Report ITU-R BS.2522-1

(11/2024)

BS Series: Broadcasting service (sound)

A framework for the future of broadcasting

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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Series	**Title**
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	**Broadcasting service (sound)**
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
TF	Time signals and frequency standards emissions

Note: *This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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(2023-2024)

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Scope

This Report presents a framework for the future of broadcasting taking into account the expectations of end users and advances in broadcast programme production and delivery technologies. It aims to inform, assist and guide the broadcasting industry, researchers and regulators about future developments of systems, technologies and applications for broadcasting.

Keywords

Future of broadcasting, future user experience, future of media production, future broadcast delivery

Abbreviations/Glossary

3D   Three-dimensional audio or video

3DoF   Three degrees of freedom

6DoF   Six degrees of freedom

AI   Artificial intelligence

AISM   Advanced immersive sensory media

AR   Augmented reality

CDN   Content delivery network

DTT   Digital terrestrial television

DTTB   Digital terrestrial television broadcasting

FM   Frequency modulation

GUI   Graphical user interface

HD   High definition

HDR   High dynamic range

HF   High frequency

HMD   Head-mounted display

HOA   Higher-order ambisonics

IBB   Integrated broadcast-broadband

IoT   Internet of Things

IP   Internet Protocol

LF   Low frequency

MF	Medium frequency
ML	Machine learning
MR	Mixed reality
OBM	Object-based media
PMSE	Programme-making and special events
PoP	Point of presence
QoE	Quality of experience
RDS	Radio data system
SAB	Services ancillary to broadcasting
SAP	Services ancillary to programme-making
SD	Standard definition
UHD	Ultra-high definition
UHDTV	Ultra-high definition television
UHF	Ultra-high frequency
VHF	Very high frequency
VOD	Video-on-demand
VPN	Virtual private network
VR	Virtual reality
XR	eXtended reality

Related ITU Recommendations, Reports

Recommendation ITU-R BS.2051 – Advanced sound system for programme production

Recommendation ITU-R BT.1833 – Broadcasting of multimedia and data applications for mobile reception by handheld receivers

Recommendation ITU-R BT.1877 – Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems

Recommendation ITU-R BT.2016 – Error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers

Recommendation ITU-R BT.2020 – Parameter values for ultra-high definition television systems for production and international programme exchange

Recommendation ITU-R BT.2054 – Multiplexing and transport schemes in multimedia broadcasting systems for mobile reception

Recommendation ITU-R BT.2075 – Integrated broadcast-broadband system

Recommendation ITU-R BT.2100 – Image parameter values for high dynamic range television for use in production and international programme exchange

Recommendation ITU-R BS.2107 – Use of International Radio for Disaster Relief frequencies for emergency broadcasts in the High Frequency bands

Recommendation ITU-R BT.2133 – Transport of advanced immersive audio-visual content in IP-based broadcasting systems

Recommendation ITU-R BT.2144 – Guidance for the introduction of new DTTB systems, technologies and applications in the broadcasting service

Recommendation ITU-R BT.2153 – The use of componentized workflows for the exchange of non-live television programmes

Report ITU-R BT.2140 – Transition from analogue to digital terrestrial television broadcasting

Report ITU-R BT.2207 – Accessibility to broadcasting services for persons with disabilities

Report ITU-R BT.2267 – Integrated broadcast-broadband systems

Report ITU-R BT.2299 – Broadcasting for public warning, disaster mitigation and relief

Report ITU-R BT.2302 – Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran

Report ITU-R BT.2343 – Collection of field trials of UHDTV over DTT networks

Report ITU-R BT.2384 – Implementation considerations for the introduction and transition to digital terrestrial sound and multimedia broadcasting

Report ITU-R BT.2385 – Reducing the environmental impact of terrestrial broadcasting systems

Report ITU-R BT.2387 – Spectrum/frequency requirements for bands allocated to broadcasting on a primary basis

Report ITU-R BT.2400 – Usage scenarios, requirements, and technical elements of a global platform for the broadcasting service

Report ITU-R BT.2420 – Collection of usage scenarios of advanced immersive sensory media systems (AISM)

Report ITU-R BT.2447 – Artificial intelligence systems for programme production and exchange

Report ITU-R BT.2448 – Technical realisation of signing in digital television

Report ITU-R BT.2485 – Advanced network planning and transmission methods for enhancements of digital terrestrial television broadcasting

Background

This Report was developed taking into account:

a)   that the convergence of consumer and professional media-based broadcasting technology is enabling new content creation, delivery and consumption opportunities;

b)   that the integration of Internet Protocol (IP) technologies and cloud computing into broadcasting technologies enables broadband access and flexible and more efficient content creation and distribution;

c)   that the crises happened both on the global level (e.g. COVID-19) and regional level (e.g. military conflicts) demonstrated the value of broadcasting through the delivery of essential information, safety advice and education to the public;

d)   that broadcasters are seeking to adapt to the growing diversity of media delivery options available to end-users;

e)   that traditional fixed physical broadcast production infrastructures are beginning to be replaced by virtualized software application-based systems;

f)   that the use of new technologies and working practices for broadcasting is expected to assist the realization of the United Nations Sustainable Development Goals;

g)   that it is desirable to agree on a harmonized framework for developing common technical, operational and spectrum-related parameters for broadcasting, taking into account the deployment of existing broadcasting systems*;*

h)   that radiocommunication broadcasting extends from the production of programmes to their delivery to the general public;

i)   that Preamble 0.2 of the Radio Regulations encourages Member States to endeavour to apply the latest technical advances as soon as possible;

j)   that Resolution ITU-R 70 resolves to develop Recommendations and Reports for the introduction of new systems, technologies and applications for broadcasting to achieve global harmonization of specifications, taking into account the requirements and situations in countries/regions;

k)   that Resolution ITU-R 70 also resolves that the development of Recommendations and Reports for future systems, technologies and applications for broadcasting shall be an ongoing and timely process with defined outputs that take into account developments external to ITU-R;

l)   that Resolution ITU-R 71 resolves that a roadmap for ITU-R activities for broadcasting should be developed by the relevant Radiocommunication Study Group to ensure that this work is progressed effectively and efficiently with other ITU-R Study Groups, ITU-T, and ITU-D as well as organizations external to ITU; and

m)   that ITU-R Study Group 6 has established globally accepted Recommendations, Reports and Handbooks on all aspects of the end-to-end broadcasting chain from programme production through assembly to delivery.

1   Introduction

The rapid advance of consumer and programme-making technologies and the drive to create a fully connected world are changing the expectations of broadcast media users. Today, audience expectations are reshaping the traditional idea of broadcasting as it merges with gaming, streaming and content-based services available through internet-connected and smart devices used in any location. Broadcasting needs to keep pace with these trends to continue influencing the development of new media technologies and to play a role in shaping the future nature of society.

ITU-R Study Group 6 remit is to study all aspects of broadcasting from content origination to international content exchange and delivery through terrestrial broadcasting networks. Many of the trends discussed in this Report began as studies resulting in Recommendations, Reports and Handbooks by ITU-R Study Group 6 and its predecessors.

This ITU-R Report encourages the consideration of user trends and broadcast technology developments that constitute a framework for developing new or enhanced broadcasting systems for the future of broadcasting.

1.1   Timescale

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.

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. These factors include the prevailing societal and media climates, the desirability, affordability and availability of receiving equipment, sufficient content and the infrastructure available for distribution to the users. The challenges faced by media providers, the needs that the new developments would fulfil, and other factors based on culture, regulation and social/economic values will mean there will be a right time for new technology, but it will not be the same in all countries.

1.2   Challenges and opportunities in future environments

Realizing a future broadcast media environment will require a range of new tools and working practices to produce and deliver content that exploits the options for new or expanded services. Broadcasting organizations need to weigh up the benefits, practicality, and economic implications of each service option that technologies offer.

–   The growing use of cloud and Internet Protocol (IP)-based services for production, distribution and delivery often rely on third-party or outsourced facilities and will require reinforcement of security and access measures.

–   Production and delivery environments will call for steps to improve sustainability[1].

–   There is a growing global awareness of the need to add measures that aid those who need options to assist in accessing media.

Future media experiences will be based on broadcast technology development trends that enable more and more options for personalizing the media experience, including but not limited to, voice interaction, digital assistants, automated translations and haptic and gesture related interaction. Users will want to securely store personal data and be able to hand it off to different devices either by choice or allow automated triggering set by the local environment, specific user needs or suggestions from the broadcaster or content creator.

The user experience, content production and media delivery options are, to a large extent, interdependent. However, each is only useful if all the elements are in place in the chain from the source production to the reproduction by the end-user. To realize any user experience, the capacity to make, deliver and receive the content must be available.

2   Future user experience

Future user-experience-based broadcasting technology developments are enabling more and more options for personalizing the media experience, including the use of voice activation, digital assistants, and haptic interaction. These options can be chosen by the user or triggered automatically by the local environment or the user's needs.

The sense of reality is heightened by a more immersive experience and increased image and sound quality. Additionally, new experiences can be created by combining the real or conventional media world with digitally created virtual worlds. A virtual community can gather around the same content in these digitally created virtual worlds.

2.1   User experience framework

Broadcast content and technology will offer a greater sense of reality. Together with additional options for media personalization and interaction, the bonds of a virtual community gathered around the same content will be substantially strengthened.

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

–   collective experience;

–   personalized user experience;

–   ubiquitous media consumption experience;

–   digital assistant and ambient computing ecosystem experiences;

–   accessible experiences;

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[1]   See ITU-R Opinion 104 – Advice for sustainability strategies incorporating carbon offsetting policies.

– immersive experiences; and

– experiences that merge the physical world and the digital world.

2.2 Collective experience

In the early days of broadcasting, listening to the radio or watching television was a collective experience. Families (and sometimes neighbours and friends) joined to enjoy this experience together. Nowadays, there is an increasing trend of individual media consumption, personalized according to user preferences and context, available on any device, anytime, anywhere. Nevertheless, there is still a powerful collective experience associated with the consumption of broadcasting content. Many people still prefer to watch or listen to their favourite content accompanied by people close to them.

During sports broadcasts, as a self-evident example, large groups of supporters of the same team gather to watch the match and cheer together. Even when, circumstantially, people consume broadcast content alone, they often comment on that programme with others over the Internet. During the COVID-19 pandemic, many of the Internet's trending topics concerned broadcast content. This demonstrates that listening to radio or watching television programmes still provides a collective experience, even if such a community does not physically meet in the same place or even if it does not consume the content simultaneously.

New technologies merge the physical and digital worlds creating virtual communities with an enhanced experience when consuming broadcast content. User experiences in the future might have more social dimensions than today, where, for example, users can experience sports events and premium content together with their friends and family regardless of their location[2].

2.3 Personalized user experience

Personalization is a key driver to new, localized, targeted, and accessible media services for broadcasting, opening many opportunities to users. Tomorrow's user experience will become more personal.

The user can receive suggestions on what content to consume at any given moment, based on a prediction using personalized data. Such prediction can be calculated on a mix of signals and data about user intent, viewing history and user context (e.g. user preferences stored on the receiver, time of day, location, movement, ambient noise, and other people present in the room). Broadcasters should consider limiting the creation of undesirable AI system-generated filter bubbles on the user side, for example, to allow the reception of the complete set of news and/or opinions. Furthermore, both broadcasters and users should be able to block the recommending engine at any time.

In addition to content recommendations that require user interaction to initiate consumption in real-time or on-demand, linear programming schedules will be customizable according to user preferences. Different programmes and commercials can be received from different distribution platforms (e.g. terrestrial broadcasting and Internet) in an automatic, seamless, and transparent manner.

The personalized experience will even extend into activities undertaken in the physical world. For example, when someone is passing close to a restaurant or shop featured in a television programme that they have watched, it is possible to receive a recommendation notification. The user will also be able to receive local, regional, or national content relevant to their current location, whether fixed or on the move.

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[2] See "BBC Together" (available at https://www.bbc.co.uk/rd/blog/2020-05-iplayer-watch-party-group-watching-viewing).

A fully personalized user experience may require the system to identify the user. There are different levels of identification, depending on the associated use cases. The option of anonymous/untracked reception will remain a requirement of free-to-air broadcasting services in many parts of the world. Even with anonymous/untracked reception, locally stored metadata can provide the user with some personalization. To protect the users' privacy, the user should be required to opt-in through clear and concise informed consent if any personal data is used by the third party. The use of personal data may be subject to distinct regional regulations. The user will be able to log in to services by their preferred method, including biometric authentication, and to stay logged in while shifting through different interfaces, services, and contexts.

Consumer devices permit the end user to access personalized video content in the home viewing environment and on the move. In-car entertainment systems can synchronize with personal mobile devices to allow seamless content consumption to form a fully integrated infotainment system that directly connects to our choice of ecosystem. It is already being witnessed the roll-out of cars with comprehensive operating systems that virtually make them digital mobile devices on wheels.

A personalized media consumption experience should in no way unnecessarily increase the complexity of using the distribution platforms. Simple, intuitive, natural, and familiar user interfaces should be deployed, unifying the media consumption experience, even when multiple distribution platforms are used in a hybrid and integrated manner (e.g. terrestrial broadcasting and Internet).

2.4   Ubiquitous media consumption experience

Broadcasting includes different types of reception; e.g. fixed antenna reception, portable reception with an attached or built-in antenna (outdoors or indoors), and mobile reception using a non-directional antenna mounted on vehicles). The advent of portable and handheld receivers enabled end-users to enjoy broadcast content almost anywhere, in and around the home, in public spaces and while on the move.

Handheld devices evolved from their original mobile telephone use into smartphones that became permanent companion devices. They are increasingly used as individual media consumption devices on the move. This use is fuelling the growing demand for the availability of media for ubiquitous consumption. Users expect their preferred media to be available to them wherever they are. This is already partially happening in the current users' media consumption experience and should expand further in the future.

2.5   Digital assistant and ambient computing ecosystem experiences

Current trends indicate that significant growth of consumer devices from smart speakers and wearables to smart cars and voice-enabled Internet of Things (IoT) products will continue to occur.

Current user interfaces are mainly based on Graphical User Interfaces (GUIs) that are essentially designed for content discovery, user experience and navigation. VOD (Video-on-Demand) 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 will facilitate new ways of discovering content. Discovery will be based on casual natural language interactions, facilitated through voice and dynamic responses from the GUI, which will have an impact on consumption patterns and the user experience, initiating a new wave of innovation and diversification in user journeys.

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

The user will 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 could break into an audio-visual augmented reality (AR) content layer when accessed via wearable devices.

Content could be produced to support different video/audio/AR consumption scenarios. The user could, for example, start reading at home and continue listening while in transit, with an option for AR if they wear an AR device. While on the move, the user can receive quick text/audio/haptic notifications about breaking news via mobile devices and would choose which stories to follow using speech, gesture, gaze or brain-computer interfaces. Subsequently, the user can be presented with up-to-date information on the stories of interest.

2.6   Accessible experiences

All users should be able to understand and enjoy any content with universal accessibility adapting to users' capabilities and circumstances[3]. For example, an automated translation service will enable users to enjoy content made in foreign languages. When combined with speech synthesis, an automated translation could be turned into an audible translation that might sound like the person originally speaking in a piece of content.

Widely available captioning will play an increasingly important role not only for the hearing-impaired or elderly but also in noisy places or places where sound is prohibited or unwanted. The continuing development of automated and AI-assisted closed-captioning services combined with traditional human-based captioning will increase the amount and quality of captioning available.

Automated sign-language services will be provided for the hearing-impaired, automatically translating speech into sign-language presented by avatars or computer-generated photo-realistic signers in a natural manner.

Audio description services that automatically generate human-realistic voice narrations of the scene, along with haptic information linked to the content will enrich the experience of visually impaired people.

2.7   Immersive experiences

Immersive technologies change storytelling. Instead of just passively watching something happening, we are taken inside stories in game-like environments that invite us to interact with the story as it goes on.

Improvements in audio-visual quality increase the perception of realism, making the reproduction of media content closer to what it would be like to be immersed in a real experience.

In audio, this quality evolution has been experienced over time both in the increase of sound fidelity of systems and in the increase of sound spatiality (from mono to stereo, to 5.1 and, more recently, to Advanced Sound Systems/Next-Generation Audio with 3D sound[4]).

In video, this evolution of quality has been experienced over time in the shift from black-and-white to colour, from standard-definition (SD) to high-definition (HD), and, more recently, to ultra-high-

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[3] See Report ITU-R BT.2207 – Accessibility to broadcasting services for persons with disabilities, and Report ITU-R BT.2448 – Technical realisation of signing in digital television.

[4] See Recommendation ITU-R BS.2051 – Advanced sound system for programme production.

definition (UHD)[5] and high dynamic range (HDR)[6]. Although the use of stereoscopic 3D video on TV has not been very commercially successful, new Virtual Reality (VR) and Augmented Reality (AR) technologies are attracting increasing interest.

An immersive experience could include, VR/AR/360° video, multiple modes of interactivity (such as three degrees of freedom (3DoF) and six degrees of freedom (6DoF)) and other sensory media systems such as haptic technologies[7].

Different types of media devices that immerse the audience in the content will evolve and become widespread. Tomorrow's immersive media will have higher degrees of freedom in content presentation. A 6DoF content, for example, enables the user to freely and omnidirectionally navigate in a three-dimensional space in the content. Users will be able to experience worlds that they have not yet experienced. The ways in which the audience engages with immersive content will be diverse. There will be different immersive devices depending on the user's preferences and circumstances.

Spatial imaging technology can create a realistic viewing experience in 3D space. Head-mounted displays (HMDs) continue to evolve giving 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 can be integrated into an eyeglass-like device. 360-degree dome displays for a single user, large screens for multiple users, glasses-free light-field 3D image displays, and portable 3D displays (used as a second screen) will become practical, giving viewers a more natural viewing experience.

A user will be able to experience 3D sound that will accompany the various forms of video, further enhancing the immersive feel. Using headphones, which may also be augmented by loudspeakers, will enable an immersive and personalized experience. The 3D audio reproduction will not only provide directionality of sound objects but will also introduce a sense of distance or depth.

Haptic devices serving the sense of touch will become more common to convey the magnitude of an impact and the direction of movements by physically pushing/pulling the surface of the device. Sense of warmth and cold and even a sense of smell and taste may also be presented to the user, giving a higher degree of reality to the content.

2.8   Experiences that merge the physical world and the digital world

There will be 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 allow humans to control machines through natural and intuitive behaviour.

Viewing modes that use AR technologies for virtual space sharing will be available in the near future, providing an environment for a virtual community gathered around the same content to meet in the metaverse. For example, television performers and friends and family in remote places can gather virtually around the TV set in the living room, facilitating their social interaction. Recording this virtual environment can be used as a life log.

The AR Cloud is a real-time 3D (or spatial) map of the world overlaid onto the real world. It enables information and experiences to be augmented, shared, and tied to specific physical locations, and to occur and persist across apps and devices.

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[5] See Recommendation ITU-R BT.2020 – Parameter values for ultra-high definition television systems for production and international programme exchange.

[6] See Recommendation ITU-R BT.2100 – Image parameter values for high dynamic range television for use in production and international programme exchange.

[7] See Report ITU-R BT.2420 – Collection of usage scenarios of advanced immersive sensory media systems.

The emergence of AR Cloud platforms opens a new domain. For example, virtual 'buttons' can be laid over the physical world to select services from digital and hyper-personalized adverts. Any surface could potentially be used as a display or part of a user interface. For example, when the user looks out of a window, the current weather information and forecast can be shown on it. That also provides news and new entertainment media opportunities. Further examples are to provide information such as an evacuation route in case of an emergency or the supply of daily necessities when needed. Computer-vision-enabled devices become the gateways for avatars in this new reality landscape layered with virtual interactive information.

Early advances in the field of medical implants will inevitably lead to implants that could be used to feed images into our visual cortex directly, and other signals could interact with our senses. Thus, an embedded chip could replace the external devices needed today. Brain-computer interfaces can allow the integration of human beings and the technology surrounding us. Users will be able to control the virtual world presented around them with their thoughts, and media experiences can fully immerse them, utilizing all their senses, sight, hearing, smell, taste and touch.

3 Future of media production

Content is delivered to the end-user through multiple distribution paths, which often require different technical formats or editorial versions, and to platforms that offer different levels of user-selectable options or services. Radio and television content is often co-produced by multiple organizations, which adds complexity to workflows for live programmes, pre-recorded programmes and non-live post-produced or packaged programmes. Broadcast content creators are very aware they compete with many other entertainment and information-based services (including gaming, social media, and user-generated content) and are learning that a single fixed version of a programme is no longer commercially viable.

New types of audio-visual content, most likely object-based content with metadata, are required to provide users with future user experiences discussed in § 2. This will require new capturing technologies and content format specifications.

3.1 Future production framework

Future production will need to realize the user trends by producing content with a greater sense of reality that also provides options for content personalization and interaction.

Future programme-making innovation can be grouped into technology-driven categories that are designed to make production workflows:
–   software-based production,
–   virtualized production,
–   cloud-based production,
–   complex media production,
–   data-driven production,
–   automated production through AI and ML,
–   immersive and accessible media production; and
–   sustainable production.

A more detailed exploration of many of the concepts mentioned in this section can be found in Report ITU-R BT.2420 – Collection of usage scenarios of advanced immersive sensory media systems and Report ITU-R BT.2447 – Artificial intelligence systems for programme production and exchange.

3.2 Software-based production

Hardware-based production systems are already being replaced by so-called 'serverless' computing technologies and on-demand software services operating in private and public cloud environments.

Radio and television infrastructures are moving from fixed hardware, which is slow and expensive to change, to Infrastructure as a Service (IaaS), Platform as a Service (PaaS) systems, and, more recently, Software as a Service (SaaS) systems.

SaaS is traditionally considered to be a business model solution where a company will use a cloud service to hold their software applications, accessing them through any internet-connected devices (tablet, laptop, smartphone and others). These services are increasingly being applied to broadcasting applications, completely changing the traditional studio and outside broadcast models.

3.3 Virtualized production

Radio carries many hours of live programming, and the virtualization of local radio infrastructure has led the way toward decentralized resilient broadcast models. This process will continue to evolve and become viable for many other media processes. Virtualization enables shared infrastructure, which not only increases resilience but also reduces the environmental impact through the efficient use of resources. Many radio broadcasters, especially those providing local, regional, and national services, have already considered virtualization as a method towards consolidating multiple content production and signal processing infrastructures.

Live television will also take significant steps forward through the use of the virtualized production systems. Programmes are already being made with virtual sets using very large screen video walls and techniques that allow remote performers to take part in live action within the same set. A fully virtualized environment will also remove the need for the studio floor operational area or remote location to be co-located with the engineering control room or outside broadcast trucks. The performance area (studio floor or the remote location) will only need the capture devices and optional minimal monitoring. The engineering or technology areas can then be centralized and fully utilized as they are no longer physically associated with a single performance area.

As part of this evolution, it is important to factor in how the high bandwidth point-to-point signal connectivity used in traditional physical infrastructures can be applied to systems that are designed to operate in local, remote and hybrid (private/public) cloud computing environments. Connectivity developments are enabling the growing use of wireless video, audio, data, control and communication streams that are required for remote and virtual production operations.

Fully flexible virtual production workflows freed from physical hardware constraints will enable longer-term resource and infrastructure planning as the need to maximize the returns from hardware investment is greatly, if not totally, removed.

3.4 Cloud-based production

Cloud-based processing will be the key enabler for the move to virtualized production and broadcasting. There is also an expectation that cloud workflows will enable much more automated scalable services and flexibility. Semantic web technologies can potentially address some of the challenges that will occur with a move to cloud operations and workflows[8].

Cloud-ready production systems will move away from serial processing and treat computing, networking, storage, and signal processing systems as abstract distributed resources. System

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[8] See "Media in the Cloud: Ontology and Semantic Web Technology Navigation Guide" (available at https://www.smpte.org/media-in-the-cloud-ontology-guide).

architects no longer talk about building and deploying applications or devices but about enabling and interconnecting services. Cloud computing will replace localized systems, databases, web hosting, and back-office processes, employing cloud storage instead of localized storage servers and network devices.

The move to virtualized production will inevitably increase connectivity demands. Traditionally, feeds from individual cameras or microphones have been limited to the studio or event location. Remote productions added to the demand for more flexible programme-making techniques for large events with increased requirements for unilateral and multilateral feeds. They will require new networking technologies to make effective use of the available spectrum for Services Ancillary to Broadcasting (SAB) and Services Ancillary to Programme-making (SAP) – also referred to as Programme-Making and Special Events (PMSE) spectrum. As with the adaption of business systems for use in programme production, the development of technologies such as fog and edge computing and networking can be adapted to meet the demands of remote production.

The merging of production and broadcaster business systems with content creation systems and cloud service providers is a new area of concern for security policies and practices. Security will need to focus on the actual workflows and the assets, not just the infrastructure running them or the storage.

Interesting options are being developed that maintain security but allow users to work securely from any location without the need for a VPN connection. Zero Trust security protocols, for example, work by moving the access control from an organization-wide approach onto individual devices and users-system.

3.5 Complex media production

The complexity of content creation and the number of versions broadcasters and programme makers are required to produce will continue to grow. Greater complexity and more versions will require increased storage and processing time unless new production workflows are adopted.

To take full advantage of the opportunities that new technologies offer, broadcasters and media production companies will need to employ new programme-making tools and be willing to adapt to increasingly more flexible workflows. Applying supply chain practices is already part of the move to a more commoditized broadcasting chain that brings together the content creation processes with business systems, rights management, sales, and distribution systems. This trend applies equally to both radio and television production, and it can be assumed workflows will be interchangeable and could be applied to any medium.

Complex content production requires a re-think of what media actually is and what content discrete constituent parts make up the expected user experience. Breaking down media into individual objects or components is the key enabler in the realization of a new immersive, interactive, and personalized experience. Object-based media (OBM) is a growing constituent of research in academia and among broadcasters and content creators. Many of the concepts are being investigated through tests, trials, and storytelling experimentation. During its development stages, OBM is beginning to demonstrate that it ticks many business-case boxes such as production efficiency, audience engagement, enhanced user experience, reduced re-versioning costs, automated multi-format and multi-platform content creation, increased media accessibility and increased revenue options.

One method of managing complex workflows is to consider each object required in a given editorial or technical format version of a programme as a component that can exist in any number of individual versions without duplication[9]. In a componentized workflow, a programme version is not a single

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[9] See Recommendation ITU-R BT.2153 – The use of componentized workflows for the exchange of non-live television programmes.

flattened file but a collection of interrelated media and data files orchestrated by a set of instructions often known as a 'composition'. It means that a group of composition datasets can be used to define any editorial or technical version of a programme. This type of data-driven workflow model allows any particular component to be a part of any number of versions without the need to create and store multiple copies of the object.

3.6   Data-driven production

Future production will capture data from any device including (but not limited to) cameras, microphones and localized data. It will also capture the location of these devices geographically and within a three-dimensional space. Such data will be used to drive the post-production processing, rights management, delivery and archiving of content version. Some of this data may be packaged and made available to the end user to add a richer more personalized experience. As object-based media data passes through the workflow, it is critical to be maintained by each process and, where appropriate, new data must be added where a production process generates it.

Content-related metadata has often been lost during processing. As content creation produces more and more complex programmes, the greater the need for standardized data transfer protocols that enable end-to-end data carriage. The scope of data in the whole production value chain is constantly evolving as the strategic importance and volume of data increases. Data will need to carry descriptive information as well as technical information to drive automated workflows and contain the personalization options available to the user.

Data from the sensors used in motor racing, attached to athletes during games and events and players in team sports, to provided information to coaches and team mangers can already be used by broadcasters to enhance sports programmes. Future delivery systems will be able to pass some of this processed data back to audiences to deliver on-screen data overlays or personalized options providing an enhanced user experience, including the ability to focus on a particular participant.

In the future, the data will drive the whole media supply chain. But there are currently very few international standards that can describe the content itself or describe the processing required and the processing history of the content or drive automation. End-to-end media supply chain data models will be essential for broadcasting, as manual re-entering to retrieve lost data is expensive, time-consuming and error prone.

3.7   Automated production through artificial intelligence and machine learning

In the programme development and commissioning stages of the media supply chain, AI/ML technologies are already being used to make predictions as to whether the potential production will be profitable or not. This data is used to assist automation in the programme approvals process by determining whether to green-light new shows based on predicted user behaviour and the actual scripted content.

There are early examples of work currently underway on how AI/ML systems are being used to optimize workflows, create new content from archives, automatically extract metadata and personalize content. AI systems are also being deployed to detect disinformation ('fake news') and 'hate speech' in the broadcast news production environment[10]. These systems are continually learning and improving. With each step forward in accuracy and efficiency, detection of augmented or synthetic media becomes more accurate as does the trust in automation systems by broadcasters for news content and opens new programme making and storytelling options to programme makers.

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[10] See Report ITU-R BT.2447 – Artificial intelligence systems for programme production and exchange.

3.7.1 Synthetic media

Computer algorithms can create completely synthetic media or merge real events with synthetically created media. Programme making tools can generate text including scripts, convert text to video and video to text, integrate virtual or remote performers into real life scenes and generate music from text-based prompts. Many of these tools require little or no knowledge of the underlying AI/ML technologies driving them and can create media that is difficult to identify as different from 'real' content. Although this could be a cause for ethical and legal concerns, synthetic media also offers new opportunities for storytelling and production efficiency.

3.7.2 Ethical, legal and social issues

The advances in AI/ML technologies have the potential to foster innovation and enable novel solutions to existing challenges or even create new application domains, such as the creation and detection of synthetic types of media. However, there are ethical issues that need to be addressed in terms of privacy of the individual and the right for example, to protect a performers voice and appearances. The term Ethical, Legal and Social Implications (ELSI) or sometimes known as Ethical, Legal and Social Aspects (ELSA), is an approach that can be considered when studying the impact of science and technology advances including the use of AI/ML on society and individuals. Academia, regulators and industry including broadcasting and programme making organizations are already developing guidelines[11] on ethical, legal and social issues associated with the use of AI/ML in order to ensure trust and accountability[12]. What is clear is that AI/ML systems will offer new opportunities in the media sector and will continue to become part of the media supply chain, not just driving the process but as an integral part of content creation, user navigation, targeted content and targeted commercial, as well as and especially for delivering ubiquitous accessible media.

3.8 Immersive and accessible media production

New programme-making technologies offer more than just content enhancement and efficiency. Media objects are an essential part of the production and delivery of immersive content and also provide opportunities to make all media accessible (see footnote 3). Objects are driving the growth of XR (eXtended Reality) technologies which includes AR (Augmented Reality), VR (Virtual Reality) and MR (Mixed Reality) in gaming, education, remote assistance, and entertainment.

Future immersive, interactive, and accessible productions will be based on the interaction of object-based content elements such as:

– sensory
  • sight – what range of sight-based options are available to each platform and device the content is targeted at, and how far can the user adapt these options.
  • sound – what range of sound-based options are available to each platform and device the content is targeted at, and how far can the user adapt these options.
  • haptic – what motion, vibration, or other related options, driven by the narrative are available and how they are represented on different physical devices.
  • taste and smell – how taste and/or olfactory options can be associated with the content and how individuals or groups can experience the sensory information.
  • cognitive – what options to assist users in engaging with the content, including age-related understanding impairments or related to users with learning disabilities or autism.

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[11] See "Partnership on AI" (available at https://partnershiponai.org/).

[12] See "Responsible AI at the BBC: Our Machine Learning Engine Principles" (available at https://www.bbc.co.uk/rd/publications/responsible-ai-at-the-bbc-our-machine-learning-engine-principles).

–   temporal

   •   where in time, a particular object is placed relative to the narrative.

–   spatial

   •   where in space relative to the user, an object appears to be located or appears to transition through.

–   contextual

   •   which object or group of objects in the narrative can be adapted (including by how much they can be adapted) by options made available to the user.

## 3.9   Sustainable production

One of the drivers for future production innovation will be the requirement to maximize efficiency reduce cost and power consumption and eliminate duplication. Future production technologies will need to incorporate these requirements at the beginning of their development (see footnote 1).

Current action includes the use of low-power lighting and ensuring essential power comes from non-carbon-producing sources. Object-based media, componentized workflows, virtualized production, and native cloud-based workflows can all be used to reduce power requirements in studios while maximizing production efficiency. Componentized workflows (see footnote 9) for example, can minimize storage requirements and, when combined with cloud-based workflows, can eliminate the need to duplicate media files that are required when creating multiple different versions of programmes. Virtual sets and remote performers can also reduce the use of disposable studio scenery and the need for unnecessary travel. Virtualized production and cloud-based infrastructure inevitably consume power, which means the use of both the direct and the indirect (use of third-party services such as non-local cloud and outsourced storage) consumption should be considered when using these technologies.

4   Future broadcast delivery

Media delivery systems sit between the broadcaster's content and the end-user devices or in-home media distribution systems used to connect portable devices to a home network hub. Figure 1 is a high-level overview of the end-to-end broadcasting service showing the various options available to deliver media from a broadcaster to end-user devices and possible return pathways.

FIGURE 1

Delivery options in the context of the end-to-end broadcasting service
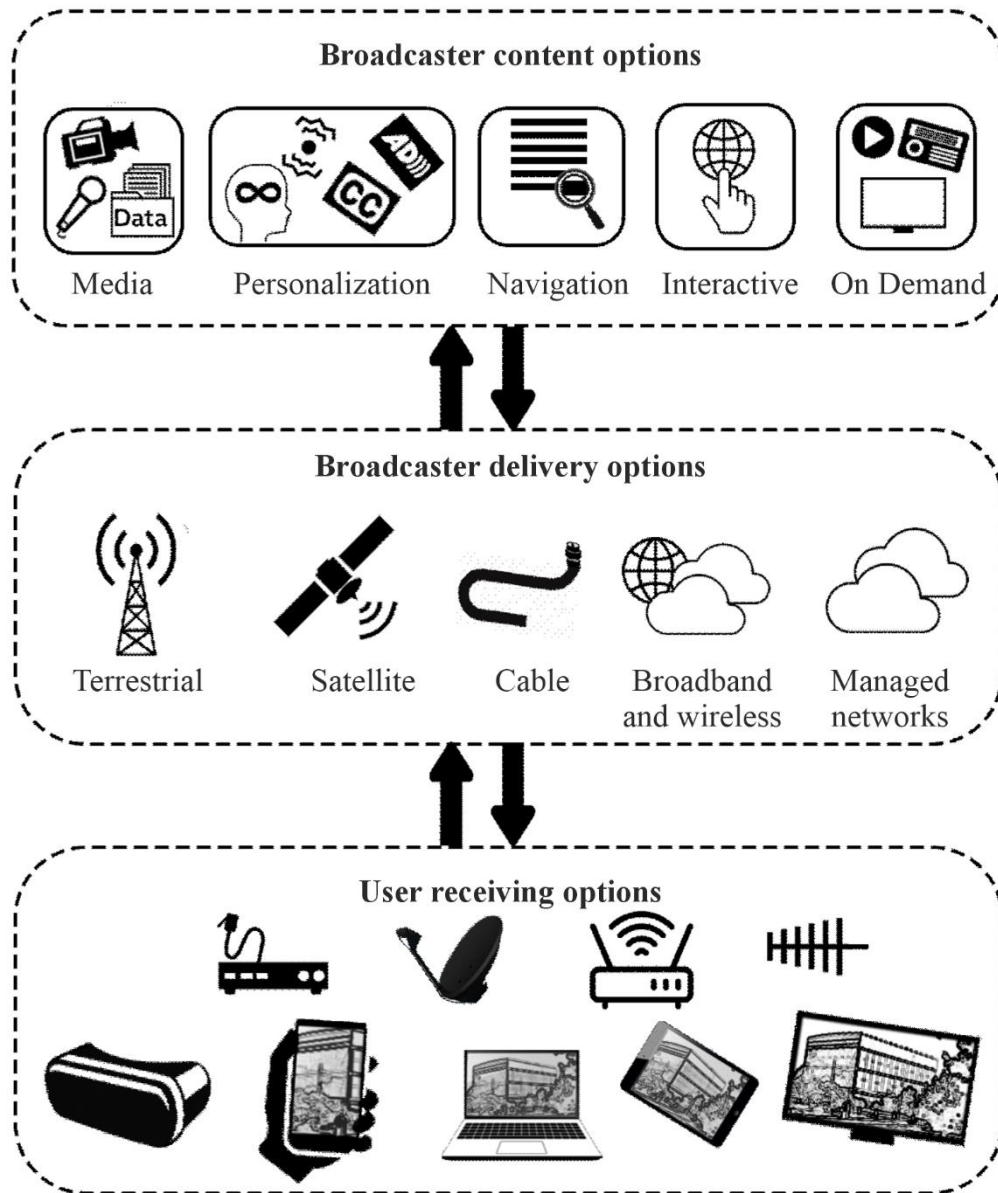
Report BS.2522-01

Currently, there are many different delivery options in use around the world, as depicted in Fig. 1, whose penetration varies from territory to territory and may also change over time. The introduction of new delivery options has not necessarily resulted in earlier options being discontinued.

Terrestrial broadcasting was the first form of media distribution to households. Over time, many countries deployed large-scale terrestrial broadcasting networks to cover their populations. It has undergone several technological transformations. In the last couple of decades, these networks have evolved from analogue to digital systems capable of delivering more sound and television services and enhanced audio-visual services (from monophonic to stereophonic and multichannel sound, from standard-definition to high-definition or ultra-high-definition television). Recently, many other media distribution platforms have emerged. Nevertheless, terrestrial broadcasting is still and will continue to be, for the foreseeable future, essential to many administrations, broadcasters and end-users around the world.

The importance of terrestrial broadcasting stems from its unique characteristics, which allow the free-to-air transmission of local, regional, national, and international content to an unlimited number of end-users, with spectral and energy efficiency. Beyond a distribution platform, terrestrial broadcasting is an essential catalyst for local, regional, and national creative industries and journalism, helping to inform, educate and entertain the public while promoting social cohesion, inclusion, and national identity. In addition, the robustness of the terrestrial broadcasting transmission infrastructure arising from the High-Power High-Tower topology and the possibility of free-to-air reception make this platform particularly useful for public warning, disaster mitigation and relief[13].

As technology develops and media consumption habits change, terrestrial broadcasting must keep evolving, distributing new media formats, enabling new user experiences and public services.

4.1   Spectrum allocated to the broadcasting service

The broadcasting service has many frequency allocations on a primary basis. The low frequency (LF), medium frequency (MF) and high frequency (HF) bands have historically been used for analogue sound broadcasting, and are now also being used for digital sound and multimedia broadcasting. The very high frequency (VHF) band is used for sound, television, and multimedia broadcasting, and the ultra-high frequency (UHF) band is used for television and multimedia broadcasting. Other allocations to the broadcasting service exist in higher frequency bands (around 12, 22, 40 and 75 GHz), but these are yet to be extensively exploited.

Each band allocated to the broadcasting service has been used based on the spectrum/frequency requirements for current and new television, sound and multimedia broadcasting systems[14].

The HF band is primarily used for long-distance broadcasting due to its propagation characteristics making it essential for international broadcasting delivery and radio emergency broadcasts for which spectrum must be continuously available 24 hours per day, 365 days per year[15].

The use of the VHF and UHF bands for analogue terrestrial television is decreasing as more countries complete the transition to Digital Terrestrial Television Broadcasting (DTTB)[16]. The frequency range 470 to 694/698 MHz is extensively used for DTTB worldwide[14, 17].

In many countries, the upper part of the UHF band (above 694/698 MHz) is no longer available for broadcasting applications or services ancillary to broadcasting. However, some countries still use this upper part of the UHF band for terrestrial television broadcasting. Terrestrial broadcasting networks have historically provided wide area coverage to mass audiences, but as new services and applications emerge, competition for access to the spectrum used by terrestrial broadcasting networks is increasing. However, considering the continuing demand and development of terrestrial broadcasting systems, it must be recognized that they will remain in use and keep evolving for many decades. Therefore, it is vital that sufficient spectrum in the appropriate frequency ranges is available for the broadcasting service.

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[13] See Report ITU-R BT.2299 – Broadcasting for public warning, disaster mitigation and relief.

[14] See Report ITU-R BT.2387 – Spectrum/frequency requirements for bands allocated to broadcasting on a primary basis.

[15] See Recommendation ITU-R BS.2107 – Use of International Radio for Disaster Relief frequencies for emergency broadcasts in the High Frequency bands.

[16] See "Status of the transition to Digital Terrestrial Television" (available at https://www.itu.int/en/ITU-D/Spectrum-Broadcasting/DSO/Pages/default.aspx).

[17] See Report ITU-R BT.2302 – Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran.

4.2 Global platform

It is essential to acknowledge that other methods of delivery of audio-visual content to the end user already co-exist with the broadcasting service. This co-existence will continue in the future, and other delivery systems will continue to evolve, as will the broadcasting service.

Broadcasters operate in a complex media ecosystem where content will continue to be sought by end users over various platforms to multiple end-user devices. To serve content to multiple delivery systems, broadcasters pursue the use of flexible production technologies (see § 3) and the adoption of common standards for interfaces, transport, source-coding, metadata, media and file formats, within distribution chains. This is particularly challenging as the different distribution platforms evolve asynchronously. The greater the flexibility in production technology and the technology harmonization among distribution platforms, the lower the time and cost required to conform the content for distribution over different platforms and/or to target different end-user devices.

The global platform[18] as a delivery platform will facilitate the distribution of broadcast content to end-users with various receiving devices in multiple reception environments, implemented using both broadcasting and non-broadcasting (e.g. broadband) technologies.

4.3 Integrated broadcast-broadband systems

Some combinations of delivery platforms can be used in cooperative networks, for example, by applying broadcast/datacast systems in conjunction with the interactive capabilities of bi-directional unicast IP-based networks. Such a combination is provided by Integrated Broadcast Broadband (IBB) systems, where broadcasting operates in parallel with broadband telecommunication systems and provides an integrated experience of broadcasting and interactivity by combining media content, data and applications from sources authorized by the broadcaster[19].

The future of media delivery lies in what may be termed 'Mixed Media' delivery environment. This is the sum of broadcast and broadband delivery, with a balance appropriate to the needs of the public, the region, and the status and availability of technology development.

The addition of IBB technologies has allowed broadcast media content to integrate with broadband media content, enabling the efficient delivery of enhanced and personalized content to users. It is expected that such enhancements will continue, allowing the delivery of yet more advanced media content in a highly developed integration of broadcast and broadband delivery platforms.

4.4 Future delivery trends

A future delivery framework for broadcasting must consider ways in which users will receive and interact with secured media content. It is anticipated that future delivery systems will need to employ flexible and diverse technologies capable of realizing the developing user experience expectations, taking into account:

–   user-driven trends for new audio-visual services;

–   types of infrastructure changes in the adoption of new delivery systems; and

–   coverage requirements of new delivery systems.

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[18] See Report ITU-R BT.2400 – Usage scenarios, requirements, and technical elements of a global platform for the broadcasting service.

[19] See Recommendation ITU-R BT.2075 – Integrated broadcast-broadband system, and Report ITU-R BT.2267 – Integrated broadcast-broadband systems.

A combination of broadcast and broadband delivery, as indicated in §§ 4.2 and 4.3, is an effective method to meet the requirements arising from user-driven trends for new audio-visual services. The mixture of delivery networks will vary between markets, depending on various factors, including previous investments in networks. And although the economics of each method will influence the eventual mixture of delivery networks used, other factors, such as regulatory requirements, will also have an influence.

Broadband delivery is complementary to broadcast delivery, especially for enabling on-demand non-linear content consumption and the interactivity/personalization use cases that require a return channel. Its pace of adoption in each territory will depend on the broadband access availability, quality, and cost. But although the proportion of content delivered by broadband has been growing, terrestrial broadcasting will still be needed for the reasons outlined in the following subsections.

4.4.1   Terrestrial broadcasting enables efficient delivery to mass audiences

Delivering linear content simultaneously to a large number of users can be done very efficiently by terrestrial broadcasting, facilitating cost-effective coverage. Terrestrial broadcasting can deliver the same content to an unlimited number of users in its coverage area while ensuring the desired Quality of Experience (QoE) to all.

Linear content remains very popular worldwide, whether live events or humanly curated content playlists that allow users to spend less time searching for what to watch or listen in massive catalogues. People also like to watch or listen with others. The shared experience creates and extends a social bond, through the ability to comment on the content as it is taking place. Major events attract large crowds to watch or listen simultaneously.

Broadband delivery is not very efficient for this use case because:

–   Currently, most end-to-end broadband delivery relies on unicast traffic, which is highly inefficient at delivering the same content simultaneously to a large number of users. Multicast traffic, which is more efficient at delivering the same content simultaneously to a large number of users, currently works only in some managed parts of the network. Content Delivery Networks (CDNs) are used to mitigate excessive traffic to a certain extent, but there is always a limit to the number of users served by each CDN Point of Presence (PoP).

–   As broadband delivery is normally a general-purpose best-effort method, the content provider cannot guarantee the user's Quality of Experience (QoE). Adaptive bitrate streaming adds resilience to broadband delivery but also results in varying video and audio quality.

–   The latency of broadband delivery will also differ from user to user and will always be many times higher than the latency of terrestrial broadcast delivery. That is a critical issue for live sports events and emergency-related information.

–   Furthermore, unicast broadband delivery employing radiocommunication networks to distribute the same content simultaneously to a large number of users would require much more spectrum than needed for terrestrial broadcast delivery.

–   The energy consumed by watching a programme via broadband delivery can be three times higher than the energy consumed watching the same programme via terrestrial broadcasting[20]. Techniques are also available for further reducing the environmental impact of terrestrial broadcasting systems[21]. As energy consumption becomes a more significant factor to consider, the value to society of terrestrial digital broadcasting will grow.

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[20] See "A comparison of a Carbon Footprint of Digital Terrestrial Television with Video On-Demand" (available at https://www.bbc.co.uk/rd/publications/whitepaper189).

[21] See Report ITU-R BT.2385 – Reducing the environmental impact of terrestrial broadcasting systems.

4.4.2 Terrestrial broadcasting enables free-to-air, anonymous/untracked reception

Terrestrial broadcasting enables free-to-air reception, accessible to everyone, regardless of their social and economic condition. Broadband delivery, on the other hand, requires an access subscription, which is generally not available for free, and, therefore, may not be accessible to all.

Terrestrial broadcasting also enables anonymous/untracked reception, which is not the case with broadband delivery. As concerns with user privacy grow, this becomes a more significant factor to consider.

4.4.3 Terrestrial broadcasting is crucial in times of crises

Terrestrial broadcasting plays a critically important role in disseminating information to the public in times of emergencies (see footnote 13).

The robustness of the terrestrial broadcasting transmission infrastructure and the possibility of free-to-air reception make this platform invaluable for public warning, disaster mitigation and relief.

4.4.4 Terrestrial broadcasting strengthens national identities

Terrestrial broadcasting is an essential catalyst for local, regional, and national creative industries and journalism. It provides trusted information, educates and entertains the public while promoting social cohesion, inclusion, national identity, pluralism and fair competition. Moreover, it allows the delivery of the content to the public without blocking or filtering the service offer, i.e. no gatekeeping.

On the other hand, media distribution based exclusively on broadband tends to be dominated by global operators that may act as gatekeepers and distribute their content worldwide, with very little local, regional, and national content (especially in smaller countries).

4.5 User-driven trends for new delivery services

The two primary content trends common to both the future user experience and production frameworks are immersive experiences and personalized media including enhanced accessibility. Alongside these is the demand for the user to access the content on any preferred device and at the most convenient time.

New technologies will increasingly allow for delivering these new types of content over both terrestrial broadcasting and broadband delivery. Some content formats coupled with users' desire to consume at any time (on-demand) will lend themselves to delivery on broadband networks. But there will continue to be a demand for collective experiences – sports events, major news items, and so on – where large numbers of people want to view the same content simultaneously, that are (and will continue to be) more efficiently distributed through terrestrial broadcasting.

4.5.1 Delivering immersive media

For delivery systems to be able to meet the users' expected quality of experience for immersive media, it is essential to define what requirements the delivery systems need to meet.

Not all current systems are capable of fully delivering the expected new immersive media content. Future delivery systems should support adaptation of immersive media content to the capabilities of individual receiving devices.

The data rate needed to deliver immersive content depends on the type of content, receiving device capabilities and quality requirements, and the source-coding technology used. VR, AR and MR systems will likely require much higher data rates than conventional television delivery. Efficient source-coding and transmission technologies are essential to enable delivery of immersive media.

4.5.2   Delivering personalized and accessible media

Some current delivery systems already support a limited range of user-controlled options such as dialogue enhancement, language selection and audio description. Future systems must expand the immersive user interaction options for audio and video to enable more personalized features.

There are many possibilities for local interactivity/personalization and accessibility enhancements that do not require a return channel. However, the user expectation of having greater control over their experience through immersive media including personalization and accessibility options will drive the development of new delivery systems and set the stage for content to span multiple platforms for simultaneous and on-demand user options.

Such enhanced services will typically involve personalized data streams from a broadcaster to a client and return signals from a client to a broadcaster facility, or cloud/edge servers. User-specific data will be used to control personalized content, local interactions with content to enable new types of service on a range of devices.

The concept of a 'one-to-many' broadcasting system is increasingly being complemented by more personalized unicast-based systems via broadband delivery, as indicated in § 4.3. Future delivery systems will combine attributes of both broadcast and unicast while providing a common toolbox to flexibly and dynamically allocate features of enhanced media services to meet end-users' requirements. They will increasingly be using IP-based transport mechanisms, not only for unicast but also for broadcast[22]. This integration enables simultaneously achieving the best of both worlds (broadcast and unicast): reach and personalization. For example, a content or network provider can seamlessly exchange certain portions of a programme with alternative content believed to be more relevant to the user and delivered separately by broadband.

The use of rights management technologies, such as blockchain, could increase opportunities for personalized subscription services.

4.5.3   Ubiquitous multimedia and datacasting reception

Multimedia and datacasting reception on individual, ubiquitous, handheld devices is becoming an essential user requirement for future broadcast delivery platforms (see § 2.4). So far, broadcasting systems receivable in mobile reception modes have all required specific hardware additions in hand-held devices, such as smartphones. A new generation of 'native mobile' broadcasting technologies already exists[23]. These are based on the same physical layer technologies used for one-to-one mobile radiocommunication in end-user hand-held devices and extended to offer seamless integration with the broadcasting service, including free-to-air. Their implementation may require access to suitable and sufficient spectrum alongside existing terrestrial broadcasting systems.

4.6   Infrastructure changes needed for the adoption of new delivery systems

Trends in emerging audio-visual delivery systems and their respective new technologies determine changes in broadcasting infrastructure, ranging from relatively minor upgrades to existing broadcasting infrastructure to a transition to new equipment and systems to meet the end-user requirements.

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[22] See Recommendation ITU-R BT.2054 – Multiplexing and transport schemes in multimedia broadcasting systems for mobile reception, and Recommendation ITU-R BT.2133 – Transport of advanced immersive audio visual content in IP-based broadcasting systems.

[23] See Recommendation ITU-R BT.1833 – Broadcasting of multimedia and data applications for mobile reception by handheld receivers, and Recommendation ITU-R BT.2016 – Error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers.

4.6.1 Introducing changes in a backwards-compatible transmission

Some changes in broadcasting delivery methods might be introduced in a backwards-compatible transmission without a change in spectrum requirements. That would be similar to what has been successfully carried out multiple times in the past to the Broadcasting Service, e.g. with FM radio (introducing stereo sound and RDS), analogue terrestrial television (introducing colour, stereo sound, and subtitles/closed captions), and digital terrestrial television (introducing new IBB systems). In each case legacy receivers continue to operate normally while new features can be enabled by either new receivers or software updates to existing receivers.

This kind of solution can continue to be used in the evolution of digital terrestrial broadcasting, e.g. by introducing a new audio coding technology (while retaining the legacy one), scalable video coding, etc. that could be developed as a transitional arrangement for both the broadcasting delivery system and consumer electronics devices.

4.6.2 Introducing changes in non-backwards-compatible transmissions

More significant changes in the technological advancement of broadcasting delivery methods to meet the increased expectations of end-users are highly likely to require new systems for both the broadcasting network and consumer electronics devices. In this case, these new transmissions may not be received by legacy consumer electronics devices.

To successfully complete such a transition, it is essential that the new system is easy to use and that there is widespread deployment of transmitters and devices capable of receiving the new broadcast signals. Transition to non-backwards-compatible technology will often require a simulcasting period where both the legacy and new systems run in parallel.

There are methods for introducing a new service in the same channel used for existing services and in a different channel not used for existing services. In the latter case, there are different strategies when there are enough channels available for simulcasting and when there are not enough channels available. All transition methods have pros and cons that need to be carefully assessed by broadcasters and regulators to choose an appropriate method to meet the requirements and situations in a country or region[24].

4.6.3 Improving spectrum efficiency

Considering that spectrum is a valuable, scarce resource, spectrum efficiency must increase after completing the transition to a new terrestrial broadcast technology, even if this may not be the case during the transitional simulcasting period. Increasing spectrum efficiency means transmitting more programme services and/or improving their quality when considering the same total amount of spectrum used by the service. That can be achieved either by maximizing each channel's capacity or by reducing their frequency reuse factor.

In the first case, more and/or better-quality programme services can be multiplexed on the same physical channel.

In the second case, independent local multiplexers can reuse the same physical channel within a shorter distance, increasing the geographical segmentation of the terrestrial broadcasting network and enabling the use of more physical channels per location. Even with a reduction in the capacity of a single channel, better-quality programme services can still be achieved, either by reducing the number of programme services per multiplex and/or due to audio-visual coding efficiency gains.

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[24] See Recommendation ITU-R BT.2144 – Guidance for the introduction of new DTTB systems, technologies and applications in the broadcasting service.

The greater the geographical segmentation of the terrestrial broadcasting network, the more relevant the content (e.g. news, advertisements etc.) to the user location. In the limit, in the case of a frequency reuse factor of one (reuse-1), the same physical channel can be used by adjacent independent stations, allowing the network to be reconfigured for a different geographical segmentation of the service area at any time without the need for channel re-planning.

4.6.4   Benefits of new technologies

The gains brought about by the transition to new technologies and the development of advanced delivery systems in any established market will ultimately require a clear benefit in each stage of the delivery chain.

For end-users, the benefits may include completely new services or significantly improved quality.

For broadcasters, the benefits may include enabling new business models and retaining control over a competitive distribution platform without gatekeepers.

For regulators, the benefits may include improving the quantity and/or quality of local/regional/national content public offerings, fostering the broadcast and consumer electronic industries, the creative industry, journalism, and educational content, improving media accessibility and enhancing public emergency warnings.

4.6.5   Continuous evolution

The transition to digital terrestrial broadcasting[25] was not the end of terrestrial broadcasting evolution. Second-generation digital terrestrial broadcasting systems have been specified[26] and successfully deployed or are planned for introduction in many parts of the world.

New generations of terrestrial broadcasting technologies continue to be researched, developed and trialed[27].

To facilitate the introduction of new technologies in the future and minimize the need for disruptive technological transitions, when developing a new terrestrial broadcasting system, all system components should provide for extensibility mechanisms that allow for such introduction in a backwards-compatible transmission. But there are always practical limitations on what extensions can be provided in a backwards-compatible transmission. Unforeseen new requirements and technologies may be developed over time, as requirements introduced by new and advanced services may operate as an accelerator for further technological evolution and subsequent changes in the delivery structure. Therefore, one should expect that new generations of terrestrial broadcasting should be implemented from time to time.

4.7   Coverage requirements of new delivery systems

Broadcasters with a public service remit, which can include public service media organizations and commercial organizations with a regulatory or voluntary remit, may have requirements of universal coverage and access (geographical availability of the service, e.g. national, regional, local) according

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[25] See Report ITU-R BT.2140 – Transition from analogue to digital terrestrial television broadcasting, and Report ITU-R BT.2384 – Implementation considerations for the introduction and transition to digital terrestrial sound and multimedia broadcasting.

[26] See Recommendation ITU-R BT.1877 – Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems.

[27] See Report ITU-R BT.2343 – Collection of field trials of UHDTV over DTT networks, and Report ITU-R BT.2485 – Advanced network planning and transmission methods for enhancements of digital terrestrial television broadcasting.

to regulatory requirements, that any future delivery system needs to meet. The possibilities for evolving delivery systems are governed by many factors, which include frequency availability and regulatory conditions. One of the most important mandates for public broadcasters is to reach the entire nation with a wide range of programmes in the best possible quality and in a cost-effective way.

Some broadcasters and content providers without public service obligations may wish to base their decisions on the delivery of content on purely economic grounds. In this case, they will need to take a view on the reach of different delivery mechanisms to their target audiences (including coverage, affordability, and device penetration). Nevertheless, in many countries, non-public service broadcasters may still be subject to regulation of their delivery, maybe including minimum population coverage criteria or mandating particular delivery technologies. In practice, therefore, even commercial broadcasters are driven to a greater or lesser extent by regulation to ensure service to users.

During a technological transition, while simulcasting services by both legacy and new systems, coverage requirements may have transitional dispositions to allow for a gradual deployment of the new technology transmitters. The time required to complete the transition by switching off the legacy system is often constrained to the pace of the slowest section of the audience but, in some cases, can be accelerated by public policies.

5   Conclusion

User expectations are driving changes in how media is created, delivered and consumed. There is a growing expectation that all services and personalized options can be accessed on any device, in any location, at any time. Although users can create and distribute their own content, the desire for communal and shared media consumption is still strong. Users want to be stimulated by increasingly immersive content from programme makers and broadcasters, presented according to their personal preferences.

To continue to meet future user demands and to compete in a global media market, technologies that assist and automate the creation and exchange of multi-version content will be essential. This is being made possible and affordable by a move from physical infrastructure to cloud-based on-demand software processing, which also enables the move away from fixed hardware intensive production centres.

The scope of programme production studies should continue to evolve, especially to encompass content and data security, efficient and sustainable programme making, cloud and virtual production and immersive, interactive and accessible content.

Future media delivery will inevitably be provided by a combination of platforms or services where broadcasters distribute their content over various platforms to different end-user devices. To that end, the use of flexible production technologies and the adoption of common standards among distribution platforms are objectives that broadcasters should constantly pursue. **Standards are vital** to maintaining interoperability between content production, distribution and reception while preserving the quality of service and fulfilling user expectations.

Among the various existing and future media delivery platforms, terrestrial broadcasting is still and will continue to be, for the foreseeable future, essential to a huge number of users around the world. As technology develops and media consumption habits change, terrestrial broadcasting must keep evolving, distributing new media production formats and enabling new user experiences. Intelligent concurrent networks employing a seamless combination of terrestrial broadcasting and internet delivery based on a user's location, devices used, and personal or accessible options, provide a means of meeting the requirements of users and content producers effectively and efficiently.

5.1 Realizing the potential of the framework for the future of broadcasting

In order to realize the potential of the framework for the future of broadcasting, the following subjects (among others) should be further studied:

– media systems and processing to facilitate making audio, visual, sensory and data media more immersive, accessible and personalized to meet the needs of all users[28];

– the use of Artificial Intelligence and Machine Learning technologies when applied to the creation of and consumer use of media[29], mindful of the ethical, legal and social issues relating to the use of these technologies;

– interfaces and data formats for virtualized programme production and the potential impact that virtualized processing using cloud-based and data-driven workflows could have on the international exchange of media [30, 31];

– content processing and automated workflows for the creation and delivery of media to any device by any service or platform, at any time[31];

– broadcasting systems to deliver new or enhanced media services[32];

– advanced public warning and disaster mitigation information delivery through broadcasting services[33]; and

– methodologies, new technologies and processes that can be used to reduce the impact of content creation and delivery on the environment[34].

Figure 2 illustrates a planning framework to develop new or enhanced systems for the future of broadcasting.

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[28] See Question ITU-R 143/6 – Advanced Immersive Sensory Media Systems for Programme Production, Exchange and Presentation for Broadcasting, and Question ITU-R 145/6 – Systems for enabling access to broadcast and cooperative media for persons with disabilities.

[29] See Question ITU-R 144/6 – Use of Artificial Intelligence (AI) for broadcasting.

[30] See Question ITU-R 130/6 – Digital interfaces for production, post-production and international exchange of sound and television programmes for broadcasting.

[31] See Question ITU-R 140/6 – Global platform for the broadcasting service.

[32] See Question ITU-R 45/6 – Broadcasting of multimedia and data applications, Question ITU-R 56/6 – Characteristics of terrestrial digital sound/multimedia broadcasting systems for reception by vehicular, portable and fixed receivers, Question ITU-R 131/6 – Common core data format for multimedia broadcasting, Question ITU-R 133/6 – Enhancements of digital terrestrial television broadcasting, and Question ITU-R 146/6 – Spectrum requirements for terrestrial broadcasting.

[33] See Question ITU-R 118/6 – Broadcasting means for public warning, disaster mitigation and relief.

[34] See Question ITU-R 147/6 – Energy Aware Broadcasting Systems.

FIGURE 2

Planning framework to develop new or enhanced systems for the future of broadcasting

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