].

[13] Large OTT providers of AV media services often invest in their own playout infrastructure, storage, or CDNs in order to retain a degree of control over the quality of service and the costs.

[14] According to the European Audiovisual Observatory, the proportion of European works is generally higher in linear TV programmes than in the online VoD catalogues. https://ec.europa.eu/digital-agenda/en/news/development-european-market-demand-audiovisual-services

The impact on the network infrastructure

AV media services tend to generate large volume of data and this places increased demands on the capacity in fixed and mobile broadband networks.



Global Internet Phenomena Report: Africa, Middle East, and North America
Sandvine: December 2015

The network operators need to make substantial investments in order to meet the growing demand, and these investments are not necessarily met by the corresponding additional revenues. This has been the source of ongoing disputes between OTT service providers and telecom network operators.

Access to online content

The users benefit from the large online offer especially as the content can be accessed from personal devices such as smartphones, tablets, and personal computers that usually cannot connect to broadcast networks.

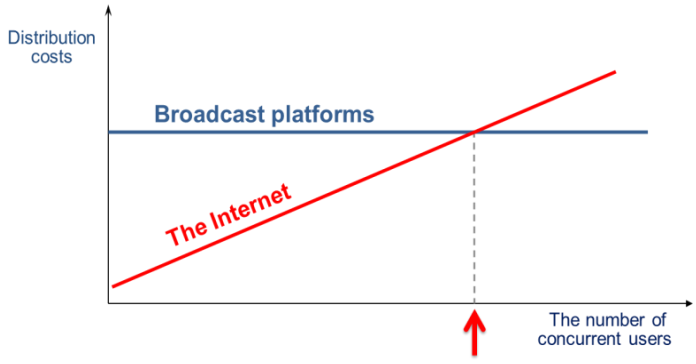
However, there is no free access to the Internet. Instead, it requires an on-going subscription and normally comes with a limited data allowance. Data caps on fixed broadband lines (where implemented), are in most cases sufficiently high and do not constrain the use of AV media services. The opposite is true on mobile broadband networks where the high costs and comparatively low data limits do not allow a substantial AV consumption, with some notable exceptions[15]. This is one of the reasons why the majority of traffic to mobile devices goes over Wi-Fi connections and fixed broadband, rather than mobile.

Once on-line, the users have a virtually unlimited choice of AV content and services. A large part of this service offer is provided to the users without additional charges and on a best-effort basis. Premium content is usually available only in exchange for some sort of payment.

Distribution costs

Distribution costs are one of the key parameters that influence the content and service providers' distribution strategies. On broadcast networks the costs are broadly determined by the size of the coverage area and the required quality of service but are independent of the size of audience.

The opposite is true on the Internet where distribution costs scale with the data volumes to be transported and the bandwidth available to the AV media service provider, which depend not only on the required service quality but also on the number of users.



Distribution costs as a function of the size of audience

[15] There are large difference between countries in terms of pricing of mobile data and the available data plans. For detailed market information see http://dfmonitor.eu/.

This means that the overall costs of on-line distribution are difficult to predict and any successful programme may cause the costs to escalate. Above a certain audience threshold these costs may become prohibitively high. The threshold depends on the type of broadband infrastructure, the service requirements, and the specific market conditions.

In general, if the audience is small then Internet distribution is less expensive than broadcasting. For large audiences it is the opposite. It should also be noted that costs considerations must be seen in relation to the benefits such as the market positioning, the possibility to reach the target audiences, and the achievable quality.

The actual distribution costs are specific to a business case, which is in turn influenced by a number of other key elements including technical capabilities and reach of different networks, regulatory conditions, relationship between different actors in the value chain, and the market environment.

Some information from the PSM organisations[16] indicate that, at present, the total costs of online distribution are several times higher per delivered viewing hour than the traditional broadcast TV distribution. This is one of the reasons why the online distribution of linear TV services is currently not viable on a large scale.

It can be expected that the overall online distribution costs for AV media service providers will decrease over time. However, it remains unclear if and when will they sufficiently drop to make the Internet a viable alternative to the traditional broadcast distribution.

1.3.3 Market trends

The audiovisual market place is increasingly complex. It is characterised by a vast choice of content and services, evolving user behaviour, and innovative business models. Some additional trends have ben identified that are likely to remain significant also in the 5G context.

Convergence

Convergence can manifest itself in different ways.

Service convergence has seen a range of different AV media services offered by the same provider. While the adoption of on-demand services continues to increase, the viewing has largely been additive to linear, although there are signs of some substitution in particular for younger age groups. Nevertheless, given the current rate of changes it can be expected that the distinction between linear and on-demand AV media services will remain relevant for a long time and that live TV viewing will represent a substantial part of the total viewing time for the foreseeable future.

Device convergence is a trend where the same device is used for different services. The best examples are personal computers, smartphones and tablets.

Network convergence occurs when the same network is used to provide different services. Broadband networks, both fixed and mobile, are capable of delivering AV media services but they currently do not scale well for large audiences. The reasons for that are both technical (i.e. the prevailing unicast mode) and commercial. Whilst broadband networks are currently not a viable substitute for the purpose-built broadcast networks, they may be increasingly important for the delivery of AV media services in the future, if their technical capabilities and economics continue to improve. However, a scenario where the same network infrastructure would serve the entire market (i.e. deliver all AV media services to all users in all situations) does not seem realistic in the foreseeable future.

It has also been suggested that 'bundling' of services, where AV media services are combined with communication services and offered to subscribers as a package, can also be seen as convergence at the retail level. Such 'bundles' are often attractively priced and well received by the users, thus help the operators to acquire and retain subscribers. However, they also potentially reduce the user choice and increase the barrier to switching providers.[17]

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[16] According to the recently reported figures from the Swedish TV, on-line delivery accounts for about 3% of the total viewing of STV programmes and carries 15% of the distribution costs. At the same time, 97% of the viewing is provided over broadcast networks and it corresponds to 85% of the total distribution costs.

The BBC reported in 2013 that, in terms of delivering on aggregate reach, traditional broadcast represents 98% of the BBC's viewing (either via scheduled broadcast or time-shifted via recording from scheduled), but only 87% of combined traditional/online distribution costs. Online distribution delivers just over 2% of the BBC's TV viewing, while the costs associated with delivery of the on-demand service is just under 12% of the BBC's total distribution bill. http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/review_report_research/vfm/distribution.pdf

[17] According to OECD: *'It should be noted that the development of these bundled offers could have a locking-in effect for entire households which would need to be assessed on a case by case basis. It seems that the*

Consolidation

Market consolidation can result in increased efficiencies and bring some consumer benefits. It has lowered the barriers to entry for new OTT entrants, can provide opportunities for the seamless delivery of audiovisual services and enable a more direct relationship with audiences.

Through market consolidation, the largest market players seek to extend their control both up- and downstream from their traditional roles in the value chain. The most relevant examples include:

- consolidation of AV content production companies
- horizontal consolidation in cable, telecom, or pay-TV markets
- mergers between telecom operators and pay-TV providers
- consolidation between telecom operators and OTT content and application providers

Despite its benefits, convergence also brings risks to AV media service providers – in particular in relation to gatekeeping.

Gatekeeping

The risk of gatekeeping mainly comes from two sides - the vertically consolidated companies, such as telecom operators which also act as AV media service providers in their own rights, and the Internet companies that act as intermediaries between service providers and the audiences.

Competition between network operators has brought about significant benefits for the consumers as they now have a wider choice of networks and AV content and services at differentiated price levels to choose from.

Broadcasters seek to be present on all relevant distribution networks and on-line AV platforms in order to reach their audiences. They can hardly afford not to do so as it would inevitably lead to the loss of audience and market share. However, with market concentration the influence of the large vertically integrated companies grows which substantially limits the negotiating power of AV media content and service providers vis-à-vis such network providers.

Gatekeeping behaviour is also evident in other areas, such as the ISP interconnection market, content aggregation, management of application stores, and control of the user interfaces on connected TV sets, smartphones, and tablets.

The key concern is that strategic objectives of the powerful gatekeepers may not be aligned with European public policies. In particular, PSM providers are unable to compete on commercial terms with the large international and global players.

Network capacity

Scarcity in the transmission capacity of the traditional broadcast networks gave rise to competition between AV media service providers for access to these networks and the competition between broadcast networks for access to the viewers and listeners. This competitive dynamics is still relevant but it is changing the growth in online distribution which is competing with the traditional broadcast networks.

Technological developments allow for the capacity of all distribution networks to increase and this potentially reduces scarcity. Indeed, the adoption of digital transmission technologies in broadcast networks has led to an increase of their capacity by an order of magnitude compared to the analogue. This has enabled both a substantial increase in the number of available services and a better technical quality (e.g. HDTV and UHDTV). Access to network capacity in broadcast networks is uncontended.

In broadband networks that operate in a unicast mode capacity is shared (contended) between concurrent users.[18] This manifests as scarcity of network capacity when the quality of service deteriorates with the increase of the number of simultaneous users. The impact on AV media services may be aggravated because they require a sustained and comparatively high bitrate, in particular when offered in HD or UHD quality.

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development of bundled offers in the telecommunications sector is a growing trend in the EU and it is necessary for competition authorities to take account of the impact it may have on telecommunication markets.' See OECD Policy Roundtables, Competition Issues in Television and Broadcasting, 2013, page 94, http://www.oecd.org/daf/competition/TV-and-broadcasting2013.pdf

[18] With the exception of the last mile in wired broadband networks where a dedicated connection is provided from each household to a street cabinet.

Increased network capacity has thus not completely solved scarcity issues, but has partly transferred these from the broadcast to the broadband domain. Furthermore, scarcity is not just a technological issue but also an economic issue. It can be artificially created or maintained. It depends on power relations in the market and on companies' willingness to invest in capacity. This issue is in the core of the on-going discussions on network neutrality.

Global competition[19]

Traditional broadcasters mostly operate within national markets. Even the international broadcasters often tailor their programmes to national or regional audiences. Competition was largely limited to the national or regional/local level and it was stimulated by the availability of multiple broadcast delivery networks. Audiovisual policies are embedded in the corresponding regulation and this includes support to prominent public service media and sustainable funding of the original content.

This market context is now increasingly under pressure from global online players whose scale and resources are unmatched by most European broadcasters. They are increasingly competing not only for viewers' attention and spend but also for programme producers and on-screen talent. This is also evident from the fact that the stock performance of "new media" companies like Netflix and Amazon have been outperforming those of major traditional media and broadcast companies. This poses a risk that potential financial weakness of the current broadcast ecosystem could have a serious impact on European TV production.

1.4 Public Service Media (PSM)

Public Service Media includes radio, TV and online AV media services, whose main purpose is to serve the general public. Through PSM, citizens are informed, educated and also entertained. PSM should be free from political interference and pressure from commercial forces. When pluralism, programming diversity, editorial independence, appropriate funding, accountability and transparency of PSM are ensured, it can serve as a cornerstone of democracy.[20]

In Europe and many other parts of the world, PSM organisations are also market players that coexist with commercial AV media service providers and compete with them for the attention of the audience.

The status and obligations of PSM are regulated by law. Some of the key PSM obligations include providing AV content for all members of the society and delivering it without additional charges[21]. This obligation can only be fulfilled if PSM content and services are universally available and prominently placed so that they are easy to find and use.

This is why PSM need to use a variety of different means to deliver their services, including both broadcast and broadband networks, to a range of devices, from large TV sets, home and car radio receivers to personal computers, tablets and smartphones, and a host of streaming devices.

As not all distribution methods are equally suitable for all services and not all user devices come with the same capabilities, this may result in some cases in poor user experience. Like the commercial AV providers, PSM providers seek to ensure the desired availability and quality of services in order to meet the user expectations.

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19 Competition issues in TV and broadcasting were the main topic of the 2013 OECD Global Forum on Competition. Submitted documents and a synthesis of the debate are available at http://www.oecd.org/competition/competition-television-broadcasting.htm

20 Further information on PSM can be found for instance on:

http://portal.unesco.org/ci/en/ev.php-URL_ID=1525&URL_DO=DO_TOPIC&URL_SECTION=201.html

21 In most cases PSM is publicly funded, e.g. via a compulsory license fee. In return, content and services are made available to the public without additional payment to the PSM provider.

PSM services are available free-to-air on terrestrial broadcasting networks and in some cases on satellite networks, although satellite signals are usually encrypted in order to comply with content rights (in which case the viewers need to obtain a decryption equipment but there are no recurring charges). On cable TV networks PSM services are often subject to the *'must-carry'* rules.

PSM content is sometimes also available via pay-TV and is normally included in a basic subscription package. Consequently, by choosing to take a pay-TV subscription the user will have access to PSM content and services without additional charges.

For on-line access to PSM content the users need to have a suitable Internet connection, for which they normally pay subscription to an ISP, but do not need to pay to PSM providers for access to content.

However, PSM organisations also have a number of additional requirements that stem from their public service remit and apply across all distribution options. These requirements address both technical non-technical issues, such as:

- The ability to provide content and services free of recurrent charges (e.g. free-to-air)
- The ability to deliver content to the public without blocking or filtering, i.e. no gatekeeping
- Content and service integrity - no modification of the PSM content or service by third parties. AV content and additional services (e.g. subtitles, HbbTV user interface) must be displayed on screen unaltered and without unauthorised overlays.
- PSM shall not be subject to discrimination compared to equivalent services.
- Quality of service (QoS) to be defined by the PSM provider, including service availability, robustness, and reliability.
- QoS for each user shall be independent of the size of the audience.
- Geographical availability of the service (e.g. national, regional, local) is to be defined by the PSM.
- A distribution network needs to support at least a minimum service offer (e.g. a minimum number of programmes) as defined by the PSM provider.
- Ease of use - straightforward accessibility and prominence of the PSM offer.
- Low barrier for access to PSM content and services for people with disabilities (e.g. provision of subtitles, audio description and signing).
- The ability to reach audiences in emergency situations

The above mentioned requirements are generally met by the broadcast networks and to a lesser degree in case of online distribution.

A number of risks have been identified that may significantly impact the effectiveness of PSM in the online environment where it is generally harder to sustain their visibility, in particular:

- The prominence rules for PSM do not apply online. Instead, a tendency is for the intermediaries to trade prominence for payment (e.g. position in search results, on-line portals, app stores, opening screens, user interfaces, programme guides, and recommendations)
- Reduced access for PSM to their audiences. Audience data is collected by a telecom operator or an OTT service or application provider who increasingly seek to monetize it. A PSM provider may be denied access to audience data or may be required to pay for it.
- Wide availability and breadth of PSM content and services may not be sustainable because of the high associated costs. This may lead to PSM being forced to divert investments in content to pay for carriage.
- The commercial interests of online service providers may not be aligned with the general interest objectives. They may be incentivised to favour their own content or other revenue-generating content, sometimes at the expense of making PSM content easily accessible.
- Globally negotiated content deals with no regard for the local or European content.

Another concern is a possible disruption of funding mechanisms for the European content production which is closely linked to the existing broadcasting model. No such link currently exists between the online AV market and the investments in the European content. The large international online providers source most of their content outside Europe (e.g. in the USA) and their commercial objectives may not be guided by the European audiovisual policies.

If the above mentioned concerns could be addressed in the 5G ecosystem, this would make the online environment more PSM-friendly than it is today.

1.5 Public policy and regulatory requirements

Audiovisual works encompass particular values, identity and meanings that very often go beyond their strictly commercial value. They play a central role in democratic societies, informing citizens, shaping public opinion and offering a window to the world. This justifies the application of specific rules to those services that aim to bring AV content to the audiences.

But audiovisual content and services also generate substantial economic value and are traded on the open market. The European cultural and creative sector generated in 2013 over $700 billion in revenues and provided 7.7 million jobs. Revenues of the TV industry alone were around $130 billion[22].

[22] *Cultural times - The first global map of cultural and creative industries*, EY, December 2015, http://www.worldcreative.org/

Provision of AV media services is subject to regulation in a number of different areas, such as:

- Sector-specific regulation (e.g. AVMS Directive)
- Law on Public Service Media
- Telecom regulation
- Copyright law
- Competition law
- E-Commerce regulation
- Consumer protection
- Privacy and data protection
- Network neutrality

Any substantial presentation of these legal and regulatory domains would exceed the scope of this paper. Nevertheless, as technology neutrality is a fundamental principle of the EU legislation, it is assumed that the above mentioned legal instruments will also apply in the 5G context, as appropriate.

The regulatory regime will continue to evolve in order to keep pace with technological and market developments, including those fostered by 5G. Otherwise, there is a risk that the general interest policy objectives, in particular those that are outlined in the EU Audiovisual Media Services Directive (AVMSD) [23] may be undermined.

The AVMSD lays down a basic set of rules which aim to guarantee key societal values and apply to all audiovisual media services. It covers both broadcast services and on-demand audiovisual media services. The AVMSD does not apply to content hosted by online video-sharing platforms and intermediaries. These platforms and intermediaries, which play an increasingly important role, are regulated primarily by the EU eCommerce Directive.

The overarching objective of the AVMSD is to create a single market for audiovisual media services whilst ensuring at the same time a high level of protection of objectives of general interest, inter alia the protection of minors and human dignity as well as promoting the rights of persons with disabilities. The AVMSD's main objective is articulated into a number of more specific objectives:

- Ensure a level playing field for emerging audiovisual media services;
- Strengthen the single market and guarantee conditions of fair competition;
- Strengthen the competitiveness of the European audiovisual industry and promote European audiovisual content;
- Protect and empower consumers (audiences), in particular minors and people with a visual or hearing disability;
- Contribute to the support of cultural and linguistic diversity and heritage in Europe;
- Safeguard media pluralism, freedom of expression and information.

The AVMSD provides for a minimum harmonisation of certain aspects of national legislation related to audiovisual media services. The Member States can apply more detailed or stricter rules to providers under their jurisdiction, as long as those rules are consistent with the general principles of EU law.

The AVMSD is based on the principle of technological neutrality: rules apply to providers of audiovisual content irrespective of the screen on which the content is watched (TV, PC, tablet, etc.). This contributes to achieving a level playing field and fair competition regardless of the technologies used[24].

5G should also be able to accommodate the requirements of the Public Service Media, in particular with regards to availability and prominence, which are also subject to specific regulation.

Another area of general interest is the provision of information to the public in times of emergencies, including natural and man-made disasters. The requirement is in many countries placed on broadcasters and relies on terrestrial broadcast infrastructure which in turn has to meet high reliability and resilience requirements.

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[23] Directive 2010/13/EU of the European Parliament and of the Council of 10 March 2010 on the coordination of certain provisions laid down by law, regulation or administrative action in Member States concerning the provision of audiovisual media services (Audiovisual Media Services Directive) http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0013

[24] The Directive is currently being assessed under the Regulatory Fitness and Performance Programme (REFIT) of the Better Regulation Framework in order to evaluate its overall functioning in the light of recent developments of the market, technology and consumption patterns. The output of the REFIT evaluation will provide input for the impact assessment on policy options for the future revision of the AVSMD. See: https://ec.europa.eu/digital-agenda/en/audiovisual-media-services-directive-avmsd#Article

2. How can 5G be a catalyser for AV media services?

As recognised by the METIS consortium[25], 5G's main contribution are developments and improvements of the infrastructure on which new applications can be built. It is these new applications which have the potential to transform entire industries and the society as a whole. This is particularly true for AV media services where the content is the main driver and the technology is a key enabler.

5G has a potential to make a difference across the whole audiovisual media value chain, including content production, distribution, and the user environment. Furthermore, the broad support that 5G enjoys by the industry and policy makers alike could facilitate a better integration of broadcast and broadband technologies and the alignment of their respective standardisation roadmaps (e.g. between DVB Project and 3GPP) with regard to the technologies that support AV media services.

2.1 Content production

Decentralised production

Most of the content production is nowadays concentrated either in dedicated facilities such as radio and TV production centres and film studios, or in particular venues such as sport arenas, theatres, and concert halls. These locations are equipped with the specialised production equipment and connectivity infrastructure in order to support the production workflows. Whilst in some cases all stages of content production can happen under the same roof, it is quite usual for different stages to be carried out in different places and at different times. Transfer of content between different locations is done by means of dedicated high capacity links (e.g. fibre, satellite, or microwave).

While the on-site production may have some operational advantages, there are situations where it is beneficial to have a decentralised or remote production workflow, i.e. where different stages of the production are carried out seamlessly across different locations.

Remote production is currently constrained by technical factors but also by the cost and availability of the required bandwidth. Technical constrains include latency (both communication and encoding delay), synchronisation between different signals and reliability, in particular if IP networks are used.

Bandwidth requirements for a mid-size production can easily get into the range of several Gbit/s[26]. This is easily achievable on-site (e.g. by laying out optical fibre connections), but remains a challenge for the remote production configuration. This level of bandwidth capacity is currently available only in limited areas and the costs are often prohibitively high.

The stated 5G performance targets suggest that the future 5G infrastructure could facilitate a distributed production of AV content, provided that the specific technical and availability requirements are met and that the costs are sustainable.

Outdoor production and exceptional events

High-quality production outside such locations requires special arrangements to be made for bringing the feeds to the production centre. Such arrangements normally require specialised production equipment and crews to be temporarily deployed on an external location (e.g. for the duration of an event) in addition to those in the production centre. Production of large and exceptionally complex events can be particularly challenging. [27]

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[25] METIS Final Project Report, https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D8.4_v1.pdf

[26] For example, an uncompressed signal from a single camera requires a sustained throughput of 100-150 Mbit/s. Multiple cameras are used in most production and, depending on the size and complexity of the production, the number of cameras could be 10-20 or even more. Thus, the total bandwidth requirements could be up to several Gbit/s for HD quality production. An Ultra-HD signal requires 400-600 Mbit/s per channel and the total bandwidth requirement may be in the order of 5-10 Gbit/s.

While the required bandwidth can be reduced by compressing the signal before transmission, this introduces additional latency and potentially impairs the quality. Therefore, there is a trade-off between bandwidth, latency, and quality requirements.

[27] A particular category of wireless devices and applications, both audio and video, for programme making and special events (PMSE) is addressed in details in the ECC Report 204: *Spectrum use and future requirements for PMSE*, February 2014, http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP204.PDF

If all feeds could be brought back to the production centre via the existing communications networks, instead of having to set up dedicated links on a temporary basis, this would be beneficial for content producers. They would have more flexibility while potentially reducing the deployment time (which may be especially important for some types of live production, e.g. breaking news) and costs (as there would be fewer people and less equipment to send out).

With the improved capabilities compared to the existing wireless broadband networks, 5G could enable some use cases for outdoor programme production (e.g. news gathering, interactive talk shows). As in the case of remote production, besides the technical requirements, 5G would need to meet the production requirements on quality of service, throughput, latency, coverage, availability, and costs.

2.2 Distribution of AV media services

Distribution networks and online distribution platforms are an essential part in the AV value chain whose main purpose is to bring the content to the users. In doing so, they have to meet both the user expectations and the requirements of the AV media service providers.

Users expect content to be available across different devices and access networks. They enjoy both the shared experience of watching TV together with their friends and family on a large screen and the convenience of watching individually on portable devices, in the home and on the move. They value choice and they are price-sensitive. The key trends point towards increased quality and personalisation but also those features that are pertinent to the user context and contribute to the overall experience (e.g. the user interface, content discovery features, overall ease of use).

The AV media service providers seek to deliver the best user experience they can, but in a sustainable way. There are a number of different distribution options to choose from. The choice of a particular option will be largely determined by its technical capabilities, reach, costs, and the ability to ensure prominence of the content and services.

At present, no available distribution mechanism is capable of serving all use cases[28]. Broadcast TV networks are optimised for the delivery of live TV services to stationary receivers and, combined, ensure near-universal availability, and guaranteed quality. Currently, their main drawback is the inability to reach personal devices (e.g. PCs, smartphones and tablets) and to deliver on-demand services. However, there are on going efforts to address the traditional limitations of broadcasting networks and extend their capabilities to serve new AV media consumption use cases. These are for example recommendations made in a DVB's recent report.[29]

Broadband networks are suitable for on-demand services and can reach personal devices, but operate on a best-effort basis which cannot guarantee the minimum required quality across the whole coverage area, in particular for live TV services. Furthermore, the costs of a broadband delivery of AV media services to very large audiences, in particular over cellular broadband networks, are substantially higher than over broadcast networks.

It is expected that the capacity requirements for the distribution of AV media services and the user expectations on choice, quality, and convenience will continue to increase. At the same time, it is unlikely that the users' willingness to pay will substantially increase for the foreseeable future. The challenge is to find a sustainable way of meeting the future AV distribution requirements within these constraints.

5G could make a difference at least in two different ways:

- as a new option for distribution of AV media services in its own right, and
- as an enabler of cooperative use of broadcast and broadband technologies.

These two options are complementary, rather than mutually exclusive.

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[28] A more detailed treatment of the available distribution options is provided in section 4.2 below. Further information can be found in the following references:
- IDATE, *Advanced TV services for all, available now with Hybrid Broadcast Broadband TV solutions,* http://www.eutelsat.com/files/contributed/news/media_library/brochures/Hybrid-TV-White-Paper-iDate-Eutelsat-Orange.pdf
- EBU Technical Report 013 https://tech.ebu.ch/docs/techreports/tr013.pdf

[29] DVB Report: *A Long Term Vision for terrestrial broadcast*, November 2015, www.dvb.org/resources/public/whitepapers/cm1621r1_sb2333r1_long-term-vision-for-terrestrial-broadcast.pdf

The first option implies that 5G will have to compete with the legacy distribution options and their future incarnations. However, with the vastly superior technical capabilities (e.g. an order of magnitude better than 4G) and the substantially lower costs, 5G could enable a range of new use cases and business models that may not be possible on the alternative networks. Increased competition would result in further benefits. The main challenge for the 5G infrastructure would be to achieve the necessary coverage and reach.

The second option leverages on the combined strengths of broadcast and broadband networks which are complementary, i.e. the strengths of one correspond to shortcomings of the other. The current hybrid solutions (e.g. HbbTV) combine broadcast and broadband delivery in the TV receivers, but further integration of the two approaches at the network level and in the user devices would be desirable (See also section 4.2.3 on Hybrid delivery solutions) to enable wider synergies.

Cooperative use of broadcast and broadband networks could be beneficial to many stakeholders in the AV media value chain:

- Content and service providers would have a better opportunity to reach their audiences in a coherent way, e.g. with a consistent quality across different devices and services. They would also be able to tailor their distribution approaches to the requirements of a particular service and the target audience (e.g. large audiences may be better served via broadcast networks, whereas niche audiences could be better served on-line), dynamically adapt to the network conditions (e.g. avoid the fully loaded or congested segments of a broadband networks by sending the traffic over broadcast networks), and would be able to implement consistent audience metrics across all networks. This would be possible without a substantial increase of the distribution costs.
- Fixed and mobile network operators would be able to cost-effectively provide an extended range of services with an improved quality and coverage but without the need for substantial capital investments in network expansion. At the same time they would be able to offload a significant portion of the traffic onto broadcast networks[30] and reduce the risk of congestion.
- Broadcast network operators could expand their business models beyond the mere transport of linear services. As some broadcast network operators also own and operate cellular mobile towers they may be able to achieve further operational efficiencies.
- Equipment manufacturers would benefit from the economies of scale brought about by the combined broadcast and broadband markets.
- The users would benefit from improved services but without the increase of costs. Furthermore, a disruptive impact on the viewers of the changes to broadcast transmission networks (e.g. to introduce a new transmission or compression system) could be reduced or eliminated.
- New types of services, including personalised and cross-platform services (e.g. content or service selection on one platform or device would be accessible via other platforms or devices) could be provided quickly, thus leveraging on the already available infrastructure.
- The network infrastructure and the radio spectrum could be used more efficiently.

There may be many other synergies that are yet to be explored.

This concept of broadcast - broadband integration is a possible extension of the 5G-PPP vision of a unified telecom and IT infrastructure where '*telecom and IT will be integrated towards a common very high capacity ubiquitous infrastructure. In order to assure the required scalability and flexibility, the network functions will be more and more "virtualised" on general purpose, programmable and specific high performance hardware that will offer resources for data transport, routing, storage and execution.*'[31]

Further efficiencies could be achieved if such an integrated telecom/IT infrastructure is also interoperable with the dedicated AV distribution networks, whether broadcast or broadband. This would allow flexible and seamless delivery of AV content and services across all available distribution networks to all user devices, which is not possible as long as different distribution networks operate entirely independent from each other.

5G could facilitate a more personal and immersive experience for the user, by facilitating the delivery of object-based broadcasting. This is the concept of delivering the individual elements of a programme

[30] The offloaded traffic could include not only the linear AV media services, but also other types of traffic such as software updates, push VoD, and pre-loaded popular content.

[31] 5G-PPP: 5G Vision brochure, https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

to the user's device separately, using different delivery mechanisms such as unicast or broadcast, as appropriate. These separate elements are then seamlessly integrated and rendered on the end device in a way that can take account of the environment, user preferences and the device's own capabilities.

This has the potential to create completely new experiences around content being more immersive, personalised, interactive and accessible. For example, a user could choose the level of immersiveness depending on whether they are using headphones or home speakers to listen to a programme, accessibility features such as adjusting the sound level in relation to background noise or making a programme more interactive by allowing the selection of a viewpoint within a stadium in the case of a sports broadcast.

2.3 Audience data and analytics

Access to audience data is one of the essential requirements for all AV media service providers[32]. A capability to collect and process user data, both in real-time and non-real-time, is required for a range of innovative AV media services, for example:

- Provision of content to the users in the right format, depending on their location, device, user interface, type of service, and the distribution network
- Personalisation of audiovisual services
- Advanced content discovery and recommendation systems
- Companion screen applications
- Quality measurements in order to ensure the best possible user experience
- Service following across different distribution options and user devices
- Quality on-demand (e.g. the basic quality is provided to all users, and higher quality only to those who demand it and have the necessary equipment
- Hybrid and cross-platform services

Access to user data and the appropriate analytics are also required for a number of different decisions in the business context, such as:

- Advertising, in particular delivering targeted and contextual advertisements
- Content protection against unauthorised access and piracy
- Traffic routing and load balancing policies to optimize performance and costs
- Decisions on future investments in content and programming, depending on the observed trends
- Decisions on future service development, depending on user preferences or behaviour

Given the privacy concerns, coherent and transparent solutions for personal data protection and security are required in conformity with the EU General Data Protection Regulation (GDPR)[33] modernising Directive 95/46/EC, the centrepiece of EU legislation on personal data protection, and with the e-Privacy Directive[34]. Such solutions should be inherent to the 5G design.

Audience data collection and processing require substantial processing and storage capabilities. The supporting infrastructure must ensure high reliability and low latency especially for the real-time data analytics which is delay-sensitive.

It is expected that 'big data services' will be an important area of growth for both the established AV content and service providers and the new entrants. Furthermore, new businesses are being created that are mostly or entirely based on audience data analytics. 5G could be an important enabler of this growth.

2.4 Standardisation

The development of mobile and broadcast technologies has traditionally followed parallel paths. As mobile broadband technologies are increasingly capable of carrying AV content and services, they have opened up new opportunities for both service providers and users.

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[32] See for example Videonet: *Boosting television prospects with enriched data analytics*, January 2016, http://www.v-net.tv/system/files/ARRIS%20report%20for%20upload%201253.pdf

[33] http://ec.europa.eu/justice/data-protection/reform/index_en.htm

[34] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al24120

One of the consequences of the take-up of AV media services has been that mobile networks are strained under a rapidly increasing traffic load. The network operators are faced with the need for substantial investments in network capacity, often without a certainty of corresponding revenues. They have recognised the need to adopt multicast and broadcast approaches, in addition to unicast, in order to benefit from technical and economic efficiencies that can be achieved.

In doing so, the mobile technology developments have not been taking advantage of the existing broadcast infrastructure, nor are the mobile standards interoperable with the dedicated broadcasting standards.

As broadcast and wireless broadband systems remain mutually incompatible, this leaves service providers, equipment manufacturers, and consumers in the situation where they have to deal with separate technologies and networks. This results in market fragmentation and the increase in distribution costs for the AV media service providers. In the event that this would change, i.e. if broadcast and mobile networks were made interoperable and interconnected, further market fragmentation could be avoided and new opportunities could arise.

Moreover, the recent research activities and the ongoing work in 3GPP, the DVB Project, and ATSC, respectively, indicate that there is an increasing degree of commonality between broadcast and mobile systems in terms of the core technologies included in the specifications[35], the range of AV media services they seek to enable, and the market segments they target.

There is a growing recognition within the AV media industry that new, sustainable delivery mechanisms are needed which will be able to meet the future needs of consumers, content producers, service providers, and network operators, as well as the regulatory requirements. This can only be achieved if the stakeholders across the AV value chain work together.

As the 5G developments enter the standardisation phase, there may be an opportunity to align the respective 3GPP and DVB roadmaps as regards their work on the technologies for AV media services. 5G could provide a unifying framework for the evolution of the existing AV networks and foster their technological convergence in the long term. This would help to reduce market fragmentation and the impact of the legacy situation which otherwise might hinder the transition to 5G.

In addition, this would further facilitate the virtuous circle between technology, content, and services. AV media services have been a key driver of the initial broadband take-up and of the development of innovative on-line business models. They could play a similar role in the adoption of 5G.

[35] See for example: Walker, G.K. (Qualcomm Technol. Inc.) and others: *Relationship Between LTE Broadcast/eMBMS and Next Generation Broadcast Television*, IEEE Transactions on Broadcasting, Vol.60, No.2, June 2014, http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6823652

3. Technical requirements for AV media services

For the purpose of developing technical requirements for 5G infrastructure to support AV media services the following definitions are adopted:

- *Network coverage* is a geographical area within which an AV media service can be provided with a sustained minimum required quality to all users. Coverage requirements are usually defined with respect to a particular location of the user device (indoor or outdoor), mobility (stationary, portable, low or high mobility), and the type of receiving antenna (e.g. fixed aerial at the roof level, external portable, or integrated antenna).[36] The required coverage for AV media services could be local, regional, nation-wide, or international. Coverage requirements are based on both commercial considerations and regulatory requirements, in particular for the PSM.
- *Throughput* is a sustained data rate between the server and the user device that needs to be provided to each user. A minimum required throughput depends on quality requirements for a given service (e.g. picture format, bit error rate) taking into account the applied compression standard. For illustration, the required throughput for distribution of an SDTV programme with H.264 coding is in the order of 1-2 Mbit/s per channel, whereas an Ultra-HDTV/4k with HEVC coding would need 15-30 Mbit/s per channel, depending on the type of content (e.g. live sports may require significantly higher throughput than pre-recorded drama or films). Throughput requirements for distribution of audio services are much lower (100-200 kbit/s per channel). In the content production environment the throughput of 100 Mbit/s or more per video channel is typical.
- *Bit error rate* is the ratio between the number of erroneous bits registered at the receiver and the total number of bits transmitted from the server within a given period of time. The bit error rate for AV media services has to be kept within predefined limits, meaning that after decoding of the incoming signal in the receiver, a maximum allowable bit error rate shall not be exceeded. The typical requirement for stationary reception of linear TV is a bit error rate of 10^{-11} and for radio a bit error rate of 10^{-4}. These values are referred to as '*quasi error free*' criteria. [37]
- *Latency* is the time delay from the moment a data packet is generated at the source application to the moment it is received by the terminal device. There are large differences between AV applications in terms of maximum tolerable latency. For example, the latency of a radio microphone used in a live performance should not exceed 3-4 ms. In the TV production the latency could be in the order of 30-200 ms, while in distribution the latency of up to several seconds can be tolerated.
- *Jitter* is the variation in latency, when in a packet flow some packets take longer to be delivered then other. Jitter is mainly caused by network congestion and route changes. Although in most cases AV media services can tolerate a certain amount of latency, they are more sensitive to jitter which needs to be kept to a minimum.
- *Time synchronisation accuracy* is the degree to which different signals that are part of the same service are time-aligned (e.g. audio, video or other components of the TV service). High time accuracy is required in content production for the so-called 'clean switching' between signals coming from different sources. The most stringent requirements for synchronisation of video sources require each video frame to be time-stamped with 10 µs precision. Audio sources require even better synchronisation accuracy and the target precision is 1 µs. In distribution of AV media services synchronisation is important when receiving simultaneously across different devices (e.g. multi-screen services and applications).
- *Traffic asymmetry* between uplink and downlink traffic. In the case of content distribution traffic is highly asymmetrical with downlink traffic substantially higher than uplink traffic. In content production the traffic may be more balanced or even the asymmetrical in the opposite sense, i.e. the traffic on the uplink may be larger than on the downlink (for instance if an output from a video camera is carried on the uplink and a control signal or a service link on the downlink).

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[36] See also section 4.2.2 for a definition of '*application coverage'*. In addition, radio network planning issues for mobile broadcast networks are elaborated in the BMCO paper *Mobile Broadcast Technologies - Link budgets* (http://www.oipf.tv/oipf-bmco.htm). A list of relevant parameters for LTE eMBMS network studies is provided in the EBU Technical Report 34 (https://tech.ebu.ch/publications/tr034) which was jointly produced between the representatives of broadcast and mobile industries.

[37] In the case of streaming audiovisual content over the Internet, the bit error rate may not be the proper parameter to describe the quality of the delivered signal. Actually, there are currently no commonly agreed criteria for the picture quality for on-line delivery of AV media services, which makes any quality assessment highly subjective. One candidate is the ESR_5 criterion which means no more than 1 erroneous second within any period of 20 seconds (i.e. <5% of the time). Any noticeable picture artefact is considered to be an error.

Two broadly defined but distinct families of AV use cases are *content production* and *service distribution*. These are addressed separately in the clauses below.

3.1 Technical requirements in AV content production

In content production the connectivity requirements include *very high throughput, low latency*, *deterministic network behaviour,* and high *time synchronisation accuracy*. In addition, it is essential to ensure a *reliable access to the network* by the production teams, and a sufficient redundancy for mission critical applications (e.g. live production for large audiences).

Coverage requirements are less critical for distributed/remote production use cases where it is important to provide the required capabilities at specific locations and between them. However, wide area coverage is very important for electronic news gathering and outdoor programme making.

A typical PMSE[38] application is a hand-held camera with a microphone, where the cameraman may operate indoors, outdoors, or even airborne. Wireless connection to the nearest hub (e.g. a production vehicle, or the studio) is preferred as it substantially reduces the complexity of operation, deployment time, costs, and safety hazards. Key prerequisite is a high-quality, reliable (guaranteed quality of service) connection and sufficient throughput. Today's wireless cameras often come with their own radio link which provides throughput up to 30-40 Mbit/s and may cover the distance of up to 2 km. The target for the new generation of radio links on a wireless camera (still in development) is 120 Mbit/s which would enable transmission of a lightly compressed UHDTV/4k signal.

3.2 Technical requirements in AV service distribution

Distribution of AV media services poses a different set of requirements on the infrastructure, as follows:

- *Coverage requirements*: A coverage area (sometimes also called service area) should be defined by the AV media service provider. For PSM services the coverage area is normally part of the PSM remit and may be defined in the relevant regulation. A particular area is considered covered if anywhere within that area all technical requirements for a given AV media service are met and, as a result, the service can be received by all users, irrespective of their number.

  The required geographical extent of the coverage could be local, regional, nation-wide, or international. Coverage criteria could be defined for indoor or outdoor reception, for stationary or mobile conditions, and for different types of receiving device and the type of receiving antenna (e.g. fixed aerial at the roof level, externally connected portable antenna, integrated antenna).

- *Throughput requirements* depend on the type of service, the desired quality level, and the compression standard. Higher picture quality will require a higher throughput, while a more efficient signal compression will reduce the required throughput. For example, a live HDTV service with the H.264 compression standard requires around 8 Mbit/s[39] while the same content encoded with the more efficient HEVC standard will require around 4 Mbit/s.

  Another important requirement is that the required throughput must be provided to each individual user. While this requirement is not an issue in broadcast and multicast networks, it presents a challenge in the best-effort unicast networks in the case of large concurrent audiences. Furthermore, in densely populated areas AV media services may cause a very high traffic density and asymmetry in the networks.

- *Bit error rate requirement:* A typical requirement for stationary reception of linear TV is bit a error rate of 10^{-11} and for radio a bit error rate of 10^{-4} ('quasi error free' criteria).

[38] The term '*Programme Making and Special Events*' (PMSE) describes radio applications used for SAP/SAB, ENG/OB and applications used in meetings, conferences, cultural and education activities, trade fairs, local entertainment, sport, religious and other public or private events for perceived real-time presentation of audio/visual information. See ECC Report 204 http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP204.PDF.

[39] This is an average value. For live sports the required throughput will be higher (e.g. 10 Mbit/s or more) while for a more static content (e.g. a talk-show in the studio) perhaps 5 Mbit/s would be sufficient. For non real time content, such as films or drama, further efficiency can be obtained by multiple encoding algorithms, resulting in a lower required bit rate. This is one of the reasons why for example Netflix, whose content mainly consists of films and TV series, recommends 5 Mbit/s throughput for HD quality. Multiple encoding algorithms are not practical for live content because they introduce an unacceptably long processing delay.

- *Access control* is required for subscription based services and where access to a particular service has been restricted to a given territory for the reason of content rights. Access control includes mechanisms for subscriber authentication and needs to ensure protection of user data and user privacy, as well as the cached content.
- *Free-to-air delivery* is important for both PSM and commercial service providers. In most countries PSM providers are required by law to make their services (either some or all of them) universally available, free-to-air and without recurring charges for the users.
- *High network reliability* is needed in order to be able to meet the user expectations but also to ensure that the same distribution infrastructure can be used in emergency situations.
- *Content protection* mechanisms need to be implemented without undue restriction of content availability. Furthermore, AV media service providers must be able to retain control over provenance, confidentiality and content and signal integrity in order to avoid unauthorised changes or overlays.
- *Network sharing requirement:* In countries with multiple mobile network operators (which is the case in all EU member states) it may be more efficient to distribute popular AV media services, such as live TV, only once and make them available to the subscribers of all operators and their roaming partners, instead of each operator distributing the content on it own.
- *Heterogeneity requirement:* The available network infrastructure, whether fixed, cellular mobile, terrestrial broadcast, or satellite networks, should be used in a flexible way in order to provide the best possible connectivity while maximising the technical and cost-efficiency.

  Better integration of broadcast and broadband technologies is required in order to enable dynamic and seamless switching between different means of distribution in a heterogeneous environment, depending on service requirements, audience behaviour, and business objectives.
- *Flexibility and scalability* of the distribution means in order to enable the AV media service providers to optimise their distribution strategies and business practices.
- *Access to audience requirement:* A distribution mechanism should enable gathering, storing, and processing of audience data, both in real time and non-real time, and should enable AV media service providers to exercise full control over the data pertinent to their audiences. 'Big data' analytic technologies should be enabled.

3.3 Overview on the relevant 5G capabilities

5G performance requirements are currently considered in various fora such as 5G-PPP, ITU, 3GPP, and NGMN[40]. The following targets, among others, are often considered in ongoing discussions:

- high throughput (peak data rate 10 Gbit/s or more, guaranteed user data rate 50 Mbit/s)
- low latency (as low as 5 ms end-to-end, 1 ms on the radio link)
- high service reliability (e.g. 99.99% or more)

Some important capabilities of the new technology are non-quantitative, including:

- flexibility and scalability
- ubiquitous access to applications and services
- substantial improvement in network capacity
- heterogeneous, multi-RAT environment with seamless handover
- support for terrestrial and/or satellite communication
- open ecosystem for technical and business innovation
- substantial reduction of costs relative to data rate and data volume

All of these capabilities will be important to support the production and distribution of AV media services. Above and beyond the above mentioned capabilities, 5G networks will need to be able to meet the specific requirements of AV media services. It is not feasible to specify these requirements in any considerable detail.

[40] This list of key 5G capabilities is considered to be relevant for audiovisual media services. It is non-exhaustive and has been extracted from the following references:
- 5G-PPP: 5G Vision brochure, https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf
- NMGN 5G White paper, https://www.ngmn.org/5g-white-paper.html
- Recommendation ITU-R M.2083, http://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf
- Report ITU-R M.2373: http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2373-2015-PDF-E.pdf
- TR22.816: *3GPP Enhancement for TV Service*, http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/SA/Docs/SP-150766.zip

Instead, the values of various parameters presented in this chapter are based on the experience with the existing technologies and networks, and experts' opinion about the future requirements. They are by necessity illustrative and serve to indicate the required order of magnitude, while the exact technical requirements strongly depend on the type of service, the actual use case, and the business objectives of different stakeholders.

It should also be borne in mind that a benchmark for 5G networks will always be defined by the capabilities of the competing alternative audiovisual platforms and purpose-built technical solutions.

4. Capabilities not yet supported by existing technologies

The capabilities of any communication technology are determined by not just those appearing in technical specifications but by several other main factors, such as:

- technical specifications incorporated in the equipment
- network deployment
- business models
- regulatory conditions

When assessing the capabilities of the existing or future technologies the impact of all the above mentioned factors should be considered.

There are examples where a particular functionality may be available in the specification but not implemented in the devices. Or, it may be implemented in the devices but not enabled in the networks. In some cases the functionality could even be enabled in the networks, but it is not used because it does not fit the operator's business model, or for other reasons.

An in-depth analysis of the existing technologies in the audiovisual domain would exceed the scope of this paper. Therefore, it is considered sufficient to outline some of the relevant features of the programme production technologies and describe in more details the current distribution technologies. The available distribution options are assessed in light of the service requirements and regulatory requirements presented in chapter 1 above.

Furthermore, it is recognised that innovation is also happening in the user environment, in particular as the new ways of AV consumption are explored such as multi-screen viewing, augmented reality and virtual reality solutions, and wearable devices. It is assumed that their connectivity requirements will be similar to those of the more traditional ways of using AV media services, although their long term impact on the network infrastructure is not yet clear.

4.1 Programme production technologies

Programme-makers are increasingly using computer systems and off-the-shelf production software and equipment to produce AV content. IP-based solutions are used as a complement to, and in some cases as a replacement of, the specialised tailor-made equipment. These new technologies are attractive to programme makers as they enable more flexibility when recording, producing, and transmitting content.

For example, the growing capabilities of cloud services will foster the trend towards decentralizing production facilities and storage. At the same time, less complex production tasks such as recording and uploading of news or an outdoor radio show could be done with personal devices such as PCs, tablets, or even smartphones.

The transition to IP-based production systems is gradual. Some elements are already widely adopted (e.g. file-based workflows) while others because of their critical importance and complexity (e.g. live TV production) still mainly rely on the dedicated equipment.

PMSE is another area where a lot of innovation is taking place. Mobile broadband or satellite connections are used to deliver audio and video signals from a field reporter to the studio. This type of application is preferred in situations where it is important to deliver news quickly (e.g. breaking news) or where it is impractical or too expensive to deploy specialised, high-quality microphones and cordless cameras with dedicated radio links. In these cases the longer network latency and possible lower technical quality of the content are accepted.

The above mentioned examples indicate the direction of change but these technologies still have some shortcomings, in particular in terms of their reliability, security, and the technical quality they are capable of supporting. They also require a reliable network access and performance, which is particularly critical for live production.

This is why, at present, they are not seen as a replacement for the purpose-built production systems. However, as the capabilities of the new production technologies and the availability of high-quality broadband networks improve, they will play an increasingly important role in AV content production as long as they can help to increase efficiency of the workflows.

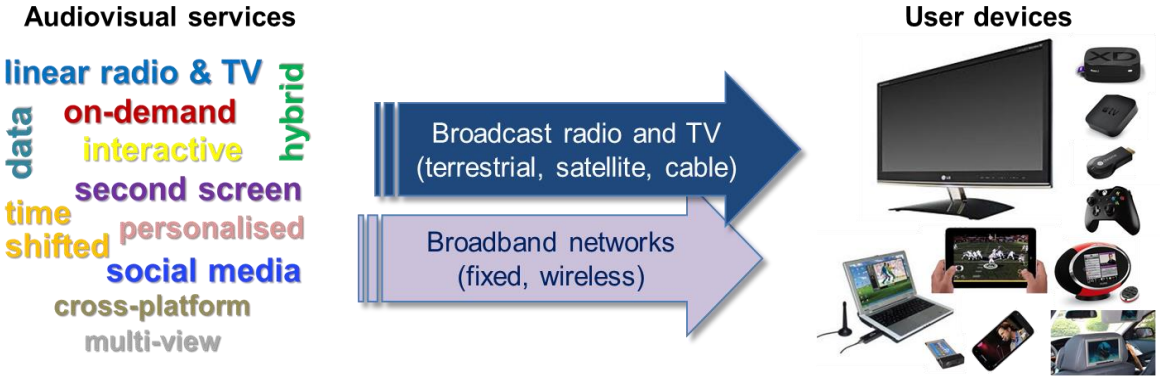
The main drivers of innovation in the AV production environment are

- The ever increasing quality requirements which places increased demand on the capability and capacity of production facilities and storage
- Growing complexity of production, both live and recorded
- The need for more flexible production workflows
- The need for the same content to be repurposed for different AV media services, distribution platforms, and user devices
- Requirements for content protection against piracy
- The demand for increased technical and cost-efficiency of the workflows

Furthermore, as the off-the shelf technologies and software-based solutions are becoming widely available, this will enable new and smaller content producers to enter the market and compete with the established production companies.

4.2 Distribution technologies

Several different technical solutions are used for the distribution of audiovisual media services, including both the broadcast networks and the broadband networks.



Distribution options for audiovisual services

Broadcast networks are purpose-built for the distribution of TV (and radio) services and include terrestrial, satellite, and cable networks.

Broadband infrastructure could be wired (typically xDSL, coaxial cable based on DOCSIS standards, or optical fibre networks) or wireless (e.g. 3G and 4G cellular networks). In addition, broadband connection can also be provided over the satellite and by means of fixed radio links. The main purpose of the broadband connection is to enable access to the Internet.

Furthermore, IPTV is a dedicated TV distribution system that uses broadband infrastructure which is also used for the provision of access to the Internet. It is based on the IP protocol but the TV services are delivered within a closed network normally owned by the IPTV operator. IPTV business models are similar to those for cable TV.

AV media services delivered online, i.e. over the open Internet, are often referred to as over-the-top services (OTT). In this model the service providers do not own or control the network infrastructure.

The demand for transmission capacity is continually increasing for all major AV distribution networks, be it broadcast or broadband. Consequently, network topologies, transmission standards, and signal compression technologies will continue to evolve on all networks.

4.2.1 Broadcast technologies

Broadcast networks include terrestrial, satellite and cable TV networks. They are purpose-built for the delivery of linear services to large audiences across large geographical areas in a cost-effective way. The high efficiency of broadcast networks stems from the fact that when a single signal is sent out anyone who is connected to the network can tune into that signal and receive it. This means a TV channel can be delivered to a very large number, indeed many millions of receivers simultaneously, by only being transmitted once, and therefore only taking up a small amount of available network capacity. This in turn justifies the efforts to optimise the network performance for a guaranteed high quality of service.

The three above mentioned broadcast options, combined, make it possible for linear TV services to be universally available in a technically achievable and cost-effective way. Indeed, the vast majority of linear TV is delivered over broadcast networks.[41]

The main limitation of broadcast networks is that they, generally, cannot deliver on-demand services nor do they reach personal user devices such as PCs, smartphones and tablets[42]. Another potential drawback for the AV media service providers is that broadcast networks are not interconnected. Since none of them has universal penetration, the AV media service providers need to be present on multiple distribution networks in order to reach all users.

As the growth of on-demand consumption could not always be met by broadband networks there are ongoing technological developments where broadcast networks are used to deliver certain type of on-demand content, i.e. by using local caching or a pre-load to the storage in the user equipment. Similar approaches are also considered for broadband delivery, where appropriate.

Terrestrial TV

Terrestrial TV networks consist of transmitters operating in the VHF or UHF band. The network coverage can be designed in accordance with service or regulatory requirements. Typically, terrestrial networks provide national, regional, and local TV services. Coverage for PSM services usually exceeds 95% (or even 98%) of the population in accordance with their remit. Commercial TV providers are usually free to chose and often do not go beyond 90% of the population coverage as this substantially reduces the network costs.

The capacity of DTT networks is constrained by the available spectrum and depends on the transmission technology. In most EU countries terrestrial TV networks are fully digital and use DVB-T or DVB-T2 standards. DVB-T2 is state-of-the art technology for terrestrial broadcasting. Globally, DVB standards are the most commonly used DTT standards. Other DTT standards are ISDB-T, ATSC, and DTMB.[43]

In terms of frequency use, DTT networks can be single frequency or multi-frequency networks. The technical framework for DTT in Europe is defined in the Geneva 06 Agreement and the associated frequency plan, which is an international treaty under the auspices of the ITU. Additional national rules exist in many countries.

If so designed, DTT can provide coverage both indoor and outdoor and can deliver not only to stationary but also portable and mobile receivers.

In addition, terrestrial broadcasting is the only delivery means that provides free-to-air services everywhere which is particularly important for PSM organisations.

The main limitation of the current DTT networks stems from the fact that they can carry signal only in one direction - from the service provider to the viewer. Therefore, if used on their own, DTT networks cannot provide interactive or on-demand services, nor can they reach personal devices, such as

[41] It is recognised that a small part of the audience relies on IPTV as their primary source of linear TV services.

[42] There are no inherent technical reasons why smartphones and tablets could not be equipped with a radio and TV receiver for direct reception from terrestrial broadcast networks. Indeed, this is common in some Asian countries (e.g. Japan and South Korea). In Europe, only a few smartphones and tablets are equipped with an integrated digital radio or TV receiver. Instead, additional equipment has to be attached to the device, e.g. via an USB port, in order to facilitate broadcast reception. Market adoption of such solutions has been modest.

[43] An overview on the global adoption of DTT standards is available at: https://www.dvb.org/news/worldwide

smartphones and tablets. Furthermore, if the audience receiving a particular TV signal is very small broadcast distribution becomes inefficient.

These limitations are common to all broadcast networks and various solutions have been proposed to address them (see also section 4.2.3 below).

Satellite TV

Satellite TV is provided via geo-stationary satellites that deliver signals to highly directional outdoor receiving antennas which are in most cases connected to a specialised receiver (set-top-box). Satellite networks have large capacity and wide-area coverage which makes them particularly suitable for linear TV services with a national or international footprint. While regional and local TV services can also be delivered over satellite, it is not particularly efficient if the target service area is small.

In most cases satellite signals are encrypted in order to protect content rights. Nonetheless, free-to-air services are available in some countries.

Satellite TV can, generally, only reach stationary receivers with an outdoor antenna. Therefore, a different solution is required to reach indoor receivers or portable devices. Furthermore, similar to DTT, satellite broadcast networks do not allow for a return link from the user to the provider and therefore cannot deliver true on-demand services.[44]

Cable TV

In cable TV networks a coaxial cable physically connects the households with the head end that is the source of the signal in the network. The signal form and the frequency range in cable TV networks are similar to those used in terrestrial TV networks. The main difference is that the signal is confined within the shielded cable and therefore, in theory, not susceptible to interference from external sources. In practice, interference issues do exist but can be successfully mitigated.

The capacity of cable TV networks is higher than that of DTT but lower than that of satellite TV.

Cable TV services are in the process of migrating to digital transmission technology on the basis of DVB-C or DVB-C2 standard.

Apart from the transition to digital TV technologies, the main trend is the roll-out of two-way broadband communication systems on the basis of the DOCSISx standard. Such cable-based broadband systems allow access to the internet and telephony, but also the provision of advanced AV media services, such as on-demand and interactive services. As both linear and non-linear AV media services can be delivered over the same infrastructure, cable systems do not suffer from the same constraints as DTT or satellite TV.

The main constraint of cable TV is that it is not universally available and the costs of expansion are rather high, especially to sparsely populated areas. Consequently, cable networks are mainly available in urban and sub-urban areas whereas deployment in rural areas is in most cases not commercially viable.

Furthermore, linear TV services and broadband connectivity compete for bandwidth available within the cable. The current trend is towards increasing the capacity of broadband connections and migrating the TV audiences from the traditional cable TV systems to IP based delivery of TV services.

As access to cable networks normally requires subscription, PSM providers rely on regulatory provisions (e.g. the ‘must-carry’ rules) to ensure that their services are delivered to the audience without recurring charges.

4.2.2 Broadband technologies

The main advantages[45] of broadband delivery are the possibility to provide on-demand, interactive and personalised AV media services and to reach a large number of user devices that cannot be reached by the traditional broadcast networks or IPTV.

[44] There are satellite broadband systems which in combination with terrestrial broadband networks can enable on-demand services. Closer integration between terrestrial and satellite broadband infrastructure would make such a hybrid use substantially more efficient.

[45] This section focuses on the technical features of broadband networks. Market dynamics of online delivery is outlined in section 1.3 above.

The following are the main limitations of the current broadband networks:

- Inability to provide predictable and sustained high quality of service in particular for large concurrent audiences
- Network capacity is not uniformly available within the coverage area which means that some users may not get sufficient bandwidth for AV media services with the required quality.
- Broadband penetration is not universal.
- Free-to-air delivery is not possible.
- The costs of distribution AV services to large audiences are higher than via broadcast networks

Some of the above mentioned limitations are largely due to network implementation and the adopted business models, rather than the inherent shortcomings of the technology.

Broadband networks, both fixed and mobile, are part of a general purpose infrastructure that supports many different services and applications, but is not optimised for any particular one. They are bi-directional networks where every user is served individually, e.g. the user is able to make requests of the network, and the network then retrieves and delivers requested content to that user only. This mode of operation, known as *'unicast'* is predominant on today's broadband networks.

Unicast is a highly effective way of providing non-linear AV media services to individual users. Furthermore, broadband technologies are the only way to reach personal devices, in particular personal computers, smartphones and tablets that are increasingly popular for access to AV media services.

The downside is that a service-agnostic Internet architecture cannot easily be optimised for the delivery of AV media services, especially when they require a sustained high bandwidth, low latency and jitter. The routing of packets is automated and AV media services are transported across the networks together with all other on-line services and applications. The achieved quality of service (QoS) depends on the overall traffic load relative to the capacity of the network and services are provided on a best-effort basis. No one is in charge of monitoring the whole delivery chain and verifying that the service requirements are met.

Furthermore, the network capacity is generally shared (contended) between concurrent users. As the number of active users increases, each of them will have access to a proportionately smaller bandwidth. [46] Beyond a certain point, at the time of peak demand, this leads to network congestion and deterioration of the QoS. The opposite happens when the number of concurrent users decreases and each user gains access to a proportionally lager bandwidth. Hence, the user experience will vary as it depends on the available network resource at any given moment.

Since users expect a high quality of audiovisual content regardless of the way it is distributed, this puts the service providers and the operators of best-effort broadband networks in a difficult situation. When network issues cause a stream failure of a prolonged buffering, this will result in an inferior user experience and the users may abandon the service[47]. This in turn leads to the loss of potential revenue for content owners, advertisers, and service providers.

While the network capacity should be adequately dimensioned to meet the expected demand it is a challenge when the demand is highly variable. Furthermore, as AV media services compete for the capacity with other online traffic, the task of assuring a minimum required quality of service in all cases is rather complex.

In particular, unicast is not an efficient way of delivery for linear TV services or for the very popular on-demand AV media content. Even though the same content is provided to all users at the same time, every user is served separately and requires a dedicated portion of the network capacity. As the number of concurrent users increases, so does the demand for network capacity and the costs.

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[46] In wired broadband networks a dedicated connection is provided from the exchange (or the street cabinet) to each household. The available bandwidth on this connection is not shared but may depend on the physical distance between the cabinet and the home (e.g. on ADSL the achievable bandwidth decreases with the length of the line). The contention issue is relevant for the shared backhaul provision. Distribution of AV media services could be improved by local caching and deployment of CDNs in local exchanges. These solutions are currently not widespread.

[47] According to a survey by Verizon, around 45% of millennials will abandon a services that experiences technical problems - https://www.verizondigitalmedia.com/content/verizonstudy_digital_millennial.pdf

Certain traffic management and adaptive streaming techniques help to ameliorate the problem to some extent but it is rather difficult to ensure a consistently high QoS for AV media services comparable to that in dedicated broadcast networks.

A more effective technical solution for linear services is 'multicast' which enables one-to-many and many-to-many communication over an IP network. When a service is requested by a user, the packets are transmitted from one multicast node in the network to another, while being replicated along the way and finally delivered to the receivers. The content is transmitted between any two nodes only once but it is delivered to all connected receivers that request it at the same time, as is the case for linear TV.

Multicast is implemented in managed IP networks, such as IPTV, where the network operator has full end-to-end control over the signal and is able to avoid congestion, limit the packet loss and provide sustained quality of service.

At present, multicast is not available on the open Internet. Perhaps one of the main reasons is that the multicast functionality must be enabled along the whole path from the source to the end device and this is generally not the case on the Internet. However, if multicast were enabled on the Internet, this would allow broadcast services to be delivered to larger audiences without an excessive use of the network capacity, and quality-of-service issues could be effectively addressed.

Another technique that would alleviate the demand for the transmission capacity is pro-active caching which could be either in-network or on the user device. It allows the most popular content to be stored close to the user in anticipation of the demand.

Wireless broadband

The rapid adoption of smartphones and tablets with the capability of receiving and rendering high quality video is driving the demand for mobile access to AV multimedia services. Mobile access is enabled by two different families of access technologies: cellular mobile broadband (also know as IMT, including 3G and 4G/LTE) and Wi-Fi. While both options are normally available indoors, only cellular networks provide wide area outdoor coverage.

Mobile broadband networks typically operate in a unicast mode, but the specifications also include multicast and broadcast mode. The main example is eMBMS - a point-to-multipoint interface specification for LTE networks, which allows the delivery of broadcast and multicast services, both within a cell as well as within the core network. For broadcast transmission across multiple cells it also defines transmission via single frequency network configurations[48].

eMBMS sessions can be set up dynamically, sharing the resources with unicast sessions in existing IMT spectrum. Different types of audio-visual services could be provided through the implementation of eMBMS, such as: OTT, broadcasting and pay TV. When providing each type of audio-visual service, further consideration should be given to their specific requirements.

Most of the audiovisual traffic to mobile devices goes over Wi-Fi which is normally using a fixed broadband connection as a backhaul. The main reason is that this is a less expensive option then mobile broadband, in particular in the home where most viewing and listening occurs. Even though mobile networks, in particular 4G/LTE, may be able to provide a better user experience than the unmanaged WiFi networks, the high prices of mobile data and comparatively low data allowance are often prohibitive.

Another reason is that a cellular network does not provide uniform capacity across the whole coverage area. For most AV apps downlink throughput is the defining factor for the overall user experience. As Ericsson explains[49], the available throughput declines within a cell in relation to distance from the base station. [50] The throughput provided to any given user is also affected by the number of other users active in the cell and the demands their apps place on the network at any one time. To the extent that apps have different network performance requirements, and network performance varies with distance from radio base stations, in effect each app has a unique amount of coverage.

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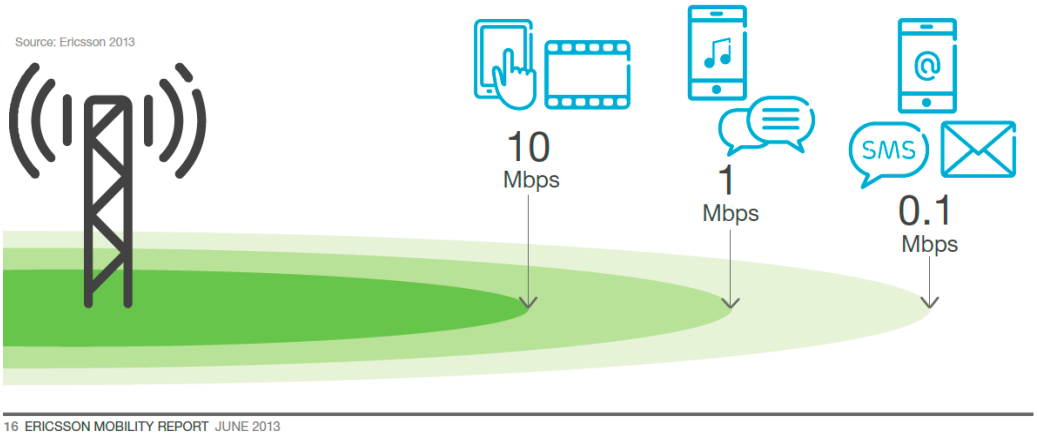
[48] A detailed description of LTE eMBMS features can be found in the ITU-R Report M.2372 http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2373-2015-PDF-E.pdf

[49] Ericsson white paper: *App coverage* http://www.ericsson.com/res/docs/whitepapers/wp-app-coverage-update.pdf

[50] This is in contrast to the broadcast networks where coverage requirements are defined in such a way as to ensure that the required bandwidth, and hence good reception, is provided to all users, including those at the edge of the coverage area.

Figure 21: A conceptual view of app coverage



A conceptual view of app coverage (Source. Ericsson)

Content delivery networks (CDN)

When delivering broadcast content and services over the Internet, there is always a risk of network congestion leading to a poor user experience. This risk increases when a large number of viewers try to access the same content at the same time, leading to a peak in the Internet traffic. One approach to reduce the risk of network congestion is to implement a Content Distribution Network (CDN).

CDNs are an overlay over the internet core network that enhances end-to-end delivery of the most popular or demanding traffic. They are widely used for the online distribution of AV content and services with the aim to fulfil several important objectives, including:

- Improving the user experience by making the most popular content available locally, hence reducing latency and buffering
- Offloading the traffic from the content provider's origin servers and possibly reducing the costs
- Improving reliability and security of the delivered content

A CDN is a network of geographically distributed caching servers that interconnect with ISP networks. The core function of CDNs consists of caching content in dedicated servers as close to the end users as possible, e.g. within the network infrastructure of ISPs. CDNs come in different size and scale, from global (e.g. Akamai) to regional and local. The number of nodes in a CDN and the choice of their locations depend on the operator's business model.

Broadcasters often use multiple CDN providers. This allows them to maintain their services even if congestions occur in some parts of the Internet. CDNs are most useful for the most popular content. Network analytic tools allow the AV media service providers to determine in real time what content is demanded by the viewers and where. This in turn makes it possible to optimise the delivery, taking into account the network conditions, capabilities of the servers and user devices.

However, the traditional CDNs architecture does not allow for high flexibility and scalability, hence they cannot always respond to rapid changes in demand. SDN and NFV solutions are being proposed to increase flexibility and anticipate future demand, although in some cases the underlying networks infrastructure may impose limitations. Other approaches include multi-CDN configurations and automated load balancing.

4.2.3 Hybrid solutions

At present neither the broadcast networks nor the Internet are capable of supporting all services on all devices and reaching the users in all situations. Instead, the two distribution methods are complementary and the strengths of the one can compensate the weaknesses of the other, as illustrated in the following table:

	Broadcast	The Internet
Strengths	• Universally available • Optimised for the delivery to large audiences • Predictable and sustained QoS • The costs are independent of the size of audience • Every user has access to the total capacity of the network; no network congestion • Free-to-air and conditional access possible	• Bi-directional, enables interactivity • Supports any type of service • Potentially unlimited choice of content and services • Access to any IP-device • Interconnected • Suitable for small audiences and long tail services
Weaknesses	• One-way, no return channel • No on-demand services, only linear (noting that this can be addressed by pre-load and local caching). • Content offer is limited by the network capacity; no niche channels • No access to IP-only devices • No interconnection	• Not universally available with the required capacity • Only best effort; sustained QoS is difficult • Capacity is shared between users; risk of network congestions • The costs scale with the number of concurrent users • No free-to-air delivery

Hybrid solutions use both a traditional broadcast network and an OTT broadband network to enable the delivery of the whole range of AV media services, from linear to on-demand, interactive and personalised. The two separate infrastructures are not correlated in any way. Service integration is achieved at the application layer. Broadly adopted European hybrid technologies are RadioDNS[51] (for radio services) and HbbTV for TV services. The IPTV Forum Japan is promoting 'Hybridcast'[52].

Hybrid broadcast broadband TV (HbbTV)

According to the HbbTV consortium[53], HbbTV is a global initiative aimed at harmonising the broadcast and broadband delivery of entertainment services to consumers through connected TVs, set-top boxes and multiscreen devices. It is an open platform, as an alternative to proprietary technologies, broadcasters to include advanced interactive services and Internet applications such as information services, catch-up services, video-on-demand, electronic programme guide, and interactive advertising. Users can access these services through connected TVs, set-top boxes, and through the connection with a companion screen, on smart phones, computers and tablets.

HbbTV can work with either a broadcast or an IP link although it is most powerful when in a connected environment with a combination of broadcast and broadband networking. Products and services using the HbbTV standard can operate over different DVB broadcasting technologies, such as satellite, cable, or terrestrial networks.

The HbbTV specification builds on the elements of existing specifications from other standards including Open IPTV Forum, CEA, DVB, MPEG-DASH, and W3C.

The current version of specification is ETSI TS102796 V.1.3.1 and it corresponds to HbbTV2.0. It includes support for new capabilities including companion device support, HTML5 user experience and support for advanced video delivery features such as UHDTV, HEVC, and Timed Text Markup Language for broadband-delivered subtitles and improved user privacy. It also supports synchronisation between an application on a TV/set-top box and a related application on a smart phone or tablet. Video/audio files can be pushed via broadcast to local storage in a device for later consumption.

[51] RadioDNS is currently used by over 1900 stations. Further information on this hybrid radio technology is available at https://radiodns.org/

[52] See http://www.iptvforum.jp/en/hybridcast/

[53] See https://www.hbbtv.org

The on-going research in hybrid broadcast-broadband

A Tower Overlay concept has been proposed by the Technical University Braunschweig[54] (Germany). It is a particular way of combining broadcast and broadband delivery where popular content can be delivered to mobile terminals via the existing high-power-high-tower (HPHT) broadcast infrastructure.

This is achieved by virtue of a feature in the DVB-T2 standard called 'Future Extension Frames (FEF)' which could be used to embed LTE signals alongside a DTT signal. Such an embedded signal can be a true LTE signal or LTE-Advanced, or a 5G signal in the future, i.e. not different from the one coming from a cellular base station.

A mobile network provides the required signalling for the mobile terminals to find and receive the HTHP signal transmitted over a DTT network. This HPHT signal can be received by all mobile terminals within the coverage area of the DTT transmitter, although the coverage area for the reception on mobile device at ground level may not match that to roof-top antennas for a given throughput.

The transmitted broadcast carrier can be seen as an overlay to the mobile cellular network. A cellular network could be LTE, LTE-Advanced or, in the future, 5G. There is no need for any additional infrastructure.

Development in satellite technology, such as multi-service flexible capacity satellite networks and the advanced DVB-S2X systems are capable of supporting a large-scale delivery of high quality AV media services in a variety of scenarios. For example, low to medium throughput nomadic and mobile applications, high throughput streaming applications (i.e. with data rates up to 1Gbps), and 'cache filler' application for storing content in user terminals, network nodes, or home servers.

Satellite can also contribute to the optimization of QoS/QoE by reducing overhead at caching nodes and end-to-end delay jitter.

[54] See https://www.ifn.ing.tu-bs.de/en/research/projects/em0/

5. Business and regulatory aspects

The demand for audiovisual content and services has never been greater. The viewers and listeners continue to value high quality content and there are no signs that this will change. The AV media services have the potential to be amongst the main drivers of 5G adoption, provided that the right regulatory and market conditions are created.

The business potential of 5G for AV media services will be determined primarily by its ability to sustain the whole value chain. This will require innovative approaches and partnerships. The key challenge will be to align the incentives of the stakeholders across the audiovisual value chain.

The AV value chain is an intricate network of commercial relationships where some participants are governed solely by their business objectives while others seek to fulfil the general interest objectives, i.e. Public Service Media. The main roles in the AV value chain are:

- Content producers
- Service providers, including content aggregators and online outlet operators
- Infrastructure operators, including broadcast and broadband network operators, CDN operators, and cloud infrastructure operators
- Equipment manufacturers
- Advertisers
- Auxiliary service and application providers
- Users
- Regulators and policy makers

This list is not necessarily exhaustive and it outlines functional roles, rather than distinct business entities. Some participants may only have a single role (e.g. 'pure' content producers, advertisers) while other assume multiple roles and seek to extend their activities upstream and/or downstream from their traditional place in the value chain.

For example:

- Network operators often also act as service aggregators, OTT service and application providers
- Some content and service aggregators also invest in the original content production
- Equipment manufacturers may act as content aggregators, or on-line outlet operators (e.g. app stores, content libraries), or both.
- The users may also be involved in content production and not only be passive consumers

There is also an ongoing trend of market consolidation, both horizontally and vertically, which further blurs the distinction between different market players. Nevertheless, it is useful to try and understand the position of different participants in the AV value chain and what incentivises them.

5.1 Stakeholders' incentives in the AV value chain

Content producers

As content producers strive to increase the quality and volume of their production, 5G may facilitate optimisation of their workflows, in particular by enabling the transition towards software-based and cloud-based solutions, the use of the standard equipment, and decentralised production, where required.

With the proliferation of media outlets content producers also seek to repurpose their content for different distribution channels. This is currently associated with significant costs as the content needs to be adapted for a large number of user devices and incompatible distribution options. Ideally, the once produced content could be readily distributed across multiple channels to all user devices, without significant repurposing costs.

Furthermore, protection of the content from unlawful access or unauthorised modifications is one of the content producers' key requirements.

AV media service providers

Service providers often act as content aggregators and seek to deliver the best possible user experience in order to ensure users' satisfaction and loyalty which lead to increased engagement and sustained revenues.

5G may provide new distribution channels for AV media services by leveraging on its advanced technical capabilities. However, above the technical capabilities the 5G networks will need to achieve wide-area coverage and provide sufficient capacity and quality of service in order to successfully compete with alternative delivery means.

In addition, 5G may play an important role as an enabler of cooperative and flexible use of the legacy broadcast and broadband infrastructures as they continue to evolve. This would unlock new opportunities not only for the AV media service providers, but also for other stakeholders such as network operators, equipment manufacturers, and ultimately the users.

Furthermore, AV media service providers want to ensure prominence and ease of access to their services. There is a lot of innovation in the area of user interface, real-time analytics, content discovery, and curated recommendations. It is expected that entirely new business practices and opportunities for new market entrants will emerge in the future.

PSM organisations have statutory obligations to provide their content and services to all citizens free of charge and they seek to do so in a sustainable and cost-efficient way (see §1.4).

Network operators

Mobile network operators consider 5G to be the next generation of mobile technology that should address the demands and business contexts of 2020 and beyond. According to NMGN[55],

> *'5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models.'*
>
> *'On top of supporting the evolution of the current business models, 5G will expand to new ones to support different types of customers and partnerships. Operators will support vertical industries, and contribute to the mobilization of industries and industry processes. Partnerships will be established on multiple layers ranging from sharing the infrastructure, to exposing specific network capabilities as an end to end service, and integrating partners' services into the 5G system through a rich and software oriented capability set. There is a need for flexibility and embedded functionality to enable these.'*

GSMA has expressed a view[56] that *'the rate of adoption of 5G and the ability of operators to monetise it will be a direct function of the new and unique use cases it unlocks. Thus the key questions around 5G for operators are essentially:*

a. *What could users do on a network which meets the 5G requirements that is not currently possible on an already existing network?*
b. *How could these potential services be profitable?'*

Furthermore, GSMA asserted that 5G should not distract from more immediate technological developments, in particular LTE-Advanced which has considerable opportunities for growth. However, 5G is an opportunity to develop a more sustainable operator investment model.

Apart from the MNOs, *broadcast network operators* and *satellite operators* are looking to adopt new technologies in order to further expand their current business models. For example, a number of terrestrial broadcast network operators also own and operate cellular towers on behalf of MNOs, i.e. on a business-to-business basis. They are well placed to facilitate convergence on a network level.

Satellite operators increasingly offer not only their transponder capacity but a host of complementary services, such as cloud-based services, backhaul for mobile networks, content management, playout, and OTT solutions.

If 5G were capable of supporting a wide range of business models, i.e. beyond the narrowly defined telecom network operator's model, it could also become attractive to broadcast and satellite network operators.

In the long term, 5G could provide a unifying framework for convergence at the level of network infrastructure, which would create new business opportunities and promote partnerships.

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55 NMGN, 5G White paper, https://www.ngmn.org/5g-white-paper.html

56 GSMA, Understanding 5G: Perspectives on future technological advancements in mobile, December 2014, http://www.gsma.com/newsroom/press-release/gsma-publishes-new-report-outlining-5g-future/

Equipment manufacturers

Economies of scale are essential for the viable development, manufacturing, and bringing to the market of new technologies. The industry is looking for global harmonisation of technical and regulatory conditions for 5G networks. Standardisation plays a key role in this process. Open standards ensure open markets and provide opportunities for small and medium-sized enterprises (SME).

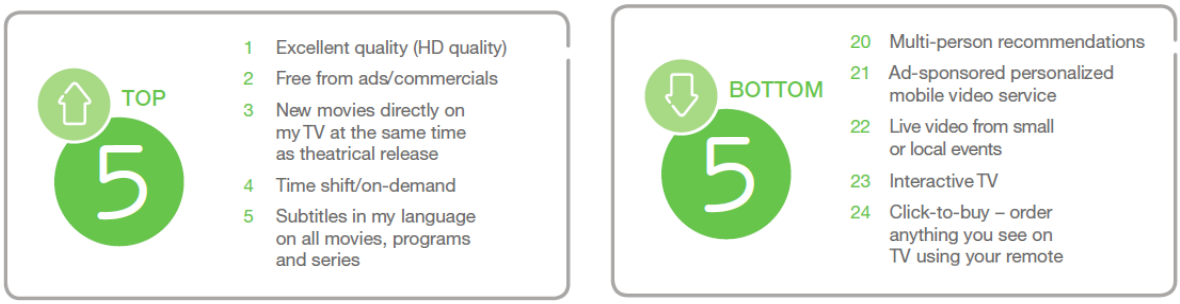
Intellectual Property Rights (IPR) are a substantial source of revenues for some manufacturers as well as for the research community and academia.

Leading manufacturers seek to expand beyond their core business into other domains, both business-to-business (B2B) and business-to-consumers (B2C). Examples are abundant. In the B2B domain some equipment vendors also provide managed services, for example network management for telecom operators, operation of a production facility for a TV station. In the consumer market, the dominant equipment manufacturers also control the user interface and sometimes act as AV content and service aggregators.

Users

The key user requirements are the choice and quality of AV media services, convenience of access and use, and affordable costs. These are the main contributing factors to user experience. The improved user experience is the main driver of the demand for a new technology or a service.

A survey carried out by Ericsson's ConsumerLab[57] has investigated the user preferences in order to determine the most and the least important features of AV media services.



Most and least important TV and video features *(showing top two answers on a seven-point scale)*
Source: Ericsson ConsumerLab, TV and Media 2014. Base: 23 markets

In addition, users value transparency, privacy, and security when using AV media services.

The above outlined user requirements could be successfully addressed within the 5G ecosystem in order to make it attractive to the users.

Case study: LTE eMBMS as a distribution technology for AV media services

A number of mobile network operators are currently looking to deploy eMBMS on a commercial basis in LTE networks. These efforts provide a suitable backdrop to illustrate the complexity of bringing a new AV technology to the market and to gain important insights which may come in useful in the 5G context.

LTE eMBMS has been part of 3GPP specifications for some time and is currently being tested in a number of trials around the world. These trials have verified the potential of the technology to deliver AV content to personal devices. 3GPP has recently initiated work on further enhancements for the delivery of TV services.

The current version of eMBMS (as per 3GPP Release 12) allows a portion of capacity in an LTE network to be used for broadcast or multicast services. Instead of serving each subscriber individually, as in the unicast mode, the same stream is being provided to multiple users simultaneously, which is particularly suitable for the delivery of popular AV content or service, such as live TV. This allows for significant savings of network resources, in particular if the number of concurrent users is high.

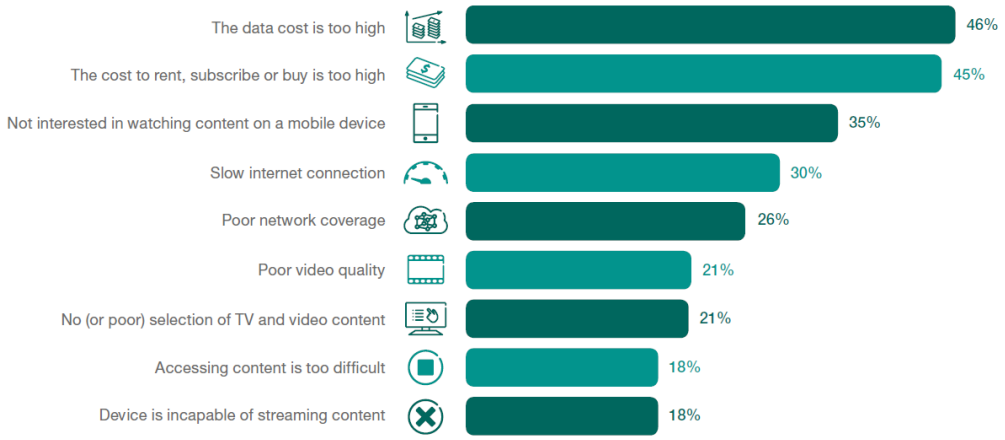
Besides the capabilities included in the specifications, performance of eMBMS networks also depends on the network topology, coverage requirements, as well as the type of terminals and their location.

[57] Ericsson, Consumer Lab: TV and Media 2014
http://www.ericsson.com/res/docs/2014/consumerlab/tv-media-2014-ericsson-consumerlab.pdf

Furthermore, the capability of LTE to combine unicast and eMBMS transmission has been indicated as a potential new way of delivering AV media services, for example delivering popular programmes to large audiences using the broadcast mode while the niche programmes are delivered via unicast. This possibility requires to be further studied because it may bring about additional efficiencies.

The relentless growth of video traffic on mobile networks suggests that there is a strong demand for AV media services to be consumed on mobile devices. However, most viewers prefer WiFi connection over cellular networks and this has also been confirmed in the above mentioned survey by Ericson ConsumerLab. The same survey has also revealed the current obstacles for wider adoption of mobile broadband as follows:

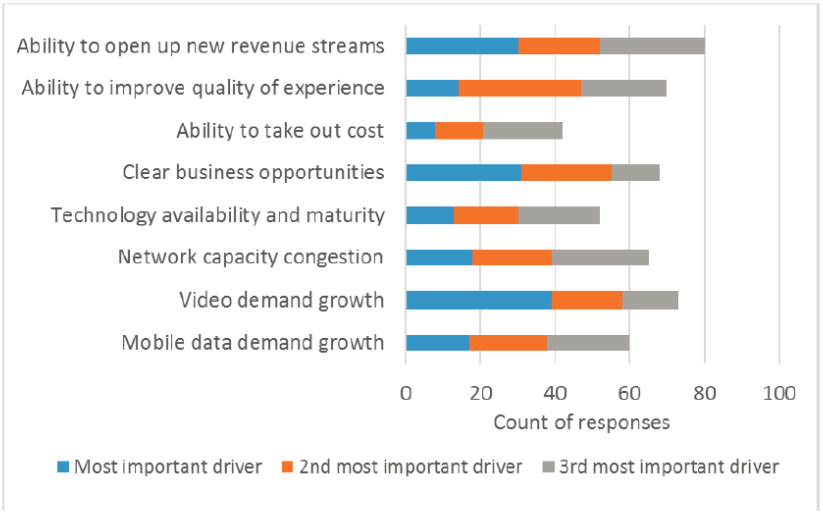
Figure 9: Mobile viewing barriers when outside of the home (showing top two answers on a seven-point scale)



Source: Ericsson ConsumerLab, TV and Media 2014. Base: 23 markets

In a recent GSA survey[58] the Association's members were polled in order to identify both the drivers and the barriers for eMBMS adoption. The following key drivers were identified:

Figure 3: Drivers of LTE Broadcast adoption



Question asked: What do you think are the three most important drivers of LTE Broadcast infrastructure and services? Please rank three only, in order. 173 respondents

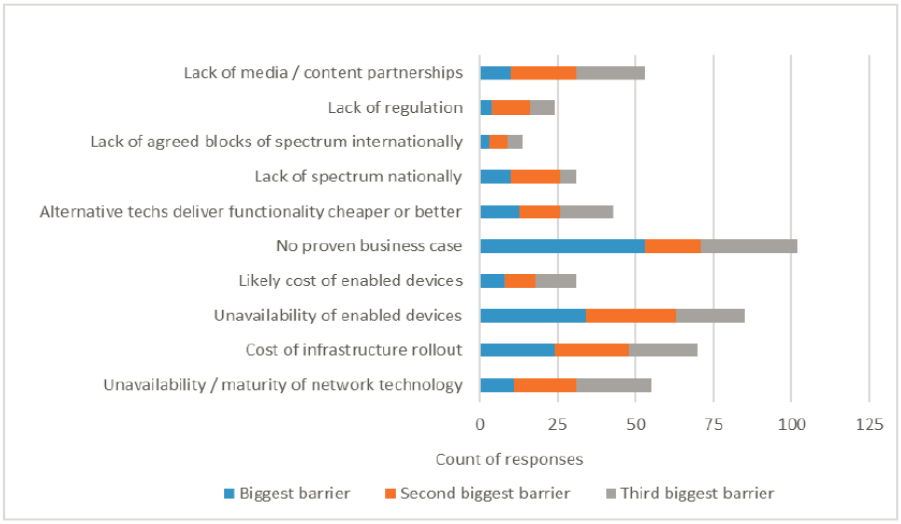
GSA also noted that *'network operator respondents' opinions were similar to those of other respondent types (vendors, service providers, broadcasters, industry commentators) except that the availability of clear business opportunities was ranked at the most important driver by operators, just ahead of video growth; and mobile data demand growth was chosen as a top three driver slightly more often than video demand growth.'*

These findings are consistent with the mobile network operators' views as formulated by NMGN and GSMA (see above).

[58] *Evaluating the LTE Broadcast Opportunity*, GSA, November 2015, http://www.gsacom.com/lte-broadcast/

The main barriers to eMBMS adoptions are the following:

Figure 7: Barriers to LTE Broadcast deployment



Question asked: What are the three most important barriers to roll out of LTE Broadcast infrastructure and services? Please rank three only, in order. 173 respondents

In addition, GSA points out that *'Cost of infrastructure deployment is a concern. Mobile operators are comparing the costs of LTE Broadcast with the costs of LTE unicast and other network improvement technologies they might deploy. Broadcasters are comparing the costs and capabilities of LTE Broadcast not with LTE unicast solutions, but with alternative broadcast approaches.'*

In their conclusion, GSA suggests that *'working out the business case for LTE Broadcast is quite different - for those operators without media assets – from previous technology business cases due to the complexity of the value chain, and the potential requirement to bring in multiple third parties covering content acquisition, programming, and play-out/streaming.'*

5.2 Regulatory and policy requirements

Provision of AV media services is subject to regulation in a number of different areas, such as:

- Sector-specific regulation (e.g. AVMS Directive)
- Law on Public Service Media
- Telecom regulation
- Copyright law
- Competition law
- E-Commerce regulation
- Consumer protection
- Privacy and data protection
- Network neutrality

As technology neutrality is a fundamental principle of the EU legislation it is assumed that the above mentioned legal instruments will also apply in the 5G context.

5G should be able to fulfil the public policy objectives such as those outlined in the EU Audiovisual Media Services Directive (AVMSD which aims to guarantee key societal values and apply to all audiovisual media services. The overarching objective is creating a single market for AV media services while ensuring at the same time a high level of protection of objectives of general interest.

The AVMSD's main objective is articulated into a number of more specific objectives:

- Ensure a level playing field for emerging audiovisual media services;
- Strengthen the single market and guarantee conditions of fair competition;
- Strengthen the competitiveness of the European audiovisual industry and promote European audiovisual content;
- Protect and empower consumers, in particular minors and people with disabilities;
- Contribute to the support of cultural and linguistic diversity and heritage in Europe;
- Safeguard media pluralism, freedom of expression and information.

5G should also be able to accommodate the requirements of the Public Service Media, in particular with regards to availability and prominence, which are also subject to specific regulation.

Another area of general interest is the provision of information to the public in case of in times of emergencies, including natural and man-made disasters. This requirement is in many countries placed on broadcasters and relies on terrestrial broadcast infrastructure which in turn has to meet high reliability and resilience requirements. As the general public increasingly also relies on broadband infrastructure it could be expected that similar reliability and resilience requirements may in the future also apply to 5G networks.

Further information on regulatory and policy issues is provided in section 1.5 above.

5.3 Business potential of 5G for AV media services

Whilst some of the constraints of the current broadcast and broadband technologies will be overcome in 5G, the need for a viable business case will always remain relevant. The audiovisual markets continue to evolve and this will affect the technical, commercial, and regulatory environment in which the market players operate. 5G may bring new business opportunities and enable value creation across the value chain.

First and foremost it will be important to ensure the availability and a superior performance of the 5G infrastructure as this is in the interest of all stakeholders, including content and service providers, network operators, advertisers, equipment manufacturers, and a range of supporting services and applications.

A particular opportunity for 5G will arise in those use cases where there is market demand that cannot easily be satisfied by the alternative means in an efficient way or where 5G will be able to deliver a superior performance compared to these alternatives. Some examples include:

- delivering AV media services to personal user devices, in particular smartphones and tablets, with a predictable and sustained quality over a wide coverage area
- connecting the distributed / remote content production facilities and enabling new workflows
- increasing the flexibility and cost efficiency of outside broadcasting and contribution services
- supporting new services and businesses based on audience data analytics

As the AV media services and the audience behaviour continuously evolve, further use cases will emerge in the future that will lead to new business opportunities.

AV media services could be one of the key drivers of demand for 5G. It is important for the 5G ecosystem to support the European cultural and creative industries by sustaining a virtuous circle between content creation, demand for new services and applications, technological developments, and the infrastructure developments.

Furthermore, 5G could play a pivotal role in fostering a cooperative use of broadcast and broadband infrastructures and the alignment of their respective evolution roadmaps. In the short to medium term interoperability and technological harmonisation between broadcast and broadband AV networks would enhance content and service diversity, portability, and access for the users. In the long term 5G could provide a unifying framework for convergence at the level of network infrastructure. This would create new business opportunities and facilitate partnerships.

The success of 5G in the AV market will strongly depend on its ability to align the incentives of the participants in the value chain. It will be necessary to strike a balance between market players' legitimate commercial interests and the public policies designed to promote general interest objectives and the public value.

6. Recommended research and innovation domains

Extensive 5G research activities, such as those within the 5G-PPP initiative, are reaching a global momentum[59]. These important efforts are directed towards achieving the envisioned capabilities of the future 5G technologies and networks.

Above and beyond the ongoing research on core 5G capabilities further work is required that focuses on future requirements for AV media services. In particular, several broadly defined areas should be addressed, as follows:

Optimised content production workflows

5G should be able to support innovative content production workflows, such as distributed or remote production, news gathering and outside broadcasting.

Key requirements for connectivity in content production are high throughput, low latency and jitter, high reliability, deterministic network behaviour, high time synchronisation accuracy, and guaranteed access to the network resources. These requirements need to be fulfilled for prolonged periods of time (e.g. several hours or even days for a single session).

Distribution of AV media services over 5G networks

5G should be able to support a large-scale distribution of AV media service.

Key requirements in AV media service distribution include wide-area coverage, sustained quality of service for all users, different delivery options including a free-to-air delivery and a range of access control mechanisms, content protection in terms of both signal integrity and copyright, flexibility and scalability, high reliability, cost-efficiency, and sustainability. These requirements are valid whether AV media services are delivered over a single network infrastructure or in a heterogeneous environment.

Audience data collection and analytics

5G should be able to support data-driven AV media services and applications.

Amongst key requirements are the possibility to implement big data technologies and data processing functions (collection, storage, management, sharing), harmonising metadata systems, and interoperability between different solutions. Further research is also required to better understand the relationship between the technically defined quality of service (QoS) metrics and a more subjective, user-focused quality of experience (QoE).

Integration and interoperability between broadcast and broadband systems

Broadcast and broadband technologies are complementary and their cooperative use leverages on their combined strengths. Better integration between broadcast and broadband technologies could be beneficial for a number of stakeholders in the audiovisual media value chain.

Bearing in mind that innovation is happening on all audiovisual platforms, and the already substantial degree of commonality between broadcast and broadband standards in terms of the core technologies and the AV-related use cases they seek to address, there is an opportunity to align their respective development and standardisation roadmaps.

The 5G-PPP vision document outlines a concept where '*telecom and IT infrastructure will be integrated towards a common very high capacity ubiquitous infrastructure. In order to assure the required scalability and flexibility, the network functions will be more and more "virtualised" on general purpose, programmable and specific high performance hardware that will offer resources for data transport, routing, storage and execution.'*

Further synergies and efficiencies could be achieved if such an integrated 5G infrastructure were at the same time interoperable with the purpose-built AV media distribution infrastructure, in particular the evolved broadcast networks. This could also help to reduce a disruptive impact on the viewers whenever the broadcast transmission infrastructure needs to be upgraded (e.g. in order to introduce a new transmission or compression system).

Closer integration of broadcast and broadband infrastructure could be foreseen in the long term, resulting in a coherent set of specifications that support an entire range of audiovisual use cases.

[59] An overview is provided in 4G America's Summary of Global 5G initiatives, June 2014 http://www.4gamericas.org/files/2114/0622/1680/2014_4GA_Summary_of_Global_5G_Initiatives__FINAL.pdf

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8. List of acronyms

3GPP	The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), and provides their members with an environment to produce the Reports and Specifications that define 3GPP technologies (http://www.3gpp.org)
4G	The fourth generation mobile technology, e.g. LTE
5G	The fifth generation mobile technology
5G-PPP	5G-Private Public Partnership
ADSL	Asymmetric Digital Subscriber Line
AV	Audiovisual
AVMS	Audiovisual Media Services
AVMSD	Audiovisual Media Services Directive
ATSC	Advanced Television Systems Committee - an international, non-profit organization developing voluntary standards for digital television based in the USA. The ATSC members represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries (http://atsc.org)
CCI	Cultural and Creative Industries
CISAC	The International Confederation of Societies of Authors and Composers – is the world's leading network of authors' societies (also referred to as Collective Management Organisations, or CMOs) - see http://www.cisac.org/
CDN	Content Delivery Network
DOCSIS	Data Over Cable Service Interface Specification - a standard for the provision of broadband data connection over cable TV networks
DSL	Digital Subscriber Line
DVB	Digital Video Broadcasting
DVB Project	The DVB Project is an industry-led consortium of broadcasters, manufacturers, network operators, software developers, regulators and others committed to designing open interoperable technical standards for the delivery of digital media and broadcast services (www.dvb.org). These standards are adopted by ETSI.
DVD	Digital Versatile Disc - a type of optical storage media
eMBMS	Enhanced Multimedia Broadcast Multicast Services - a part of LTE specifications
ESR	Erroneous Second Ratio; ESR_5 is a method of assessing picture quality received by the user device.
ETSI	The European Telecommunications Standards Institute (www.etsi.org).
FEF	Future Extension Frames - a feature of DVB-T2 broadcast transmission standard
GSMA	The GSM Association - a global association of mobile network operators (www.gsma.com)
GSA	The Global mobile Suppliers Association (http://gsacom.com/)
HDTV	High Definition TV picture format
HEVC	High Efficiency Video Coding is a video compression standard
FTA	Free-to-air
HbbTV	Hybrid Broadband Broadcast TV standard (https://www.hbbtv.org)
IMT	International Mobile Telecommunications - an ITU framework for mobile telecommunications standards
IPR	Intellectual Property Rights
IPTV	Internet Protocol Television
ISP	Internet Service Provider
IT	Information and Telecommunications
ITU	International Telecommunications Union (www.itu.int)
IXP	Internet Exchange Point
LTE	Long Term Evolution - a 4G mobile broadband technology standardised in 3GPP
NGMN	Next Generation Mobile Networks - a mobile industry association (www.ngmn.org)
NFV	Network Functions Virtualization
OTT	Over-The-Top is an online distribution model where a service provider does not own or control the distribution network infrastructure.
PBS	Public Broadcasting Service in the USA
PC	Personal Computer

PMSE	Programme Making and Special Events
PSM	Public Service Media
PVR	Personal Video Recorder
QoE	Quality of Experience
QoS	Quality of Service
SDN	Software-Defined Networking
SDTV	Standard Definition TV picture format
SME	Small and Medium-sized Enterprises
STB	Set-top box
SVoD	Subscription VoD
UHDTV	Ultra-High Definition TV picture format
VoD	Video on demand