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BROADCAST TECHNOLOGY FUTURES GROUP 2020

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ABOUT THE EBU

The **European Broadcasting Union (EBU)** is the world's foremost alliance of public service media (PSM). Our mission is to make PSM indispensable.

We represent 115 media organizations in 56 countries in Europe, the Middle East and Africa; and have an additional 34 Associates in Asia, Africa, Australasia and the Americas.

Our Members operate nearly 2,000 television and radio channels alongside numerous online platforms. Together, they reach audiences of more than one billion people around the world, broadcasting in almost 160 languages.

We strive to secure a sustainable future for public service media, provide our Members with world-class content from news to sports and music, and build on our founding ethos of solidarity and co-operation to create a centre for learning and sharing.

Our subsidiary, Eurovision Services, aims to be the first-choice media services provider, offering new, better and different ways to simply, efficiently and seamlessly access and deliver content and services.

We have offices in Brussels, Rome, Dubai, Moscow, New York, Washington DC, Singapore, Madrid and Beijing. Our headquarters are in Geneva.

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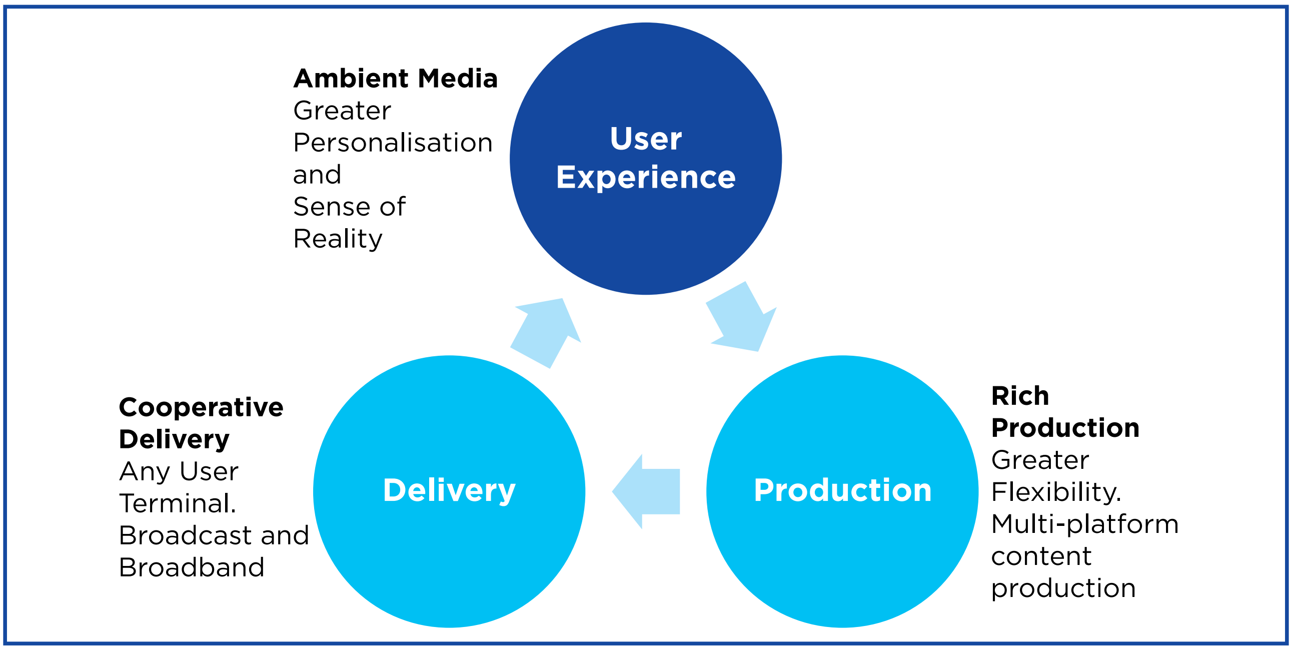
OPTIONS FOR FUTURE MEDIA TECHNOLOGY

WHAT HAPPENS NEXT?

A VISION OF THE FUTURE MEDIA LANDSCAPE FROM THE PERSPECTIVE OF CURRENT PUBLIC SERVICE MEDIA RESEARCH AND DEVELOPMENT



"RUN TO MEET THE FUTURE, OR IT WILL RUN OVER YOU"

History has shown that media technology developments, shaped by the context of the external environment, change society more than any specific content that the media carry [1]. If we influence new media technology today, we will create the future world. The impact of 'FAANG' [2] technologies has shown this. If we fail to influence new media technology today, we are leaving to others the future nature of society. Media Innovation, Research and Development (R&D) is therefore an important way to make the world a better place.

There is more to the value of R&D. Over time, R&D can save operating costs, can directly generate income, and can spawn valuable new services. As the Controller of the BBC R&D Department calculated several years ago: "Every pound spent by BBC R&D delivers a return of at least five to nine pounds".

1 This is termed technological and/or cultural determinism by social scientists. The sentiment is encapsulated by the enigmatic maxim of formative social scientist Marshal McLuhan: "The Medium is the Message". More recent social scientists argue that it is the combination of the new technology and its context that shapes society's future.

2 FAANG is the acronym for five major, successful US tech companies: Facebook, Amazon, Apple, Netflix, and Google.

This is a report by the group of Innovation and R&D laboratories of PSM Members who believe that, as part of the public service mission, we should strive to bring to the public that we serve, the best that technology can viably and practically offer. Their purpose is not to make money, but to efficiently add to, and improve, the media experience.

PSB companies will never be the wealthiest or largest R&D laboratories in the world, but they can, as history has shown, make a real difference. The world has digital television and radio today because of the work of PSM R&D in France, Germany, Italy, Japan, the UK, and others.

The all important 'context' of the media future will include the environment of games, social media and other future elements such as autonomous vehicles, which may influence, compliment, and compete with media for the time and interest of the audience.

New media technology will arrive as parts of three 'trends'. The trends and their components may arrive simultaneously or sequentially. They are shown in the figure above. Exactly what arrives, and when it arrives will depend on local contexts and on what is developed.

The first trend can be termed the rise of 'ambient media', which has two components.

The first component will give the user **ever greater control** over what is before them – greater 'personalisation'. Services can include elements that: provide additional information about the current viewing experience; help to find content of interest for the user; recommend content; and more.

The second component will give the user a **greater sense of reality**. This will include more realistic images, sound that can reproduce width, height and depth, and multimodal presentations that may include haptics (technology that stimulates the senses of touch and motion). 'Space sharing' [3] (outlined in the reference in the footnote) content viewing may be possible, through which people in remote locations may share their emotions.

The second trend can be the rise of 'rich production' for media content, which also has two components.

The first component is the arrangement of the content production facilities to allow **production locally or remotely** or a combination of them. This will include outsourcing some or all of the production chain, and the use of 'Clouds'.

The second component comprises arrangements for making it possible for content production to be made separately, or at the same time, for a range of different content formats, that would each serve different markets or different groups of users. This is **production flexibility**.

The third trend can be the rise of 'cooperative delivery', which also has two components.

The first component is the emergence of a mixed delivery environment, where both broadcasting and wireless or wired broadband provide media services. Each will have their strengths, and different combinations will be used in different countries. 5G may be combined with satellite and terrestrial broadcasting in **intelligent cooperation**.

The second component is the increasing availability of **all services on any terminal**, including fixed TV or radio receivers, portables, tablets, or smart phones, and in so doing, making use of the specific capabilities of these devices to reach and engage with audiences.

Though not exhaustive, this report is intended to set out for readers the major longer term components of each of these three trends in more detail, as they are seen by those working in media R&D. It is intended to encourage discussion and action about which of them should be the focus of PSM endeavours in the coming years, to improve the quality of life.

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3 K. Yoshino, "AR/VR based space sharing services: Watching programmes together with performers and distant friends and family members," NHK STRL Bulletin, Broadcast Technology, No. 81, Summer 2020. https://www.nhk.or.jp/strl/english/publica/bt/81/5.html

BACKGROUND TO THE REPORT

The Broadcast Technology Futures (BTF) group brings together senior staff from media research and development laboratories. This report is base don the insights of BTF group members on possible future technologies that may be part of, and help shape, the media experience in the coming years.

The report includes contributions from, in alphabetic order, the following organizations:

BBC	British Broadcasting Corporation, UK.
EBU	European Broadcasting Union, Switzerland.
IRT	Institute für Rundfunktechnik GmbH, Germany.
NHK	Nippon Hōsō Kyōkai, Japan.
RAI	Radiotelevisione Italiana, Italy.
YLE	Yleisradio Oy, Finland.
VRT	Vlaamse Radio- en Televisieomroeporganisatie, Belgium.

The rate and timing of the adoption of new technologies will depend on the local circumstances of media organizations and the societies they serve. There will be differences in the take up times from country to country and region to region, and some technologies may not be widely adopted in certain countries.

The technologies and services that will be successful in practice will depend not only on the novelty and capability of the technology itself, but on a collection of success factors that include the prevailing societal and media climates, the desirability, affordability and availability of equipment and content, the challenges then faced by media providers, the need that the new development would fulfil, and others. There will be a 'right time' for new technologies, but it may well not be the same in all countries.

This report is a **'dossier of options'** rather than a timetable for the introduction of new media technologies. There are important and influential media technologies such as UHDTV and IP production that are currently available in some organisations, but the purpose of this report is to look beyond them to technologies that are not yet in use, but which will be important in future decades.

There are three Annexes to this report. They consider innovations in the **user experience, content production, and media delivery**.

CHALLENGES AND OPPORTUNITIES FOR PUBLIC SERVICE MEDIA (PSM) IN FUTURE ENVIRONMENTS.

- The only constant in media technology is change. The future media environment will mean a range of options for new or expanded services. PSM organizations may wish to weigh up the benefits, practicality, and economic implications of each them, and prepare **plans for the coming years**.
- The COVID 19 pandemic has demonstrated the critical value of PSM including in circumstances of public stress. PSM providers may wish to consider **how their offer and technology may best be used** in such circumstances.
- The growing use of the 'Cloud' for production and distribution calls for reinforcement of security measures when using such systems. PSM organizations may wish to develop **new security tools** to meet the times.
- Both Cloud services and potential new IP based delivery networks may rely on third party or outsourced facilities in the future. It will be important to **ensure fairness and customer neutrality** for such services. PSMs are advised to develop or adopt appropriate tools and practices.
- The production and delivery environments will call for steps to **improve sustainability**. PSMs may wish to make plans to do so.
- There is a growing global awareness of the need to add measures **that aid those with sensory or other deficiencies** to consume media content. PSM organizations may wish to plan how to do so.
- The future media environment may allow users to personalize their media services to an ever greater extent. The personalized content they consume may effectively become less varied and risks becoming victim of a 'filter bubble'. However, it may be part of a public service mission to **encourage users to expand their interest and awareness horizons**, and to explore a wider range of content. PSM organizations may wish to consider how this can be achieved.

ANNEX 1: **TOMORROW'S USER EXPERIENCE**

GREATER PERSONALISATION OPTIONS AND CONTROL FOR USER

GREATER SENSE OF REALITY FOR USER

SUMMARY OF ANNEX 1

The next decades may bring more options for 'personalising' the media experience, including using 'voice activation' and 'digital assistants'. The options may be chosen by the user or triggered automatically by the local environment or the user's needs. The sense of reality may also be heightened by more 'immersion' and increased image and sound quality. A further new experience may be created by the combination of the real or conventional media world with digitally created worlds.

1. INTRODUCTION

The underlying and continuing trends in user experiences will be **greater personalization** and a greater sense of reality for users. New technologies will become available in the coming years to advance these trends.

New user experiences can be grouped into five categories, discussed in the sections that follow:

- personalized user experience
- digital assistant and ambient computing ecosystem experiences
- adaptive experiences
- immersive experiences
- experiences that merge the physical world and the digital world.

Subsequent annexes in this report include consideration of content production and content delivery for these user experiences.

2. PERSONALIZED USER EXPERIENCE

Tomorrow's user experience may become more personal. The user may receive suggestions on what content to consume at any given moment, based on a prediction by the service of what they need at a given moment. Prediction may be calculated on a mix of signals and data about user intent, viewing history and user context (time of day, location, movement, ambient noise, company present, etc) while PSMs may seek to avoid recommending filter 'bubbles', particularly in news.

The personalized experience may even extend into activities undertaken in the physical world. For example, when passing close to a restaurant or shop that you viewed in a television programme, you may receive a recommendation notification.

In addition to being personal, user experiences might have more social dimensions than today and might, for example, allow us to experience sport events and premium content together with friends and family regardless of their location.

A fully personalized user experience will require the system to identify the user. The user may be able to login to services by their preferred method, including facial and voice recognition, and to stay logged in while shifting through different interfaces, services, and contexts.

Smart TV Apps can be a way of accessing video content on the large screen in the living room. On the move, in car entertainment systems may initially synchronize with personal mobile devices to allow seamless content consumption and later have a fully integrated infotainment system that collects our data and directly connects to our choice of eco system. Already we are witnessing the roll out of cars with comprehensive operating systems that make them somewhat like digital mobile devices on wheels.

Future large screens could also serve as monitors for smart devices that will 'project' content onto them. This would allow digital content applications to be developed at speeds faster than is possible for Smart TV manufacturers and would relieve consumers from the need to continuously update their devices to keep up with new technologies and cyber threats. Consumers currently tend to consider the lifetime of a TV set as being longer than the lifetime of a smartphone, and this may continue to be the case.

3. DIGITAL ASSISTANT AND AMBIENT COMPUTING ECOSYSTEMS

Over the coming years we can expect to see significant growth in 'ambient environments' from smart speakers, wearables and smart cars to voice enabled IoT devices. We may expect this to have an impact on consumption patterns and the user experience. It may initiate a new wave of innovation and diversification in 'user journeys'.

Current GUIs (graphical user interfaces) are essentially designed for content discovery, user experience and navigation, and are similar regardless of provider. VOD or audio players are 'carousels' of genre based content, based on viewing history, editorial curation, or a mix of both. In the future, voice assistants may facilitate new ways of discovering content. Discovery may be based on casual natural language interactions, facilitated through voice and dynamic responses from the GUI.

Assistants will evolve to become more companion like, such that they may be an ambient presence with consumers. Assistants may therefore demand their own presentation language, resulting in the emergence of a new field of expertise. Content providers may rethink their online branding presence as a result.

4. ADAPTIVE EXPERIENCES

All users may be able to understand and enjoy any content with universal accessibility adapting to users' capabilities and circumstances. For example, an automated translation service may enable users to enjoy content made in foreign languages. When combined with speech synthesis, automated translation could be turned into audible translation that might sound like the person originally speaking in a piece of content.

An automatic closed captioning service would continue to play important roles not only for the hearing impaired or elderly, but in noisy places or in places where sound is prohibited. Automated sign language services may be provided for the hearing impaired, automatically translating speech into sign language presented by avatars in a natural manner.

Audio description services that automatically generate voice explanations of the scene, along with haptic information linked to the content may be provided to enrich the experience of visually impaired people.
The user may be able to continue consuming content when passing from one device to another. The modality of the content would adapt to each device. For instance, a full video news report on a TV screen may break into a visual AR (augmented reality) content layer and an audio layer when accessed via a wearable headset display.

Content may be produced to support different video/audio/AR consumption scenarios. The user could, for example, start reading at home and continue listening while cycling, with an option for AR if they wear an AR headset device.

While on the move, the user may receive quick text/audio/haptic notifications about breaking news via mobile devices, and would choose which stories to follow using speech, gesture or brain computer interfaces. Subsequently the user may be presented with up to date information on the stories of interest.

5. IMMERSIVE EXPERIENCES

Different types of media device that immerse the audience into content may evolve and become widespread. Tomorrow's immersive media may have higher degrees of freedom in content presentation. Users may be able to experience 'worlds' that they have not yet experienced. The ways in which the audience engages with immersive content may be diverse. There will be different immersive devices depending on the user's preferences and circumstances.

Spatial imaging technology may create a realistic viewing experience in 3D space. Head mounted displays (HMDs) may evolve to higher image quality both in resolution and in field of view, which will give the audience a sense of being in the scene in a more natural manner than HMDs currently do. In the future, technology that out performs today's HMDs may be integrated in an eyeglass like device. 360° 'dome' displays for a single user and large screens for multiple users may be available as well. Glasses free light field 3D image displays may be practical, which would give the viewers natural viewing experiences. Portable 3D displays may be used by individual viewers as a second screen

At some distant point in time, it is possible that a chip could be used to directly feed images into our visual cortex, and other signals could interact with our senses. Thus, an embedded chip could replace the external devices needed today.

The audience may be able to enjoy 3D sound that matches the various forms of video and enhances the immersive feel. The 3D audio reproduction would provide not only directionality but also the depth of field. This is an enhancement to current systems that requires audio devices such as headphones or sound bars.

Haptic devices serving the sense of touch may become more common. One such haptic device could be equipped with vibrators and servomotors so that it could convey the magnitude of an impact and the direction of movements by physically pushing/pulling the surface of the device.

Immersive technologies may change storytelling – instead of just passively watching something happening, we may be taken inside stories in game like environments that require us to act while the story goes on.

6. THE MERGING OF THE PHYSICAL AND THE DIGITAL

We may see the wider adoption of video user interfaces. These vision based human computer interactions provide a wider and more expressive range of input capabilities by using computer vision techniques to process data from one or more cameras. Natural user interfaces such as gestures may allow humans to control machines through natural and intuitive behaviour.

The AR Cloud is a real time 3D (or spatial) 'map of the world', overlaid onto the real world. It may enable information and experiences to be augmented, shared and tied to specific physical locations, and to occur and persist across apps and devices. This may allow computer vision enabled devices to become the gateways for avatars in this new landscape of reality layered with virtual interactive information.

For innovators, the emergence of a dominant AR Cloud platform may open a new domain; virtual buttons may be laid over the physical world to hail a cab or buy products and services via digital and hyper personalized adverts. Any surface could potentially be used as a display or part of a UI (user interface). For example, when the user looks out of a window, the current weather information and forecast may be shown on it. This may also provide news and new entertainment media opportunities. Further examples may be to provide information such as an evacuation route in case of an emergency or the supply of daily necessities when needed.

At home, viewing modes that use AR technology for virtual space sharing may be available in future. For example, television performers and friends and family in remote places may appear virtually around the TV set in the living room, commenting on the television programme. The viewing space may be recorded with AR glasses and used as a life log.

Finally, in the longer term, brain computer interfaces may allow integration of human beings and the technology surrounding us. We may be able to control the world around us with our thoughts, and media experiences may fully immerse us, utilizing all our senses; sight, hearing, smell, taste and touch.

ANNEX 2: **TOMORROW'S PROGRAMME PRODUCTION**

GREATER FLEXIBILITY

GREATER MULTI FORMAT PRODUCTION

DISTRIBUTED PRODUCTION

SUMMARY OF ANNEX 2

The next decades will bring programme production that meet the needs of future user experiences in a multiformat world. Infrastructures will provide local, remote, and distributed production by applying IP, Cloud and serverless computing. Production resources will become more 'available on demand'. New 'workflows' will become possible and they will have a major impact on programme making. Metadata will continue to be key enablers. AI and ML tools will support editorial staff in a variety of tasks, including programme generation and detection of fake news. Sustainability and content accessibility will be strategic topics for content production.

1. INTRODUCTION

The main elements of future programme production may include the following:

The underlying trend in programme production infrastructure is **increasing flexibility** to meet the demands of the kinds of user experience described in the preceding chapter. New technology may increase the possibilities for flexibility, widen the potential range of content production, and improve its efficiency (including cost management). Hardware based production systems will be replaced by software and will increasingly operate in private and public Cloud environments. (Meta)data and AI will play a significant role in future workflows.

Broadcasters' production capabilities may be designed to create content and allow storytelling for a range of possible personalized consumer formats and user experiences.

The characteristics of future production centres are changing. There will be a maximum of flexibility in technical production infrastructures, including use of live IP based production, Cloud technologies – including hybrid on premises/public Cloud – distributed and remote production capabilities involving wireless infrastructures and extensive media cybersecurity. Production applications – the software systems used in programme production – will move towards the Cloud and the 'Edge of the network'.

A multi format production environment (from low end to high end content genres, with comprehensive access services, etc.) will be required, also providing sufficient quality headroom to cover current and future audience expectations.

The use of AI (artificial intelligence) and ML (machine learning) may increase, with a high degree of automation and involving extensive use of metadata along the media supply chain for more efficient workflows. There may be extensive use of AI based tools for content creation, for example in radio (e.g. audio mining), in archives, to create objects, in newsrooms or for detecting fake news, for personalization or for organizational decision making.

AI may help to produce immersive audiovisual media formats that range from UHDTV to object based media formats (including volumetric capture) and new possibilities on accessibility.

2. PRODUCTION FOR IMMERSIVE MEDIA EXPERIENCES

In recent years, XR technologies (encompassing augmented, virtual and mixed realities; AR, VR and MR) have continued to be used in industries such as games, education, remote assistance and entertainment. Volumetric capture technology with game engines is evolving accordingly. Light field 3D imaging technology has been evolving as well. The standardization of immersive media codecs (MPEG I and others) has continued.

Meanwhile, personalized media based on on demand services and object based media are growing, while the smart speaker is an example of an IoT (Internet of Things) device becoming almost ubiquitous. With the evolution of communication technologies such as 5G and beyond, ever more devices will be connected to the Internet, and media devices will become more and more diverse. Such devices and services will need to be served in production.

Public service media will need to reach these emerging devices to fulfil its role, while continuing to provide traditional 2D services. There will thus be a need for an efficient and flexible production system that can produce a variety of content for a variety of devices, from simple IoT devices to high end immersive devices. It may also be necessary to respond to the need and demand for the enhancement of video and sound with the expansion of expressive space from a conventional 2D screen and multichannel sound.

Therefore,

(a) *spatial sensing technology* will be needed for acquiring the shape and texture of objects, lighting conditions, sound properties, vital signs, etc.

(b) *3D modelling and spatial processing technologies* will be needed for enabling producers to present the object images and sound fields to best effect.

(c) *situation understanding technology* will be needed for assisting the production flow, such as automation of shooting, switching, sound mixing, and 3D processing; and

(d) *a cross modal production platform* that provides signalling of bodily sensations in conjunction with audiovisual content will be needed, so that end user devices can cause immersive sensations in the best way possible exploiting device features.

3. MOVE TO NEW PRODUCTION INFRASTRUCTURES

Production infrastructures, in house, distributed and remote, are to a large extent adapting IT technologies, processes and functionalities. As a first step, broadcasters have begun to use IP technologies (e.g. based on SMPTE ST 2110, NMOS, NDI, AES, and others) in production centres.

However, the infrastructure components (switches, networks, servers, etc.) in these facilities are still mostly fixed during the design and fit out stages, meaning that large changes can only occur during a re fit. The business operating model of a current generation IP facility is also inflexible, with large upfront capital expenditure being required.

R&D centres are working to enable broadcast centre style production operations to occur within a software defined Cloud environment. The COVID 19 crisis has necessitated a transition to remote Cloud based production in some areas, and this has sped up the digital transformation in production. The benefits of this will be huge, making physical IP facilities more flexible and enabling the deployment of fully virtualized production systems on demand - and only at the time when needed. Ultimately, this will help ensure more efficient use of resources and will allow delivery of more content to audiences.

To join up the worlds of broadcast centre production and the Cloud we will need to understand how to take the high bandwidth point to point signals that are used in our physical facilities today and turn them into something that works well in a local, remote and hybrid (private/public) Cloud computing environment. This may require a complete reinvention of how we handle media; traditional broadcast centres are typically built to move media in a serial manner, yet Clouds achieve much of their flexibility, scale and resilience by exploiting parallelism.

A ‘Cloud fit’ production system may need to be highly parallel and treat computing, network and storage as abstract, distributed resources. Furthermore, system architects will no longer talk about building and deploying applications or devices, but services.

A Cloud service is a user defined, distributed, universally available unit of functionality, which depends on dynamically provisioned underlying Cloud components. Each service will provide an API, through which it can be given production instructions.

Services will not depend on specific instances of an underlying resource (e.g. a particular virtual machine, or a particular IP address), but will use abstraction and encapsulation principles such as load balanced APIs and DNS to provide parallel, scalable, and resilient subsystems.

Going even further, serverless computing might provide API functionality without the need to manage any underlying infrastructure at all. (of course, the infrastructure still exists, but the Cloud provider manages it in response to demand).

All of this will add up to something quite different to a conventional production facility, where single instances of processing devices (such as a video encoder) are connected by means of point to point signals (rather than APIs).

At the other end of the chain, content distribution increasingly leverages IP and the Cloud, and thus having programme production already taking place in the Cloud will also simplify the distribution aspects.

For the successful implantation of these new infrastructures it will continue to be important to pay attention to security, as they may be vulnerable to cyber attack.

4. THE USE OF METADATA, AI AND ML ACROSS ALL TECHNOLOGY DOMAINS IN THE PRODUCTION CHAIN

The scope of metadata, AI, and ML in the whole production value chain is constantly evolving as the strategic importance and volume of data increases. This goes alongside the application of unique identifiers for all content elements. Metadata will contain descriptive information as well as technical information; these are vital for the whole production workflow and feed distribution and consumer applications too.

AI offers new opportunities in the media sector - generally and specifically in the production chain. In some cases, ML technologies are already in use, but there is room for improvement in terms of accuracy and efficiency (e.g. recommendation systems), whereas in other cases these technological advances have the potential to foster innovation and enable novel solutions to existing challenges or even create new application domains (e.g. creation and detection of synthetic types of media).

In the programme development stage of the production chain, ML technologies may offer predictions on whether a potential production will be profitable or not. This will help towards automating the approval process of new shows, by determining whether to green light new shows based on users' behaviour and/or scripts. Moreover, the growing availability of data wealth (as mentioned in previous sections) may result in the growing need to manage content, make intelligent decisions about finding content using specific criteria, and also to make decisions whether to store, delete or make content instantly available.

In the production stage, AI technologies may help reduce productions' costs through automated production at scale, i.e. providing more qualitative content at reduced cost. For instance, automated camera production in sports or cultural events.

Another important application area that is going to benefit substantially from AI technologies during the production stage is accessibility. These technologies will dramatically raise the quality level of accessibility, for instance by automating subtitling of live shows as well as archived content, in addition to automatic language translation. In this way, more content will be accessed by more people with disabilities.

In the newsroom, automation may reach a level such that journalists are substantially supported and there will be more room left for creativity. For example, time spent on searching for appropriate content can be saved by meaningful recommendation and personalization services. Robust summaries and extracts can be generated by AI prior to human engagement. Moreover, AI synthetic personalities (that can be fully customizable) may be used for automated news presentation and for accompanying personalized recommendations, including translations into multiple languages. AI technologies will aim at more precise content discovery and content creation by means of creating stories based on structured information, generating storyboards and audiovisual animation sequences by interpreting natural language descriptions as input. For certain broadcast products and genres or for automated creation of derivatives and repurposing, the production process may become completely AI/ML based, with manual supervision only on occasion.

Another aspect that is of critical importance with huge societal consequences, is the battle against misinformation. Journalistic investigations powered by AI may be able to detect and flag misinformation in forms of audio, video and text across a wide range of media types (television, newspapers, radio, social media etc.). Such an example is the case of the newly emerged DeepFakes (i.e. synthetic media manipulated by deep learning algorithms), whose quality is rapidly increasing, and even human experts can easily be deceived by them. Furthermore, the mining of meaningful information based on a vast amount of heterogenous data, as well as its analysis and visualization, prove to be great tools that will support and allow investigative and data journalism to thrive. Language barriers may be removed by AI, allowing investigations in real time, from sources all over the world.

Moreover, AI technologies can help with identifying bias in the news, automatically detecting hate speech in social media, and monitoring gender under representation in public media, thus supporting transparency and diversity in journalism. Last but not least, AI may be used for security, to protect audiences (especially young audiences) from malicious digital attacks. Examples include scanning and filtering of the activities in smartphones for hate speech detection, sentiment analysis, etc. Every new technology that is based on data and AI technologies will also have to be accordingly adjusted to be permissible under the AI related ethical guidelines that will be established at national as well as European levels.

5. SUSTAINABILITY IN MEDIA PRODUCTION

In the next twenty years, ever stricter sustainability goals will be applied across nations. There will be national goals, EU goals for EU members, and UN sustainability goals for all UN signatory nations. They will thus need to be interpreted and applied to media programme production organizations.

These will influence programme production working methods, though production will also be influenced by other growing needs for more flexibility, greater production quality headroom, and greater cost effectiveness. Overall, the influences may sometimes support each other and sometimes may be in conflict. Green measures will be a major shaping factor for content production in the next decades.

Sustainability measures fall into two interrelated categories.

The first includes measures to *indirectly* reduce carbon emissions by reducing internal energy consumption and *directly* by reducing transport vehicle use, which creates carbon emissions. Such measures can be complemented by others that offset the emission of carbon such as, for example, tree planting. These all help the total organization to move towards carbon neutrality.

The second category includes measures to reduce waste that can damage the planet's ecosystems. This involves reducing or avoiding the use of plastics or other non biodegradable materials.

As general trends, media organizations will need to use ever more software based production systems and make increasing use of remote computational power via general or specialist Cloud services. These will lead to financial savings and possible staff reductions but may *increase* total power consumption.

Programme creation is also likely to use more consumer equipment rather than professional equipment ('commoditization'), and thus will likely consume less power. There may be less full studio production in the future in content areas such as news, following the experiences of remote production during the COVID 19 pandemic, which may also *reduce* power consumption.

Thus, the future will see changes in programme production that will both increase and reduce power consumption. Companies will need to make calculations to be certain that they are in control of the situation and that they can meet sustainability requirements.

Companies will be asked to be carbon neutral by as early as 2030 in some cases, and to be sure that they can do so they need to plan today for implementing energy reducing measures and to increase their carbon offset measures either in areas local to the production centre or elsewhere. Many companies have already begun to do this.

Measures to reduce the use of non biodegradable materials will continue and may be the subject of national regulations.

Several broadcast groups in different countries have developed sets of rules that programme production should follow to encourage sustainability. These include *Albert Sustainable Production Certification* in the UK, *Ecoprod* in France, and *Green Shooting* in Germany. Other countries can be expected to agree similar rules in the next ten years.

ANNEX 3: **TOMORROW'S MEDIA DELIVERY**

NEW CONTENT FORMS AND USER EXPERIENCES

AVAILABLE ON ANY RECEPTION DEVICE

COMBINATION OF DELIVERY PLATFORMS

SUMMARY OF ANNEX 3

The next decades will bring the delivery to the user of new content forms and user experiences. Media services will also be available on a wider range of different types of receiver: TV sets, tablets and smart phones. The range of delivery platforms will remain as terrestrial, satellite, cable, IPTV, Wired and Wireless Internet and Wi Fi, but some will be limited in the new kinds of service they can provide. The new 5G and 6G wireless broadband systems may play a significant role in providing media services. An attractive option may be to combine broadband services with broadcast services and create intelligent concurrent networks.

1. INTRODUCTION

The challenge for future media delivery systems is to provide the means to make available the new content forms that are produced (Annex 2 of this report) to provide the desired future media user experiences (Annex 1 of this report).

Thus, user experience, content production and media delivery are, to a large degree, all interdependent elements [4]. Future delivery systems must take into account what needs to be delivered, the availability of delivery channels and the circumstances in which they are to be received by the user. There are many other factors that would determine the success of specific media services and delivery systems in practice. They include user costs, service and content availability, and others. These will be important influences on the possibilities for the development of future media delivery systems. Future delivery systems also need the possibilities and prospects for acceptable transitions from current to new systems.

2. THE MAIN TRENDS IN NEW SERVICES

As mentioned previously, one of the two main trends postulated for future user experiences for the next 20 years is the provision of more immersive viewing and listening, providing a greater sense of reality for the user. The other postulated trend is the provision of more personalized content and services providing more choices, user options, and content features.

At the same time, the main trend postulated for the future receiving environment is the need for the universal availability of the new service formats in all types of receiving circumstances. That is to say, the user should be able to receive the content on either (or all) smartphones, tablets, TV sets, or new kinds of terminal for any future services. This could be summarized as the trend to having content available on any terminal in an appropriate form for the terminal. The next 20 years may also bring wider use of autonomous vehicles, which may be a major user terminal for media delivery. Regarding media delivery, fast moving vehicles may have greater robustness requirements than would stationary or slower moving environments.

The capacity needed to deliver media depends on the technologies of audio and video compression used. New compression systems which are more efficient than previous systems are standardised every 6 - 10 years. This opens the possibility of image and sound quality rising in steps over time, though the possibility of doing so can be limited by the provision of new receiving devices that use the new compression systems.

3. THE CURRENT PLATFORMS

Current platforms that can be used for media delivery include terrestrial broadcasting, satellite broadcasting, cablecasting, wired IPTV, wired and wireless internet, and by extension, Wi Fi.

Some combinations of the delivery platforms can be used in **'cooperative networks'**, for example, by applying broadcast systems in conjunction with the interactive capabilities of IP based networks. Some combinations of content can be provided using a plurality of platforms at the same time as **'cooperative content'**. Such services can be provided by HBB (hybrid broadcast broadband) systems, including HbbTV (Europe) and Hybridcast (Japan). HBB delivered content is largely provided by the organization providing the related conventional media content.

4 Eachof them is only 'useful' if all the elements are in place in the chain from production source to user, to allow the creation, passage, and use of the service. To make the user experience available, the capacity to make, deliver and receive the content must be available.

There may be exceptions in that programme production systems that provide a higher quality than we wish to deliver can provide 'production headroom'. This can help conversion to multiple formats and can help to future proof content.

4. SYSTEMS TO BE CONSIDERED FOR DELIVERY

There are current systems that will need to be available for future services.

The new services that could be candidates to be introduced in the next 5 - 10 years may include the following.

a) New Immersive services that may need to be accommodated

- Ultra high definition television (UHDTV) services which include 4K (already available to some degree by satellite and online), 8K, and (if the trend continues) 16K video. The bandwidths needed for each of these systems would depend on the compression technology used and latency requirements, but could be expected to be of the order of up to 30 Mbit/s peak for 4K, with proportionately higher bit rates for 8K and 16K. New compression technologies which halve the bit rate needed to achieve a given quality are developed approximately every 6 - 10 years.

- Extended reality (XR) services, which include virtual reality, augmented reality, mixed reality, and 'pseudo object wave' services using three dimensional spatial sampling (Integral TV) or light field techniques. Virtual reality bandwidths may be at least double those for 4K delivery. AR and MR would require additional data.

- New Generation Audio (NGA) services, which include multichannel, object based, and Higher Order Ambisonics (HOA). The bit rates needed will be higher than for surround sound, but small compared to those required for video.

b) New Personalization systems that may need to be accommodated

- New accessibility systems such as the provision of tactile information or aids for cognitive differences.

- New home equipment control and activation systems using in vision photo realistic avatars and sound.

- New home participation systems such as physical company providing automatons.

- New home equipment monitoring. Programme content that can make use of information about what is available in the user's home.

- Targeted advertising or other inserts for groups of users. A content or network provider can seamlessly exchange certain portions of a programme with alternative content that is believed to be more relevant to the user, and which is delivered separately by internet.

- The use of blockchain can add traceability and transparency to the execution of rights related workflows in controlled environments, as for example being standardised in MPEG for controlled environments and smart contracts. This could open the option to personalised subscriptions and delivery efficiency as a single high quality stream can be used by several content bouquet providers.

c) New Cooperative Content and Network Systems

- Hybrid systems such as DVB I and similar systems, which allow access to both internet services (OTT) user interfaces and broadcast service user interfaces.

- Applying the convergence potential of Cloud based infrastructures to create `network slices` by seamlessly integrating northbound Edges with distributed Edge devices through a virtualised delivery connection that can include traditional broadcast systems. Such a network slice optimizes functionalities between decentralized Edges and those closer to the core of the network using traditional broadcast solutions as a virtualized communication network.

This would allow the integration of broadcast media services in online distribution paradigms (such as CDNs) or enable caching and content manipulation through Cloud and Edge computing.

5. TYPES OF INFRASTRUCTURE CHANGE CAUSED BY NEW SYSTEMS

There can be several circumstances to consider.

- The first is where changes can be accommodated by uploading new software to an established domestic smart receiver, without a change in spectrum requirements and possibly even without a change in the lower layers of the transport and delivery protocols. This group will be the least disruptive to introduce.

- The second is the provision of changes that would require new baseband or radio frequency systems, at either or both the transmitter and receiver. In this case new hardware is needed.

- The third is where new spectrum would also be needed to accommodate the new services. This may be because of the need for simulcasting, or because the new services require greater radio frequency bandwidths. This group will be the most disruptive to introduce.

- New enhanced services will typically involve personalized data streams and return signals from a client to a broadcast station or to Cloud and Edge servers. These may be personalized content, local interactions with non personalized content, or any device or user specific exchange of data that is required in new service types.

- Pure ‘broadcasting’ may not cover all delivery requirements, whereas a pure IP and unicast based system may be able to provide certain of them, while lacking free to air access, scalability, and cost efficiency. A future delivery system could combine advantages of both worlds, broadcast and unicast, while providing a common toolbox to flexibly and dynamically allocate features and capacity to enhanced media services. As a further consequence, new delivery systems would have to be designed to handle broadcast, unicast, upstream and downstream data, all together in a flexible and configurable way.

While the evolution of content production can involve disruption because of the need to replace production equipment and infrastructures, the scale and overall cost of the disruption, if needed, of transmitter and domestic equipment is very much larger. A single production centre can provide content for delivery to hundreds of transmitters and millions of domestic broadcast users.

Thus, the gains brought about by changing a delivery system in an established market will usually need to be very large to justify the change. There must be a clear benefit to the user and for all parts in the delivery chain – such as enabling completely new services and improved playout quality. At the same time, requirements introduced by new services may operate as an accelerator for changes of the delivery structure.

6. COVERAGE REQUIREMENTS OF NEW DELIVERY SYSTEMS

Public or private broadcasters with a public service mission have requirements that any future delivery system needs to meet. These are outlined in a recent EBU Report[5].

The possibilities for evolving delivery systems are governed by many factors, which include frequency availability and the regulatory climate. One of the most important mandates for PSM organisations is to reach the entire nation with a wide spectrum of programmes in the best possible quality in a cost effective way.

7. TECHNOLOGY OPTIONS

There are a range of broadcast delivery platforms in widespread use today that, bearing in mind the wide penetration of services using them, may be costly and complex to discontinue. However, some technology options may be terminated while new ones evolve. Implementing such changes in some cases would need a major nationwide and international transition programme, extensive public information, and possibly subsidies for new receivers. Furthermore, their continuation also depends on the continuing availability of terrestrial spectrum.

8. TERRESTRIAL BROADCASTING

The future situation regarding radio frequency for terrestrial broadcasting is unknown, but there is pressure to use frequency spectrum used in the past for terrestrial broadcasting for services other than broadcasting. This suggests that it may be difficult to provide a simulcast service with a new broadcast format or use a format that requires wider channel spacing for the new services. However, existing terrestrial broadcasting services are likely to remain in service in at least some markets for a considerable time in the future.

9. SATELLITE BROADCASTING

There is room for growth to new services in satellite broadcasting, as the spectrum is not at such a premium as for terrestrial broadcast. It would be potentially possible to deliver many of the new user experiences outlined in Annex 1 by satellite broadcasting, provided that for interactive services, upstream channels and personalized downstream paths for enhanced media services are added and inherent latencies can be managed.

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5 Universal Coverage and Access: Geographical availability of the service (e.g. national, regional, local) according to regulatory requirements

I Free to air Access: Users can consume content without the need to subscribe to the service provider or the network operator

II Defined Quality of Service (QoS): To be defined by the broadcaster, e.g. availability of network transmissions, robustness, up time, latency, and reliability

III Scalability: QoS for each user shall be independent of the size of the audience.

IV Service integrity: No modification of the PSM content or service by third parties. For example, TV content and additional services (e.g. subtitles) must be displayed on screen, unaltered and without unauthorised overlays.

V Prominence: Provisions should exist for adequate prominence of several PSM services intended to be offered (e.g. position in programme guides)

VI Ease of Use: Straightforward accessibility and prominence of the PSM offer

VII Accessibility: Support for people with disabilities (e.g. subtitles, audio description and public Warning: Ability to reach audiences in emergency situations

VIII No Gatekeeping: Deliver PSM content to the public without unduly constraining the service offer e.g. blocking or filtering content, restricting access to services or network infrastructure

IX Costs: Nationwide content distribution and universal access should be affordable for PSM (including content royalty fees) and consumers alike. Specific use cases may entail several additional requirements that need to be considered, for example data rate, bit error rate, targeted peak concurrent audience size, mobility, etc.

10. BROADBAND AND "XG"

A potentially significant influence on delivery systems may be the need for a mixture of downstream broadcast, downstream unicast and upstream unicast. This could be done by broadband and 5G or 6G systems.

The development of broadcasting technologies has been a success in the last 60 years. The evolution of IP delivered services, including media services, has recently challenged the role of terrestrial and satellite broadcasting for the coming years.

11. INTELLIGENT CONCURRENT NETWORKS

The deployment of combined Cloud based and 5G technologies may be a way to `rejuvenate` satellite and terrestrial broadcast based platforms.

Previous mobile telecommunications technologies established a closed communication eco system dominated by large mobile network operators. 5G is designed to integrate vertical industries by a flexible system architecture enabling the deployment of software based network elements, and the provision of standardized interfaces and APIs towards service providers.

A future solution may be to use a Cloud based network architectural approach of media optimised network 'slices` to seamlessly integrate broadcast functions with online delivery. Broadcast systems could be used to distribute popular media content over a large region to the home network or network head end in a gateway or base station - in so doing, converging existing DTT or satellite delivery mechanisms with online media services. While the end users' access to media content remains unchanged (i.e. they will consume media through a content provider's online service and enjoy an interactive experience using their normal, connected devices), the playout application will seamlessly connect to the application running on the 'Cloud/Edge' solution (for example using DVB I).

These (distributed) Edges can run applications for immersive and personalised services with an optimal Quality of Experience by caching the playout content as close as possible to the media consuming audiences. Content can be cached and processed closer to the end user to include on demand use, personalisation, localisation and optimisation of the quality of the media consumption experience of end users in vehicles such as cars, trains, planes, ships or those audiences in fixed locations such as houses or apartment complexes.

Different types of network infrastructure and protocols - terrestrial and satellite, wired and wireless, unicast and broadcast - have evolved over time and have been optimized for different purposes (e.g. coverage, capacity, interactivity, resilience, reliability and cost). No single infrastructure can provide the service level required everywhere (bandwidth, upstream, etc.). By combining different physical infrastructure, we may create a resilient, reliable and sustainable infrastructure to deliver essential services to virtually the whole population and in the whole territory.

An example would be audiovisual content such as news, live events, or entertainment that is produced once and consumed by multiple users at the same time. This kind of content is best distributed using broadcast/multicast technologies to reduce the impact of peak traffic on unicast distribution infrastructure, especially the congested interconnection points.

Even where a unicast distribution network has sufficient capacity to serve mass audiences, multicast/broadcast would bring advantages in terms of costs and environmental impact.

The availability of concurrent networks is also fundamental to guarantee reliability and security of service delivery. A single infrastructure will not meet all needs. Using a combination of several layers of security on different physical supports will provide redundancy and reliability.

The recent impact of the COVID 19 crisis once again underlines the advantages of direct broadcasting not suffering from network congestion at a time when reliable access to news and information is essential and indispensable for the whole of society.

During the initial weeks of the crisis, it became apparent that networks became congested due to the increase of video calls, VOD streaming services and multi player gaming. The impact of network congestion during a crisis is even more evident when looking at delivering emergency alerts that should instantly reach 100% of the population. The most efficient and reliable way of doing this is using broadcast, starting from the delivery of critical information to any citizen but also to vehicles, those being autonomous or just connected.

By combining different infrastructures and technologies we could have a sustainable communication and media distribution network.

12. THE OPTIONS FOR FUTURE MEDIA DELIVERY

Excepting intelligent concurrent systems that may be developed, major new services that need new receiving systems, may need to be principally provided using the Internet, where bandwidths and formats are less limited, and introduction would be less disruptive. Satellite broadcasting could also be an option for major new services, but could be less attractive than internet delivery, because of the disruption to existing consumers.

To provide some of the new experiences described in Annex 1, large Internet bandwidths and low latency would be needed. These would therefore benefit from the high delivery bit rate potential of 5G and 6G. A 5G broadcast profile is being developed, which will allow the requirements set out earlier to be met.

At the same time, in the short term, switching off existing terrestrial broadcasting services will not be practical in some markets. Equally, terrestrial and satellite broadcasting may still be the most efficient and reliable methods of delivering media, though services with more advanced user experiences and personalization may not all be possible.

We can conclude that future media delivery will be provided individually or by a combination of terrestrial and/or satellite broadcast and 5G delivery with a potential upstream component. The combination used will vary from country to country. It may be that intelligent concurrent networks that use combinations of different delivery platforms will ultimately provide the most cost effective delivery.

“FUTURA PUGNANT NE SE SUPERARI SINANT” LATIN PROVERB.

THE FUTURE WILL STRUGGLE AGAINST BEING MASTERED

CONTRIBUTORS TO THIS REPORT

BBC R&D
British Broadcasting Corporation
represented through **Judy Parnall**

IRT
Institut für Rundfunktechnik GmbH
represented through **Dr Rainer Schaefer**

NHK STRL R&D
Nippon Hōsō Kyōkai
represented through **Mitani Kohji** and **Kamoda Hirokazu**

RAI CRITS
Radiotelevisione Italiana
represented through **Gino Alberico**

VRT
Vlaamse Radio- en Televisieomroeporganisatie
represented through **Mike Matton**

YLE
Yleisradio Oy
represented through **Anssi Komulainen**

EBU TECHNOLOGY & INNOVATION
European Broadcasting Union
represented through **Antonio Arcidiacono, David Wood, Hans Hoffmann, Bram Tullemans**

For more information contact: **Dr Hans Hoffmann** at hoffmann@ebu.ch

EUROPEAN BROADCASTING UNION
L'Ancienne-Route 17A
1218 Le Grand-Saconnex
Switzerland

T +41 22 717 21 11
ebu@ebu.ch

Learn more about the EBU at
www.ebu.ch

Learn more about EBU Technology & Innovation
tech.ebu.ch

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Twitter: @EBU_HQ
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