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Getting a clearer view on the sustainability challenge

Plus

T&I Award 2021 – the nominees
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Advances in fake news detection

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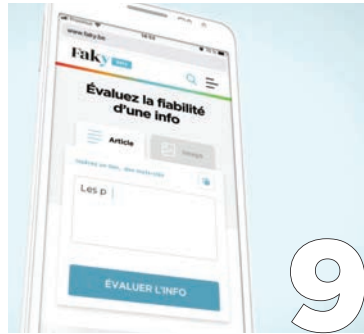
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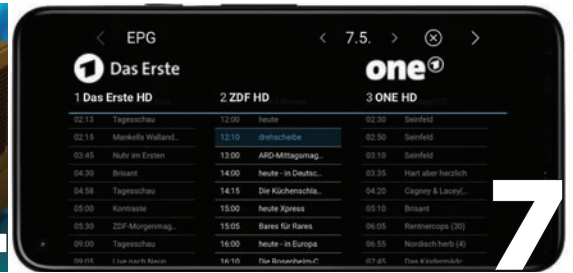
Contents

Keeping innovation alive through the next crisis

Antonio Arcidiacono, Director of Technology & Innovation, EBU

Later this month we will name the winner of the EBU Technology & Innovation Award 2021 from among the 24 projects listed on pages 4–5. Looking through the entries – the highest number received since the award was inaugurated five years ago – I take heart from the fact that the spirit of innovation is clearly alive and well across the EBU membership. The diversity of topics and approaches is also heartening, from remote production and authoring tools to innovative devices, apps and platforms, virtual studios, AI implementations, cloud, sustainability and much more. (I encourage you to make connections – a new collaboration may be just around the corner!)

That many of these projects have come to fruition in the difficult conditions of the past year is a testimony to the resourcefulness and resilience, and often to the passion, of the technologists and creators in our community. Of course, in some cases it was specifically the pandemic that generated the necessary momentum, but all of these projects represent public service media (PSM) innovating under increasingly difficult circumstances.

RECURRING CRISES
The recurring economic crises of recent decades have pushed many companies in Europe to progressively stop innovating and to reduce investment in research and development. While the COVID-19 crisis has served to spark and accelerate innovation in some domains, in the longer term its deep budgetary impacts will also be felt – and PSM will not be immune.

Large companies often look at short-term financial results; the small and medium-sized enterprises (SMEs) that represent the vast majority of all businesses in the EU do not have the necessary cash for R&D and innovation (R&D&I) and often live on the brink of a funding crisis. Even public structures, also under the pressure of recurring crises, are victims of reduced funding and must almost mechanically reduce their staff and in particular their medium- and long-term investments.

Innovation only works in the medium to long term. And restarting it, despite the best political claims, is complicated. A 'normal' company will often prefer not to draw on funds for innovation if it risks financial strain later, having to repay loans, however subsidized, or to continue paying the salaries of people hired.

What, then, is the solution? How can we unblock sustained innovation?

INNOVATION ON-DEMAND
What we need are stable structures with which companies, public and/or private, can partner for their R&D&I with an 'on-demand' approach. We must join forces to support the creation of these flexible and modular structures. This is what would make it possible to innovate, limiting the risk for motivated companies and reducing expensive medium–long-term investments that they, at that specific moment in time, would not likely make.

This new innovation effort should receive substantial and urgent support from European funded R&D and national innovation projects. This is explicitly indicated in the December 2020 action plan[1] of the European Commission. A specific reference is made to "Recovery and Resilience Plans" providing national reforms and investments to contribute to "*strengthening European news media and audiovisual digital capacities, including through multi-country projects, such as co-productions of European content, EU media data space infrastructure, or equity investment to foster European audiovisual production or distribution.*" Such support should go beyond the development phase and also help with initially commercializing the results of the innovation projects.

As I have previously observed[2], the EBU is today the largest structure coordinating European media R&D&I activities. I believe it is thus the natural candidate to lead such an effort targeting innovation in media technology. If we can take the innovative spirit epitomized by the 2021 T&I Award nominees, working alongside our counterparts in the private media sector, and fuse that with Europe's deep pools of academic and industrial talent, we can build a sustainable structure that will keep alive the flame of innovation, sustain growth, and develop a resilient ecosystem that would also generate the momentum required to survive through future crises.

1 tinyurl.com/media-action-plan
2 See tech-i 47, March 2021

T&I Award 2021:
and the nominees are...

Now in its fifth year, the EBU Technology & Innovation Award provides an opportunity to shine a light on some of the most creative technologists, developers and researchers from Europe's public service media community. A total of 24 projects were nominated for this year's award; here we present a brief description of each one, along with contact details you can use to request more information or enquire about a potential collaboration.

The winner of the T&I Award 2021 will be announced during the EBU Technical Assembly on 9 June after 16:30 CEST. For information on how to access the stream, visit: tech.ebu.ch/events/ta2021

Audio Orchestrator production tool for multi-device audio experiences

BBC, UK • Contact: Jon Francombe, jon.francombe@bbc.co.uk
A software tool for prototyping audio experiences that are orchestrated across multiple devices, opening immersive and interactive audio to a much wider range of listeners.

EAR (EBU ADM Renderer) Production Suite

BBC, UK & IRT, Germany • Contact: Chris Pike, chris.pike@bbc.co.uk
A set of production tools that empowers broadcasters to create spatial and personalizable audio using open standards, driving interoperability in production tools and workflows.

BBC Sounds: an integrated audio platform

BBC, UK • Contact: Lloyd Shepherd, lloyd.shepherd.sounds@bbc.co.uk
Sounds is the new home for radio, music and podcasts at the BBC, giving listeners a personal, relevant experience and offering them more control and flexibility.

BBC News Virtual Production Tools

BBC, UK • Contact: Morwen Williams, morwen.williams@bbc.co.uk
Three transformational tools: Toucan *for fast-turnaround remote TV interviews;* Pre Rec *for quality audio on pre-recorded distanced discussions;* Virtual Audience *for connecting audiences with studios.*

Low-cost mobile Augmented Reality production kit

France Télévisions, France • Contact: Christophe de Vallambras, christophe.devallambras@francetv.fr
The "JP Tech" kit – named after its inventor – uses technology from video games and virtual reality to enable low-cost production of live, mobile and interactive AR sequences anywhere.

Newsgathering vehicles with low carbon emissions

ITV, UK • Contact: Tim Guilder, tim.guilder@itv.com
The ITV Daytime team developed a lightweight, agile streaming solution for remote newsgathering, housed

in plug-in hybrid vehicles, reducing both operating costs and emissions.

Home Planet app to gamify sustainable living

ITV, UK • Contact: Matt O'Shea, matthew.oshea@itv.com
This mobile application, built in-house using a no-code platform, underpins a campaign to encourage all staff to live more sustainably, driving real cultural change within ITV.

Remote cloud-based editing solution

ITV, UK • Contact: Tim Guilder, tim.guilder@itv.com
The ITV Studios team accelerated its development of remote and cloud-based editing solutions that are both agile and scalable, reducing the carbon footprint and increasing productivity.

OBECA – evolving the 5G Broadcast ecosystem

ORF, Austria • Contact: Stefan Babel, stefan.babel@ors.at
OBECA (Open Broadcast Edge Cache Appliance) is a modular open-source 5G Broadcast receiver platform enabling the community to develop tomorrow's hybrid "broadband meets broadcast" solutions.

Digital data hub

ORF, Austria • Contact: Jürgen Schöner, juergen.schoener@orf.at
A software stack to aggregate and transform the

huge amounts of programme-related metadata generated by linear broadcast systems for use on non-linear online services.

Agile video editing

ORF, Austria • Contact: Sebastian Blaha, sebastian.blaha@orf.at

A solution for remote editing of broadcast quality video over public internet but rendered in the central broadcasting MAM. Already commercialized and in use by other broadcasters.

Efficient production of companion screen applications

Rai, Italy • Contact: Alberto Messina, alberto.messina@rai.it

The RaiBridge system enables editorial teams to efficiently author companion screen content, delivered on a single customizable app, greatly enriching the user experience.

An avatar for sign language applications

Rai, Italy • Contact: Gino Alberico, gino.alberico@rai.it

A platform based on a virtual actor (avatar), enabling applications for LIS (Italian Sign Language) such as teaching and automatic generation of weather forecast reports.

Producing live in "hyper sound"

RTVE, Spain • Contact: Carmen Pérez Cernuda carmen.perez.cernuda@rtve.es

A concert streamed live from the Prado Museum was mixed and encoded using Dolby Atmos, enabling placement of sounds in three-dimensional space for total audio immersion.

Pilot broadcast of 8K UHD over DVB-T2

RTVE, Spain • Contact: Adolfo Muñoz, adolfo.mb@rtve.es

A broadcast in October 2020 demonstrated the feasibility of delivering 8K UHD services over terrestrial networks with existing technology, using HEVC video coding and DVB-T2.

5G and cloud for multiplatform content production and distribution

RTVE, Spain • Contact: David Corral, david.corral@rtve.es

A live concert produced by Radio3 was delivered to both online and broadcast platforms in multiple formats using a multi-camera signal routed via 5G to a cloud-based virtual mixer.

News values – the public service algorithm

Sveriges Radio, Sweden • Contact: Jörgen Bang, jorgen.bang@sr.se

The algorithm used to automate SR's news playlists is centred on news values and gives prominence to stories rated as having high public service value.

Reimagining the future of radio apps

SWR, Germany •
Contact: Daniel Freytag, lab@swr.de
The SWR mobile app gives users the ability to instantly replay and save both music and segments to their personal playlist, all in an easy-to-use radio service.
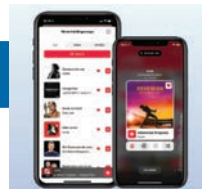
Virtual studio production using game engines

VRT, Belgium • Contact: Dries Tastenhoye, dries.tastenhoye@vrt.be

Demonstrate the capabilities of a virtual studio based on COTS hardware, leveraging the power of game engines for high-value to small-scale live productions.

Automated metadata extraction from online videos

Yle, Finland • Contact: Pia Virtanen, pia.virtanen@yle.fi

Implementation on the Yle Areena player of automated thumbnail selection and preview video extraction, reducing the manual work involved and increasing click-through rates.

Automated subject indexing

Yle, Finland • Contact: Irene Nikkarinen, irene.nikkarinen@yle.fi

Adopting an open-source subject indexing tool called Annif *has reduced manual work and improved the quality of Yle's metadata, contributing to improved discoverability of content.*

Monitoring regional TV news using audio fingerprints

Yle, Finland • Contact: Toni Ljungberg, toni.ljungberg@yle.fi

This proof of concept uses audio fingerprinting to automatically monitor regional news output, helping to avoid the wrong content being played out in a given region.

get.it – a cloud-based metadata platform

ZDF, Germany • Contact: Thomas Urban, urban.t@zdf.de

A solution to map and translate data from different applications into a common ZDF-specific model, making it available to anyone, to support cross-media production and publication.

HoLo Box: an all-in-one communication box

ZDF, Germany • Contact: Michael Hoitz, hoitz.m@zdf.de

Compact voice-guided system allowing journalists in the field to connect to ZDF's infrastructure via LTE/KA-SAT, enabling communication and secure access to archives and drives.

Sharing video expertise and enthusiasm

Video technology forms the basis of most of the EBU Members' activities. It allows content and services to be created in ever higher quality, ever faster. At the same time available technical expertise is falling. Here is how the EBU helps.

Public service media organizations are a heterogeneous group. They vary in size, age, resources, R&D capacity, market position, and so on. Technical staff working for these companies typically share a great enthusiasm for video technology and its use, but the expertise to use it optimally is not always at hand or the scale to perform large testing exercises is missing.

The EBU helps by pooling Members together, maximizing the sharing of knowledge, experiences and available resources. History has shown this model works very well, especially in times of crisis, but also that it needs continuous adaptation. Recently the EBU's video work has undergone such changes. The liquidation of the German research institute IRT accelerated a process that was under way already, namely the shift to a larger set of smaller projects led by different Members. Here we present four leaders of such work.

For more details, or to follow or contribute to the work, see: tech.ebu.ch/video

Simon Thompson (BBC)

Simon is leading the umbrella group for the EBU's video work, *Video Systems & Workflows*. Its main focus at the moment is on the measurement of professional video monitors, especially when used with HDR (high dynamic range) images. Simon has undertaken much pioneering work in this domain, including many live HDR production trials, SDR <> HDR format conversions, colour/levels research and monitor tests. The group is currently finalizing an update to EBU Tech 3325, which helps Members measure their own studio monitors. The new version will be accompanied by new test material, including more challenging test colours.
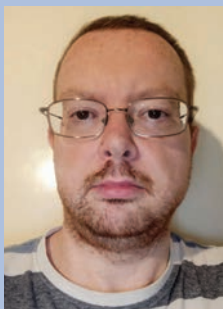
Kayatri Rangarajan (CBC / Radio-Canada)

Kayatri is driving the creation of EBU guidance on the use of 'non-standard' aspect ratios in production and archiving. Social media applications often use 9:16 and even 1:1 aspect ratios, which has raised questions about the optimum way of handling such material in editing and archiving operations. An internal CBC study on the topic and an EBU Tech Roundtable have helped to define the main options and a set of *do's and don'ts*. Besides writing up guidance for other Members, the work also includes encouraging better support for non-standard aspect ratios in standards and production tools.

Karl Petermichl (ORF)

With his managerial background and operational expertise as a broadcast engineer, Karl understands the need for clear, practical guidance on complex topics. This is exactly what the *UHDTV Strategy Support* group is aiming to provide. This initiative, which Karl leads, is currently creating guidance for the contribution of UHDTV material both in live and file-based form. This will facilitate UHDTV content exchange and help Members that are not yet using UHD and NGA technologies to start putting future-proof practices in place. His energetic and to-the-point style mean the group's calls never include a dull moment and the speed is high.
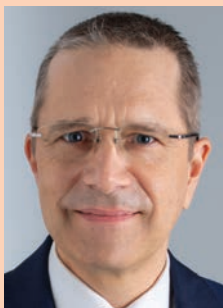
Roberto Iacoviello (RAI)

In April 2021, a new group covering work on subjective and objective evaluations was created. This *Video Evaluation* group covers the quality-checking of codecs, the creation of test sequences, and the testing of AI-powered algorithms. The latter are especially relevant for the upsampling of content from SD to HD and from HD to UHD. Leadership is in the trusted hands of Roberto Iacoviello (RAI). His current research is on AI techniques applied to video compression and point clouds. Roberto is actively involved in several codec standardization organizations.

Securing a place for television in the age of the internet

Public service media must use their existing reach to direct users to new platforms and services. Rundfunk Berlin Brandenburg (rbb), part of the ARD network, is exploring how DVB-I can help with this, writes **Remo Vogel**.

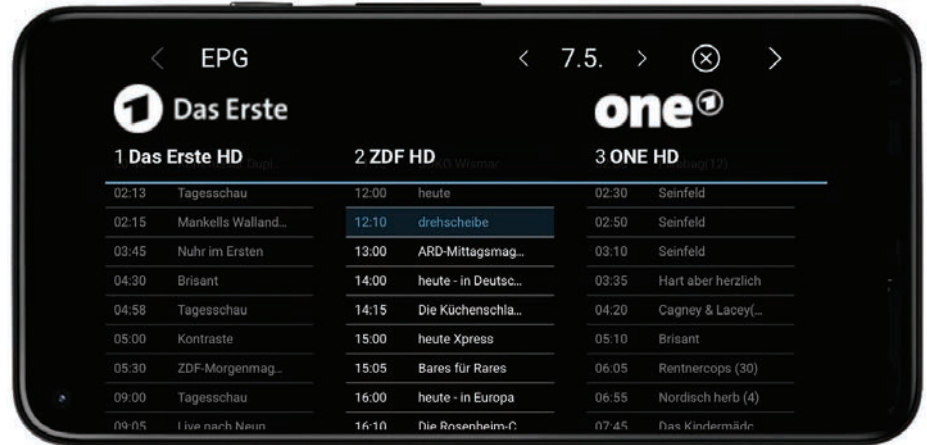After I saw the Eurovision Song Contest broadcast as a live stream in the late 90s, I was totally convinced that television would be devoured by the internet within 10 years. It didn't happen that quickly. But today, those working on the transformation of public service media (PSM) distribution can see that we have a final window of opportunity for television to secure its place in the age of the internet.

A smartphone showing an EPG delivered with DVB-I

SERVING THE CORD-CUTTERS

The digital transformation is still at a relatively early stage for PSM. While other industries have already had to completely turn their business models upside down, classic broadcasting continues to work amazingly well. At the same time, we are experiencing a strong change in user behaviour, especially among younger generations. On the one hand, there is a tendency towards consuming content on demand, without regard for linear schedules; on the other hand, we also see a trend towards the use of linear services via IP. While the big screen is booming, there is a growing number of so-called 'cord-cutters' – users giving up entirely on multichannel television services – seeking only OTT-device support, from big screens to smartphones.

Up to now, live streaming has taken place in an unstructured way using proprietary solutions. While the streaming technology itself is (most recently with MPEG-DASH) very mature, there has been no standardized approach for access on the big screen. This is exactly where DVB-I comes in, combining classic broadcast with OTT in a hybrid approach and allowing a homogeneous user experience. Thus DVB-I allows a smooth migration from broadcast to broadband and gives control to PSM organizations over priorities and quality parameters.

While the technology is still in an early phase, several markets are examining the potential of DVB-I. In addition to the private broadcasters, completely new players are emerging. Therefore, it is extremely important for us to actively shape the start-up phase and to secure the interests of PSM. This includes both service prominence on future devices and applications as well as the availability of features like accessibility. ARD and ZDF are collaborating on describing a service scope that reflects our interests in a first draft "Profile for DVB-I usage".

DVB-I PILOT

To really get a picture of the potentials and weaknesses of a technology, you simply have to try it out and gain practical experience. That's why we decided in mid-2020 to start with a DVB-I pilot at rbb. As we use the DVB-SI (service information) playout for the entire ARD network in Potsdam, we can provide the service lists and programme data for ARD and ZDF in our DVB-I service list with modest effort. We have been using MPEG-DASH livestreams for other use cases for quite some time. Thanks to the DVB-I reference application provided by the DVB Project, we can concentrate completely on our role, the provision of metadata and streams.

We are at the beginning of our implementation and intend to expand it in iterative steps. We will ensure our activity aligns with developments in the global and national ecosystem and aim to support the market introduction of DVB-I.

EBU HbbTV and DVB-I Group
The HbbTV and DVB-I interoperability group is designed for broadcasters to share best practices. It will also work to improve the interoperability of HbbTV in the markets where EBU Members are active. The group is chaired by Christian Klöckner (WDR) and Remo Vogel (rbb). See: tech.ebu.ch/groups/hbbtv_dvb-i

Finding the right transcription tool for the job

An EBU-led project helps Members to select the right transcription tools for different use cases. **Eyal Lavi** (BBC), **Alberto Messina** (RAI) and **Alexandre Rouxel** (EBU) explain how BenchmarkSTT is evolving.

Two important aspects of the public service media remit are accessibility and the preservation of language diversity. The burgeoning market for translation and transcription tools may not always sufficiently account for these needs, making it all the more important to pick the right tool for a given job.

Automatic speech-to-text (STT) algorithms can have enormous operational value where large amounts of audiovisual content are processed. Examples include metadata generation and the production of subtitles, enabling new accessibility services and for the more efficient use of archives.

Every language has its specificities. When it comes to using STT transcription services, special characters, accents, capital letters and punctuation can all impact the meaning of a transcript. The large number of commercial STT vendors and the rapid development of new algorithms make for a dynamic and complex landscape. BenchmarkSTT was developed as a simple and service-agnostic tool to help choose the best STT implementation for a given use case.

This production-ready tool, first released in April 2020, was created in response to requests from the EBU membership, where there is a huge diversity of native languages. Unlike other tools in the area of AI and machine learning, this command-line tool was designed to be used by non-specialists.

The word error rate (WER) is the standard metric
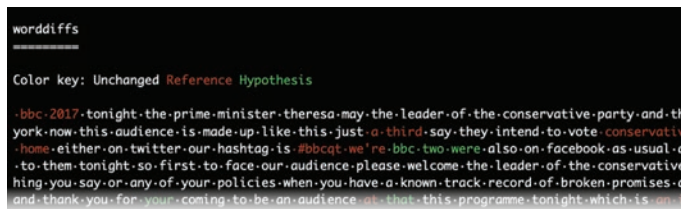
for benchmarking automatic speech recognition models, but it can be a blunt tool. It treats all words as equally important but in reality some words, like proper nouns and phrases, are more significant. When these are recognized correctly by a model, they should be given more weight. Version 1.1 of BenchmarkSTT, recently released, thus introduced new metrics, namely the character error rate (CER) and – to address the problem just described – the 'bag of entities' error rate (BEER).

BenchmarkSTT is open source and available on both GitHub and PyPI, where there is extensive documentation and a detailed step-by-step tutorial. The team is now developing metrics to evaluate the quality of speaker diarization, showing 'who spoke when'.

BenchmarkSTT was developed by the Flemish Institute for Archiving (VIAA), BBC (UK), Rai (Italy), Sveriges Radio (Sweden) and France Télévisions, under the umbrella of the EBU. Visit tech.ebu.ch/production *and click on AI Benchmarking.*

Who is using BenchmarkSTT?

Deutsche Welle, Germany
DW is evaluating transcription, translation and voice synthesis AI tools for the development of a cognitive platform. Subjective and objective evaluation metrics are combined, with BenchmarkSTT used for evaluating transcription.

TV 2, Norway
Benchmark STT allows TV 2 to compare progress in quality development for different vendors. The broadcaster's backend AIHub obtains transcripts from different vendors for clips taken from an internal FTP video receiver tool, using release 1.1 of BenchmarkSTT running on Docker to evaluate them.

Radio France
BenchmarkSTT is used to assess the added value of transcribing audio content into text to feed search and recommandation features. Already using the WER for a rough evaluation of the transcription quality, they plan to use the BEER feature to help improve performance with respect to the words selected by the recommendation engine. Finally, they

try to identify the content types for which the automated transcription gives the best results (e.g. news content).

Sveriges Radio
The Swedish broadcaster contributes to the BenchmarkSTT project with a view to having a better way to benchmark different transcription engines and help evaluate them. The use of WER and CER provides data to be used as part of ongoing evaluations of different vendors.

Rai – Radiotelevisione Italiana
In the context of a greater focus on integrating available AI cloud services in strategic production and publication processes, BenchmarkSTT is used for the evaluation of different STT vendors.

BBC
BenchmarkSTT was used to compare various STT algorithms used in the in-house transcription API as well as for a small-scale study of subtitles as ground-truth data. The study suggested that it may be possible to use subtitles, rather than expensive, manually created transcripts, as reference for calculating WER.
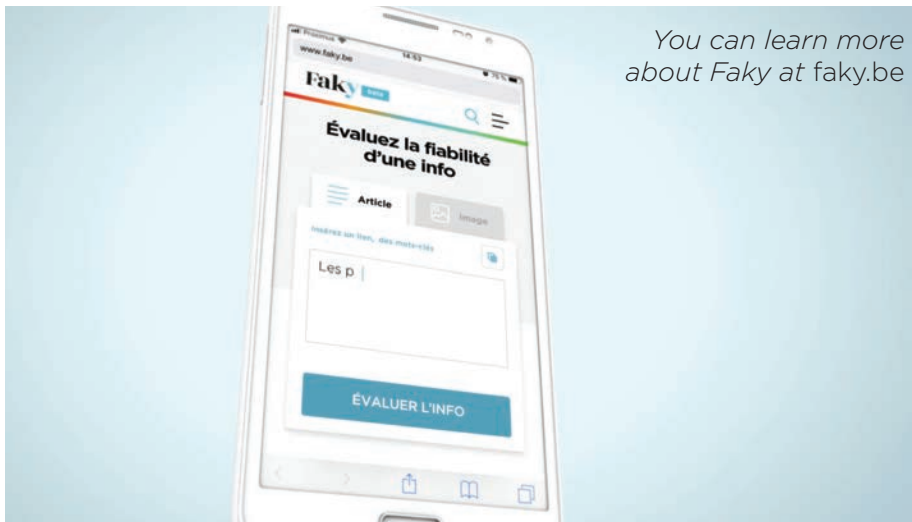
You can learn more about Faky at faky.be

Faky: fighting the spread of misinformation

A new platform from Belgium's RTBF provides users with access to a range of tools to evaluate online information. **Grégoire Ryckmans** explains what it offers.

In an effort to fight against misinformation, which has been on the rise in recent years, RTBF has developed a fact-checking platform accessible to everyone. Faky offers several tools to help both journalists and citizens to evaluate the reliability of a given article, website or image.

There are four main features on the platform. First and foremost is the possibility to submit for analysis any article (in the French language) by pasting its URL into the search box. Independent and partner-developed tools then analyse the URL through different information prisms such as source, content, syntax or dissemination.

The article's reliability is assessed by the Crowlingo platform; its content is analysed by an AI-based 'disinformation detector' developed on behalf of RTBF; and its subjectivity is evaluated by Textgain, a tool that relies on natural language processing (NLP). Articles are also cross-checked using two products from the French newspaper *Le Monde*, the *Décodex* tool that checks the source of the article and the *Les Décodeurs* series of fact-checking articles.

Those articles from *Le Monde* also form part of the second element of the platform, which is its feed of the latest fact-checking articles published by partner newsrooms. Alongside those published by RTBF journalists, there are also the articles from *Les Décodeurs*, and similar services run by Franceinfo, TV5 Monde, France 24 and Radio-Canada, as well as from the collaborative platform Hoax Net.

As a third option, Faky also offers a general search, allowing users to search for fact-checking articles related to a given theme or based on keywords. For example, should a visitor want to know whether Bill Gates really said "we should eliminate three billion people", with a few clicks, they will find the answer. (Hint: he didn't!)

Finally, there is an image verification tool. It uses a 'reverse image search' to help discover whether a photo has been retouched, hijacked or decontextualized. This feature allows the user to find the different sites where the same image has been published to find the source and see, for example, whether it has been the subject of fact checking.

An EBU tool for fake news detection

Alexandre Rouxel and **Pierre Fouché** (EBU)

Human performance in detecting fake news by analysing only the content without knowing the context and the facts is very poor – not much better than random choice. This has been confirmed through rigorous experiments by psychologists. At the EBU, we have developed our own AI models to detect fake news using linguistic properties.

As a complement to the fact-checking approach, which requires a thorough understanding of the context, the EBU eXplainable tagging tool uses natural language processing. The tool computes a reliability score and explains how the text's lexical, grammatical, psychological and semantic properties influence the score. It also goes one step further by indicating the sentences or psychological traits of the text that most affect the score.

We are developing an API, open for EBU Members, to attribute explainable reliability scores to their content. As we design and train our models, we can quickly adapt them to new trends and emerging topics. We are now collaborating with RTBF to handle articles in French and open our API to Faky.

We are also working towards exposing a new API for authorship and source attributions. *rouxel@ebu.ch*

MDN Workshop 2021
The projects described on this page were presented by the authors during the recent Metadata Developer Network workshop. The slides and videos are available here: tech.ebu.ch/mdn21

Measuring and reducing the carbon footprint of arte.tv

Existing measurement tools don't provide a complete picture of the carbon footprint for online platforms, but new approaches are emerging, writes **Kemal Görgülü**, CTO of ARTE.

Sustainability is one of ARTE's core values. Not only have environmental issues always had a place in our programme catalogue, but they also play an essential role in shaping our in-house energy policy, technical infrastructure, and various other fields – including digital activities. By identifying potential for reducing our digital carbon footprint, we aim to induce a sustainable change in mindsets and behaviours as early as the programming stage. But where to start from?

An important first step towards prioritizing appropriate actions was to get a clear picture of the carbon footprint of our digital system, specifically our arte.tv platform. However, existing measurement tools proved to be insufficient to obtain a comprehensive end-to-end vision of the impact. They evaluate the footprint of only one part of a digital system – the client, the server, or the network. In doing so, they create an incentive to move emissions from one part of the system to another part that isn't measured, thus improving the visible metrics but not the overall footprint.

Furthermore, while it may be possible to quantify the environmental impact of server-side infrastructure fairly easily, doing so on the client side is all the more difficult. The only way to get accurate system metrics like CPU or network consumption on the client side is to have users install third-party software with administrator privileges – not a viable option with regard to security and data protection requirements.

FULL-STACK MODEL

The good news is that some experimental solutions are emerging to fill this gap. We have realized a proof of concept with one of them, GreenFrame (formerly Argos), a promising framework based on scientific models and addressing the main issues listed above. GreenFrame allowed us to measure the carbon footprint of an entire

end-to-end stack within a controlled environment.

GreenFrame isn't yet capable of giving an accurate estimate of the footprint of the arte.tv system in production. It focuses on reproducing the digital system in a lab environment. But by doing so, it provides precious and reproducible key indicators that make it possible to assess the evolution of the arte.tv carbon footprint over time as new features are regularly added by developers. It allows us to raise awareness of good and bad development practices with respect to carbon footprint. It also allows us to clearly highlight the link between sustainability, performance, and the user experience on our platform.

HOW DOES IT WORK?

On the frontend, GreenFrame conducts end-to-end tests by simulating typical user scenarios (Fig. 1).

It uses Docker to encapsulate each component of the system in an isolated container.

While running the scenarios, GreenFrame gathers technical metrics (CPU, memory, network I/Os, disk I/Os) in real time, and

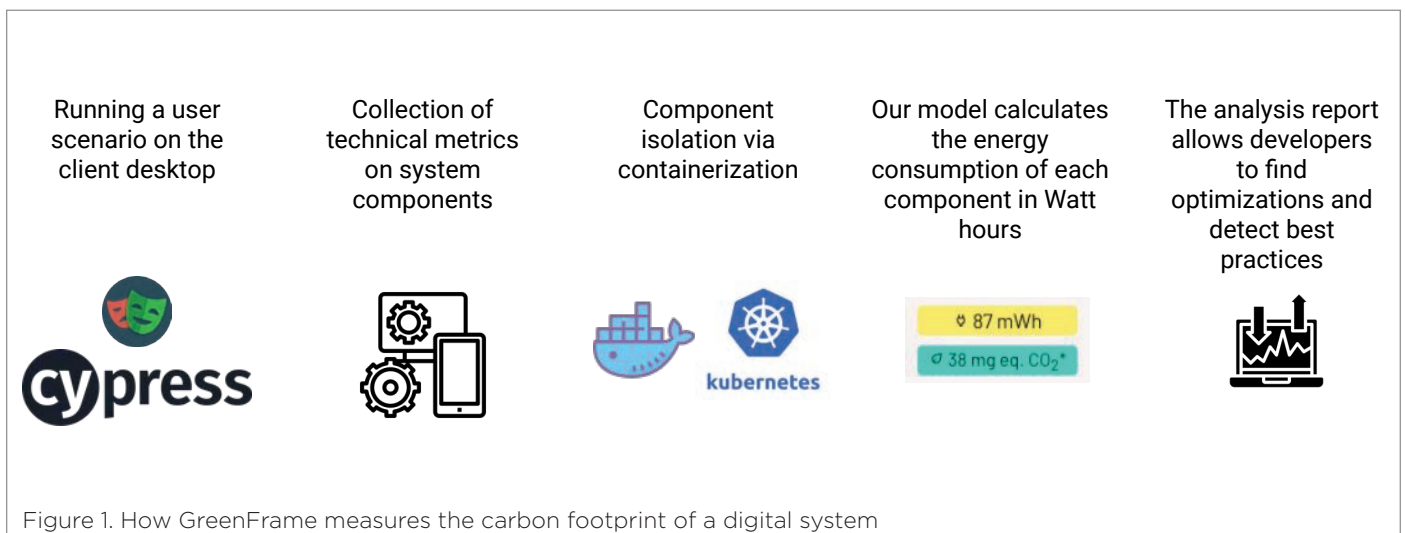| Running a user scenario on the client desktop | Collection of technical metrics on system components | Component isolation via containerization | Our model calculates the energy consumption of each component in Watt hours | The analysis report allows developers to find optimizations and detect best practices |

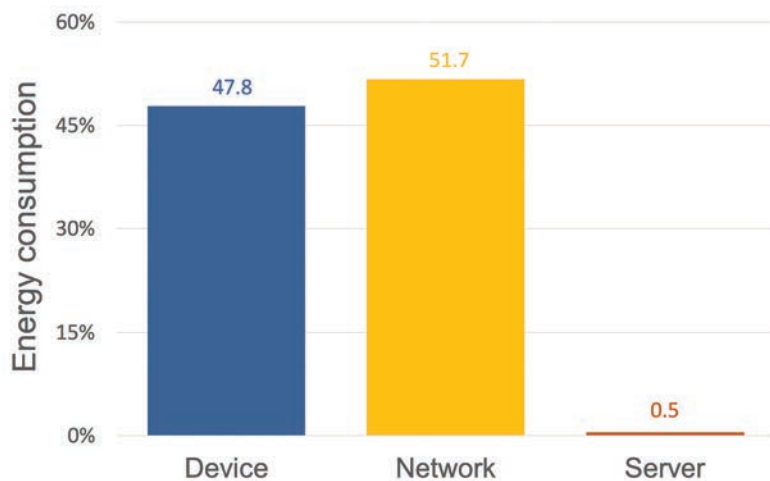Figure 1. How GreenFrame measures the carbon footprint of a digital system

Figure 2. The client device and the network account for the vast majority of energy use.

> "The challenge will be to find a balance between reducing the carbon footprint without compromising the UI/UX."

transforms them into the same unit, watt-hours. Based on an energy mix, watt-hours can easily be converted to carbon emissions, which convey a clear overview of the digital system footprint. Each scenario is run a dozen times to get a strong, accurate signal and reduce the standard deviation.

That means GreenFrame tracks the entire system: the frontend, the backend, the database, and the network.

The process of running GreenFrame tests is fully automated and, thanks to its container-based architecture, it runs smoothly in any continuous integration (CI) and deployment (CD) system. New analyses can be triggered each time a developer pushes a change in the code, giving us the possibility to detect any kind of improvement or regression in the environmental footprint of the global system before deploying a new feature to production.

LIMITATIONS AND RESULTS
For our proof of concept, led by François Dume and Olivier Hoffschir, we were able to get the project started quickly because we were already in the process of converting all our applications to a container-based infrastructure. Having this kind of architecture in place is a strong requirement for using this tool. But some services (databases, APIs, CDN) proved to be more difficult to integrate into this controlled environment. In some cases we thus had to simulate services, for example using static text files, which may have led to underestimates.

The initial results weren't necessarily revolutionary and basically confirmed our assumptions that the majority of energy consumption is indeed on the user side (browser, screen, network, …). They also highlighted that video transit and decoding form the bulk of the carbon emissions of a media service like arte.tv (Fig. 2).

Reducing our *global* carbon footprint means first and foremost reducing our client-side energy consumption. The challenge will be to find a balance between reducing the carbon footprint without compromising the UI/UX. As a positive side effect, this will also mean significantly improving page and video loading times.

WHAT'S NEXT?
We will continue to use GreenFrame at ARTE and integrate it into our CI system in order to detect regression early in our development processes. We will also take the example of other important issues like web performance and security, and determine a monthly 'carbon budget', combined with an internal set of rules to limit (and reduce) energy consumption.

A further approach will be to give greater consideration to environmental criteria when choosing, for example, a new CDN provider, as this represents a large part of our video infrastructure. CDNs currently don't provide CO_2 emissions metrics, but they will if enough customers require them.

Finally, we're aware that optimizing the footprint of a service can lead to more usage, and ultimately to greater emissions. We want to offer transparency to our viewers so that they can make informed decisions about how they watch ARTE videos.

Then, all requirements will be met for a virtuous circle allowing us to induce sustainable business transformation at ARTE, thus meeting our responsibility as public service media to do our part in improving the environmental impact of our industry.

GreenFrame (greenframe.io) was created by Marmelab (marmelab.com/en). EBU Members can view Kemal Görgülü's presentation on this topic at BroadThinking 2021 here: **tech.ebu.ch/broadthinking2021**

Sustainability and media technology: start with an honest assessment of the facts

One key takeaway from the recent EBU Sustainability Summit was the need to base actions on hard data, writes the EBU's **Hemini Mehta**.

The EBU's first Sustainability Summit, aptly held on Earth Day (22 April), attracted more than 400 online participants from around the world. They came together around a shared commitment to finding ways to reduce the environmental impact of the media industry.

Opening with a look at policy-driven approaches at the global and European levels, the programme moved onto foundational concepts such as the circular economy, sustainability strategies and targeting net-zero impacts. A session on green tech – see below – was followed by parallel workshops on green production, held in multiple languages.

DESIGN FOR SUSTAINABILITY

Kicking off the green tech session, Tim Davis of ITV (UK) discussed the need to "design for sustainability". With a public goal of achieving net-zero carbon emissions by 2030, and based on the principle that "information generates insight", ITV has joined DIMPACT. This is a collaborative project that aims to take the complexity out of calculating carbon emissions across the entire digital media value chain. It enables ITV to model the impact of its digital offerings by calculating energy consumption both internally (e.g. data centres) and externally (e.g. when viewers consume the content, with delivery bitrates being one key variable).

ITV found that, for digital content, the delivery mechanism made the single biggest contribution to the total carbon emissions. Furthermore, while cellular networks represented roughly 50% of the carbon generated for digital distribution, that related to only 2.5% of the actual content consumption, with the vast majority of consumption
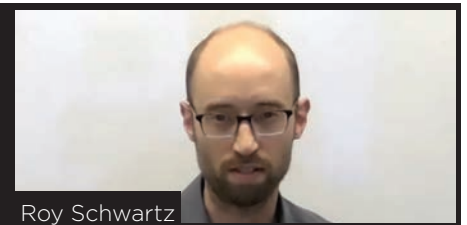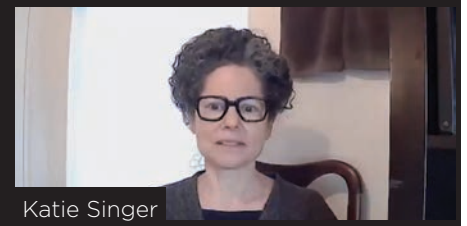

Tim Davis
Roy Schwartz
Miguel Coma
Katie Singer

relying on fixed line internet. Data like this gives ITV a much clearer idea of where changes can have the biggest impact.

GREENER AI

Data is also key to research on making AI more sustainable, presented by Roy Schwartz of the Hebrew University of Jerusalem. With this technology becoming ubiquitous in many fields, including media (e.g. for translation and in voice interfaces), concerns include the environmental impact of deep-learning models that grow bigger all the time, but also the billions of smaller AI-driven interactions that happen daily with web searches, recommendations, etc.

The hardest challenge in calculating the true carbon footprint of AI is in how to measure it. This challenge is addressed by, in the first place, enhancing the reporting of AI success rates so that the achievement of different levels of accuracy is mapped against a given budget level (where that budget could be stated in terms of electricity or carbon). Dr Schwartz and his colleagues, who have been promoting efficiency as a core evaluation for AI, have seen that there is a growing awareness of this aspect of using AI.

5G ON THE WAY

A third technology of growing interest to broadcasters and where sustainability is increasingly in focus is 5G. IT architect Miguel Coma summarized the likely environmental impacts as 5G rolls out: the biggest culprits in terms of energy consumption will be the access networks and data centres, and the embodied energy (i.e., energy spent on manufacturing, including the devices and batteries, etc.). Impacts related to extraction of fossil fuels and rare earth elements also need to be accounted for.

It's an area that requires an honest assessment, said writer Katie Singer: "I live in the 'I don't know' a lot; they are just enormous problems, but unless we're honest about the whole cradle-to-cradle situation, we're not going to be getting honest answers."

For 5G, the answers could lie, for example, in deploying it only where really needed, such as in small-scale private networks targeting Industry 4.0, or using wired alternatives wherever possible.

Videos and slides are available from: tech.ebu.ch/sustainability2021
Find out more about EBU T&I activities around sustainability: tech.ebu.ch/groups/spsm

Content distribution and production in the UHF band: a virtuous circle for broadcasters

David Hemingway (BBC), chair of the EBU strategic programme on spectrum, explains why stability in how the UHF band is allocated is essential to maximize innovation and public value.

For the last 50 years, we have relied on the UHF frequency band for delivery of terrestrial television. The move from analogue to digital allowed the release of some of the UHF band to be used instead for mobile broadband systems – first 4G and now 5G. Broadcasters also use the UHF band for programme production technologies, interleaved between the television transmissions: radio mics, talkback systems and in-ear monitors. We have innovated in those too: moving to digital systems, squeezing more channels into the same spectrum and moving out of spectrum earmarked for mobile broadband. Regardless of how we distribute our finished content or how important DTT is in our countries, we all use those production systems for making programmes – without them, our content offering would be much poorer.

YOUNGER AUDIENCES

And we continue to innovate in the technology we use to deliver our content. We need to respond to changing audience behaviour, especially among younger audiences. Reaching younger audiences is challenging, due to both the type of content they enjoy and the ways we deliver it. Their preferred viewing device has moved from TV sets to smartphones and tablets. Direct delivery to those devices, in a way that is both spectrum- and cost-efficient, is key.

The EBU has been looking at ways to utilize mobile networks that could be beneficial to Members. To that end we have added elements into the 5G standard that can enable a '5G Broadcast' system capable of delivering content to mobile devices efficiently and without

David Hemingway

data costs. Even better, it can be used in the existing UHF band, under the rules of the Geneva 2006 Agreement, requiring no new spectrum to be allocated. Broadcasters could (subject to agreement with their national regulator, of course) swap out DVB-based systems for 5G Broadcast – this is especially attractive in those countries where DTT take-up is low. For those Members operating in countries where DTT is important, they could continue to use DTT for as long as their audiences demand it.

One of the great innovations of the last decade or so, of course, has been the ability to deliver content by IP. This isn't just a great leap forward in technology, but has enabled, and will continue to enable, new types of

content to be made and delivered to our audiences. That, however, should not detract from the continued importance of broadcast delivery of our programmes. Consumption of AV content is shifting to IP, but slowly, much more slowly than many predicted. For public service content, delivering high social and cultural value across Europe, broadcasting remains supremely important. More than 80% of our viewing and listening is still delivered through broadcast platforms: terrestrial (DTT, FM, DAB), satellite and cable. These numbers very between countries, of course – for some EBU Members, online delivery is higher but for many it remains low.

CHANGES NOT NECESSARY

At the 2023 World Radiocommunication Conference (WRC-23), national regulators from Europe, Africa and the Middle East will discuss the future use of the remaining UHF spectrum that we use for DTT. The EBU believes that we can continue to innovate in our use of this band, both to create and to deliver public value for our audiences in new and exciting ways, without the need to make changes in the international treaty that governs use of radio spectrum.

Broadcasters have created a virtuous circle in their use of UHF spectrum: it allows us to both distribute our programmes in a highly efficient way, helping to ensure universal access to public service content, and we use it for programme-making applications, creating content that would not be possible without it. Destabilizing this arrangement by amending spectrum management regulation is both risky and unnecessary.

Testing production of Next Generation Audio in an all-IP environment

Having embraced SMPTE ST 2110 for its new facilities, SRF is exploring how Next Generation Audio can be handled with maximum efficiency. **Adrian Hilber**, **Andreas Weiss** and **Markus Brockmann** describe a recent proof of concept.
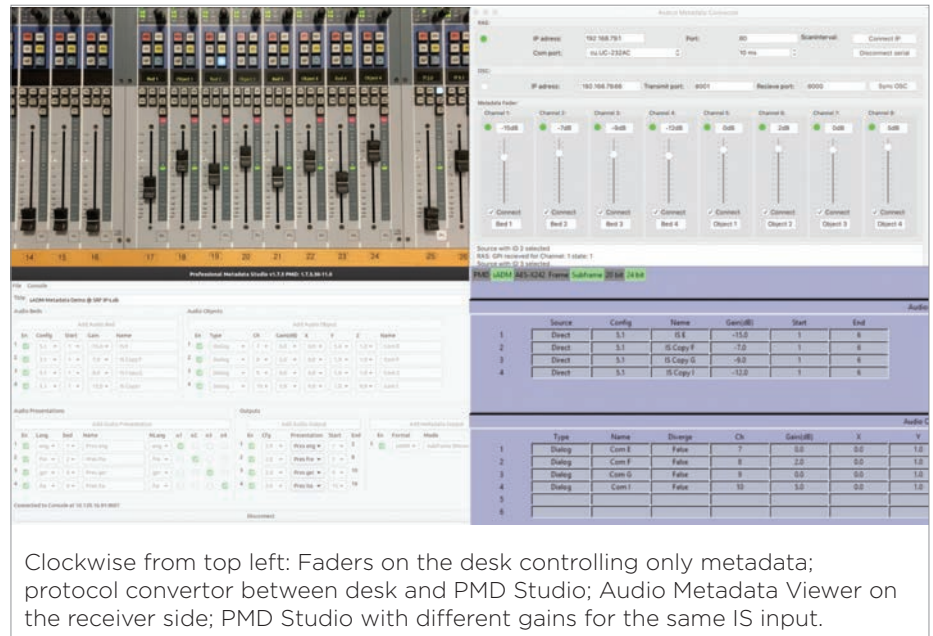
The use of object-based audio (OBA) allows us to kill two birds with one stone: we can offer personalized sound experiences while also optimizing the use of bandwidth. An obvious use case would be a movie or live sports event with one multichannel audio bed and a variety of different languages plus audio description. With OBA, an 'object' is essentially an audio stream with accompanying descriptive metadata. By using *dynamic* metadata, the end user can be given the freedom to choose how the available audio objects are played back in their specific listening environment.

For SRF, doing all of this with ST 2110 IP-based workflows is critical. This was the driver for our proof of concept in collaboration with Dolby Laboratories Inc.

The solution takes the mixing parameters of an audio console and uses this data to control an authoring tool (Dolby PMD Studio) generating the desired metadata. Bringing these parameters into a standard protocol (in our case S-ADM) allows the use and routing of the metadata in any standardized broadcast environment.

Serial ADM – a new professional audio metadata format derived from the ITU's Audio Definition Model file format – seems to be the right choice for OBA metadata. It is clear to us that even in a modern facility there is always a need for backward compatibility. And though a full IP-based workflow is the goal, in reality we often have to deal with legacy SDI infrastructure and links.

The use of open standards and protocols to ensure maximum interoperability between different products is becoming more and more important for us as

Clockwise from top left: Faders on the desk controlling only metadata; protocol convertor between desk and PMD Studio; Audio Metadata Viewer on the receiver side; PMD Studio with different gains for the same IS input.

a broadcaster, as technology is changing faster and faster.

PROOF OF CONCEPT

Our test aimed to prove how dynamic metadata could be used for a sports transmission where we have an 'international sound' (IS) object and three commentary objects (for different languages). Each object is only transported once but on the receiver side we have a different representation for each combination of commentary plus IS, with the mix controlled by generating dynamic metadata.

This means that the IS object needs three different gains in the metadata, one for each representation, and each commentary also needs a gain. As audio engineers, it is important to be able to generate metadata directly from a mixing desk. Control rooms are already cluttered with controllers and web interfaces, so having another UI for the metadata control should be avoided.

The first challenge was to get the fader positions from our console to the metadata

authoring tool. Here we had to develop our own protocol converter to interface our console with the PMD studio. In our view, a good way to go is the open sound control (OSC) protocol with an S-ADM profile, as OSC is widely used in audio gear and, with a defined S-ADM profile, the vocabulary of each device would be compatible.

Our test environment used an ST 2110-31 stream to carry the S-ADM dynamic metadata. This worked well, even if converted to SDI and back. However, as ST 2110-31 is intended for bigger audio streams rather than very small metadata streams, working towards a solution that uses ST 2110-41, specifically intended for ancillary data, seems obvious to us.

With the audio and the metadata in separate streams, care also must be taken to ensure the indexing data in the S-ADM stream that maps audio objects to given channels remains intact during transport.

We'd be happy to share more information about the tests. Don't hesitate to get in touch!

Designing better audio experiences: put the user at the centre

The EBU Audio Systems group hosted a series of sessions aiming to come up with fresh approaches to user interfaces and experiences for audio. Interaction design researcher **Lalya Gaye** led the process.

Next Generation Audio (NGA) promises significant benefits to audiences, content creators and broadcasters. It uses metadata embedded in the audio files and streams. Instead of creating multiple audio mixes, producers can deliver a single, multi-purpose audio package, which can then be rendered and played back appropriately on anything from mono devices to sophisticated and fully immersive audio setups. Accessibility and personalization features are also enabled in this way, such as the ability for users to control the relative playback volume of voice commentaries over the rest of the programme audio.

While there is already a good understanding of the value of immersive audio, many in the industry believe that personalization of audio has the potential to be even more widely appreciated. For example, the ability to adjust dialogue levels relative to other sounds will address one of the most frequent complaints received by broadcasters.

INTERACTION DESIGN
During a discussion among members of the EBU Audio Systems group in the spring of 2020, the idea of revisiting the definition of the user experience (UX) and user interface (UI) in the context of NGA applications on both television receivers and mobile apps emerged. With a view to providing design pespectives for rich and meaningful user-centred experiences, and for more intuitive and enjoyable interfaces, it was decided to run a series of interaction design sessions. Having a background in interaction design and related methodologies, I was asked to guide this process.

Design sessions with several Member representatives participating were held every two weeks. We dived into methods such as persona design, scenarios of use, bodystorming (brainstorming by physically trying things out) and wireframing (drawing overviews of interactive products to establish the structure and flow of possible design solutions). These sessions helped identify essential design rationales for the interfaces and sketch out user interfaces based on Members' use cases. This preliminary work is intended to form the basis for potential future development aimed at providing UI design guidelines to TV manufacturers and app designers.

The results of these sessions, and a description of the process used, have now been published as EBU Tech Report 061, *User Experience and Interface ideation for NGA* (available via tech.ebu. ch/publications). The report describes how interaction design methods put the end user, rather than the technology, at the centre of the thinking process and create interfaces that are more intuitively understood and better adapted to the end user's daily life. The report will be of interest to professionals working on designing any kind of media user interface, but especially those related to personalized and immersive sound experiences.

Visit the EBU Audio Systems group page to follow and contribute to activies related to audio technology and experiences: tech.ebu.ch/as

Go deep on NGA
A new publication from the EBU and FAME (Forum for Advanced Media in Europe) goes into detail on *Ten things you need to know about Next Generation Audio*. From applications and workflows to costs and timelines, the report offers comprehensive overview of the state of the wider NGA ecosystem today. Download it from tech.ebu.ch/publications

Surfing the change-waves as a smart follower

Having adopted a smart follower strategy, Ireland's RTÉ is better prepared for change, writes **Richard Waghorn**, Director of Operations, Technology and Transformation.

The pandemic forced us all to change, rapidly. At RTÉ, we implemented some changes in a matter of days, with new ways of working that were previously unthinkable: when choice is no longer an option, necessity drives innovation.

SELF-DISRUPTION
Of course, relying on an external disruptor, such as a worldwide pandemic, to force change is not a sustainable model. We need to disrupt ourselves all the time to ensure that we are ready to face the next change-wave, and the one after that. If dealing with change is challenging, given resource constraints and the regulated environments we operate in, then failing to prepare for change is disastrous.

When I first arrived at RTÉ, I said to the technology teams that we needed to be smart followers. We didn't need to be the early bird that catches the worm – that risks wasting the limited money and resources that we have. Instead, we needed to be the second mouse that gets the cheese – the wily follower often secures the sustained competitive advantage.

Being the smart follower required us to disrupt established norms. In order to be ready to surf the next change-wave we needed to be agile, efficient, and clever in the way we invested and innovated.

Over time, we shifted the investment focus away from upgrades and maintenance to transformative projects, projects that are now delivering real value across the organization. We are unlocking efficiencies in every area of the business, enabling us to better serve and reach our audiences. Projects

Richard Waghorn

"While RTÉ doesn't have a research and development function, we do have teams of people who want to push boundaries."

such as our private cloud, our content management system and storage platform, our flexible TV studios and new productivity solutions are doing their job – they've disrupted the way we work, facilitated change and ultimately enabled RTÉ to strengthen its game.

INNOVATION CULTURE
And we're becoming smarter innovators. While RTÉ doesn't have a research and development function, we do have teams of people who want to push boundaries. Using collaborative approaches, we are building an innovation culture that helps our staff to think beyond the current horizon and see the waves of change that are coming our way.

We are now in our third year of participating in the IBC

Accelerator programme: RTÉ will co-champion five projects this year, covering 5G, LEO satellites and AR/VR. Staff from technology and operations are involved in various EBU groups, and we continue to innovate with projects that will transform the way we work. And, along the way, we've picked up two IBC Innovation Awards.

Getting the smart follower strategy right means we can make the organization more agile and efficient, and better prepared for change. The proof of the smart follower strategy is in our response to COVID-19. Part of that response is down to the smart investments we've made, but part of it is also down to the building of a culture that is more conditioned to facing and responding to change. The self-induced disruption has (so far) paid off.

How standards boost the benefits of broadcasting

Headquartered within 2 km of each other in Geneva, the EBU and ITU have collaborated closely over several decades. ITU Deputy Secretary-General **Malcolm Johnson** describes some of his organization's current top priorities.

For the last 71 years, the International Telecommunication Union (ITU) has led global standardization across the broadcasting value chain. Broadcasting and multimedia-related standards, from advanced sound systems to video compression, are as crucial as ever in today's digital world.

As we saw at our last Future of Television for Europe workshop, broadcasting is a driving force in the European creative sector. Radio and television also bolster disaster risk reduction.

STANDARDS ARE KEY
In the aftermath of the COVID-19 pandemic, new technical standards will underpin global efforts to build back better and create a more sustainable and prosperous future. ITU study groups and working parties – despite radically curtailed in-person interaction – continue their work to enable news, entertainment, and education. Common technical standards support openness and interoperability, helping to reduce costs through economies of scale.

Yet increasingly stringent video and audio requirements, combined with competing demand over naturally limited spectrum, pose a dual challenge for today's broadcasting industry. In Europe, television reaches 800 million viewers, accounts for annual turnover of EUR 84 billion and employs 1 million people. Even so, the upper 700 MHz band and 3400-3800 MHz C-Band downlink are gradually becoming less available for use in broadcasting.

This double bind has spurred the industry to adopt more efficient distribution standards,

Malcolm Johnson

such as DVB-T2 and DVB-SX2. A new task group is set to review the spectrum needs of radio services in the UHF band in Region 1 (Europe, Middle East and Africa), assessing service compatibility in the 470-694 MHz range ahead of the next World Radiocommunication Conference, WRC-23.

BROADCASTING AND ITU
Audiovisual output depends on spectrum governed by the ITU-managed Radio Regulations. Broadcasting standards developed via the ITU Radiocommunication Sector (ITU-R) are key to international programme exchanges and quality assessment.

Two years ago, ITU member states adopted two resolutions (ITU-R 70 and 71) on future broadcasting, calling for a roadmap for quality and accessibility, audio and video coding, integrated broadcast-broadband (IBB), multimedia, and emerging applications like artificial intelligence. Other initiatives study '5G Broadcast' systems for television reception on mobile handsets.

ITU has helped to set basic specifications for digital

television and sound, HDTV, UHDTV, and high dynamic range (HDR), while forthcoming work examines the way forward for digital terrestrial television broadcasting (DTTB).

ENSURING ACCESSIBILITY
Media services, regardless of their underlying technologies, must be accessible to all. Universal design, affordability, and equal access to information and communication technologies (ICTs) are key to building inclusive societies, with assistive technologies integrated across the board.

In Europe, this means facilitating services in more than 200 European languages, as well as promoting gender equity and full inclusion for persons with disabilities, the elderly and vulnerable groups. ITU, in parallel, promotes comparable measures in developing countries.

As David Wood, previous co-chair of ITU's Intersectoral Rapporteur Group on Audiovisual Media Accessibility, expressed it: "Those with reduced abilities can and will make a vital contribution to society if we help them to share the media experience. Let's start by working together as much as we can on the technical standards for the systems they deserve."

I could not agree more. Technologies to personalize media, reviewed through ITU study groups with organizations like the EBU, offer a prime example of public–private, cross-industry collaboration.

As partners in the standardization endeavour, we can make new technologies interoperable, accessible, and available for the benefit of all.

Competitive pressures underscore the need for partnership at European level

A new report from the EBU's Media Intelligence Service paints a stark picture of the competitive challenges facing European PSM and commercial media groups alike, writes **Florence Hartmann**.

The constant evolution of the global media landscape makes identifying and benchmarking the main competitors to public service media (PSM) an increasingly complex challenge. To help EBU Members gain a better understanding of their competitive environment, a report on "Public Service Media's Competitive Environment" analyses the biggest tech companies and commercial media groups operating in Europe, providing insight into their activities and business models.
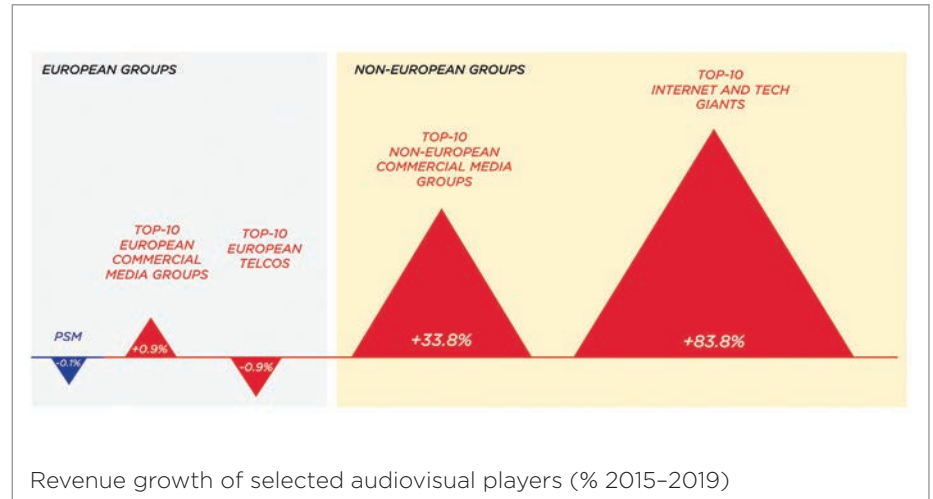
The analysis covers 40 groups in four categories of conglomerates: internet and tech giants, non-European commercial broadcasters, European telecom operators, and European commercial broadcasters.

By comparing their financial results, degree of internationalization, and investment in audiovisual markets, the report provides a wider perspective on where European PSM sit among these larger, highly diversified international players.
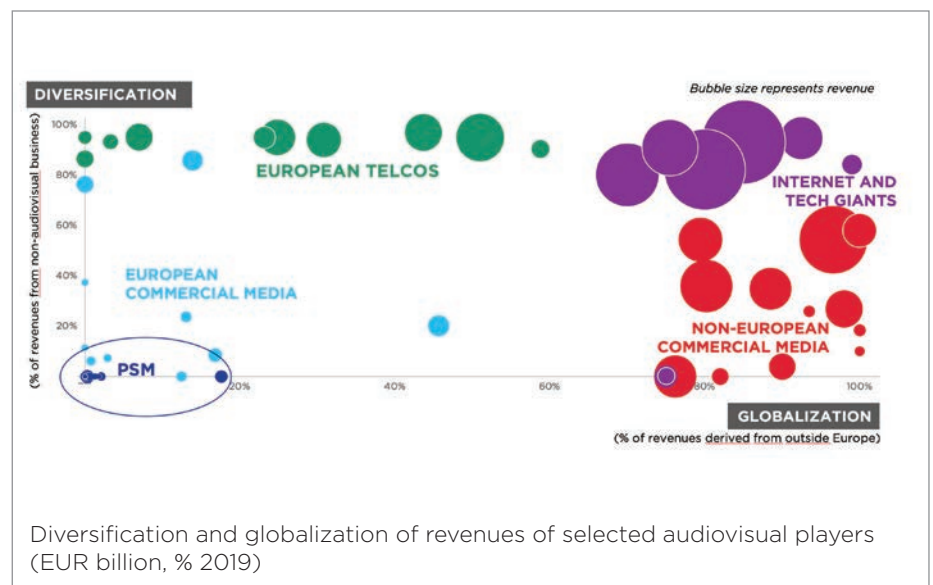
MASSIVE REVENUE GAP
Internet and tech giants' revenues are skyrocketing, increasing by 84% from 2015 to 2019. Also, they are the clear winners from the COVID-19 crisis and the subsequent lockdowns. Furthermore, these behemoths are sitting on mountains of cash: over EUR 500 billion at year-end 2019.

On the other side, European commercial media groups have experienced limited growth in recent years: +0.9% between 2015 and 2019. They remain highly focused on European markets and on audiovisual business, representing

respectively 80% and 72% of their income on average. In a much-changed competitive environment, they no longer appear as PSM's main historical competitors but rather as natural partners.

Indeed, the combination of a crowded competitive environment, under the growing influence of large extra-European conglomerates, with the impact of the COVID-19 crisis makes the case for building strong and innovative alliances across Europe.

The report includes a range

of financial data, enabling benchmarking of the main commercial conglomerates active in European media markets. It also assesses the impact of the COVID-19 crisis and highlights PSM's positive economic impact on media markets across Europe.

The full report is available to EBU Members only, with an abridged public version also available. Visit ebu.ch/publications *and select Research.*

Revenue growth of selected audiovisual players (% 2015–2019)

Diversification and globalization of revenues of selected audiovisual players (EUR billion, % 2019)

Sources: EBU based on Members' data and companies' financial statements.

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▶

HBBTV STATE OF THE ART
KLAUS MERKEL (IRT)
The latest developments, with a focus on Germany

▶

SALTO: HOW TV AND SVOD CAN BE RECONCILED
DANIELLE ATTIAS (SALTO)
A new OTT player on the French market

▶

DESIGNING FOR SUSTAINABILITY
TIM DAVIS (ITV)
Measuring and reducing ITV's carbon footprint

IN THE SPOTLIGHT

Krzysztof Kucharski

SENIOR EXPERT, TECHNOLOGY
DEPARTMENT, TELEWIZJA POLSKA S.A.

Krzysztof Kucharski is the EBU Technical Liaison Officer for TVP

WHAT ARE YOUR CURRENT RESPONSIBILITIES?
I am a member of the TVP Technology team. My responsibilities focus on technical investments and technology topics in corporate strategy. I'm also involved in many fascinating technology-related projects like the new building for news, the first IP studios in TVP, and our file-based deep archive. I am also proud to be the EBU Technical Liaison Officer for my company.

WHAT DO YOU CONSIDER AS YOUR FINEST ACHIEVEMENT SO FAR IN YOUR CAREER?
I believe that my finest achievement is still ahead of me! But so far, I am proud of my work on a long-term mission to connect technology islands to create a single orchestrated environment, including moving our archives to a file-based domain.

WHAT ARE YOUR PREDICTIONS FOR MEDIA TECHNOLOGY IN THE FUTURE?
I expect a progressive unification of technologies for online and television production. The technology progress that we see today, an increasing number of IT-based and networked solutions, including those using cloud technologies, will change television in a way comparable to the transition to colour broadcasting or to digital broadcasting. We see more and more exciting new opportunities but also new threats that require competences that our industry is still building. For this reason, in my opinion, media technology could do more to learn from the experiences of other fields where IT has been an element of the core business for years, for example in the field of security.

WHAT, FOR YOU, ARE THE BIGGEST CHALLENGES FOR EBU MEMBERS TODAY?
We must learn and adopt the world of IT in broadcast technology, including areas where, until recently, solutions other than classic changes in media consumption and new habits and preferences among viewers, so equipment were unimaginable. The challenge for us, public broadcasters, is also to be ready to take advantage of changes in media consumption and new habits and preferences among viewers, so we find ourselves strong in this new reality. To predict, try, create and lead seems to be the key to success here, not to just follow.

TELL US ABOUT SOME OF YOUR INTERESTS AWAY FROM THE WORKPLACE.
I love spending my free time with my seven-year-old daughter, whose creativity, artistic and technical passions I try to support. I have a lot of fun during family cycling trips around Warsaw and doing DIY exercises with her. I like to practice landscape photography, maybe some day she will accompany me on some photography field trips?

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