ICT-687655

Delivering Single and Multi-Screen Content Services for Immersive, Customised and Shared Experiences in Homes and Social Spaces

D6.3 Final Report on Dissemination, Standardisation and Exploitation Planning

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2 IMMERSE

Abstract

This document provides the final 2-IMMERSE project exploitation plans and activities, dissemination activities and standardisation efforts. It is an update of deliverables D6.1 and D6.2. The exploitation plans developed by each partner as presented in D6.2 have been updated to reflect the latest ambitions, project results and activities.

D6.3 also includes a complete overview of all dissemination activities of the project including all publications, talks, workshops and demonstrations at trade shows to present the 2-IMMERSE project results.

The section on related standards activities, where we identified relevant organisations and groups in previous versions of this deliverable, is updated with conclusions and our recommendations for a future evolution of those specifications.

Target audience

General public. Everybody interested in plans for the exploitation and dissemination of the results from 2-IMMERSE.

Impressum

Full project title: Delivering Single and Multi-Screen Content Services for Immersive, Customised and Shared Experiences in Homes and Social Spaces

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Executive Summary

The deliverables of WP6 present the innovation management for the knowledge created in the H2020 project 2-IMMERSE. Besides being a source of information for the public and for the European Commission, they also provide guidance to the 2-IMMERSE consortium partners.

This document is D6.3 and is the final report of WP6. It updates D6.1 and D6.2 which were issued after years 1 and 2 of the project respectively. D6.3 gives an update on our activities and plans for the exploitation of project results. It summarises all dissemination activities conducted throughout the project, including our award-winning peer-reviewed publications and trial applications, and it provides an overview about relevant standards that influenced the 2-IMMERSE architecture. The document also concludes with recommendations for the future evolution of those standards.

The key changes in D6.3 compared to previous versions of the document are as follows:

- The business models presented in the last revision of the WP6 deliverables have been included at the start of this document as they are providing our visions of future potential use of the concepts and architecture developed, tested and evaluated during 2-IMMERSE. Where appropriate these are referenced within the exploitation plans.
- The exploitation strategy and plans have been revised again, and detailed plans from each partner have been adapted to changes and new results achieved in the last year of the project.
- The dissemination section summarizes all dissemination activities carried out by partners during the project, and reports on publications, talks, workshops, presentations at trade shows and the website including regular blog posts and the link to our twitter feed.
- The standardisation section includes a detailed list of relevant standardisation bodies and working groups. Where appropriate recommendations for the evolution of those standards are given.

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1   Introduction

2-IMMERSE is funded under ICT-19, with the following scope:

> *The focus is on research, development and exploitation of new or emerging technologies (e.g. 3D and augmented reality technologies) for digital content creation to support the creative and media industries and for unlocking complex information and media and interacting with them.*

2-IMMERSE is an Innovation Action, as opposed to a Research & Innovation Action. Its focus is more on taking ideas and concepts out of the labs and into trials rather than on developing concepts within labs. The Work Programme describes Innovation Actions in this way:

> *Innovation Actions*
>
> *Demonstration of the viability of new technologies and validation of innovative solutions through large scale demonstrations, pilots or testing of use cases so as to guarantee sustainable deployment that facilitate convergence and integration between broadcasting, broadband Internet-based services, audio-visual and social media. Multimodal and multidisciplinary approaches for searching technologies responding to the new demands from the content side (3D, user-generated, real-time media, social media, …) and from the user context (context-centric, semantic, relevant community feed-back, …). This also includes new forms of experiencing environments (immersive, surrounding, multi-sensory and interactive, in any device, always connected).*

The framework and the activities through which 2-IMMERSE has planned to manage the innovation within the project and has tried to maximise the impact of its work and results, was described in detail in previous versions D6.1 and D6.2.

To summarise, innovation management in 2-IMMERSE includes the exploitation, dissemination and potential standardisation of project results within and outside each partner's organisation. 2-IMMERSE has built four different pilots on its novel platform for multi-screen services. The assets that will be exploited from the project are grouped into the following categories:

- Exemplar productions
- Production Tools and Workflow Insights
- Reference Architectures
- Reference Implementations
- Design Specification and Insights

These assets have been identified in D6.1 and refined in D6.2; please refer to these deliverables for a more detailed description. In D6.3 we provide final reports per partner of how the assets are planned to be exploited and which activities each partner is taking to achieve its goals.

Target audiences for our dissemination activities have included executives in the broadcast value chain, such as at ARD network and BT Sport content owners including Dorna Sports and Donmar Theatre, venue owners and technology developers who may build on and extend our platform and production tools to deliver new experiences in the future. The main dissemination channels have been, as they will remain, the project's Web site, deliverables defined in the technical annex, videos on our YouTube channel, scientific publications, workshops with practitioners and international trade fairs.

On the project website we run an active blog in which 2-IMMERSE experts report news about the project as well as relevant events and publications in the broadcasting industry. By the time of the editorial deadline of this deliverable the blog published:

- **45 blog posts**
- At an average rate of 1.5 articles per month

We ran workshops with practitioners from the broadcasting industry to gather feedback on the project's object-based broadcasting approach, the design of pilot trial applications and the authoring tools. This was also an opportunity to raise awareness of the project and its activities with one of the relevant target groups of broadcasting professionals.

- With professionals from BT sports, Dorna and the FA
- With the Royal Shakespeare Company and Donmar
- With German public broadcasters, including rrb and Arte

We demonstrated the 2-IMMERSE platform and pilot trial experiences at international high-profile trade fairs, including:

- International Broadcasting Convention (**IBC**), in Amsterdam, 2018
- Internationale Funkaustellung (**IFA**), Berlin, 2018

A number of our publications and one of our pilot applications have been awarded prestigious prizes by international expert juries from academia and industry. These successes have significantly enhanced the visibility and ultimately the influence of our dissemination activities. The prizes recognising the work of the project are:

- **Best Paper Award** at ACM TVX 2017
- **Best Paper Award** at ACM TVX 2018
- **Best Paper Award Nominee** at ACM DocEng 2018
- **HbbTV Award 2018** for the "Best multiscreen HbbTV service"
- **Judge's Grand Prix Runner-up** at HbbTV Awards 2018

The 2-IMMERSE architecture builds on open standards recognised and deployed by the broadcast industry. The project evaluated their applicability for its four pilots, extending or modifying specifications where necessary. From this we concluded our recommendations to relevant standardisation bodies. New specifications arising have been evaluated for their applicability for the project, e.g. as happened with MPEG MORE in year 1 of the project. Active membership of 2-IMMERSE partners in relevant standard bodies are documented and updated from D6.1.

Section 2 of this deliverable introduces business models that are enabled by the underlying concept of object-based broadcasting and hence the 2-IMMERSE platform. Readers learn about potential services that monetise the 2-IMMERSE platform. Section 3 presents the exploitation plans and actions taken by each partner to the make the most of the project results. It includes the plans to publish the 2-IMMERSE core platform as open source, the licensing conditions for this, and the actions being taken to make the software sustainable.

Section 4 summarizes all our dissemination activities from the web site, with the Twitter feed and blog posts, to a number of workshops including content producers, content owners and also manufacturers, as well as demonstrations of the 2-IMMERSE scenarios and platforms on many occasions, and last but not least a substantial list of scientific publications, two of which won best paper awards at the TVX conference.

Section 5 lists the standardization bodies and groups, the specifications that have had an impact on 2-IMMERSE and recommendations based on the experience of implementing a multiscreen platform and of evaluating a number of different multiscreen experiences.

2   Business models

2-IMMERSE is advocating an object-based broadcasting approach as we believe it offers highly flexible possibilities for viewers to have opportunities to more deeply immerse themselves in media experiences.

This section was first published in D6.2 and is repeated here to provide the reader a full overview of 2-IMMERSE's exploitation planning.

In section 3 we describe the 2-IMMERSE exploitation strategy and the concrete assets that will result from the project and are expected to be employed by each partner. The main assets will be the 2-IMMERSE platform consisting of a number of production tools, cloud services and exemplar client applications accompanied by design guidelines. This section also presents a set of business opportunities that are grounded in the object-based broadcasting approach. The models reflect a broader vision of the project partners' perspective as commercial and public service broadcasting houses, as content producers and technology providers.

The following six business models are analysed:

1. **Flexible content packages:** The development of flexible content packages for upselling/differentiating subscription-based content experiences.
2. **Third party app insertion**: The opportunity for third party providers to situate their app in a context that is relevant to the viewer and likely to enhance a viewer's overall experience and at the same time meet the objectives of the third-party app provider.
3. **Object protection:** Managing and enforcing the rights for viewers to access different packages.
4. **Premium pricing for enhanced cultural content:** Cultural experiences, watching a filmed performance of a play for example, are available through OTT video service providers today. The object based approach offers providers the opportunity to positively differentiate their offering and create a higher value and / or a more popular service through such differentiation.
5. **Customer usage analytics:** On-line media experiences can reveal much richer analytical data that can help with (for example) more precise customer segmentation. Knowledge of the viewer segments can be used by service providers and ad agencies to increase the value of the advertising spots they sell within an object-based media experience.
6. **Targeted ad insertion**: A feature of the object-based broadcasting approach is that the service provider will glean more knowledge of their viewers, either explicitly - through registration - or through implicit means, making inferences from expressed preferences. Knowledge of the viewer enables service providers to sell ad space that is targeted to specific demographics/customer segments.

In the following sections, each of these different value creation opportunities is described with reference to a business model canvas. The form of the business model canvas is shown in Figure 1 below. It offers a way to describe some of the key characteristics of the business that could be created through the object-based media approach that underpins the 2-IMMERSE platform.

Business type

KEY ACTIVITIES	KEY PARTNERS	VALUE PROPOSITION	CUSTOMER RELATIONSHIP	CUSTOMER SEGMENTS
•..what roles must the business conduct to realise the value?	•..with which other business types will this business need to make effective working relationships?	•Why will the customer buy this service/product rather than an existing alternative? This should be answered per facet of the business model.	•(per segment)	Business models may be multi faceted And within each facet there may be particular customer segments that are clear targets.
	KEY RESOURCES		**CHANNELS**	
	•That distinctive roles that must exist within the business for it to operate effectively		•(per segment)	

COST STRUCTURE	REVENUE STREAMS
•Key costs to which the business will be subjected	•Where is the money coming from?

Figure 1: Business Model Canvas template

This business model canvas approach is used in helping new ventures to develop and is discussed in some detail at the following link: https://www.alexandercowan.com/business-model-canvas-templates/. The two key boxes (in red) are the value proposition and the customer segment boxes. Prospective ventures that cannot populate these two boxes convincingly seem unlikely to thrive. We report the results of applying the business model canvas approach to each of the opportunities identified above.

2.1 Flexible content packages

The business canvas described in Figure 2 below outlines the way this business opportunity works. The fundamental premise is that the object-based nature of the viewing experience will allow service providers to present a given core rights asset (let's say Football) in different packages offering different value to the viewers.

For deaf viewers, for example, additional components could be included such as signing or auto subtitling; likewise blind viewers might benefit from different commentary streams that included more description than typical TV commentary. Such services could help service providers to meet accessibility goals.

More commercially, subscription and ad-supported services may be able to offer versions of a service that include enhanced features such as additional always available statistics, additional camera views or more control over the audio – possibly including selecting alternate commentaries or by varying the audio mix perhaps emphasising crowd noise over commentary – or vice versa.

Likewise some viewers may seek greater participation through messaging capabilities and through gaming and gambling services that could be added in to the service as part of particular bundles.

Flexible Content Packaging

KEY ACTIVITIES	KEY PARTNERS	VALUE PROPOSITION	CUSTOMER RELATIONSHIP	CUSTOMER SEGMENTS
• Content package development • Marketing and sales • Content scheduling • Content curation • Customer analytics	• Content producers • Data providers • Rights owners • Analytics providers **KEY RESOURCES** • Content producers curators • Content distribution platform • Software developers	**From a TV service operator** Broad flexible portfolio of content services with different associated rights costs and customer value propositions **To viewers** Choice & control over your content experience	Billing relationship with the account holder and direct viewer profiles mediated through sign in and customer IDs **CHANNELS** • To viewers - Direct	**Viewers** • Subscribers to bundled TV services • Subscribers to OTT content services (multiple niche).

COST STRUCTURE	REVENUE STREAMS
• Content rights • Network distribution / platform management • Software development and maintenance • Billing/customer service	• Increased number of viewers/subscribers • Increased ARPU • Increased retention

Figure 2: Business Canvas for "Flexible Content Packaging"

The flexible content package would, in the first instance, address subscribers to particular content services, but the nature of the service would mean that much greater customer segmentation could be achieved. Currently, for example, it is hard for TV companies to meet the specific needs of those with hearing or sight loss. Likewise, the programming is largely a "one size fits all" option with editorial decisions being taken to appeal to the viewership "in general". The flexibility of the object-based approach would enable service providers and viewers to negotiate the features and characteristics they want and for clear customer segments to emerge – so the sports fan with a deep enthusiasm for statistics could be distinguished from the social sport fan who wants atmosphere rather than possession percentages.

The value proposition is multi-faceted, offering value to viewers, advertising agencies (and ultimately brands) and to those developing content components that could sit within the object-based experience.

The flexible content packages would operate within the normal world of content service provision and would be sold using the same mechanisms that content service providers currently use, for example:

- Transactional video on demand (tVoD)
- Subscription based video on demand (sVoD)
- Ad supported video on demand
- Public service broadcasting (PSB)

Value, for each of these models is measured differently, particularly for public service broadcasters. In many cases it can be correlated with the numbers of viewers, and for ad-supported services with the accuracy with which viewers can be identified for advertisers and the perceived value of the targeted demographic.

The value proposition to viewers is that they could control and augment their viewing experiences through access to additional content, services and data related to the main content. In the context of sport (football say), the ability to review replays, to observe match player and league statistics or to view additional camera feeds or hear alternative commentaries may all offer value to the

viewer. (Note that another example for the cultural experience business model, is described in the section related to the enhanced cultural content business model.)

The value proposition to those generating content components is complex and still to be entirely resolved. We anticipate that cash flows could be in both directions. Sometimes the owner of the flexible content packages may feel the value added to the experience of the viewer by incorporating a particular content component is worth paying for. In other cases a content component creator may really value being present in this particular context and be prepared to pay for that privilege. For example, sports data adds to the experience of watching sport and that data may be paid for by the flexible content package owner. Betting applications also increase the value of watching sport for some viewers, but the betting being available in a context that is likely to be a fertile sales ground for the betting vendor would be of value to betting companies and they would, presumably, be prepared to pay for that.

The value proposition to advertising agencies is that the ad spots are more valuable as more is known about the viewers, due to understanding of the viewer gleaned from registration and inferred from the preferences they have expressed. Clearly an ad spot that is known to be seen by a female aged 20-30 would be more valuable than a generic ad spot that may be seen by any demographic.

Likewise ad sales would operate within the current advertising chain. The content component may (as described above) appear like content rights acquisition (for example, sports data) or ad sales as in the case of the betting app example.

2.2 Insertion of third party applications

TV and film production depend upon a wide range of highly skilled teams to create the content that we watch. But we, the viewers, have no opportunity to deselect or to promote the contributions of particular teams to change the way we enjoy a particular programme. Enabling this is the opportunity of third party app insertion. With object-based delivery and access to a flexible multi-screen canvas we believe it should create a market for apps that can augment and enhance certain programming.

Insertion of 3rd Party Apps				
KEY ACTIVITIES	**KEY PARTNERS**	**VALUE PROPOSITION**	**CUSTOMER RELATIONSHIP**	**CUSTOMER SEGMENTS**
- Negotiations with app providers and content producers - Advertising new services - Compliance checking - Content curation - Content scheduling	- Content authors - Tracking data provider (sports) - Betting agencies **KEY RESOURCES** - Infrastructure to embed 3rd party apps, e.g. app store	- Improving attractiveness of service for viewers - Keep or increase number of subscriptions - Cost effective outsourcing of content production - Higher reach of service (the 3rd party app) by sharing viewers	- direct - Open app store **CHANNELS** - direct - 3rd party app store	**App providers** - Bookmakers - Sports content, e.g. stats - Accessibility service provider - News, stock feeds - Weather
COST STRUCTURE			**REVENUE STREAM**	
- Content rights - CDN and platform management - Development and operation of 3rd party apps platform incl. service interfaces - Billing and customer service			- 3rd party provider sharing revenue with service provider - 3rd party to be paid by service provider - Subscription fees	

Figure 3: Business Canvas for "Third Party Applications"

For example, with sports programming, a viewer may be particularly keen on the statistics relating to the game and may value additional components that allow them to access and display such statistics. It is possible that a number of providers of statistics packages, all with access to broadly the same core numbers, generated and sold by companies like Opta, may compete with each other based on the way they present the data, perhaps on the ease of use of their service or the granularity of the statistics or the frequency and accuracy of updates. It is quite conceivable that such companies could either compete to be the provider of choice in the bundles the service provider creates for their customers, or they could be accessible through an open market sold direct to viewers as 'add-ins', much like phone-apps compete within the app stores of iOS and Android.

A different commercial model is to include service components from third parties that improve the attractiveness of a broadcaster's offering or that help to fulfil the broadcaster's obligations for providing accessibility services like sign language and audio description. The coverage with sign language currently is rather poor, with public broadcasters in Germany, for example, having only one news programme each day that includes a burnt-in video with a sign language interpreter. A reason is that production costs are quite high. With the 2-IMMERSE platform that allows the embedding of external audio-visual sources via Internet a third party can provide authoring and production of single audio-visual service components. This kind of offering could be included through bilateral agreement between the broadcaster and the third party including a revenue flow from the broadcaster to the third party or from the viewer to the third party.

Whilst these third-party apps may offer some viewers more value, the payment model is not yet clear but the options include the following:
- The TV service provider pays for the apps and bundles them into packages that are then promoted and sold to subscribers/viewers (see Flexible content packages)
- Apps could be free to the viewer – like apps that may enhance accessibility and these may be paid for by the service provider and available to all as part of a regulatory and compliance obligation.
- Apps, like betting apps for example, may be freely available to the viewer but the betting companies may pay to be the betting app provider of choice – or they may enter into revenue share deals with the TV service providers.

2.3 Provision of premium cultural content

In Europe and the United States there is a developing marketplace for the provision of cultural content, including arthouse films, theatre performances, opera and dance, directly to individuals as OTT media as well as to educational organisations. The cultural organisations that own this content and that create it in partnership with media producers are seeking ways both to distinguish their offerings in a strongly competitive marketplace and to justify premium pricing, whether of individual events or as subscriptions.

The 2-IMMERSE platform will offer the opportunity for cultural organisations to offer enhanced and enriched services that complement their existing offers. The cultural organisations can attract larger audiences and grow their subscriber bases with these enhanced services, at the same time as being able to develop a premium pricing structure. And this is applicable both to transactions for individual events, for consumer subscriptions and for the provision in bundled form to educational establishments.

In many contexts, however, the provision of cultural content is motivated by concerns other than direct revenue. Cultural organisations supported by public subsidy and/or philanthropy wish to see their productions disseminated as widely as possible, to be extensively available for educational use and to be explored and used intensively.

The enhanced services facilitated by the 2-IMMERSE platform can differentiate the offers of the cultural organisations that develop them, as well as deepening their value to users, and as a consequence the organisations can secure extended subsidy and more sponsorship support.

Provision of premium cultural content

KEY ACTIVITIES	KEY PARTNERS	VALUE PROPOSITION	CUSTOMER RELATIONSHIP	CUSTOMER SEGMENTS
• Media and DMApps production and provision of support • Creation and delivery of enhanced cultural content • Operation of complementary services	• Cultural orgs; e.g. film distributors, theatre companies • Media producers • Streaming services **KEY RESOURCES** • Cultural rights • Production expertise	• Offer of enhanced and enriched cultural media with related content and services • Differentiation of cultural media offerings in competitive marketplace	• Online activities of cultural institutions • OTT platforms **CHANNELS** • Real-world + online presence of cultural organisations • OTT platforms	• Cultural consumers seeking in-depth experiences • Members/friends of arts organisations • Life-long learners • Educational institutions

COST STRUCTURE	REVENUE STREAM
• Creation of additional media • Acquisition of additional rights • Production and support costs	• Premium charging to individuals and to educational institutions for subscriptions and access to individual events • Greater opportunities for sponsorship attracted by distinctive and enhanced service

Figure 4: Business Canvas for "Premium Cultural Content"

Related to such provision by cultural organisations is the business model available for development by media producers such as the 2-IMMERSE partner Illuminations. Media producers partner with cultural organisations to develop their content for broadcast and online provision. This activity is funded by the cultural organisations, by providers such as broadcasters and via public subsidy and sponsorship. The production and support of enhanced services using the 2-IMMERSE platform is a business opportunity that we expect taken up by media producers, including Illuminations themselves.

2.4　　　Customer Analytics

Through object-based broadcasting, 2-IMMERSE brings the ability to orchestrate an experience seamlessly across multiple screens at the same time. This environment also offers the unique opportunity to document customers' behaviour synchronously across all the devices participating in the experience.

Today, Pay TV providers and OTT content platforms work with third parties (e.g. Conviva, Looker) to manage the capture, processing, analysis and presentation of rich data related to the performance and usage of their services. This business canvas illustrates how this role could be applied to multi-screen experiences. The opportunity is clearly most relevant to industry segments who are most likely to enhance their traditional broadcast or on-demand content by targeting complementary content at companion screens in order to differentiate their service. These are most likely to be sports broadcasters, public service broadcasters or production company owners of specific high-value content brands.

Figure 5: Business Canvas for "Customer Analytics"

The proposition addresses two main benefits – behaviour insights and performance. The TV service provider will value behaviour insights because these indicate engagement with their content at a fine-grain level and can be used to create a sticky, personalised experience – potentially in near real-time. Behaviour insights can also add significant value to targeted advertising, increasing the value of ad spots sold inside an instrumented, multi-screen experience.

Performance data is equally vital for a TV service provider because it helps them to manage their service while minimising churn and cost to serve. This is especially true of multi-screen experiences which are complex and place additional demands on devices and home infrastructure while raising customer expectations as premium services.

Platform providers should see customer analytics as an essential tool to help service providers optimise performance. Indeed, some of today's analytics providers publish anonymised aggregated data to establish industry-wide service benchmarks and indicate how well a particular service provider is doing in comparison.

Customer Analytics is generally a managed service, based around building strong relationships with TV service providers and use constant feedback to inform requirements and evolve the product.

2.5 Dynamic Ad Insertion

Dynamic ad insertion for commercial broadcast services is currently a hot topic. This is reflected not only by the high number of showcases at IBC 2018, but also by a study mission installed by the DVB consortium. For commercial broadcaster advertising is the main source of funding. In 2017 Broadcast advertising held 50% of the German advertisement market revenue share. Whereas advertisement on Internet and mobile platforms together account for only 12% of the share[1].

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[1] http://www.nielsen.com/de/de/insights/reports/2017/top-ten-trends.html

Figure 6: Business Canvas for Targeted Ad Insertion

Air time for advertisements is rare, as regulation restricts the share that can be devoted to this in a programme. Nevertheless, broadcasters do not achieve top prices for every available ad slot. Broadcasters compete with other broadcasters and also with a growing number of OTT platforms. The ability to regionalize and personalize advertisements can help them to defend their business. Platforms that support object based broadcasting like HbbTV, allow to individually overlay the broadcast signal with personalized ads, implemented as for example:

- Graphical overlays

- Replacing some spots of an ad break to increase the revenue for the individual slot

The first option is already applied by broadcasters in Germany. As it is not strictly synchronised with the broadcast signal there is also no need for changes to the broadcast infrastructure. Also, it can be deployed to TV devices which support version 1 of the HbbTV specification. This option has therefore a large potential market reach as there are already 11.5 million German households that own an HbbTV version 1 device that is connected to the Internet. The second option requires some synchronisation of the broadcast service with the playback of the personalized ad. Depending on the requirements for accuracy this means an additional investment to upgrade the broadcast infrastructure allowing for a synchronised transition between broadcast and broadband for an individual viewer.

Information that helps to personalize content can be inferred from different sources, including the usage history (which could be collected per device) or the information associated with the account of a logged in user.

2.6 Object protection

The business canvas previously presented in Figure 2 for 'flexible content packaging' requires a capability for managing and enforcing the rights to access the different packages by viewers. The 'Object Protection' business canvas presented below in Figure 7 summarises the business opportunity for this capability for a Digital Rights Management (DRM) technology or 'as-a-service' provider. This can be seen as an evolution of their existing business model, which is typically direct to TV Service Providers.

The value proposition to TV Service Providers (be that traditional Pay-TV Service Providers, or 'Over-the-top' (OTT) content platforms), is to offer DRM technology and services that make it simple to manage protection of multiple media objects within a set of content packages i.e. a Distributed Media Application (DMApp). This would include enabling management of access to different content (object) packages, and potentially the re-use of protected objects in multiple DMApps.

In providing this capability, the expectation would be of increased licencing or usage revenues driven by increased numbers of viewers / subscribers, and an overall increase in the number of protected objects per content package (i.e. viewing experience).

Key activities for the DRM technology or 'as-a-service' provider include DRM technology development (both servers and client device ecosystem), 'as-a-service' operations and breach management / enforcement, with cost structure and key resources reflecting these activities. Key partners include distribution encoder / packager suppliers, platform provider / CDN and Device manufacturers, each of which requires some level of DRM system integration / support.

Figure 7: Business Canvas for "Object Protection"

3 Innovation Management and Exploitation Plans

D6.1 and D6.2 have laid the foundation of the 2-IMMERSE innovation management and exploitation planning. The result was the identification of the most useful assets of 2-IMMERSE that we seek to make available for exploitation to the consortium and the wider creative community and industry. The assets are outlined in section 3.1. Sections 3.2 to 3.8 provide updates, on a per partner basis, of the steps being taken to effect successful exploitation. Finally, 3.9 summarises IPR management and licensing issues.

3.1 Assets – short descriptions

The section highlights the assets that 2-IMMERSE has created. We categorise the assets as:

- Exemplar productions
- Production Tools and Workflow Insights
- Reference Architectures
- Reference Implementations
- Design Specifications and Insights

3.1.1 Exploitation of Exemplar Productions

A key asset that 2-IMMERSE has developed is the set of exemplar prototypes, i.e. the four prototype service use cases described in D4.3[2]. These can be used to help 'sell' both the concept of object-based broadcasting and the platform we use to distribute the productions.

Such assets work best when they are compelling and persuasive and enjoy the best craft design in terms of normal TV attributes – content quality, framing, editing, graphics, animations etc. Key to the success of the project was the project access to first class (and commercially valuable) content from RSC, Donmar Theatre, the Football Association and Dorna Sports. It was also advantageous that the exemplar productions we developed were trialled in focussed, professional deployments and that the feedback we received from triallists reflected the users' experience in a normal viewing situation.

3.1.2 Exploitation of Production Tools and Workflow Insights

Having developed a micro-services based platform for object-based media, 2-IMMERSE has recognised a number of implications for workflow changes required to achieve object based media delivery for multi-screen entertainment experiences. Based on results of the earlier trials we have generated tools that will simplify the workflow for object-based media.

3.1.3 Exploitation of Reference Architectures

Based on the first architecture defined at the start of the project aiming at multiscreen services and with the experience of trials differing in genre, sports and cultural content, as well as viewing environment, at-home vs public spaces, 2-IMMERSE extracted a more general reference architecture for object-based media delivery. The reference architecture is included in the D2.6 and as such published on the 2-IMMERSE website. It will also be linked from the Reference Implementation asset which provides an example implementation of this architecture. The Architecture description has been kept quite high level and is presented in a way that highlights the similarities and points of difference between different use cases of object-based broadcasting.

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[2] Deliverable D4.3 can be downloaded from the web site www.2immerse.eu

The motivation is to emphasise the similarities of two platforms and to help current technology platform operators assess the technical migration that might be necessary to support object based media delivery.

3.1.4 Exploitation of Reference Implementations

2-IMMERSE has implemented a platform for object-based media which is an example of the 2-IMMERSE Reference Architecture and has constantly improved the platform by developing and trialling various Exemplar Productions.

The core of the 2-IMMERSE platform, which is the software developed in the project, is published as open source to make it available to the creative community and industry together with extensive documentation, tutorials and example apps.

3.1.5 Exploitation of Design Specifications and Insights

2-IMMERSE generated design insights required to develop object-based broadcasting. Such insights have been gained from experiments that did not work as well as had been hoped, as well as insights from experiments that were more successful. These craft insights, including guidance from practitioners, have been documented in WP3 deliverables and many were presented to the community via papers submitted to and presented at conferences. Examples of design guidance include:

- Candidate guidance (being tested): Attending Theatre is ritualised and a general working approach in developing mediated versions of highly ritualised experiences is to adopt and reflect the rituals in the multi-screen representation. In the case of the representation as-live of theatre productions this has been approached by not allowing viewers to use video chat whilst the play is running and to not allow the play to be paused or rewound. It also embraces the familiar interval.
- From the Football experimentation, the project has gained a clear sense that in designing multi-screen experiences based on fixed screens in public spaces it is sensible to consider a 'primary viewing area' – an area that a viewer can view without moving their head

1. Single screen
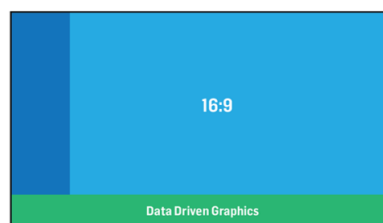
2. Landscape – Landscape - Landscape
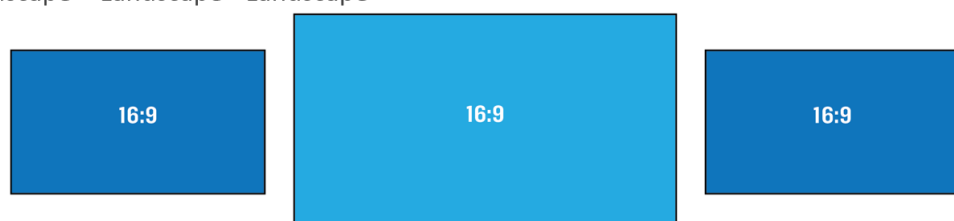
(Figure 8)

3. Portrait – Landscape - Portrait

4. 3x2 Video Wall
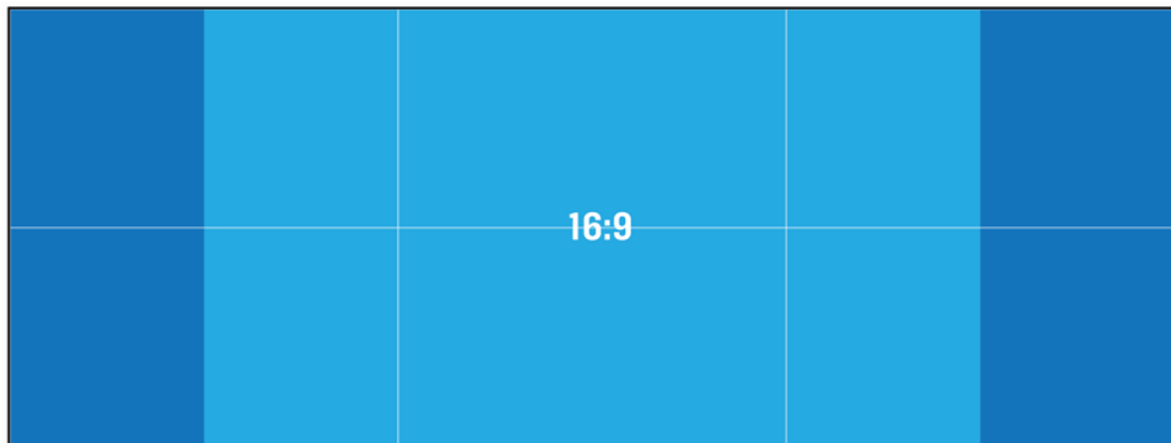
Figure 8: Illustration of different screen layouts that may constitute a primary viewing area. Of these options, 3 is the only one we have not seen in UK bars carrying sport.

- We recognised that it is bad practice to offer more than one representation of the game as a whole within the primary viewing area. Therefore, the design choices iterated towards offering additional shots of the manager and the crowd.
- The choice of shots of the manager and the crowd plays to the tribal nature of the occasion and helps build empathy, for the partisan viewer with their 'tribe' placed in the stadium by allowing you to observe and mirror the behaviour of the leader (the manager) and of your supporter peers.

Figure 9: A screen grab from a render of showing three synchronised shots taken from the match. Whilst not obviously incomprehensible as an image - the video version soon becomes very uncomfortable to watch.

- From the MOTOGP experience the lack of responsive design for TV screens has become apparent. With normal broadcasting a single render of a screen design is broadcast to all viewers. This means that viewers receiving on a handheld device or on 65" TV screen receive the same image – just scaled. Object-based broadcasting approaches provide broadcasters with an opportunity to adopt responsive design techniques borrowed from web page design world (see Figure 10 and Figure 11). To do so the clean feed of, in this case the race, needs to be accompanied by the objects such as the data and rules required to render the leader board in the way most appropriate for the screen on which the flattened composite image will be displayed.

Figure 10: Showing the leader board scaled from a size readable on 32" screen (the left hand screen). When scaled to the 65", the TV on the right, the text becomes unnecessarily large and occupies too much screen real estate. (The example is more convincing on actual size screens)
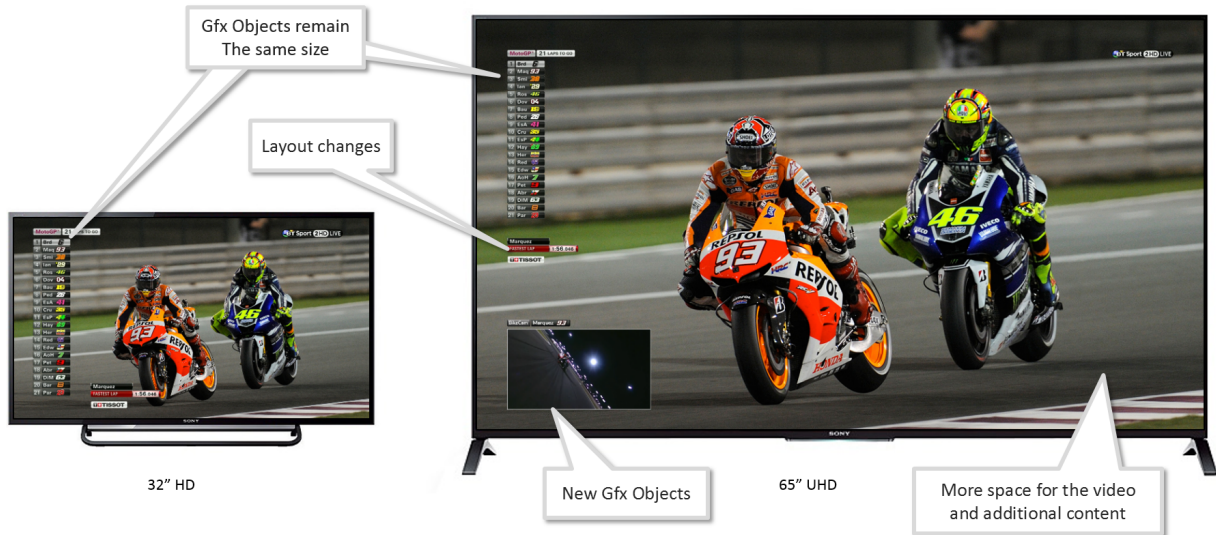
Figure 11: Showing how a leader board remaining the same actual size on screens of 32" and 55". It remains readable but releases additional screen real estate which could be used for PiP of for example the bike cam (The illustration is more convincing on actual sized screens!)

- From synchronisation experiments carried out in WP3 we have found that, when watching a theatre production in which words spoken are being highlighted within a transcript displayed on a second screen delays between the text being highlighted and spoken between -0.5 and +1 second were within the tolerance of audiences (-ve implies highlighting leads the audio). See Figure 12.
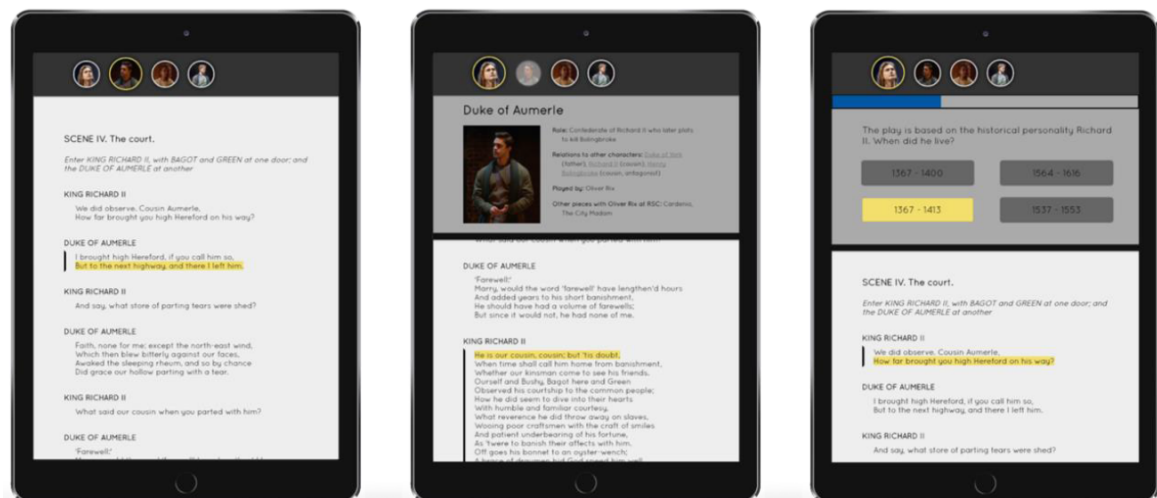
Figure 12: Showing the three modes of transcript highlighting used in our multi-screen synchronisation experiments. No differences in the reported assessment of coherence

between the two screens was observed provided synchronisation was between -0.5 and +1 second.

3.2 BBC Exploitation Activity and Plans

The BBC (British Broadcasting Corporation) remains a public service organisation. Its core mission is to inform, educate and entertain audiences and to contribute to the success of the Creative Industries in the UK. BBC R&D's role is to enable the BBC to fulfil this mission now and in the future through the effective use of technology.

The BBC believes that digital convergence across the technologies and processes within media production and distribution brings new opportunities for programme makers and audiences. BBC R&D has been working to imagine how the BBC and the wider industry can take advantage of these opportunities.

Internally, BBC is looking at the opportunities made possible by distribution of broadcast content over IP networks. To build closer and relevant engagements with audiences a number of explorations have focused on responsive media. This is media described as objects that can be combined later in the delivery chain and based on audience context.

Through prototype testing with audiences in the lab and pilots broadcast online BBC R&D has explored the value and feasibility of object-based media approaches for production and audience engagement. We believe that this offers the key to creating increasingly tailored and adaptive interactions that are:

- Personal – tailored to the requirements and situations of individuals.
- Adaptive – optimised to the media device and format to give the best experience in real time.
- Dynamic and responsive – they respond to the needs of the audience during playout in terms of length, depth of interest, location, preferences, lifestyle and age and accessibility needs.
- Interactive – the audience engage more actively with content to learn new skills or explore new places, concepts and perspectives at their own pace.
- Immersive – content presented in environments that give the audience enhanced experiences that can be perpetual and pervasive and delivered through multiple formats (audio, video, 360, VR, MR) to suit the time, location, attention and intention.

2-IMMERSE has supported these ambitions through collaborative prototyping and field trials. Collaboration is a pillar of the royal charter as it applies to BBC R&D function.

3.2.1 Exploitation of Exemplar Productions

Through 2-IMMERSE the BBC has tested assumptions and hypotheses by building and operating a platform to deliver new object-based experiences. These experiences have been object-based in that they invite audiences to select video streams, enjoy synchronise synergistic content on multiple screens and set infographics content to reflect their experience.

Working with theatre companies and broadcasters and sports producers and broadcasters and the partners in the consortium BBC R&D has delivered knowledge, knowhow and co-authored the 2-IMMERSIVE platform for further exploration. Insights from the exemplar productions have been disseminated at conferences, through internal checkpoint meetings, 'show and tells' and regular reporting, in addition to disseminating to departments within BBC. They have been key in communicating the ideas behind synchronised, object-based, multiscreen delivery and audience engagement to practitioners and sponsors.

3.2.2   Exploitation of Production Tools and Workflow Insights

The work on 2-IMMERSE has contributed to the BBC's view that the delivery of responsive experiences is valuable and feasible at broadcast scale. In addition to the development of the technology the BBC is working to accelerate the emergence of production craft and new content experiences.

- Community of Practice (CoP)
  Over the next year by releasing tools to encouraging a Community of Practice around object-based media the BBC hopes to develop a group of enthusiastic explorers of new production craft and audience experiences. Earlier awareness has been created through presentations and workshops describing early results and ambitions backed up by accessibility to open source software and early prototypes. Commissioning through a sandbox-style process has started to be run by BBC's Connected Studio and BBC3. When the 2-IMMERSE platform is integrated to extend these tools, creative developers and producers will be given a wider palette of responsive options.
- Software
  The BBC is also committed to making software tools available for our growing community of practice through open source licensing agreements. In 2017 two Java Script Libraries from 2-IMMERSE were published as Open Source for use by the wider community. These are the "dvbcss-clocks" library and the "dvbcss-protocols" library. In early 2019 the 2-IMMERSE platform will be published through Open Source under Apache Licence v2.0 on GitHub. Further details are provided in D6.3 and D2.6.

3.2.3   Exploitation of Reference Architectures

The BBC has developed a reference architecture for the 2-IMMERSE platform published in D2.6. This will be a key pillar of BBC R&D's object-based media technology workplans. 2-IMMERSE has tested the idea of Distributed Media Apps as the basis for experience design, delivery and engagement across multiple devices and levels of synchronisation and synergy.

In 2018 the BBC successfully released an AR experience to accompany its AAA production of 'Civilisations'. The 2-IMMERSE reference architecture will enable all such productions to be produced more simply. The 2-IMMERSE platform will form the core of a scalable, extensible and sustainable tool for exploring more genres of flexibly composed services. The challenges of implementing the platform have informed the broader R&D thinking about the scalable IP delivery of multiple streams to multiple devices and multiple users.

3.2.4   Exploitation of Reference Implementations

Currently there is more interest within the BBC in the platform and the distributed media app implementation than in the service pilots. The 'on-boarding' experience and resulting module is of particular interest. By on-boarding we mean the system and processes that enable audiences to sign up for new multi-device responsive experiences.

To facilitate further development and as part of the sustainability strategy an internally hosted instance of the 2-IMMERSE platform has been created on Open Nebula, the configuration of which will be included in the open source software release.

3.2.5   Exploitation of Design Specifications and Insights

Object-based media became one of the top priorities for BBC R&D during the project and now at the end of the project it is one of the top priorities for BBC Design and Engineering (D&E). D&E supports the present and future of BBC's Radio, TV and Online output. As a significant project

within this area, 2-IMMERSE tools and workflow insights have been influential in the thinking and sponsorship of people within the BBC's technical management team.

The 2-IMMERSE cloud-synchronisation service was used to synchronise object-based audio content in the BBC's 'Vostok-K Incident' published on 'BBC Taster' and previewed at the Manchester Museum of Science and Engineering.

In December 2018 2-IMMERSE was demonstrated to BBC's Executive Committee as an enabler of the future of responsive broadcasting.

Going forward, the design of the reference architecture and the insights from the exemplar productions will be in the DNA of BBC R&D's existing projects aimed at creating a new broadcast ecosystem with partners internal and externally.

3.3   BT Exploitation Activity and Plans

3.3.1   Introduction to BT

BT's purpose remains to use the power of communications to create a better world.

The BT team working in 2-IMMERSE operate within the BT Applied Research team which is part of the BT Group. The primary route for exploitation that BT Applied Research pursue is within the family of BT businesses. BT has recently re structured along the following lines:

- Technology (Which includes Applied research) is the internal technology unit responsible for creating and operating BT's networks, platforms and IT systems
- Openreach, the UK's digital network business – connecting homes and businesses large and small. We want to make sure everyone in the UK is connected to the network of their choice.
- Consumer, with almost 30 million customers, and more than 620 stores on the high street, we're the largest provider of Consumer mobile and fixed broadband communications services in the UK.
- Enterprise, selling communications and IT services to around 1.2 million businesses and public sector organisations in the UK and Republic of Ireland and provide network products and services to more than 1,400 communication providers (CPs) operating in Great Britain.
- Global services, a leading business communications provider with customers in 180 countries. Across the world we enable customer's digital transformations so they can thrive. Our focus is simple: be the global provider-of-choice for managed network and IT infrastructure services.

For the BT Applied Research team working within 2IMMERSE, the route to impact has been through Consumer and technology. We seek to influence Consumer's so that they desire to support an object-based media service and we seek to make this eventuality more likely by enabling technology to deliver it based on transferring a knowledge of the reference architecture developed in the project to Technology – the part of the business that will deliver the solution.

3.3.2   Previous insights - assets

There have been two previous versions of this document. In the first we looked, on a partner by partner basis, at the assets that were likely to be exploited. In the second we described, using a

business canvas model, 6 possible business opportunities emerging from the work of 2-IMMERSE.

BT recognised a number of outputs from the project (assets) that we expected to be useful in driving the innovation in the project through to money earning services. The table below updates BT's assessment of the utility of these different exploitable assets.

New forms of multi-screen programming based on:	
Filmed Theatre for a school audience	BT has not been able to generate any pull through for this form of content.
Filmed Theatre for people at home	We have, through conversations and market assessments with the BTTV team, assessed the commercial opportunity to BT of filmed theatre at home. The prospect is intriguing; particularly the prospect of the social TV watching and enticing as BT now has a pay per view capability (very recent last few months) and has separately explored social TV watching with technology partner Sceenic in a sports context. This opportunity is not dead, but dormant. It is dwarfed by the sports related opportunities.
MotoGP for people at home	The demo was a highly persuasive and essential stepping stone. However, given the way that MotoGP programming is produced, i.e. by Dorna Sports generating an international programming feed, there is little room for manoeuvre for BT. Dorna are aware of the opportunity and will continue to discuss innovations around the presentation of MotoGP with BT.
Football for people in pubs and clubs	As discussed at the review in the second year this is not a high priority for BT. Nevertheless at the insistence of the project reviewers we generated an impactful Football Fan Zone demo. Taking this forward is not a priority for BT.
Football at home	Based on the assets generated from the live technology trial, the project did develop a prototype Football at home demo. Those inside the project understood the value of working with this use case given the commercial importance to the home TV market, of Sport. The multi-screen programming format based on Football has generated the most interest within BT. BT's football coverage is produced by BT so we have considerable more control over the way the programming can evolve. In the narrative that follows we describe how we have worked through the year to make BT Sport aware of the opportunity posed by the object-based media approach for football.

Production tools, insights and workflows	
New production tools that support new workflows for Object Based Production of Content	The tools developed within the project are good illustrative prototypes.
Insight and know how about content capture	The understanding gained through the various experiments leading up to and subsequent to the live trial from Wembley has

and handling to support the production of multi-screen programming	been critical in developing a convincing narrative about the implications for production of the object-based media approach.

Reference architecture and implementation	
Development of a reference architecture which has been validated through iterative implementation over the four service prototypes.	The reference architecture we are developing is helping us to abstract from the implementation architectures to reflect more generically on what is required to deliver object-based media. This is informing our continuing discussion with our IPTV architects
A set of platform service components, client applications and Distributed Media Application com-ponents, which we aspire to open source at the con-clusion of the project	The components have been essential within the project. How BT and other organisations will use them henceforth is uncertain. Certain components however appear to have more "worth" than others as they offer specific capabilities uniquely required for the delivery of object-based media experiences. These include the on-boarding process and launcher app, the screen synchronisation mechanisms and the bandwidth orchestration modules – though more work is required to fully understand the performance of the last of these. BT were heavily involved in the development of the client applications and we expect this know how to be an asset when developing further applications beyond 2-IMMERSE.

Designs specifications and recommendations	
For the proven delivery of content streams, to multiple devices and multiple users simultaneously (future smart TV, set top box, content steamer, iPlayer)	This know how is essential in developing a credible and cogent story with BT Sport and s helping us as we examine how the features and capabilities developed in the 2-IMMERSE use cases could be brought to the wide array of devices through which BT Sports content is delivered. See comments against reference architecture and implementation
For the successful delivery of coherent and appropriately synchronised content across multiple devices.	See comments against reference architecture and implementation
For effective and user-friendly set up and management of end-user multi-device	See comments against reference architecture and implementation

environments (building on the specific examples of Drama and Sport).	
For effective end-user interaction within multi-device experiences (building on the specific examples of Drama and Sport).	BT designers were heavily involved in the development of the Sports use cases and their know-how is available to be used as BT Sport considers how to take the object-based media concepts forward. Insights from drama are expected to have less relevance given the forms of content BT currently produces.
For the development of distributed media applications to extend the services and experiences offered to users of multi-screen environments	The insights generated will be disputed, in productive ways. For example, the degree to which the additional screen can be used for content or simply for control is not clear and there is no one answer. The project and the experimentation within it has exposed some ideas that will inform and instruct future designs, though the answer is not declarative.

3.3.3 Previous insights – business models

Of the six business models described in Section 2, through the canvas models, whilst all of them may remain true and viable, the focus in BT has been on one of them i.e. **Flexible Content packages:** The development of flexible content packages for upselling/differentiating subscription based content experiences.

The Flexible Content packages concept is manifest in the multi-screen service concepts 2-IMMERSE is developing. They represent a significant evolution of the TV 'offer' that BT Consumer presents to its customer; it demands significant evolution in the production chain; and significant evolution in technology used to deliver the service. For exploitation then, the concept then has to be "sold" into BT Consumer and delivered with help from Technology.

3.3.4 Exploitation update

Successful exploitation in BT will be achieved when a customer can enjoy a TV experience using multiple synchronised screens and when that content has been delivered using an object-based media approach.

Our challenge is to make the case for the multi-screen TV experiences delivered using object-based media so compelling that key decision makers in BT will risk corporate investment on developing a live service. Understanding this, we have from the outset considered the task to be akin to a sales challenge which is sometimes described using the acronym "AIDA" reminding us that Awareness (A) may lead to Interest (I) may lead to Desire (D) and that this may lead to Action (A). Success in the selling of complex products and services depends upon relationships and within the project as part of our strategies we have concentrated on building and nurturing relationships. With these two thoughts in mind we can reflect that our approach has affected our approach to the way we work, the relationships and to design decisions.

Design decisions

- Designing experiences that clearly build upon existing services that Consumer provides and that bears comparison with current services and that further the objectives of BT Consumer's 'BT Sport' brand ("Getting closer to the heart of sport")

Relationships

- Developing relationships with key decision makers in BT Sport
- Developing relationships with key decision makers responsible for designing and delivering the technology platform that enables our BT TV service

Working practices

- Working, to the extent that we could, within the live production environment used by BTSport, so that we can better anticipate the end-to-end changes required to enable multi-screen experiences delivered using object based media approach
- Working to ensure that developments within the project can be used by BT after the project has finished.

These three work together; making "good" design decisions will attract the intention of key decision makers and enable relationships to be built. Having good relationships will enable the team to work closer to the normal production environment, build further important relationships and also enable better design decisions.

BT's primary focus within 2-IMMERSE has been on developing great experiences of Sport across multiple screens. Sport, most notably football, is BT's most valuable content; we have built an established TV brand because of our Sports rights portfolio and, importantly, it is programming that BT produces itself (rather than programming we buy in) and thus programming over which we have an opportunity to affect the associated production practice and look and feel.

The focus on Sport has meant that design concepts should at least be considered or reviewed by senior decision makers within the company, particularly in BTSport.

The following narratives will show how the inter-relationships between relationships, design and working practices has played out in practice.

3.3.5 MotoGP

MotoGP is produced by Dorna Sports who film the races and develop an international programme feed which BT uses in its MotoGP coverage. The MotoGP work acted as an important bridgehead. Our relationship with Dorna Sports was sponsored originally by the CEO of BT. The CEO was keen that BT would demonstrate that it was an innovative and responsible steward of the MotoGP rights in the UK. Prior to 2-IMMERSE BT's Applied Research had explored multi-screen experiences concepts but not really explored how they would be delivered.

The multi-screen MotoGP demo was a safe place to experiment and to attract the interest of senior decision makers in BT. It has also prompted detailed discussions with Dorna Sports about the implications for their production process that an object-based approach would have. Specifically Dorna currently sell rights to content packages that include a "dirty" international programme feed. (In this context "dirty" means the feed is the clean video coverage with graphics overlaid and "burned in" so they are inseparable and unalterable.)

Dorna Sports now recognise that, in an object-based media delivery world, they would have to make available the clean feed of the race as well as data feeds, additional video and graphics as independent assets. This is an example of the Flexible Content Packages business model described in Section 2.

In 2017 BT renegotiated rights with Dorna Sports to retain the right to broadcast MotoGP until 2021. The most important exploitation outcome was that, due to the positive responses to the multi-screen MotoGP experience, from users, Dorna Sports executives and key decision makers

in BT, the project received considerable support and encouragement to work on the football use case.

3.3.6   Football Use Case

The positive response to the work done on MotoGP earned us the right to pursue the Football use case in a much more embedded way. Initially we were able to receive recordings from all the isolated cameras and subsequently to gain accreditation and access to conduct experiments at live football matches.

During this period the COO of BT Sport began monthly meetings with the team to learn more about progress. These meetings increased understanding of the distinctive nature of object-based media distribution and the opportunities it represented.

Our experiments at live matches culminated in a live technology trial that took place at the 2018 FA Cup final between Manchester United and Chelsea at Wembley Stadium. Through this trial we showed how the object-based delivery approach could be enabled with some changes to the current delivery chain. The COO was included as a participant in this technology trial and the trial was, we believe, a critical proof point that acted as a strong persuasive argument in the attempt to "sell" the idea of object-based delivery.

It was also during the period of the football use case being developed that COO BT Sport started publicly commenting on the opportunity related to object-based broadcasting. In the online TV magazine "Advanced television[3]" it was reported that Jamie Hindhaugh (COO BT Sport) *"...didn't see VR and 3D as necessarily the future for sports viewing, as they lacked the social aspect, with BT preferring to offer such options as different camera angles, instead suggesting that object-based delivery would grow with the spread of IP. "We will start giving you objects, packages, templates, so you can create your own version of what you are watching."*

Hindhaugh said that hardcore fans of MotoGP could benefit from additional graphics and stats available to the broadcaster. BT would curate the data, and allow the viewer to choose their preferences from the programme feed. "That's where we're going. That's where the next big initiative is coming through, combined with 5G mobile."

In terms of our exploitation strategy and our sales approach (and with reference to the AIDA mnemonic) this indicates that the attitude of the key decision maker of BT Sport was probably at the "Desire" level; object-based delivery was something the COO wanted to do.

3.3.7   OFCOM

Discussions with the match directors enabled by conducting experiments at live matches and thus having access to key personnel in the standard production teams helped us to understand the complex role they play in telling the story of the match. It has also allowed us to start discussions with them about the implications on their role of moving to an object-based media approach.

One role the match director and the team in the truck have is to help ensure that the broadcaster meets their compliance objectives (in the UK, compliance rules are described by codes and guidelines published by the regulator OFCOM) relating to, but not limited to, broadcasting anything that may be considered rude, offensive, racist or bigoted. The implications on compliance from broadcasting an object-based programming form in which not every viewer would see exactly the same thing, were not immediately recognized but, hearing the issue raised by match directors led us to arranging early conversations with OFCOM in June 2018, alerting

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[3] https://advanced-television.com/2018/06/28/bt-sport-object-based-delivery-next-big-thing/

them to the fact that object-based media production would have implications for the way they regulated the industry.

Object-based media delivery will not happen unless the media regulation framework for it is understood. Meeting with OFCOM and helping them to understand more about object-based media delivery and to prompt them to begin considering the implications for the regulatory framework is a necessary step in enabling a commercial service based on object-based media delivery.

3.3.8 IBC

IBC describes itself as the world's most influential media technology show. Incorporating a vast exhibition and one of the leading conferences for broadcasters and broadcast technologists, it has justification for making such a claim. One of the key features of the show, often of more interest than the new product technology pitches from the vast number of suppliers, is the Future Zone. Here broadcasters and technologists are invited to review pre-commercial innovations and to consider the implications for their industry. 2-IMMERSE took a stand in the Future Zone and there launched the open-source software that supports all the object-based experiences the project has developed. To illustrate the capabilities of the platform, we also demonstrated the Football Fan Zone prototype, the Theatre at Home prototype, the Football at Home prototype and the live triggering tool. All but the MotoGP demo and the Theatre at Home prototype depended absolutely upon the work done at Wembley.

We took a risk at IBC; this was the first opportunity for the COO BT Sport and his colleagues to see the demo live. It was important to us that he approved of the work we had completed and that he was happy to continue advocating the research that the project was undertaking. The work was presented to a wide range of influencers in BT Sport including Jamie Hindhaugh (COO BT Sport), Andy Beale (Chief Engineer), Fergus Garber (Controller for Production operations), Gemma Knight (BT Sport Director), Matt Stagg (Head of Mobile and Video content) and Simon Jones (Chief IPTV architect). Most importantly, Jamie was really pleased with the progress we had made saying: "This is the best thing I've seen at IBC; you just know that has been designed with the fans in mind, I think it's beautiful."

Figure 13: (from the left) Fergus Garbur, Gemma Knight and Jamie Hindhaugh with Ian Kegel learning about the Football at Home prototype

We also rubbed shoulders with producers, directors, technologists, analysts and broadcasters from all over Europe and around the world.

Visitors to the stand were particularly encouraged to see that the project's software contributions were being made available through open source software licenses, and every time we showed the Fan Zone demo, they smiled. We lost count of the number of times we were told 'I like that' and 'this is the future'. As the teams dispersed back to their work places we were encouraged, feeling that our focus on exploitation was paying dividends.

3.3.9 Post IBC

Following IBC, the BT team have received four direct and encouraging challenges.

1. To draft a specification for a Set Top box that will support the Football At Home use case
2. To establish, for all the platforms to which BT Sport is distributed, which of the key features would be supported.
3. To hold a mini IBC at Stratford and to invite the key supplier and partners of BT Sport to see the Football at Home use case and to assess how they would deliver the new forms of experiences.
4. To place the Football at Home demos in the BT Showcase to be used in discussion with regulators, analysts, suppliers and customers.
5. To work with the IPTV architect team to establish how our delivery chain should evolve to support object-based media distribution

This work is being actively pursued.

3.4 ChyronHego Exploitation Activity and Plans

ChyronHego operates in two business areas (broadcast and sport). Within the broadcast segment we are a global leader in graphics creation, playout, and real-time data visualization and offer a wide variety of products and services for live television, news, sports, corporate and government video production. ChyronHego's graphics products are used by thousands of broadcasters from around the world including ABC, FOX, CBS, ESPN, Turner Entertainment Networks, The Golf Channel, Home Shopping Network, ITV News, the BBC, Sky Sports, Sweden's TV4, Korean Broadcasting, Germany's BR and NDR networks, plus local stations in every U.S. television market.

Within sport we are mainly focused around our optical and wearable player tracking technologies where the more mature TRACAB Optical Player Tracking system is installed in over 300 stadiums. The system is capturing player positions in over 4,500 games every year, and it is the official tracking technology for football leagues such as the English Premier League, German Bundesliga and Spanish La Liga, having also been selected for the major international UEFA and FIFA tournaments. TRACAB is also deployed in all Major League Baseball parks, powering MLB's Emmy® Award-winning Statcast. TRACAB is also used in sports like American Football, Rugby, Cricket and Tennis.

2-IMMERSE is beneficial for both business areas. Within broadcast we have identified how our existing graphic authoring tool PRIME graphics can be utilized to support a 2-IMMERSE and broadcast-based workflow simultaneously. This is described in more detail in 3.4.6.

Within sports, 2-IMMERSE enables the viewer to interact with graphics and data and gives us more options to provide tracking data and analytics to the viewer, hopefully increasing the demand for such information.

Apart from exploring further the Exemplar Productions we will in lab tests showcase:

• Tracking data of player positions synchronized to video as client rendered overlay
• Tracking data aggregations and statistics as overlay graphics
• Selectable augmented reality "overlays", combining camera tracking and player tracking.

3.4.1 Exploitation of Exemplar Productions

As ChyronHego is especially strongly connected to sports broadcasters and wider sports rights holders such as leagues and federations, it is very important for us to be able to refer to the two use-cases of Football at Home and MotoGP at Home, to highlight two different sports type categories and two venue consumption options. From the results of both of these use cases we can much more easily convince our customers to engage in commercial projects based upon the underpinning architectures and technology components for any team-based field sport or any racing-based sports.

The Exemplar Productions are very valuable to us and has already been showcased for both existing clients and non-existing clients on different occasions, including at the tradeshows IBC and NAB. They act as very good starting points for client engagement since the demos trigger creative discussions on how to apply this technology for their own programmes. That gives us opportunities to be the natural partner for bringing both our graphics production tools and knowledge into the discussions.

3.4.2 Exploitation of Production Tools and Workflow Insights

ChyronHego already has a large portfolio of in-house developed production tools. It also has well-established workflows between its own tools and out to technologies from third party suppliers. These tools and workflows have been designed to cater to the existing and long-established world of SDI video feeds and timecodes with the primary delivery end-point being a TV.

Learning from the project, we have already begun creating a new workflow incorporating an existing product called PRIME Graphics to support both 2-IMMERSE graphics and traditional broadcast graphics in the same tool. This is described in more detail in 3.4.6.

3.4.3 Exploitation of Reference Architectures

Our development teams will be able to use the reference architectures to help expedite the productisation process within ChyronHego and to guide best practise in design to ensure learnings from 2-IMMERSE are implemented. This will also help ensure that any eventual technology standards that emerge are able to be easily integrated into next generation of our products.

We also see business opportunities, where clients already have an OTT platform and would like to enhance it with 2-IMMERSE functionality. This would be based on the Reference Architectures rather than the Reference Implementations as the technology stack probably differs. ChyronHego, as would other partners, could be a preferred choice for this work.

3.4.4 Exploitation of Reference Implementations

For ChyronHego to convince its broadcast and media clients to engage in a paradigm shift of how to produce and deliver content to audiences, it is crucial to have proven exemplar productions to demonstrate a working solution. Broadcast customers are particularly wary about trying out any new technologies or workflows until they are proven to have already worked. They are highly risk-adverse and have too much at stake in their reputations and revenues to risk deploying systems that are not thoroughly proven to have worked.

3.4.5 Exploitation of Design Specifications and Insights

The knowledge and insight captured from the trials especially will help ChyronHego in making more informed decisions on the best approach to take in its product design specifications.

3.4.6 PRIME Graphics

After the MotoGP trial we realised we needed a more effective way to produce on-screen overlay graphics for 2-IMMERSE. The way graphics was produced for MotoGP was code centric and our experience from the broadcast industry tells us a designer should be able to implement the graphics with as little code as possible. This brought us the idea of implementing a 2-IMMERSE graphics renderer which could read graphics scene descriptions from our existing PRIME graphics tool. From ChyronHego marketing:

> "PRIME Graphics is ChyronHego's universal graphics platform that stacks an array of diverse applications into a single design and playout solution. Media professionals from news, sports, in-venue, entertainment, and government/corporate are embracing PRIME Graphics' "**One Platform, Multiple Solutions**" model."

As this tool is already marketed as a "Multiple Solution" it would be a perfect fit to enable it for the 2-IMMERSE platform. And the tool brings several advantages:

- Creating graphics and animations with a WYSIWYG design tool more natural for a designer, and speeds up the workflow
- Dynamic data binding (like replaceable text and images) are done visually.
- A current PRIME Graphics user can reuse existing broadcast assets for 2-IMMERSE and vice versa

And even for traditional SDI based clients it can be an assurance for them to know that an investment in PRIME Graphics is somewhat future proof as it supports emerging technologies such as 2-IMMERSE.

3.5　　　　Cisco Exploitation Activity and Plans

Cisco is a multinational company that has been at the heart of the development and deployment of Internet technologies. Cisco's mission statement is to 'Shape the future of the Internet by creating unprecedented value and opportunity for our customers, employees, investors, and ecosystem partners.'

Video accounts for the overwhelming majority of Internet traffic delivered to homes and mobile devices. As such it is key for Cisco, its customers and partners to understand how video consumption and delivery will evolve in the future. 2-IMMERSE is a stimulus for such an understanding and has demonstrated how the application of technology will enable audiences to engage with visual information, data and entertainment in new ways. 2-IMMERSE has been presented to customers and partners at a Cisco media summit in 2018. Going forward we are looking to bring the 2-IMMERSE demonstrations into multiple Cisco global Innovation centres so that the 2-IMMERSE work can be exposed more widely.

A business focus for Cisco is to identify industry transitions that are driven by the adoption of IT technology. The media production industry is starting just such a transition – the move from SDI connected appliances to all IP data centres. This transition will enable flexible orchestrated production workflows that open new creative opportunities for content creators. The 2-IMMERSE architecture and an object–based workflow is well aligned with a software defined approach to live media workflow orchestration. The exemplar productions from 2-IMMERSE have been used to illustrate to customers the opportunities that the move from SDI connected appliances to all IP data centres will enable.

At the start of the 2- IMMERSE project Cisco had a business unit focussed on Service Provider Video, that provided solutions for the delivery and consumption of video. Recently that business unit has been sold and is now a separate company called Synamedia. Key people in that organisation have been exposed to the 2-IMMERSE project.

3.5.1　　　　Exploitation of Exemplar Productions

The exemplar productions have been extremely valuable in bringing to life creative ways for audiences to engage with visual information, data and entertainment in new ways. These have been valuable for engaging with customers and partners around the future of video consumption and delivery. Going forward we are looking to bring the 2-IMMERSE demonstrations into multiple Cisco global Innovation centres, so the 2-IMMERSE work can be exposed more widely.

3.5.2 Exploitation of Production Tools and Workflow Insights

As noted earlier, Cisco is active in enabling the media production industry transition live media production workflows from SDI connected appliances to all IP data centres. This is a major technology transition for the industry and flexible orchestrated production workflows will open new creative opportunities for content creators. The 2-IMMERSE workflows to support object-based production are great examples of how the new production technology could be used.

3.5.3 Exploitation of Reference Architectures

The Reference Implementations give us a practical validation of end-to-end architectures including layout, timing and synchronisation, based on a cloud and micro-service platform. These technologies have the potential for exploitation within Cisco in domains beyond media, including within the enterprise, digital signage and next-generation customer experiences.

3.5.4 Exploitation of Reference Implementations

As described previously Cisco has recently divested the Service Provider Video business unit that would have been the original target to exploit the 2-IMMERSE Reference Implementations. However, the Reference Implementations are also applicable to adjacent domains:

- Elements of the 2-IMMERSE layout service have been used to manage the presentation of multi-element experiences on large immersive displays, where Cisco has begun exploring how it could be used to build better multi-modal collaboration solutions for other projects, including 'Smart City' demonstrations and visualisations.
- 2-IMMERSE implemented a real-time bandwidth orchestration service that can distribute the available bandwidth between video/audio objects according to priorities and QoS requirements. This approach is potentially applicable whenever you have multiple clients using bandwidth at the same time and you need to manage them (not only video/audio).

3.5.5 Exploitation of Design Specifications and Insights

Validation of the user experience with the end consumers of content is critical to prove design paradigms that can inform both future customer products and user experience design. These specifications and insights will likely have value to our UX design teams, who work on a range of UX activities including TV and multi-screen, and we plan to share the specifications and insights with them.

3.6 Illuminations Exploitation Activity and Plans

3.6.1 Background to Illuminations

Illuminations is a SME that makes and distributes films and related digital content about the arts and performance for broadcast television, cinema screening and online dissemination. Our recordings of performances act as archival records of transient events but are also creative artefacts in their own right intended to engage a large and diverse audience. Our creative and commercial interests are in using the findings, technologies and prototypes of 2-IMMERSE to enable us to create multi-screen experiences for audiences to engage more fully and effectively with our performance content.

Over the past two decades Illuminations and lead producer John Wyver have produced more than 35 full-length screen versions of stage performances. These have been developed in partnerships with major cultural organisations in Britain including the Royal Shakespeare Company (RSC), the Almeida Theatre, Chichester Festival Theatre, the Donmar Warehouse, Sadler's Wells, Matthew Bourne's dance company New Adventures, the London Symphony Orchestra and the

commercial theatre producers ATG. Projects during 2018 have included collaborations with Studio Wayne MacGregor and the Hofesh Shechter Company, as well as large-scale projects with the RSC and New Adventures. This work continues to position Illuminations as the leading independent producer of screen performance in Britain.

The market for screen performance in Britain is comparatively healthy, as it is to a perhaps lesser degree across much of the rest of Europe. Cinema screenings of plays, opera and dance have been established as an entirely new hybrid form in the past decade and have proven their popularity. This is despite increasing signs that the market in cinemas is reaching saturation point, so that only performances with star names or with additional attractions are proving to be profitable. Broadcasters have taken notice of this interest, and both the BBC and the digital channel Sky Arts have once again embraced this form of programming. And the Arts Council/BBC funding initiative The Space is offering support to the creation and dissemination online of performance. The opportunities as a viewer to watch screen performance, as well as the possibilities for producers and cultural organisations to create this, have almost certainly never been more extensive or more varied.

3.6.2 Exploitation of Exemplar Productions

Whilst the recent history of distribution of screen performance is encouraging, for producers and distributors of screen performance the market continues to feel volatile and uncertain. IN LATE 2018, As has been the case for the past year or more, there is concern that the cinema audience for individual productions is unpredictable because of possible market saturation and an over-supply of product. While broadcasters currently fund such work, they do so largely for returns in the form of cultural prestige and fulfilment of cultural public service obligations, and not because screen performances attract large audiences. And the economics of online distribution are highly uncertain, and have a high degree of dependence on public funding.

Producers, cultural organisations, distributors and funders are, as a consequence, eager to identify ways in which screen performance can be developed in innovative ways and can be extended so as to provide richer experiences for audiences. Audience satisfaction remains a key goal, as des the establishment of sustainable structures for monetisation of products and services, but for collaborators and funders, short-term aims include the wish to be associated with projects that are seen to be exploring potential new forms in this space.

The domestic market for streams of live or as-live theatre remains undeveloped, both in Britain and in the rest of the world. This is developing slowly, most prominently through the operation of Digital Theatre, which offers streams of performances produced by RSC, Donmar and Shakespeare's Globe, to consumers on an individual purchase or subscription basis. But this market is small and shows little interest, as yet, in offering parallel services such as those developed for the Theatre at Home prototype. NonethEless, Illuminations is seeking the opportunity to demonstrate both Theatre at Home and Theatre in Schools for Digital Theatre early in 2019.

We are convinced, however, that there is significantly more potential for extending the 2-IMMERSE prototype for Theatre in Schools in partnership with the education departments of both cultural organisations with which 2-IMMERSE has collaborated: Donmar Theatre and RSC. We plan to seek cultural funding from Arts Council England and other potential supporters such as The Space to develop this work, which is necessary before a fully realised product can be taken to market.

The creation of a fully functioning, stable and resilient demonstrator for Theatre in Schools, together with the results of the schools trials to date, has transformed our dialogues with both Donmar and RSC, allowing increasingly broader groups within both organisations to understand far more fully than previously the potential of object-based media and multi-screen offerings.

The Donmar Theatre production of *Julius Caesar*, which is the title used in the Theatre in Schools prototype, is, along with two other related productions of *Henry IV* and *The Tempest*, distributed by National Theatre On Demand. In Schools (ODIS): https://schools.nationaltheatre.org.uk/app/os Currently, this distribution is simply as linear streams that participating schools can access, together with related web pages.

Illuminations is in the early stages of developing a proposal with Donmar for integrating the Theatre in Schools functionality with the ODIS offer, and this will be explored further with Donmar and ODIS in 2019.

In a separate development, Illuminations has demonstrated the Theatre in Schools prototype to the RSC, where the education department has expressed enthusiasm for its successful operation, its flexibility, its integration of a range of elements, and its implementation of object-based media functionality. As at the Donmar, Illuminations is discussing the possibility of extending a stream of a RSC Live in Stratford-upon-Avon production to schools with elements of the Theatre in Schools prototype. This may be practicable for the RSC's schools stream of *Measure for Measure* in November 2019. Both this and the Donmar initiative are dependent on accessing a combination of public funding and corporate support, but if successful this would be an exciting development for both Illuminations and the performance companies.

The RSC's schools presentations are seen as a core offering by the RSC to fulfil stakeholder expectations of public funding, and they also benefit from commercial sponsorship. The hope is that a successful multi-screen prototype for these showings could strengthen both of these forms of support.

Longer-term there remains the aim for Illuminations of interesting and engaging other performance companies to develop the principles that the Theatre in Schools prototype demonstrates. In relation to the RSC our target remains the engagement of the company in a project to develop multi-screen experiences for the full catalogue of plays recorded live from the RSC under the stewardship of Artistic Director Gregory Doran. The company is two-thirds of the way through a project to achieve by 2021 recordings of performances of each of the 36 plays by William Shakespeare included in the 1623 "First Folio". This collection will be only the second time that such a catalogue has been created by the single production entity, the first being *The BBC Television Shakespeare* produced between 1978 and 1985. The BBC's Shakespeare series continues to sell to individual buyers and is extensively used in education around the world – and this despite many of the productions themselves looking exceptionally old-fashioned. The RSC series is intended to achieve a comparable position in the twenty-first century, and Illuminations hopes to see each of those productions accompanied by a multi-screen complement.

3.6.3 Exploitation of Production Tools and Workflow Insights

As noted, having a strong Theatre in Schools prototype has been critical to engaging the performance companies in further discussions. Similarly significant to achieving the types of mutli-screen educational offerings envisaged are the invaluable insights developed within 2-IMMERSE into the workflows required to create multi-screen productions, the types of assets that need to be created and the best ways they required to be treated and presented. For all of this, Illuminations has benefitted enormously from its participation in 2-IMMERSE.

Less crucial to for the company's future work is the successful implementation of the 2-IMMERSE production tools, which have been primarily focussed on the processes of fast-moving live or as-live sports experiences. Nonetheless certain of the production tools have been vital to the development of the Theatre at Home and Theatre in Schools prototypes, including that developed by BBC and IRT and used within Hamlet, to enable the development of the timed script.

3.6.4   Exploitation Reference Architectures

Illuminations' interest and contribution within 2-IMMERSE has been focused tightly on the production part of the value chain. We do not see our work as involving directly the exploitation of the architectures developed within the project, although we would expect future commissions such as those outlined for Donmar and the RSC to use the platforms developed within the project.

3.6.5   Exploitation of Reference Implementations

As for the above comment in relation to Reference Architectures, Illuminations' interest is focused on the production element of the value chain. We do not see our work as involving directly the exploitation of the architectures developed within 2-IMMERSE, although we would expect future commissions to use and extend the platforms developed within the project.

3.6.6   Exploitation of Design Specifications and Insights

Working on the Theatre in Schools prototype in particular, and being centrally involved with Donmar Theatre in the development of the design specifications, has given to Illuminations a far deeper knowledge of the challenges and potentials of multi-screen experiences. This knowledge will be invaluable as we develop the Theatre in Schools prototype in the ways envisaged above with both Donmar and the RSC.

3.7   CWI Exploitation Activity and Plans

The mission of CWI is to discover and develop new ideas, and the transfer of theoretical and fundamental knowledge to academia and to European industry. The group involved in 2IMMERSE, the Distributed and Interactive systems group (DIS), focusses on facilitating and improving the way people access media and communicate with others and with the environment. We address key problems for society and science, resulting from the dense connectivity of content, people, and devices. We use recognized scientific methods, following a full-stack, experimental, and human-centred approach. The group transfers knowledge through scientific publications, standards bodies, open-source implementations and consultancy. We pride ourselves on pushing boundaries, leading the way for others to follow.

In 2-IMMERSE DIS seeks to explore new models and workflows (and roles within the production chain) to support broadcasters and producers to create and curate novel multi-screen interactive experiences. With this purpose in mind, within the project we aim at the development and evaluation, in large trials, of production tools and the delivery platform. In addition, we participate in the development process of the platform, with particular interest on the timeline service.

3.7.1   Exploitation of Exemplar Productions

The exemplars multi-screen interactive productions are essential assets for CWI to showcase the potential of the platform and of the production tools. Moreover, our group has been particularly active in the creation of the experience, as a primary mechanism to gather requirements for the development of the object-based broadcasting production tools.

Exploitation of these productions during the project happened through demonstrations at large academic (ACM CHI 2017 and ACM TVX 2018) and commercial (VRT Media FastForward 2017 and IBC 2018) events. The primarily expected exploitation mechanism includes:

- Invitation to other projects (European or National projects) in the area of multi-screen and immersive media creation, delivery, and consumption. As a research institution, this

is a major source of income, which allows us to continue doing ground-breaking research.

3.7.2   Exploitation of Production Tools and Workflow Insights

One major interest of the group is on new workflows and models for the production of novel multi-screen interactive productions. The research group has a long tradition in developing authoring tools for rich media experiences (e.g., Ambulant player[4]) and support infrastructures for these. In particular, within 2-IMMERSE we have led the task following a user-centred approach, involving the end-users from the beginning. Based on the experiences of creating these new types of experiences from scratch, we ran a number of focus groups and interviews to identify the requirements. The development of paper prototypes allowed us to test different alternatives and ideas, concluding a novel design for the production tools. This user-centred process has as well resulted in the identification of a new role that needs to be fulfilled by the production team (multi-screen director) and the development of new production tools for such teams, which were successfully deployed at Wembley Stadium during the FA Cup Final in 2018. This work has been published, and won the best paper award, at ACM TVX 2018. We believe that these novel production tools will be valuable assets, enabling producers to create novel and innovative productions, which are customizable, multi-screen, object-based and interactive. The primarily expected exploitation mechanisms include:

- Collaboration with companies interested in the production process for object-based broadcasting. This may include innovation projects (European or National) and direct contracts (Public-Private Partnerships).
- Open source availability of selected parts of the production tools, as part of the reference architecture of 2-IMMERSE

3.7.3   Exploitation of Reference Architectures

While CWI has actively participated in the definition of the architecture, there are no specific plans at the moment for its exploitation.

3.7.4   Exploitation of Reference Implementations

CWI has actively participated in the implementation of the platform (particularly in the timeline service). Initially, the team had the intention of contributing to standardisation activities in W3C, but more recent evaluation of the alternatives and possibilities discourages us from doing so.

As a common effort together with the other project partners, CWI intends:

- Open source availability of the reference implementation based on the reference architecture for object-based broadcasting. In particular, CWI will make available the timeline server and the relevant parts of the production pipeline.

3.7.5   Exploitation of Design Specifications and Insights

The project offered a unique opportunity to acquire know-how regarding production, delivery, and consumption of novel multi-screen immersive media experiences, a core research area within

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[4] The AMBULANT Open SMIL Player is an open-source media player with support for SMIL 3.0. The current AMBULANT release provides namespace-based support for the SMIL Language, Unified Mobile and SMIL Tiny profiles. The current release also provides full backward compatibility with SMIL 2.0. aaa.ambulantplayer.org

the DIS group. We intend to exploit such valuable knowledge acquire during the project using a number of mechanisms:

- Training: CWI has updated its curricula and knowledge based and start disseminating in different for a: keynotes at conference and courses.
- Consultancy: we are now equipped with knowledge and insights about new media experiences, allowing us to create public-private partnerships with interested commercial collaborators.

The knowledge has come from the architecting, designing, and development of the platform, infrastructure, and production tools. Moreover, evaluation (though trials and experiments) has been fundamental for consolidating such knowledge. These activities will lead us to research sustainability, with the acquisition of more projects in this area of research.

3.8 IRT Exploitation Activity and Plans

As a pioneer in digital media technology, IRT investigates and develops technologies for augmenting TV content with interactive audio-visual broadband content. In doing so, we support our shareholders, the public service broadcasters of Austria, Germany and Switzerland, in making their services more attractive for their audiences. IRT promotes HbbTV2.0 as a cost-effective solution with broad market reach.

IRT's exploitation plan is focussed on the following assets (as identified above):

- Reference Implementations
- Exemplar Productions

Content and scenarios of the 2-IMMERSE trial have been and will continue to be used to demonstrate the capabilities of HbbTV2.0 and the HbbTV-based 2-IMMERSE platform to our shareholders and potential customers of IRT. The MotoGP trial application was successfully ported to available HbbTV2.0 television sets. The application, among a number of other HbbTV2.0 prototype services developed in the project, has been showcased at IFA 2018 in Berlin, where IRT joined the booth of ARD digital, and IBC 2018 in Amsterdam at IRT's own booth. (See also the section on Dissemination below).

The following list represents the current set of HbbTV2.0 applications that are fully or partially based on 2-IMMERSE implementations, IRT demonstrates at trade fairs and other occasions to its stakeholders:

- HbbTV adaptation of MotoGP trial application from 2-IMMERSE
- "Pirate Radio" and "Dohoam is dahoam": a broadcast service with additional audio tracks via IP (on mobile devices or on the TV) for pre-produced programmes provided by arte and ARD/BR (Bayerischer Rundfunk)
- ARD Mediathek: Allows casting videos from the mobile version of the ARD networks video-on-demand portal to the TV screen. In cooperation with ard.de, the group offering ARD wide catch-up service for all platforms.
- Tagesschau: Sign-language interpreter on a HoloLens (AR goggle) in sync with the TV program. Content provided by ARD Tagesschau, which produces the ARD wide news show.
- *1, 2 oder 3*: Headless companion device to play along with a children's quiz show. Content provided by ZDF.

Both of the shows IFA and IBC have excellent opportunities to show our 2-IMMERSE and HbbTV2.0 work to our shareholders from ARD and ZDF, potential customers including commercial broadcasters like RTL and ProSieben and the HbbTV community (mainly manufacturers). Especially IFA is also a good place to get in contact with associations for special needs, such as organisations for people with hearing or visual impairments. These groups are addressed by special HbbTV2.0 applications that are providing e.g. audio description via IP for broadcast services. Events where we have also shown these demos are the Münchener Medientage in Munich, one of the most important events in the media industry in Germany with special focus on media politics, and the HbbTV Symposium in Berlin in November 2018.

IRT's strategic and commercial interest is to cooperate with German broadcasters including all major broadcast groups to enhance their offerings with HbbTV2.0 features by jointly implementing showcases, but also supporting their roll-out into actual products. The demos at trade fairs and conferences put us in contact with number of broadcasters to discuss collaboration opportunities. This resulted in a number of new demos/showcases (above), but more important in concrete planning for actual on-air pilot services. At the time of writing IRT is working with ARD/RBB to implement the required signalling for accurate media synchronisation of broadcast services with IP content, e.g. audio tracks, for pre-produced programmes. Prototype services developed in 2-IMMERSE are planned to be further developed to be used as test applications for the trial phase.

Demo applications that show the use of HbbTV2.0 features in attractive programming contexts have proven to be very useful in raising interest among broadcasters. During the development of our showcases we collaborated with market-leading TV manufacturers like Panasonic and Samsung. All parties were able to benefit from the mutual interoperability testing. As these manufacturers equipped us with TVs for trade fair demonstrations, we were among the first to demonstrate HbbTV2.0 features on actual TVs. This attracted other TV manufacturers to contact us to get access to our service prototypes for testing their HbbTV implementations or even use it for internal and external demonstrations. This helps improving the existing assets regarding the set of supported features and interoperability across end-devices from different manufacturers.

Two manufacturers who used the test applications, for demos as well as for the validation of their terminal implementations, have released their HbbTV2.0 firmware in 2018 products:

- Panasonic (at least for the German market, including Austria and Switzerland)
- Samsung for Italian market

For the pre-mentioned demos IRT has reused libraries from 2-IMMERSE and developed a set of tools needed to realize 2-IMMERSE-like applications for DVB broadcast services.

The libraries from 2-IMMERSE provide the following functionality

- Automatic discovery of HbbTV devices by an application running on a mobile device
- Application launch on an HbbTV device triggered by an application on a mobile device
- Tight synchronisation of content presentations on an HbbTV and mobile device based on the DVB-CSS protocols.
- hbbtv-lib: wrapper and utility library for HbbTV and HbbTV2.0 functionality (used for the HbbTV adaptation of the MotoGP app)

These libraries are currently used in 2-IMMERSE pilots to provide the HbbTV2.0 multi-screen features for the Android-based mobile applications.

The additional tools for using HbbTV2.0 with DVB broadcast are

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- TEMI generator: a tool to generate and ingest special broadcast timelines (MPEG TEMI) into DVB services for testing and demos.
- MRS service: a Web service providing correlation between broadcast timelines and IP content.

The TEMI generator was mainly developed to be able to generate (offline) content for the demos and provide test content to TV manufacturers. It also serves as kind of a reference to broadcasters implementing the broadcast timeline in their headend. The MRS service will be reused and extended for the ARD/RBB trial project.

IRT develops test applications for HbbTV2.0 features relevant to 2-IMMERSE and makes them accessible to interested parties. This includes major TV manufacturers and other HbbTV terminal-stack developers. IRT hosts interoperability events (IOT) on behalf of the HbbTV consortium. During these events, tests are performed on a broad set of TV devices (prototypes and latest retail devices) of different TV manufacturers. Currently IRT hosts 3 IOTs per year, usually in early spring (March), early summer (June/July) and late autumn (November).

Through collaboration and technical experiments within the framework of 2-IMMERSE, we have built up extensive knowledge to implement HbbTV2.0 multiscreen and media sync applications, which we can exploit also through training courses. Two training sessions – called Intensive HbbTV Seminar – took place in 2017 and 2018 at the premises of IRT and were mainly attended by broadcasters and other content and service providers. In the future IRT plans to cooperate with the ARD Medienakademie, an institution for professional training of ARD employees to offer its seminars.

3.9 IPR Management and Licensing

The 2-IMMERSE consortium agreement defines how access rights to project results will be granted between project partners during and also after the end of the project.

Requests for access rights for exploitation must be made in writing within 24 months after the end of the project and will be subject to a separate agreement between the parties involved.

Access rights will be granted under fair and reasonable conditions; except where they are needed for internal or collaborative non-commercial research, for academic, and/or for public service broadcasting activities, then they will be granted on fair and reasonable conditions on a zero-royalty basis.

Project results will be owned in equal shares if they are jointly generated by more than one party and it is not possible to separate them into component elements for the purpose of IPR protection (Sections 8.1 and 8.2 of the CA). Unless agreed otherwise, each joint owner will have a worldwide right to use, modify and exploit Joint Results as it sees fit (including the right to grant non-exclusive sub-licences to third parties).

3.9.1 Open Source Licensing

3.9.1.1 Introduction

At IBC 2018, the members of the 2-IMMERSE consortium publicly announced that the object-based broadcasting platform it had developed, funded by the Horizon 2020 Framework Programme of the European Union, would be released as open source:

> *"2-IMMERSE is an EU co-funded innovation project which has developed and is launching a new open-source platform for Object Based Multiscreen Entertainment. The open-source platform is based on reusable components that will accelerate the development of new immersive multi-screen experiences, encourage the take-up of the HbbTV2.0 specification and contribute towards its evolution".*

See Appendix A – IBC 2018 Flyer

The 2-IMMERSE software is licensed according to the terms of the Apache Licence v2.0 and published to GitHub under the 2-IMMERSE organisation as a set of publicly visible repositories.

The following sections highlight the objectives and motivation behind the open source release.

3.9.1.2   Motivation

3.9.1.2.1   Sustainability

One of the key reasons for publishing the 2-IMMERSE software under an open source licence is to address sustainability. Sustainability means that the software we use today will be available and continue to be improved and supported in the future. With so much having been created and stored digitally, we have to ensure we do not lose knowledge, culture or the ability to run old software. Sustainability can be improved through the publication of standards and having a healthy community supporting the software to ensure information remains easy to access well into the future. Disclosure of the software source code and technical documentation mitigates the risk of it being discontinued or becoming unavailable after the project completion.

3.9.1.2.2   Fostering a creative community

We are providing the 2-IMMERSE software to the community as a starting point for further investigation into multi-device experiences. It is an example implementation of the 2-IMMERSE multi-screen service reference architecture and may or may not be leveraged directly as-is by third parties. We set out at the start of the 2-IMMERSE project to make our software freely available with the goal of fostering a community of creatives around the production of multi-device experiences and stimulating a market sector to achieve a persistent change in the industry. The announcement at IBC 2018 was the first step towards raising awareness in the industry of the benefits of multi-screen experiences and of our intention to publish working open source software.

3.9.1.2.3   Reuse, exploitation and dissemination

Open sourcing the platform is a way of maintaining the software for our own reuse too and exploiting the intellectual investment of the 2-IMMERSE project. Most of the 2-IMMERSE software repositories have been co-authored and co-designed by several consortium parties, so the ownership of the software components is shared. Publishing our work as open source is the best way for consortium parties and the community to continue to collaborate and make improvements to the software

This also helps to fulfil the requirement of project dissemination. Software itself is a good source of documentation and the repositories themselves are a rich source of written documentation. To borrow from the Manifesto for Agile Software Development, we value "working software over comprehensive documentation".

3.9.1.3   Objectives

The overall goal is to encourage users to contribute changes and improvements back to the software repositories to evolve the functionality further, supporting the goal of sustainability not just the process of sharing software. This involves breaking down barriers that might prevent this.

From the perspective of a future user of the 2-IMMERSE software, we have made it possible for them to download the software, build it and launch a platform instance to host a tutorial demonstrating an orchestrated multi-screen application using simulated OTT delivery of content.

The 2-IMMERSE software is one possible implementation of a more general 2-IMMERSE reference architecture. Therefore, we have made it relatively simple for adopters to replace components with alternatives, whilst allowing other components to be extended and developed further.

3.9.2 Open Source Summary

The 2-IMMERSE open source software complements the reference architecture presented in this document by providing a working example implementation on which third parties can base their projects. The software represents three years' worth of continued incremental development and is comprehensive enough to run all five diverse multi-screen experiences created by the 2-IMMERSE consortium. It is offered to the community to accelerate further research and development and to enable SMEs, developers and other institutions in the media industry to build new multi-screen experiences quickly, especially for HbbTV2.0 devices, to run at scale.

3.9.3 IPR protection

2-IMMERSE publishes the core platform under an open source license and as a consequence project partners decided the majority of IPR generated by the project will not be protected by patent applications.

4 Dissemination

This section documents actions conducted to disseminate results of the 2-IMMERSE project. Target audiences for our dissemination activities have been and continue to be:

- **General Public** – who require information described in easy to understand language.

- **Academics** – who require rigorous presentation of scientific results.

- **Programme makers and commissioners** – who require exemplars of production practice and object-based experience design and production workflows and tools with which to explore these.

- **Production engineers and suppliers** – who require concise and convincing presentation of exploitation opportunities and potential business models (from ITC suppliers, broadcasters, production houses and public venues).

Stakeholders and the broader communities for whom the project is of interest include:

1. **Commissioners**: who need to be convinced of the value of experiences to their audiences;
2. **Content Producers** who need to be convinced of the value to and consequence for their art and their craft;
3. **Broadcasters** who need to understand the business value against the challenges of delivering broadcast quality content in new interactive formats;
4. **Venue owners** (such as hospitality chains who own pubs and restaurants) who need to understand the business benefits to their establishments;
5. **Audiences** who need to know why they should try new experiences:
6. **Project partner organisations and the EU Commission** who need to know whether the project's targeted and achieved contributions are worth the resource investment;
7. **Software developers and hardware manufacturers** who need to be able to build on and extend the platform and conform to its specifications to deliver the targeted experiences;
8. **Standards bodies and regulators** who need to monitor the performance of standards specifications and the evolution of new ones to enable industries to thrive;
9. **Academics:** who need to have an understanding of the social and technical science behind the contributions made;

The standardisation community was addressed by public presentations at trade fair shows, as 2-IMMERSE made use and tried to promote open standards from DVB and HbbTV. For further details on 2-IMMERSE work on standardization refer to section 5.

4.1 Achievements

This section lists all the dissemination activities of 2-IMMERSE since the start of the project including those already documented in previous versions D6.1 and D6.2. Subsections will indicate new additions.

4.1.1 2-IMMERSE presentation at IBC 2018

The project sought, and was awarded, an opportunity to present the results of the project in the Future Zone at the 2018 International Broadcast Convention (IBC) in Amsterdam. IBC describes itself as the world's most influential media technology show. Taking place each year at Amsterdam's RAI exhibition centre IBC attracts about 50,000 media professionals to attend the combined trade show and technology conference. 2-IMMERSE project partners worked to maximise our presence at IBC and submitted a paper for the conference on object-based broadcasting, we proposed a stand in the Future Zone and we negotiated opportunities to have 2-IMMERSE demonstrations visible on the stands of 2-IMMERSE partners ChyronHego and IRT. All of these endeavours succeeded, ensuring that
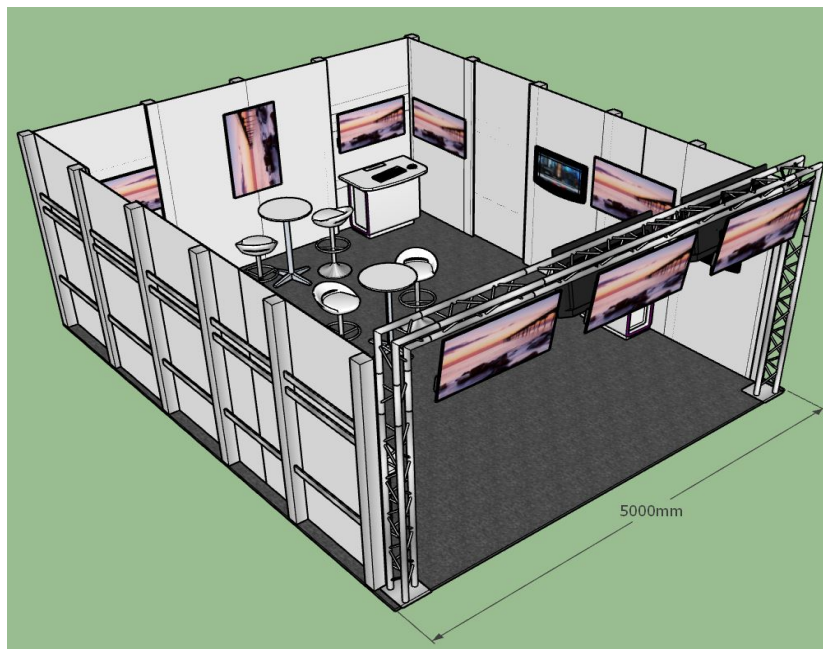
Figure 14: Bird's eye view of the 2-IMMERSE exhibition stand in the Future Zone at IBC 2018

2-IMMERSE had four points of presence across the exhibition. The stand design for the 2-IMMERSE presence in the Future Zone is shown above in Figure 14. A photograph of the stand is shown in Figure 15.

We chose IBC to publicise the open source software components and the reference architecture that 2-IMMERSE is publishing and making available at the end of the project. We used the use-case prototypes to illustrate the benefits of the object-based approach that is enabled by the software and the architecture.

The stand displayed:

- The MotoGP demo (1 TV screen, 1 tablet, 1 mobile phone)
- The Theatre at Home video (1 TV screen)
- The production tools (2 TV screens, 2 laptops)
- The platform (2 TV screens)
- The Foootball Fan Zone (6 TV screens, 1 mobile phone, 1 tablet
- 1 Project Video
- 1 Project logo (1 screen)

During the five-day event, three or four, and sometimes more, people from the 2-IMMERSE project team were on the stand at all times. In advance of IBC we contacted colleagues, suppliers and rights holders known to us and invited them to visit the stand and took full advantage of the IBC marketing channels, as well as promoting our presence through Twitter, blog posts and on the 2-IMMERSE web site. With the additional 2-IMMERSE presences at the stands of ChyronHego (where the Prime HTML5 graphics engine with working name 'Prime OTT' was demonstrated as well as the Football at Home demo) and IRT (where the MotoGP demo was shown working natively on a HbbTV2.0 TV) the stand attracted a lot of visitors and was busy at all times during all five days.

Figure 15: Photograph of the 2-IMMERSE stand in the Future Zone of IBC 2018

Visitors to the stand included:

- Filmmakers
- Producers
- TV executives
- TV directors
- Media analysts (technical and financial)
- TV facilities providers
- TV channel owners (CEOs)

We estimate we saw and spoke to more than 500 people over the five days and we distributed all of the 200 flyers describing the projects achievements that were printed for the exhibition (see Appendix A). An agency dedicated to delivering curated tours of IBC for the Dutch media industry included the 2-IMMERSE stand on their tour and this introduced a further 80 people to the project's achievements.

Some visitors returned to the stand several times during the exhibition; others pointed co-workers and their direct reports to visit the stand. For example, Jamie Hindhaugh, the COO of BT Sport and a key contact for 2-IMMERSE partner BT, saw the Football demos for the first time at IBC and declared them 'the best thing I've seen at IBC'. Jamie went on to instruct suppliers and collaborators at BT Sport to visit the stand; he subsequently requested a 'mini IBC event' at BT Sport so that all his direct reports and their teams could see the progress that had been made.

Further, during IBC, Paolo Pescatore, renowned UK technical media analyst, tweeted about his visit to the stand.

https://twitter.com/paolopescatore/status/1041648830909960192

We were left with two recurring impressions:

- that the definition of the open source TV service platform that 2-IMMERSE had developed for the project was of interest;

- that many visitors were struck by the project's focus on personalised TV experiences and contrasted this approach with the traditional evolution of TV which focuses on improved picture quality (fidelity, gamut, dynamic range etc.).

- whilst difficult to quantify, observed body language when we demonstrated the Football Fan Zone suggested strongly that this was the moment that people 'got it' – the relaxing of the shoulders, the nods, smiles and eye contact made that clear.

The following opportunities emerged directly following IBC.

- For BT: a mini IBC follow-up for BT Sport suppliers, partners and colleagues to help all the BT Sport family understand the opportunity revealed through 2-IMMERSE and to start considering the actions that could be taken locally to enable them to come to fruition.
- For ChyronHego: a series of follow up opportunities with customers across the globe intrigued by the opportunities to use Object Based Broadcasting to develop a distinctive form of television that would enable service providers to develop distinctive forms of TV
- From RTL: follow-up re-use of the approach for personalised news.
- For Illuminations: Meet with Ravensbourne to explore possible follow-on work based on the Theatre in School work.

We arranged to develop short videos from IBC to document our presence there. These videos are available on the web site https://www.2immerse.eu, and they provide:

- An overview of the presence at IBC
- The production tools

- The football demos
- The software platform

4.1.2 Web Site, Blogs and Social Media
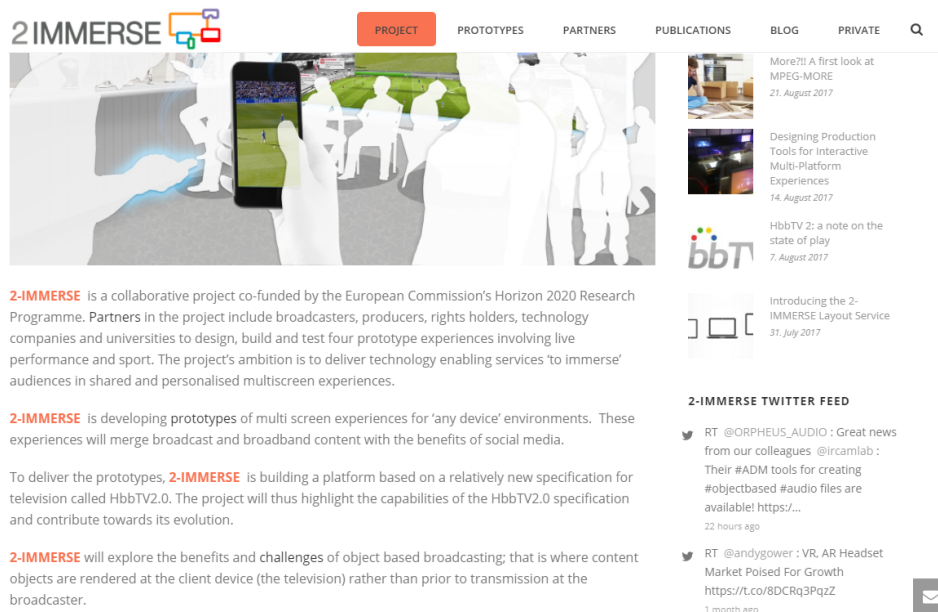
Figure 16: the project web site available at https://www.2immerse.eu

After its first release, during year two significant improvements were made to the project website, including the following changes:

- a re-worked Home page with text highlighting the question of the audiences to which the project as a whole, and the website specifically, is addressed; a re-structured menu of options as well as the inclusion at this level of a link to Blogs, so as to enhance the profile of our contributions; and a more elegant integration of the Twitter feed;

- refinement of the slideshows for the four prototypes, to ensure that these are displayed far more effectively;

- a more active and productive publication schedule of blog posts that both report on the progress made by the project and that highlight activities and technologies that relate to the interests and concerns of 2-IMMERSE;

- the inclusion of the videos produced by and about 2-IMMERSE, which also feature on a linked Youtube channel - this was populated more fully and publicised more widely as the further prototypes became available for dissemination.

4.1.2.1 Blogs

John Wyver from 2-IMMERSE project partner Illumination writes a blog under the company web site Illuminations http://www.illuminationsmedia.co.uk/blog/ John is a respected and authoritative figure in the broadcasting of arts TV in the UK. As and when there was a 2-IMMERSE related story or an experience about which it was relevant to write John used the blog to mention the outputs of this project.
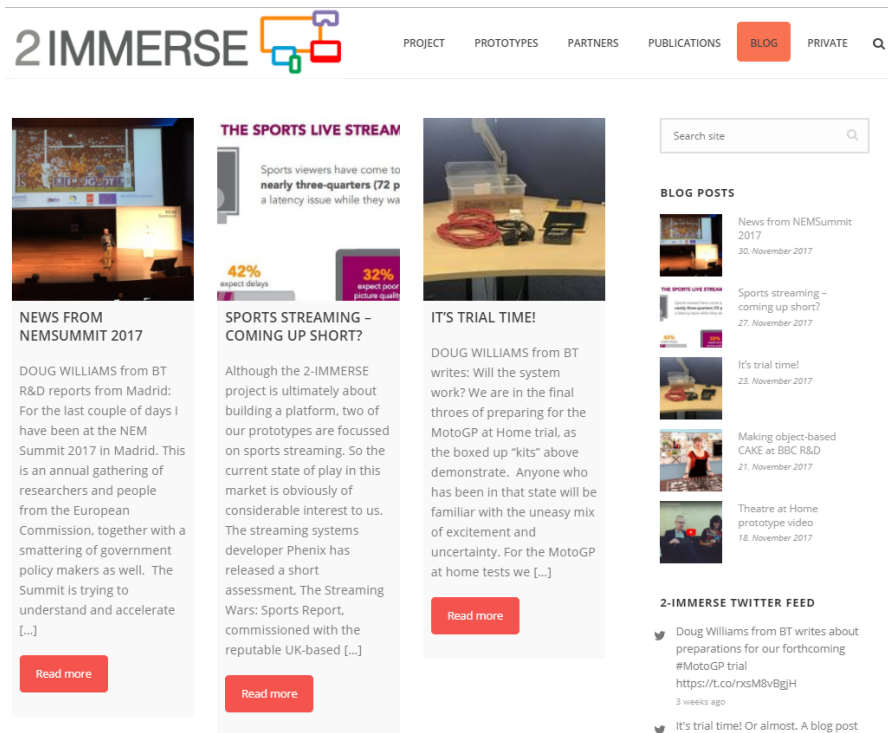
Figure 17: A selection of blogs on the website

All 2-IMMERSE partners have been writing blogs on a regular basis, coordinated by John. All blogs have been published on the web page: https://2immerse.eu/category/blog-post/. Since the start of the project following blogs have been published. Posts attempted to be light, short, accessible and timely.

Since the last dissemination report the following blogs have been added:

- BT: We won! "A very sophisticated application …"
- IRT: Alternative TV companions
- CISCO: The 2-IMMERSE Layout engine packing algorithm
- CWI: Fine-tuning the live production tools
- BT: 2-IMMERSE in IBC's future zone
- ILLUMINATIONS: IBC launch for 2-IMMERSE open source software
- BT: Object-based media: The 'Next Big Thing'
- CWI: Success for 2-IMMERSE at TVX
- IRT: MotoGP roars out on a HbbTV2.0 television
- BT: Back of the net!
- BT: Making it into 'Making it happen'
- BBC: What is a DMAPP?
- BT: Wins for Chelsea and 2-IMMERSE at Wembley
- BT: MotoGP – "Nearly there"
- CHYRONHEGO: 2-IMMERSE at NAB 2018
- CWI: MediaSync: a new handbook
- CHYRONHEGO: Immersive statistics and advanced data capture

- ILLUMINATIONS: 'Television and the Second Screen'
- ILLUMINATIONS: More Things to come
- BBC: Open-source DVB CSS libraries available
- ILLUMINATIONS: Things to come
- BT: Presenting to the presenter
- BT: MotoGP at Home – the video
- CWI: A Day in Brussels: showcasing our production tools
- BT: Fake News at NEMS 2017
- BT: News from NEMSummit 2017
- ILLUMINATIONS: Sports streaming – coming up short?
- BT: It's trial time
- BBC: Making object-based CAKE at BBC R&D
- ILLUMINATIONS: Theatre at Home prototype video

Blogs published in the second year of the project (2017):

- BBC: Beyond the Video Wall – Responsive Content Projection
- BBC: MORE?!! A First Look at MPEG-MORE
- CWI: Designing Production Tools for Interactive Multi-Platform Experiences
- IRT: HBBTV 2: A Note on the State of Play
- CISCO: Introducing the 2-IMMERSE Layout Service
- BT: How we Watch Football in a Pub
- ILLUMINATIONS: 2-IMMERSE at Half Time
- BT: Never Work with Children or Animals
- ILLUMINATIONS: Researching the Landscape of Live-to-Digital Theatre
- BBC: Getting in Sync with Shakespeare
- ILLUMINATIONS: 'A Great Thing': Watching Theatre at Home since 1939
- BT: It's not 'or', It's 'and'
- BT: KISS: Keep it Simple, Stupid
- BT: Signing on
- BT: FA CUP

4.1.2.2 Social Media

The project has a Twitter feed https://twitter.com/2Immerse managed by Illuminations. This has been mainly used to announce 2-IMMERSE related events and presentations. Latest tweets are included and referenced on the website.

Project partners use their own Twitter accounts to announce 2-IMMERSE related events. See Figure 18 for a photograph taken during the IFA Berlin 2017 where IRT presented HbbTV 2.0 prototypes, which were implemented using technology shared with 2-IMMERSE. The photograph shows Miss IFA wearing the Hololens device that is used as a companion screen adding additional video feeds next to the TV screen.

Figure 18: Miss IFA with IRT's HbbTV 2 demo

4.1.2.3   Videos

2-IMMERSE has completed and posted online a number of videos, with at the time of writing a small number still to be completed. These include a narrated demonstration of the Theatre at Home and MotoGP prototypes, as well as videos with a narrower technical focus those with broader messages about the project as a whole. These videos will appear on the project's public YouTube channel and are also be linked to from relevant points elsewhere in the website. The list of videos is as follows:

Theatre at home use case - 2min 40seconds	www.youtube.com/watch?v=SDnS9mow4V4
Are three screens better than one? - 2min 01sec	https://www.youtube.com/watch?v=V3EnXXp8pkA
Instructional video for the MotoGP experience - 4min 22sec	https://www.youtube.com/watch?v=u6-B7fgsyjk
The MotoGP at Home experience - 3min 56sec	https://www.youtube.com/watch?v=FZIhrnGzC4I
The MotoGP at Home experience at BT Innovations 2017 - 4 mins 03 secs	https://www.youtube.com/watch?v=FZIhrnGzC4I
The 2-IMMERSE Production Tools - 2 mins 42 secs	https://www.youtube.com/watch?v=rhZa14OmA00
On Boarding - 2min 03 seconds	https://www.youtube.com/watch?v=bquRSF7d9Kw

Year 2 progress - 3min 30seconds	https://www.youtube.com/watch?v=j5arbXZQg0U
The Rancher video - 3min 34s	https://vimeo.com/251798706/d1a8f9cbaf
Here we are at IBC - 1min 29s	https://youtu.be/1JcxvMgBl7Y
IBC Football at home + FFZ - 3min - 34s	https://youtu.be/3yBNNQSZZYs
IBC Production tools - 2min 59s	https://youtu.be/vhFY5UFgmvo
Jamie Hindhaugh endorsement	[To be posted]
Theatre in Schools use case	[In production]
Platform video	[In production]
The Wembley Trial video	[Waiting on final permissions]
Football at Home use case	[Waiting on final permissions]
Football Fan Zone use case	[Waiting on final permissions]
Production Tools video	[In production]
HbbTV video	https://youtu.be/xNjuvS1PBfo
Project Achievements	[In production]

4.1.3 Publications

This section lists all publications based on work performed in 2-IMMERSE. Publications that are available freely can be downloaded via https://2immerse.eu

4.1.3.1 Book Chapters

4.1.3.1.1 Applications and Usability of Interactive TV

Title	*"From Secondary Screens to Socially-Aware and Immersive Experiences"*
What is the publication about?	The first conceptualizations of the usages of the secondary screen in the television environment were proposed around ten years ago. At the time, the challenge was to convince stakeholders that interactivity was not a threat, but an opportunity. A decade on, the mass adoption of smaller devices has reshaped the media landscape, truly enabling interactivity while consuming media content at home. What was perceived as hindering the user experience - the second screen - has resulted into an essential companion to the television. Paradoxically, even though key players are investing in secondary screen applications, there are very few successful examples. In this chapter we provide an overview of the present state of the art through representative examples and discuss future possibilities and challenges. In particular, we focus on the importance of immersion, taking into account the surrounding of the users, and of sociability, involving her social network. The chapter concludes by highlighting the importance of storytelling for crafting experiences that take advantage of the new media landscape, and the still relevant work of professionals that master such a craft.
When was its content created?	This chapter summarises the keynote talk of Pablo Cesar at the Interactive Digital TV Congress, which took place in Palma de Mallorca (Spain) from 14th to 16th October 2015. The full talk is freely available here:

		https://www.youtube.com/watch?v=hCGYdg1qbPI
How was its content derived?		The original talk already included inputs from 2-IMMERSE (project proposal), which was accepted by that time. The book chapter was updated with further information from the project in 2017.
Bibliographic information	Authors	Pablo Cesar
	Organisation	CWI
	Publisher	Springer
	Webpage	http://www.springer.com/us/book/9783319226552
	Book Title	Applications and Usability of Interactive TV
	ISBN	978-3-319-22656-9
	Publication type	Book Chapter
	Date of publication	2016

4.1.3.1.2 MediaSync: Handbook on Multimedia Synchronization

Title		***"Media synchronisation for television services through HbbTV"***
What is the publication about?		The paper presents use-cases for media synchronisation in the context of interactive TV experiences and overviews technical solutions provided by HbbTV version 1 and version 2 as well as the relevant referenced standards including DVB-CSS, MPEG TEMI and DIAL.
When was its content created?		The invitation to contribute to the book came at the beginning of the project. Research that led to the presented results was conducted in the first six months of the project. The first draft was submitted to the book's reviewers on 1st of June 2016 We received a provisional acceptance of the chapter on 12th of March 2017. A major revision had to be implemented for final acceptance by the reviewers. The camera-ready paper was submitted on 9th of May 2017.
How was its content derived?		The results were derived from a survey of standards HbbTV version 1 and 2, DVB-CSS and MPEG TEMI and hands-on experience gathered during implementation of client API's for media synchronisation, application discovery and launch and the TEMI timeline inserter.
Bibliographic information	Authors	Oskar van Deventer, Michael Probst, Christoph Ziegler
	Affiliations	IRT and TNO
	Publisher	Springer
	Webpage	http://www.springer.com/us/book/9783319658391
	Book Title	MediaSync
	ISBN	978-3-319-65840-7
	Publication type	Book Chapter
	Date of publication	2018

4.1.3.2 Conference papers

4.1.3.2.1 ACM CHI Conference on Human Factors in Computing Systems: ACM CHI

Title	*"Interaction Design for Online Video and Television"*	
What is the publication about?	This course teaches attendees how to design and evaluate interaction with online video and television. It provides attendees a pragmatic toolset, including techniques and guidelines, which can be directly applied in practice. The different tools are contextualized based on current developments, giving participants a complete overview of the state of the art and industry.	
When was its content created?	This is a tutorial at the prestigious ACM CHI conference that happened on an annual basis. It provided newcomers to the field insights about interaction design for online video and television. It is linked to the ACM TVX conference.	
How was its content derived?	The course organisers update the topics and slide set of the course on a yearly basis. For May 2016 we incorporated the principles and use cases of 2-IMMERSE .	
Bibliographic information	Authors	David Geerts, Pablo Cesar, Marianna Obrist
	Affiliations	KU Leuven, CWI, University of Sussex
	Publisher	ACM
	Publication type	Course
	Conference	ACM CHI
	Year	2016
	Link	https://dl.acm.org/citation.cfm?doid=2851581.2856684

Title	*"Designing an Object-based Preproduction Tool for Multiscreen TV Viewing"*	
What is the publication about?	Multiscreen viewing experience is a paradigm that refers to a spectrum of media productions that can be watched using TV and companion screens such as smartphones and tablets. In the last several years, companies are creating companion applications to enrich the TV viewing experience, but viewers are demotivated to consume them because they have to download dozens of applications. This paper proposes to integrate the creation of companion screen content in a single object-based preproduction tool. It identifies, from the perspective of TV production professionals, the best paradigm and the needed features to support content authoring for multiscreen viewing experiences.	
When was its content created?	2018	
How was its content derived?	Results of the initial user-centred studies (focus groups) for identifying requirements for the production tools	
Bibliographic information	Authors	J. Li, Z. Zheng, B. Meixner, T. Roggla, M. Glancy, and P. Cesar

Affiliations	CWI, BBC
Publisher	ACM
Publication type	Conference Proceedings
Conference	ACM CHI
Year	2018
Link	https://doi.org/10.1145/3170427.3188658

Title	**"From the Lab to the OB Truck: Object-Based Broadcasting at the FA Cup in Wembley Stadium"**	
What is the publication about?	While traditional live-broadcasting is typically comprised of a handful of well-defined workflows, these become insufficient when targeting at multiple screens and interactive companion devices on the viewer side. In this case study, we describe the development of an end-to-end system enabling immersive and interactive experiences using an object-based broadcasting approach. We detail the deployment of this system during the live broadcast of the FA Cup final at Wembley Stadium in London in May 2018. We also describe the trials and interviews we ran, the infrastructure we used, the final software developed for controlling and rendering on-screen graphics and the system for generating and configuring the live broadcast-objects. During this process, we learned about the workflows inside an OB truck during live productions through an ethnographic study and the challenges involved in running an object-based broadcast over the Internet which we discuss alongside other gained insights.	
When was its content created?	2018	
How was its content derived?	This article is based on the football field trial at Wembley during the final match of the FA Cup.	
Bibliographic information	Authors	Thomas Röggla, Jie Li, Jack Jansen, Stefan Fjellsten, Ian Kegel, Luke Pilgrim, Martin Trimby, Doug Williams, Pablo Cesar
	Affiliations	CWI, ChyronHego , BT
	Publisher	ACM
	Publication type	Conference Proceedings
	Conference	ACM CHI
	Year	2018
	Link	Not known yet (accepted)

4.1.3.2.2 ACM International Conference on Interactive Experiences for TV and Online Video: ACM TVX

Title	**"On Time or Not on Time: A User Study on Delays in a Synchronised Companion-Screen Experience"**

What is the publication about?	The paper presents results of a user study. The study evaluated the potential influence of different delays, between the TV and the companion screen, on how users experience watching a Shakespearean play on the TV, using a synchronised, interactive textbook application on the companion screen.
When was its content created?	Literature review around how delays in media synchronisation influence media experiences started in the beginning of the project. Work on the study design started in month 4 of the project. Implementation of the lab trial experience started in month 6. User studies were conducted in month 8 and 9. The paper was submitted in month 13. The camera-ready version was submitted in month 17..
How was its content derived?	A prototype experience was created and tested in a user study in the framework of WP3. Study and its results are also documented in D3.2.
Special note	The paper was awarded the TVX '17 conference's *BEST PAPER AWARD*. See social media coverage of TVX conference here https://twitter.com/What2DoNext/status/875655443665768448

Bibliographic information	Authors	Christoph Ziegler, Christian Keimel, Rajiv Ramdhany, Vinoba Vinayagamoorthy
	Organisation	IRT, BBC
	Publisher	ACM
	Publication type	Conference proceedings
	Conference	ACM TVX
	Year	2017
	Link	https://dl.acm.org/citation.cfm?id=3077557

Title	*"Multi-Screen Director: A New Role in the TV Production Workflow?"*
What is the publication about?	Multi-screen applications have been a research topic for the last 10 years. Recent technical advances make authoring and broadcasting of interactive multi-platform experiences possible. However, most of the

	efforts have been dedicated to the delivery and transmission technology (e.g., HbbTV2.0), but not to the production process. The hypothesis of this paper is that studio and outside broadcast production requires radical changes in the production workflow, in order to allow for an efficient management of interactive multi-platform experiences. This paper explores such changes, investigating workflows and roles, and identifying key requirements for supporting these. The final objective is to create a new set of tools, which are extending current processes, that allow broadcasters to curate new types of experiences. We conducted a set of interviews with broadcast producers and directors that allowed us to identify two major (sub-)workflows, one for pre-recorded and one for live experiences. We could then assign roles to the different stages of the workflows and derive a number of requirements for the next generation of production tools.	
When was its content created?	2017	
How was its content derived?	The paper reports the results of the user-centred design process followed to identify the requirements of the 2-IMMERSE production tools	
Bibliographic information	Authors	Britta Meixner, Maxine Glancy, Matt Rogers, Caroline Ward, Thomas Röggla, Pablo Cesar
	Organisation	CWI, BBC
	Publisher	ACM
	Publication type	Adjunct proceedings
	Conference	ACM TVX
	Date of publication	2017
	Link	https://dl.acm.org/citation.cfm?id=3089924

Title	**"2-IMMERSE: A Platform for Orchestrated Multi-Screen Entertainment"**
What is the publication about?	This demonstration showcases a new approach to the production and delivery of multi-screen entertainment enabled by an innovative, standards-based platform developed by the EU-funded project 2-IMMERSE. Object-based production enables engaging and interactive experiences which make optimal use of the devices available, while maintaining the look and feel of a single application. The 'Theatre at Home' prototype offers an enhanced social experience for users watching a live or 'as live' broadcast of a theatre performance, allowing them to discuss it with others who are watching at the same time, either in a different room or in a different home.
When was its content created?	2017
How was its content derived?	The paper describes and showcase the technical infrastructure of 2-IMMERSE that makes possible the trials.

Bibliographic information	Authors	I. Kegel, J. Walker, M.Lomas, J. Jansen, J.Wyver
	Organisation	BT, CISCO, BBC, CWI, Illuminations
	Publisher	ACM
	Publication type	Adjunct proceedings
	Conference	ACM TVX
	Year	2017
	Link	https://dl.acm.org/citation.cfm?id=3089909

Title	*"A New Production Platform for Authoring Object-based Multiscreen TV Viewing Experiences"*
What is the publication about?	Multiscreen TV viewing refers to a spectrum of media productions that can be watched using TV screens and companion screens such as smartphones and tablets. The opportunity of multiscreen TV viewing is immense with broadcasters. They are promoting an interactive and engaging way of viewing TV by offering tailored applications for TV programs. However, viewers are demotivated to install dozens of applications and switch between them. This is one of the obstacles that hinder companion screen applications from reaching mass audiences. To solve this, TV producers need a standard process for producing content for multiscreens, allowing viewers to follow all kinds of multiscreen content in one single application. This paper proposes a new object-based production platform for authoring content for multiscreens. The platform consists of two parts: the preproduction tool and the live editing tool. To identify whether the proposed workflow is appropriate, validation interviews were conducted with professionals in the TV broadcasting industry. The professionals were positive about the proposed new workflow, indicating that the platform allows for preparations at the preproduction stage and largely reduces the workload during live broadcasting. They see as well its potential to adapt to the current production workflow.
When was its content created?	2017
How was its content derived?	This paper shows the results of evaluating the production tools developed in the project, with a particular focus on the live triggering functionality
Special note:	Awarded with the BEST PAPER AWARD for TVX conference 2018

Bibliographic information	Authors	J. Li, T. Roggla, M. Glancy, J. Jansen, and P. Cesar
	Organisation	CWI, BBC, TU Delft
	Publisher	ACM
	Publication type	Conference proceedings
	Conference	ACM TVX
	Year	2018
	Link	https://doi.org/10.1145/3210825.3210834

Title	*"2IMMERSE Production Suite: A Platform for Creating Interactive Multi-Screen Experiences"*
What is the publication about?	We present a software solution for creating and playing back interactive multi-screen experiences. The system consists of a pre-production application for editing layout and timing of interactive media objects and a live-triggering software for inserting on-demand content during live streams of these edited experiences. The system is governed by a hierarchical file format that defines the temporal relationship and synchronisation of media objects. We also briefly introduce the concept of DMApp Components, an open specification which is used to describe and create custom interactive media objects.
When was its content created?	2018
How was its content derived?	This paper demonstrates the production tools developed in the project, with a particular focus on the live triggering

Bibliographic information	Authors	T. Roggla, J. Li, J. Jansen, A. Gower, M. Trimby, and P. Cesar
	Organisation	CWI, BT
	Publisher	ACM
	Publication type	Adjunct proceedings
	Conference	ACM TVX
	Year	2018
	Link	https://doi.org/10.6084/m9.figshare.c.4092236.v4

Title	*"Personalising the TV-experience with augmented reality technology: synchronised sign language interpretation."*
What is the publication about?	This paper explores the potential of augmented reality technology as a novel way to allow users to view a sign language interpreter through an optical head-mounted display while watching a TV programme. We address the potential of augmented reality for personalisation of TV access services as part of closed laboratory investigations.
When was its content created?	We developed the prototype of the HoloLens + AR sign-language interpreter as part of early prototype work in 2-IMMERSE WP3 "User Interaction Design"
How was its content derived?	Based on guidelines of regulatory authorities and research on traditional sign language services on TV, as well as feedback from experts, we justify two design proposals. We describe how we produced the content for the AR prototype application and what we have learned during the process. We develop questions for user studies.
Bibliographic information	Authors	Vinoba Vinayagamoorthy, Maxine Glancy, Paul Debenham, Alastair Bruce, Christoph Ziegler, Richard Schäffer
	Organisation	BBC, IRT
	Publisher	ACM
	Publication type	Conference proceedings
	Conference	ACM TVX
	Year	2018
	Link	https://doi.org/10.1145/3210825.3213562

Title	*"2-IMMERSE: MotoGP multiscreen experience with HbbTV 2 retail devices"*
What is the publication about?	This demonstration showcases the 2-IMMERSE platform - a system built on open standards that enables broadcasters, and other content providers, to deliver novel multi-screen entertainment services. These services are based on the concept of object-based media. Our implementation is currently being tested and validated with HbbTV 2.0 prototype devices, as well as retail devices that are entering the market, to ensure the 2-IMMERSE platform can be used in an HbbTV ecosystem. In cooperation with Samsung the demonstration will show the 2-IMMERSE MotoGP experience (Silverstone 2017) on a recent HbbTV 2.0 terminal implementation.

When was its content created?	We created a prototype on the basis of the MotoGP trial application.	
How was its content derived?	Paper describes the prototype and its key features.	
Bibliographic information	Authors	Vinoba Vinayagamoorthy, Rajiv Ramdhany, Christoph Ziegler, Michael Probst
	Organisation	BBC, IRT
	Publisher	ACM
	Publication type	Adjunct proceedings
	Conference	ACM TVX
	Year	2018
	Link	https://doi.org/10.6084/m9.figshare.c.4092236.v4

4.1.3.2.3 FITCE Congress

Title	*"Why the future of Media Distribution may be object based. Exploring the power of this new approach to media distribution using content genres as diverse as live theatre and sport."*	
What is the publication about?	We suggest that a debate about future distribution mechanisms that considers over-the-top (OTT) distribution and broadcasting without considering object-based broadcasting, is too narrow. This presentation contributes to the debate on the future of TV distribution by introducing the idea of object-based broadcasting as an alternative form of distribution in addition to the established broadcast and OTT contenders. The presentation does not focus on the technical infrastructure for OBB delivery; instead it explores the benefits to viewers of adopting this style of media delivery. Because of this focus on the viewer experience the talk also speaks to the debate about the future user interface and draws that discussion away from a relentless debate about higher fidelity and towards modes of interaction and managing presentation across multiple screens.	
Bibliographic information	Authors	Doug Williams
	Organisation	BT
	Publisher	Institute of Telecommunications Professionals (ITP)
	Publication type	Conference presentation
	Conference	FITCE Congress
	Year	2018
	Link	https://www.theitp.org/membership/fitce_congress_2018

4.1.3.2.4 Workshop Digital Broadcasting

Title	*"Object-Based Broadcasting im EU-Projekt 2-IMMERSE"* *(presentation language: German)*	
What is the publication about?	We present the 2-IMMERSE project, its objectives and achievements. We introduce key concepts such as DMApp and DMApp components and hwo they relate to our understanding of object-based Media. We present the client, service and reference deployment architectures and outline the four trial applications and gave insight into to the UX design, feature set and results of the MotoGP trial. The presentation concludes with an outlook to planned activities before end of the project, i.e. platform evaluation and open-source release.	
When was its content created?	Lifetime of the project	
How was its content derived?	The presentation is essentially a wrap-up of the 2-Immerse project achievements.	
Bibliographic information	Authors	Christoph Ziegler
	Organisation	IRT
	Publisher	Fraunhofer IDMT
	Publication type	Conference presentation
	Conference	Workshop Digital Broadcasting
	Year	2018
	Link	https://www.idmt.fraunhofer.de/de/events_and_exhibitions/wsdb-2018.html#tabpanel-68826900

4.1.3.2.5 International Broadcasting Convention: IBC

Title	*"2-IMMERSE: A platform for production, delivery & orchestration of Distributed Media Applications"*	
What is the publication about?	Presentation of 2-IMMERSE platform and infrastructure including FA and MotoGP experiences as use cases.	
When was its content created?	Lifetime of the project	
How was its content derived?	The presentation is essentially a wrap-up of the results the projects work on the 2-Immerse platform	
Bibliographic information	Authors	James Walker
	Organisation	Cisco
	Publisher	IBC
	Publication type	Conference presentation

Conference	IBC
Year	2018
Link	www.ibc.org

4.1.3.2.6 The ACM Symposium on Document Engineering: ACM DocEng

Title	*"Workflow Support for Live Object-Based Broadcasting"*
What is the publication about?	This paper examines the document aspects of object-based broadcasting. Object-based broadcasting augments traditional video and audio broadcast content with additional (temporally-constrained) media objects. The content of these objects as well as their temporal validity are determined by the broadcast source, but the actual rendering and placement of these objects can be customized to the needs/constraints of the content viewer(s). The use of object-based broadcasting enables a more tailored end-user experience than the one-size-fits-all of traditional broadcasts: the viewer may be able to selectively turn off overlay graphics (such as statistics) during a sports game, or selectively render them on a secondary device. Object-based broadcasting also holds the potential for supporting presentation adaptivity for accessibility or for device heterogeneity. From a technology perspective, object-based broadcasting resembles a traditional IP media stream, accompanied by a structured multimedia document that contains timed rendering instructions. Unfortunately, the use of object-based broadcasting is severely limited because of the problems it poses for the traditional television production workflow (and in particular, for use in live television production). In order to effectively support dynamic object-based broadcasting, the production workflow needs to retain a familiar creative interface to the production staff, but also allow the insertion and delivery of a differentiated set of objects for selective use at the receiving end. In this paper we present a model and implementation of a dynamic system for supporting object-based broadcasting in the context of a motor sport application. We define a new multimedia document format that supports dynamic modification during playback; this allows editing decisions by the producer to be activated by agents at the receiving end of the content. We describe a prototype system to allow playback of these broadcasts and a production system that allows live object-based control within the production workflow. We conclude with an evaluation of a trial using near-live deployment of the environment, using content from our partners, in a sport environment.
When was its content created?	2018
How was its content derived?	This paper reports the work on the timeline service (2IMMERSE infrastructure) for supporting the different use cases
Bibliographic information	Authors	J. Jansen, D. Bulterman, and P. Cesar
	Organisation	CWI
	Publisher	ACM

Publication type	Conference proceedings
Conference	ACM DocEng
Year	2018
Link	https://doi.org/10.1145/3209280.3209528

4.1.3.2.7 New European Media Initiative: NEM Summit

Title	***Evaluating the potential benefits of object-based broadcasting***	
What is the publication about?	About 15% of the TV hours watched in UK homes is brought into people's homes using Internet protocols and about 85% of the data carried by the Internet to people's homes is video. As the worlds of the Internet and video and television continue to converge this paper explores the impact of treating TV content more like web content. In particular it examines, through a use case based on the delivery of filmed theatre, the proposed benefits to end users of adopting an object-oriented approach to broadcasting.	
When was its content created?	2016	
How was its content derived?	The paper describes the approach and methods chosen for evaluating the concepts of object-based broadcasting and the claimed benefits for the users as planned for the Theatre-at-Home prototype.	
Bibliographic information	Authors	Doug Williams, John Wyver, Maxine Glancy
	Affiliations	BT, Illuminations, BBC
	Publisher	NEM
	Publication type	Conference Proceedings
	Conference	NEM Summit
	Year	2016
	Link	https://nem-initiative.org/nem-summit-2016/

Title	***"Multi Screen Football Assessment"***
What is the publication about?	An evaluation of the subjective enjoyment levels reported by judges of school age in response to different presentations of televised football is described. Four different presentations of football are evaluated including two presentations using multiple screens carrying synchronized views taken from isolated camera feeds recorded from the 2016 FA Cup Final in the UK. Student's t-test evaluations suggest that the only subjectively assessed difference that has less than 5% probability of being caused by chance is that the three screen presentations are preferred to single screen presentations.
When was its content created?	This experiment was designed and built between January and March 2017
How was its content	The content reports the results of a set of subjective tests used to assess the perceptions young people had of different presentations of football.

derived?		
Bibliographic information	Authors	Doug Williams, Martin Trimby and Jonathan Rennison
	Affiliations	BT
	Publisher	NEM
	Publication type	Conference Proceedings
	Conference	NEM Summit
	Year	2017
	Link	https://nem-initiative.org/nem-summit-2017/

Title	*"Theatre at Home evaluation"*	
What is the publication about?	This paper describes an evaluation of a flexible and personalised Theatre At Home Experience. It presents details of a home theatre service pilot constructed using an extensible platform. The platform is being created to support tailored configuration of devices and content across a number of experience genres including drama and sport.	
When was its content created?	This work was created between project start and February 2017.	
How was its content derived?	The work reports the evaluation that took place of the Theatre At Home Experience	
Bibliographic information	Authors	Maxine Glancy, Matt Rogers, John Wyver, Phil Stenton, Jimmy Lee, Doug Williams
	Affiliations	BBC, Illuminations, BT
	Publisher	NEM
	Publication type	Conference Proceedings
	Conference	NEM Summit
	Year	2017
	Link	https://nem-initiative.org/nem-summit-2017/

4.1.3.3   Journals and Magazines

Title	*"BT Sport gears up for MotoGP trial"*
What is the publication about?	This paper explores whether object-based broadcasting in combination with IP delivery can create a genre of entertainment experiences that are more immersive and compelling than current TV. This question is being probed through a collaborative project called 2-IMMERSE which uses skills from the BBC, BT and Cisco (among others). 2-IMMERSE adopts a use case driven approach to develop multi-screen experiences using content based on sport and live theatre. The project is developing prototypes for an 'any device' environment that merge broadcast and broadband content with the benefits of social media. We recognise a number of challenges, with the primary one being conceiving personalised multi-screen experiences that hold the promise of promoting deeper engagement.

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	Object-based content distribution with client-based composition is central to our vision.	
Bibliographic information	Authors	Andy Gower
	Organisation	BT
	Publisher	Broadcast
	Webpage	https://www.broadcastnow.co.uk/bt-sport-gears-up-for-motogp-trial/5100158.article
	Journal/Magazine	Broadcast Now magazine
	Publication type	Journal/Magazine
	Date of publication	2016

4.1.4   ACM CHI: Conference on Human Factors in Computing Systems

Title	*From the Lab to the OB Truck: Object-Based Broadcasting at the FA Cup in Wembley Stadium*
What is the publication about?	While traditional live-broadcasting is typically comprised of a handful of well-defined workflows, these become insufficient when targeting at multiple screens and interactive companion devices on the viewer side. In this case study, we describe the development of an end-to-end system enabling immersive and interactive experiences using an object-based broadcasting approach. We detail the deployment of this system during the live broadcast of the FA Cup final at Wembley Stadium in London in May 2018. We also describe the trials and interviews we ran, the infrastructure we used, the final software developed for controlling and rendering on-screen graphics and the system for generating and configuring the live broadcast-objects. During this process, we learned about the workflows inside an OB truck during live productions through an ethnographic study and the challenges involved in running an object-based broadcast over the Internet which we discuss alongside other gained insights.

Bibliographic information	Authors	CWI, BT, ChyronHego
	Organisation	CWI
	Publisher	ACM
	Publication Type	Conference Proceedings
	Conference	ACM CHI
	Year	2019
	Link	http://chi2019.acm.org/

4.1.5   Training and Courses

Training and workshops are important dissemination activities of the project, aiming at instructing others with the knowledge gained during the project. 2-IMMERSE particularly targeted audiences outside the consortium institutions.

1. May 2016 San Jose: CWI delivered a course at the prestigious ACM CHI conference: D. Geerts, P. Cesar, and M. Obrist, "Interaction Design for Online Video and Television," in the ACM CHI Conference on Human Factors in Computing Systems (CHI 2016).

2. Nov 2017 York: BT gave a masterclass to undergraduates and post graduates in Theatre Film Television and Computer Science at York University. The talk showed examples of the work carried out at BT, including reconfigurable love stories in Finnish, flexible documentaries of the Renaissance in England, social games played through telepresence, live production of The Tempest in Cornwall from two separate theatres, new multi-screen productions of MotoGP, and offer some reflections on this work and its likely progression.

4.1.6 Demonstrations, workshops and meetings with practitioners

Workshops and meetings have been held with creative industry practitioners during the project to canvas their views and experiences, and to inform our experience designs and technology implementations. Others canvassed included a broader group of sports and drama commissioners and producers.

Figure 19: 2-IMMERSE demo at BT innovation week in June 2017

The following is a list of meetings with practitioners held since the start of the project.

1. September 2016: BT met with the production team delivering the RSC's current Theatre At School Experience; they expressed interest in the opportunities of object based broadcasting that would be embodied in the 2-IMMERSE pilots.

2. September 2016 - IBC Amsterdam: IRT showcased HbbTV 2.0 companion screen features and media synchronisation with partners from German broadcasters ARD and ProSiebenSat1 and manufacturers Samsung, Panasonic and Tara Systems (middleware vendor) using the HbbTV stack that was implemented in 2-IMMERSE for the Android platform. The showcase received significant interest from the HbbTV community (as it was announced to relevant DVB CSS and HbbTV specification working groups) and also among broadcasters.

The demo was a stop on the tour of the Dutch HbbTV Forum.

3. October 2016 Medientage München: The Medientage in Munich is an important German event for the media industry discussing not only technical topics but also media and network politics, regulation and societal aspects. It is a good opportunity for IRT to show the development of TV standards to non-technical audience including executives, producers, journalists etc. As part of the HbbTV 2.0 demo at the Medientage the media synchronisation and companion screen demos were shown that included 2-IMMERSE developments.

Figure 20: IRT's HbbTV 2 demonstration at Münchener Medientage

4. September/October 2017 - IFA Berlin, IBC Amsterdam and Medientage Munich: IRT showed an updated HbbTV 2.0 demonstration from the previous year. The major difference was media synchronisation between broadcast and broadband on the technical side, and some experiments to use AR devices like Microsoft's Hololens in combination with HbbTV 2.0. At IFA in Berlin IRT had a demo stand in the ARD hall, which are IRT's major shareholders. It was a good opportunity to present work to different groups and levels within ARD, from higher management to production to technicians. IFA was also used by special interest groups, e.g. those requiring special accessibility services, to get an update about new technical features that support their members. For details on target audience for IBC and Medientage please refer to the two entries above.

5. October 2017: BT met with the Dorna team delivering the MotoGP. This resulted in small-scale side experiments around some responsive design approaches to visual layout carried out between BT and Dorna. This acted as a very early introduction to the characteristics and potential benefits of object-based production.

6. March 2017: IRT - Workshop on joint HbbTV 2 developments/showcases with Samsung – The workshop was used to discuss joint efforts in developing HbbTV prototypes and their promotion. IRT took the opportunity to present the 2-IMMERSE project, its ambition, esp. the 4 trials and the plan to prepare a test/demo on 'real' HbbTV 2 devices/prototypes. It was decided to continue cooperation including a 2-IMMERSE showcase.

7. May 2017: CISCO – Knowledge Share Call „Microservices - a Cisco research perspective" – Cisco, BT Research & Innovation and invited guests (researchers and TV architects) joined a

call where Cisco gave an overview of the 2-IMMERSE microservice platform architecture, with some lessons learned, plus insights into the use of microservices and containers in Cisco's service provider applications team.

8. June 2017: The concepts for the MotoGP and Football trials were presented during the BT innovation week in June 2017 at Adastral Park/Ipswich to Industry visitors and BT employees. Demonstrations were available all time during the week to interested visitors and specially promoted in interviews and video presentations on stage hosted by professional BT presenters.

9. September/October 2017: The MotoGP at Home experience was demonstrated by BT at the "New Scientist Live" event in London. It is a four-day event with some approximately 20,000 visitors.

10. October 2017: Cisco gave a project overview within a broader presentation to invited Cisco customers in Oct 2017 at the "2nd Annual Sport Summit" at Cisco HQ in New York. Within a 90 minute CTO presentation on Industry & Cisco developments in media production, there were slides giving an introduction to the 2-IMMERSE project and highlighting the scope and showing select wireframes for the MotoGP service prototype. This was presented in the context of new media formats, as an example that would benefit from the flexibility offered by software defined media production workflows running on generic data centre infrastructure.

11. October 2017: BT and BBC presented 2-IMMERSE at Brussels: "2-IMMERSE Delivering the right content, to the right screen, at the right time."

12. November 2017: The MotoGP service prototype was presented to BT attendees at a two day Showcase Event at the Adastral Park by Cisco and BT.

13. December 2017: CWI showed a working prototype of the production tool(s) at the Media Fastforward networking event organized by Vlaamse Radio- en Televisieomroeporganisatie (VRT). The tools interface with the 2IMMERSE platform, and in real-time can trigger broadcast events, showing and hiding collections of objects. https://2immerse.eu/a-day-in-brussels-showcasing-our-production-tools/

14. December 2017: BT gave a presentation of the project as well as a hands-on demo of the MotoGP trial to BT Sport employees during the BT Sport All Hands day on December 13th 2017.

Figure 21: BT stand at New Scientist Live 2017

15. January/February 2018: BT presented to Department for Digital, Culture, Media and Sport (DCMS) and HM Treasury the MotoGP service prototype at Adastral Park/Ipswich about how advances like object-based broadcasting may affect the types of IPTV service available.
- DCMS help define government policy towards, media distribution, TV, national infrastructure networks etc. An understanding of the way TV is developing and becoming, through object based broadcasting approaches, more customisable and multi screen helps them understand the framework for which they should develop policy, strategy and regulation.
- HM Treasury are concerned with the efficiency of UK plc and on the impact on our efficiency and effectiveness of available bandwidth. They will seek to secure through partners in government such as OFCOM, that the right policy and regulation framework is in place to nurture growth and efficiency. An understanding of the way TV is developing and becoming, through object based broadcasting approaches, more customisable and multi screen helps them understand the landscape within which policy, strategy and regulation should be seen to be effective.

16. February 2018: At the BT Sport offices the MotoGP demo was presented to the race director for Dorna Sports. Following the demo the setup was handed over to Dorna Sports who demonstrated the demo repeatedly to their colleagues in Spain.

17. March 2018: BT Sport arrange regular updates with OFCOM - our regulator. In this one we invited OFCOM to BT Sport's offices to understand what object-based Broadcasting is in order that they can begin to understand the way that such experiences should be regulated. It is important, in the big picture of making the market ready for OBB, that the issue of regulation is aired with the relevant authority. The work from 2-IMMERSE is the one of the most complete examples of object-based broadcasting available and certainly the best

example available to BT Sport, so it is appropriate that 2-IMMERSE results were used to illustrate the issues that OBB raises for the regulator.

18. March 2018: Cisco, Illuminations and BT attended the Tommy Flowers 'Future of TV' conference and presented the MotoGP service prototype and the talk '2-Immerse: A Platform for Immersive Object-Based Multi-Screen Experiences'. The latter introduced the theatre and sports-based service prototypes, highlighting their key features and also presented the architecture and implementation of the cloud-based platform developed in realising these service prototypes, and the approach to orchestrating the media objects of a Distributed Media Application within the end-user's device environment. The event was attended by some 120 researchers and industrialists.

19. March 2018: Workshop to develop HbbTV 2.0 pilot services with arte. IRT first presented HbbTV 2.0 showcases and introduced the technical capabilities of HbbTV. arte and IRT discussed opportunities for HbbTV 2.0 pilot services. One service planned is to offer additional audio tracks for broadcast via a companion app on the user's mobile. The main issue and challenge discussed here with arte colleagues was how to realise the synchronisation requirements for this service. A second service shall be realised that includes interaction from TV to the mobile device to offer additional on demand content.

20. March 2018: IRT met with Samsung engineers from the HbbTV development teams from HQ in Seoul and Samsung Research UK to update each other with their HbbTV 2 plans and to discuss further collaboration for HbbTV 2.0 developments and demonstrations.

21. April 2018: IRT presented the HbbTV 2.0 demo that adds sign language interpreter to a broadcast service via AR devices, e.g. through Microsoft Hololens, to the Gehörlosenverband München (GMU) which is the association for the deaf in Munich.

22. April 2018: ChyronHego demonstrated the MotoGP service prototype for invited guests on their booth at NAB in USA. NAB is the largest trade show for media, with over 1.700 exhibitors and over 100.000 attendees from over 160 countries.

23. May 2018: At the BT Consumer launch event in Birmingham BT demonstrated the MotoGP service prototype as an example of the research BT Consumer are sponsoring with respect to Future of TV - in this case Object Based Broadcasting. The event is attended usually by some 20,000 visitors, internal and external BT audience.

24. May 2018: BT presented at the Suffolk show also the MotoGP service prototype to the external public at a show for local business to showcase their work.

25. September 2018 IBC: 2-IMMERSE stand by BBC, BT, CISCO and CWI. See section 4.1.1

26. September 2018: ChyronHego demonstrated the MotoGP and Football service prototype on their booth at IBC in Amsterdam.

27. September/October 2018 IFA Berlin, IBC Amsterdam and Medientage Munich: Presentation of updated HbbTV 2.0 demos developed in 2-IMMERSE including the MotoGP demo. For further details for the attended events please refer to the entries above.

28. November 2018: London: A Theatre in Schools demo was given to the MD and head of Marketing at Donmar Warehouse presenting the two lessons developed within the project using content provided by Donmar Warehouse.

29. November 2018: At Adastral Park: Permanent installation of a MotoGP-at-home demo. As a Customer Showcase it will enable the MotoGP and Object based Broadcasting concept to be demonstrated to a wide range of senior company executives as well as representatives of government at all levels. The customer centre receives more than 1,000 high level visitors each year.

30. November 2018: BT presented the MotoGP showcase in Stratford/London to Key influencers for BT TV, including technical, production and commercial teams from BT and partner companies.

31. November 2018: Stratford-upon-Avon. BT and Illuminations presented the Theatre in Schools demo to members of the RSC education and digital departments to explore how the work of 2-IMMERSE project might be extended with further initiatives with the company.

5   Standardisation

As an innovation project 2-IMMERSE has strived to evaluate emerging technologies and standards, to employ them where possible and thus foster their market relevance. An obvious use case is with the HbbTV association's adoption of specific profiles of the TM-CSS specification from DVB to which HbbTV adds further protocols for device discovery and communication between applications running on multiple devices. The latest version of the specification, namely HbbTV 2.0, already covers some of the use cases and requirements envisioned by 2-IMMERSE. Rather than producing contributions to new standards, we have seen our role in assessing whether existing specifications fulfil the needs and the requirements of the industry.

The project has evaluated first available implementations of HbbTV 2.0, that came to market in 2018, and assessed its suitability for the use cases envisioned. For more details please refer to the HbbTV section below.

2-IMMERSE has followed and discovered other specifications like MPEG MORE and MPEG SAND. A detailed analysis of MPEG MORE and its relevance and impact to 2-IMMERSE has been performed. The analysis can be found in D6.1r1 as Appendix I.

The sections below give some additional information about activities in standard groups and recommendations derived from the experiences made during the 2-IMMERSE project.

5.1   Relevant standards

5.1.1   HbbTV2/DVB-CSS – companion streams and screens

5.1.1.1   Overview

2-IMMERSE decided to adopt and evaluate the HbbTV 2.0 specification. The specification profiles and extends the DVB-CSS specification which provides the mechanisms for accurate synchronisation of A/V content within the home network. Also, HbbTV 2.0 provides the means for device discovery and application communication across the home network.

The requirements derived from the use cases envisioned in 2-IMMERSE go beyond the mandatory features of HbbTV 2.0. For example, HbbTV 2.0 TVs are only required to support one video decoder. It is down to the TV manufacturer to add more than one video decoder to their HbbTV terminals. Therefore, we cannot assume that all or the majority of HbbTV sets in the market will be equipped with more than one video decoder.

2-IMMERSE has evaluated its platform on HbbTV 2 implementations by a dedicated HbbTV 2.0 showcase of its platform making use of the MotoGP service prototype. This evaluation is documented in D2.5 "Platform evaluation/HbbTV implementation". While its intention was to validate the technical 2-IMMERSE platform against one of the important broadcast eco systems in Europe, it generated a great example use case of HbbTV 2.0, which will help to promote it to both broadcasters and manufacturers. IRT presented the HbbTV version of MotoGP as part of their HbbTV demos at IFA, IBC and the HbbTV Symposium.

Beside companion screen APIs and media synchronisation, HbbTV 2.0 brings other improvements that are of interest for 2-IMMERSE. One example is the updated browser profile, now supporting HTML5 and related APIs. These are required by professional tools like Adobe Animate that 2-IMMERSE uses to produce interactive, animated on-screen graphics rendered as a video overlay on the client side rather than being rendered into the broadcast video before

transmission. Tests with the graphics as generated for the MotoGP service prototype showed that current HbbTV TV sets are suitable for a client-side composition of on-screen overlays.

The MotoGP trial application allows viewers to cast 360° rider cam videos from their personal device to the TV as a picture-in-picture overlay. The latest version of the HbbTV standard does support the playback of 360° video. However, we were able to observe two interesting developments in this area during the course of the project. At IBC 2017 Eutelsat, arte and Samsung have shown 360° content making use of HbbTV 2.0 features like device discovery and app to app communication. The use case is quite close to 2-IMMERSE sports trials, it is envisioned to include this feature in the 2-IMMERSE HbbTV 2.0 showcase. IRT started a discussion with partners from the HbbTV consortium whether there is sufficient support to standardize delivery of 360° content in HbbTV. A related activity will be the work on commercial requirements (CR) by DVB in the CM VR group on delivery of 360° video in DVB broadcast and broadband networks.

A completely different approach is server-side rendering of 360° scenes and making use of existing video playback capabilities of TVs. Fraunhofer Fokus have showcased server-side rendering of 360° video on HbbTV terminals in 2017 and 2018 at various events like IBC, and the technology was used in a first on-air trial with Greek broadcaster ERT during the world championship in soccer 2018. The implementation includes a standards-based version in principle working on HbbTV 1 devices, and an advanced version offering a better user experience that goes beyond HbbTV 2.0 as it makes use of W3C features that are not included yet in HbbTV but are widely supported by the latest models of all major TV manufacturers.

5.1.1.2   Conclusion and Recommendations

The evaluation of the MotoGP service prototype (D2.5 section "Platform Evaluation") has proved that the latest HbbTV TVsets are suitable client devices for the 2-IMMERSE platform services. But there are some restrictions in the HbbTV specification as well as on implementations that prevented us to show all features of the MotoGP service prototype.

- PIP on TV: not a limitation of the specification, manufacturers limit available decoders to just one unless there is a content provider with a business case.
- 360° on TV: There are at least to technical proposals, one using a client side rendering with a native 360° decoder (i.e. not based on WebGL or others) and the other one with server side rendering as described above. The latter seems more likely to be included in a future version of HbbTV as it requires mainly the inclusion of W3C Media Source Extensions only, which is already on a "shortlist" of requirements for the next version of the specification.
- Bandwidth orchestration: currently not possible with HbbTV 2.0, but if Media Source Extensions are included in future, this can be achieved on the application level.

From our observations it can be concluded that HbbTV as a TV platform is basically suitable for the type of multiscreen applications that have been investigated in the project. Some high-end features like 360° video or PIP overlay videos, are not explicitly required by the standard. However, TV manufacturers are free to implement these features. The availability of attractive content, and the resulting interest of end customers, could motivate manufacturers to upgrade their devices accordingly.

5.1.2   DVB CM VR

DVB started to look into VR and AR for any commercially viable applications that require standardisation. The report of a study mission proposes to start working on a technical specification which for DVB means to compile a set of commercial requirements.

2-IMMERSE partners will continue to monitor this DVB activity, especially as part of their HbbTV ambitions.

5.1.3 MPEG DASH

The DVB profile of MPEG DASH - DVB DASH - which is included in HbbTV 2.0, was created with substantial contributions from BBC and CISCO. DASH is used as the transport protocol for audio-visual content by the current implementation of the 2-IMMERSE platform.

The streaming community currently looks into low-latency (http://biblio.telecom-paristech.fr/cgi-bin/download.cgi?id=14719) and tiled streaming (http://ieeexplore.ieee.org/document/7888522/?reload=true) that are two aspects to optimize the DASH protocol in terms of end-to-end delay and bandwidth usage for VR/360° applications. These activities are monitored by the companies of the project, not necessarily by the colleagues working in 2-IMMERSE.

Although such optimization would make sense in combination with 2-IMMERSE applications, media streaming technology was not part of the innovation that was planned to be created by the project. Hence it is not planned to make any contributions based on project results to either MPEG-DASH or DVB-DASH groups.

5.1.4 MPEG MORE

We previously analysed the similarities between MPEG MORE[5] and the 2-IMMERSE platform architecture because they are both concerned with media orchestration. MPEG media orchestration is a work item within the MPEG-B specification suite that came to the attention of 2-IMMERSE after having defined the initial architecture and having started the work for the Theatre at Home service trial. At the time of writing, MPEG-MORE was at the Committee Draft (CD) phase and this is still the case at the end of the 2-IMMERSE project:

> ***"MPEG issues Committee Draft of the Media Orchestration (MORE) Standard***
>
> *At its 117th meeting, MPEG promoted its specification for "Media Orchestration" to Committee Draft. The specification supports the automated combination of multiple media sources (cameras, microphones) into a coherent multimedia experience. It also supports rendering a multimedia experience on multiple devices simultaneously, again giving a consistent and coherent experience. MPEG expects Media Orchestration to be especially useful in immersive media settings. The specification contains tools for orchestration in time (synchronization) and space."[6]*

The original internal analysis report is attached to D6.2 as an appendix.

During the third year of the project, we investigated cloud-based composition, cloud-based synchronisation and bandwidth orchestration scenarios in detail, looking further at the MPEG-MORE object model and its communication channel architecture which is based on MPEG-SAND. This was with a view to exploiting and contributing to the specification.

5.1.4.1 MPEG-MORE Glossary

For a glossary of terms, see the latest Committee Draft available from the ISO content server[5]

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[5] http://isotc.iso.org/livelink/livelink?func=ll&objId=18714925&objAction=Open&vernum=7

[6] https://mpeg.chiariglione.org/meetings/117

5.1.4.2   Remote Composition

5.1.4.2.1   Objective

For the MotoGP service trial, we investigated whether it was feasible to use the MPEG-MORE object model and its corresponding DVB-CSS synchronisation scheme to design a 2-IMMERSE remote video composition service that could off-load compute intensive video compositing operations to more powerful devices.

One of the aims was to perform a more thorough evaluation of MPEG-MORE object model with a view to contributing back to the standard but also to investigate how we might satisfy the MotoGP service trial requirement of multiple video decoders and support for video mixing which is currently beyond the capability of the current generation of HbbTV 2.0 devices. Migrating video compositing to a remote device would allow less capable consumer devices to run the MotoGP experiences, leading to improved audience reach.

5.1.4.2.2   MPEG-MORE-based System Design

The remote composition system was comprised of three building blocks;

1.   A component to process composition instructions and generate resource management and provision requests.
2.   A system for provisioning and managing a pool of video processors
3.   The video processors themselves

The MPEG-MORE M-Processor model was used to describe a system that delayed the processing of timed composition instructions, such as blends, transitions and picture-in-picture overlays. This delay was necessary to allow sufficient time for M-Processors performing the actual compositing operations to be provisioned and primed with content; a requirement that has to be satisfied in order to maintain an uninterrupted live output feed. The diagram in Figure 22 below shows a sketch of the architecture, designed in terms of the MPEG-MORE object model.
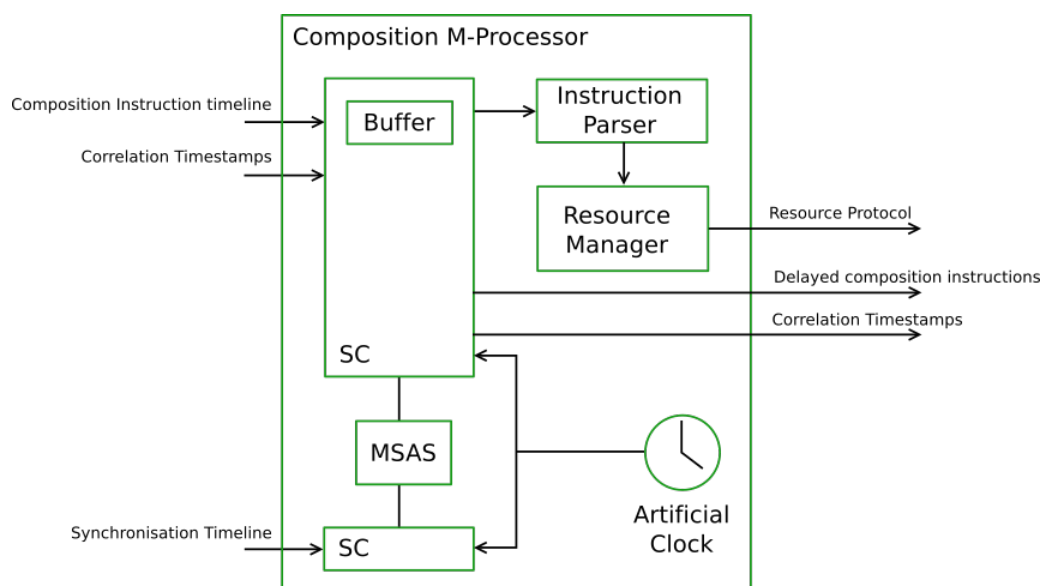

Figure 22: Composition M-Processor Architecture base on MPEG-MORE object model

The delayed compositing instructions and pre-emptive resource provisioning instructions generated by the Composition M-Processor are then consumed by a managed pool of video

processing M-Processors, also designed using the MPEG-MORE object model concepts. Figure 23 below, shows how all the M-Processors were arranged into a remote composition scheme capable of generating a single timed composition. It also illustrates how the Composition M-Processor interacts with the manage pool.
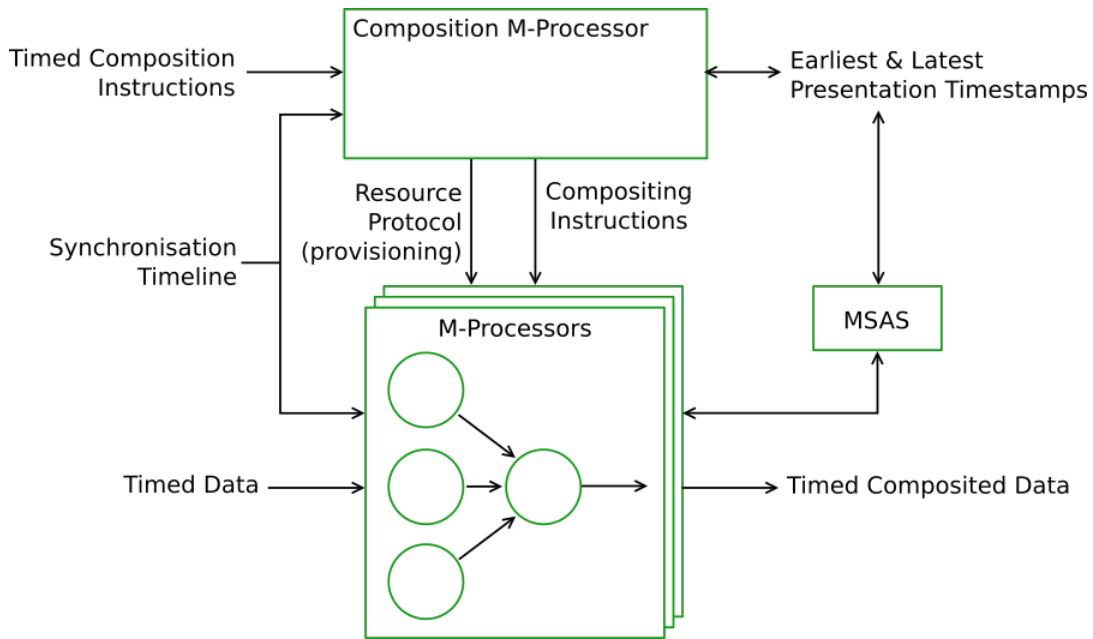

Figure 23: Remote composition scheme using MPEG-MORE object model

Figure 24 below, shows the MPEG-MORE source and sink concepts being used to describe one example of a M-Processor provisioned to do video mixing.
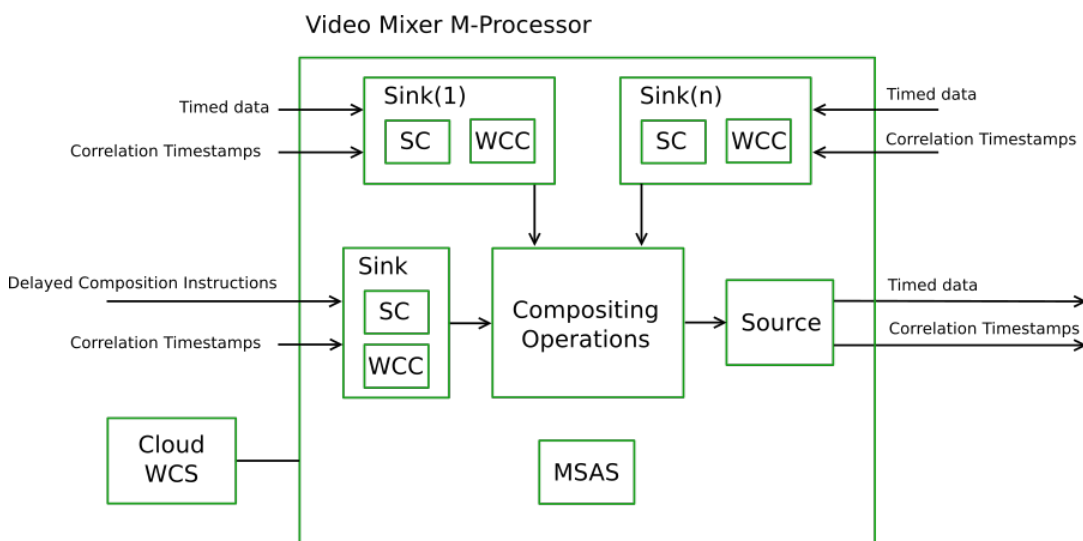

Figure 24: Example M-Processor video mixer using MPEG-MORE object model

5.1.4.2.3 Conclusion

The conclusion we reached having completed this modelling exercise is that MPEG-MORE's object model is currently too high-level and abstract to provide practical benefits for 2-IMMERSE. For example, the MPEG-MORE specification describes its MessageDispatcher object as follows, without any further technical details.

> *"The message dispatcher is the function that abstracts the dynamicity of the networks away. It knows all the ways to connect to each object, and whenever it needs to send a message, chooses the most appropriate one. No other entity in the architecture needs to know anything about networks going up or down. It also manages load balancing in case of large orchestrations."*[7]

This doesn't provide anything substantial to leverage when attempting to apply the MPEG-MORE specification to an existing cloud-based service architecture deployed on AWS, such as 2-IMMERSE.

The MPEG-MORE 'source, sinks and processors' paradigm is an existing stream processing design pattern and has been adopted by many media processing architectures. In this respect, MPEG-MORE does not offer anything new over these architectures, other than the application of a standard design pattern to the domain of media orchestration. Also, the DVB-CSS synchronisation used by MPEG-MORE has already been adopted by the 2-IMMERSE service architecture as a result of targeting HbbTV2.0 which includes DVB-CSS in its profile.

The long-term benefit of the MPEG-MORE data model is to foster interoperability between the sources, sinks and processing nodes of different networked systems or ecosystems, hence the goal of standardising the object model. But the specification is not sufficiently detailed at present to help us arrive at a technical implementation that would achieve this goal of interoperability and long-term sustainability.

The MPEG-MORE object model includes dispatcher, registry and discovery concepts because it is aimed at having source, sink and processor 'nodes' distributed across a networked system. It is natural to arrive at such a graph-based design for media processing pipelines if one sets out to emulate traditional broadcasting equipment in software, where the media pipeline is fixed-function and static. However, network discovery and registration are very slow operations compared to the duration between one frame of video and the next. As a result, the MPEG-MORE design is less suited towards supporting the low-latency requirements of highly personalised live user experiences, where media processing pipelines need to be completely reconfigured on a frame-by-frame basis in response to user interactions or live events triggered in production.

A pragmatic solution that addresses the requirement of low-latency media orchestration is to perform as much processing as possible on as single high-performance device, where the dynamic orchestration of composition operations can be achieved in real-time. A more natural architecture for this would be similar to that of a rendering engine, where media processing operations are described using render command lists sent to a GPU and are designed to be changed completely from frame-to-frame without any overhead.

A notable omission from the MPEG-MORE committee draft is the description and preservation of media source identities when media streams are consumed by M-Processors to create new sources. Other more mature specifications such as "Networked Media Open Specifications" (NMOS) are alternative starting points for describing systems capable of media orchestration. NMOS models many of the same ideas presented in MPEG-MORE[8].

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[7] http://isotc.iso.org/livelink/livelink?func=ll&objId=18714925&objAction=Open&vernum=7

[8] https://github.com/AMWA-TV/nmos/blob/master/NMOS%20Technical%20Overview.md

A challenge in constructing a streamlined media orchestration service is good resource management. The MPEG-MORE specification does not address how compute and media content resources are managed to minimise latency through the system. The emphasis on distributing sources, sinks and processing nodes across a networked system in the MPEG-MORE object model may increase end-to-end latency due to data being buffered at the inputs and outputs of each node on the network. These latencies could be avoided if several processing steps were able to be aggregated together on a single device. MPEG-MORE lacks the ability to permit a logical (or virtual) processing graph to be mapped onto arbitrary physical compute/network topology in a way that makes optimal use of the compute resources and bandwidth available, whilst striving to reduce the latency.

Finally, despite inclusion of message dispatching, registration and discovery which help support the goal of scalable deployments, user privileges are not modelled, meaning there is no provision in the MPEG-MORE object model for the users of the system and safeguards against unauthorised exploitation of resources.

5.1.4.3 Cloud-based Synchronisation

MPEG-MORE uses a general formulation of DVB-CSS synchronisation allowing the MSAS to be hosted in the cloud. 2-IMMERSE developed a cloud-based synchronisation system that is based on DVB-CSS, but works across arbitrary networks by hoisting 'synchronisation as a service' into the cloud. The cloud-based synchronisation service developed and published as open source software by the 2-IMMERSE consortium is an example service of this general formulation of DVB-CSS synchronisation. As a working solution that follows the same principles as MPEG-MORE, it serves as a valuable resource alongside the MPEG-MORE specification itself.

5.1.4.4 Summary

MPEG-MORE is not a standard that will be developed or investigated further by 2-IMMERSE, but the feedback presented here may be useful for formulating alternative approaches to media orchestration.

- MPEG-MORE object model is powerful but still very abstract and lacking in practical details.
- It is aimed at fixed media orchestration pipelines that are set up in advance and distributed across a number of network nodes, but is less suitable for high frequency, low-latency orchestration changes such as total reconfiguration of the processing graph.
- MPEG-MORE lacks a strong media identity model that is preserved end-to-end to help identify the origin of media and therefore preserve meta-data associations.
- Security concepts are not present in the object model to help govern who has the right to consume or manipulate compute resource and media content.
- In a distributed network architecture MPEG-MORE introduces buffering through its discrete source, sink and processing nodes resulting in greater throughput latency.
- MPEG-MORE does not provide architectural support for optimising resource usage and minimising end-to-end latency or the ability to map virtual processing graphs onto arbitrary physical network resources.
- Being cloud-based, the 2-IMMERSE synchronisation service hosts off-the-shelf mechanisms for discovery, session management, registration and messaging to support its micro service architecture. So, whilst it is positive that MPEG-MORE identifies that these capabilities are also required to implement a media orchestration system, it perhaps goes too far by integrating them into its object model.
- The 2-IMMERSE open source cloud-based synchronisation service serves as a valuable resource alongside the MPEG-MORE specification.

5.1.5 Bandwidth Orchestration

A finding from our early pilot of Theatre at Home was that multiple devices compete with each other for available network bandwidth. This was the result of the greedy nature of the algorithms used inside DASH players that perform bitrate adaptation and the absence of any coordination mechanism for throttling bandwidth between video player instances. We subsequently developed a Bandwidth Orchestration Service (BOS) based on MPEG-SAND to investigate the effect of centralised coordination to achieve fairer playback.

Unfortunately, web browsers do not yet expose network layer metrics to JavaScript to allow adaptive bitrate systems to make fairer decisions and improve the job that MPEG-SAND does. The most promising candidate is the "Resource Timing API". When we developed the 2-IMMERSE BOS, this API was a "candidate recommendation"[9]. Since then, the API has evolved but it is still not finalized so existing implementations[10] cannot be relied upon. This draft API has been implemented by most browsers so a future iteration of the BOS client could use this API to get more accurate data usage for the segment XHR requests combined with XMLHTTPRequest hooking and the DASH player functionality be augmented to track real-time segment download progress.

There is also the "Network Information API", which is still in development but might be able to help assess the network connection properties for the client. There is a proposal for "Network Stats API 2.0" that gives access to bandwidth/network usage statistics down to individual requests. This is a non-standard API implemented only in some Firefox browser versions and Firefox OS which was abandoned in late 2017.

In addition, DASH delivered via HTTPS is opaque, making it difficult to perform bandwidth estimation purely at the application layer. The network layer is the best layer at which to achieve fairness, yet the DASH application layer does not have enough of a global view to ensure fairness between DASH and other adaptive bitrate systems, such as the WebRTC video conferencing used in the Theatre-At-Home service trial. The conclusion is that metrics from both the application layer and the network layer are required to devise a system to improve fairness of bandwidth utilisation between networked DASH clients. See 'Client-Driven Network-level QoE fairness for Encrypted DASH-S' [11]

Bandwidth orchestration is still an active area of research and MPEG-SAND is likely to evolve further. Consequently, MPEG-MORE's adoption of MPEG-SAND is an area may be revised in future and it might have been better to abstract away the mechanism used to achieve communication and fairness in MPEG-MORE.

5.1.6 W3C

5.1.6.1 Overview

Activities around the former Web and TV Interest Group within W3C, which will be re-chartered as the Media and Entertainment IG, have been monitored by 2-IMMERSE partners. There have been no contributions related to 2-IMMERSE, although partners recognised the potential for future contributions, e.g. in improving the community draft of Web Timing objects (http://webtiming.github.io/timingobject/) such that in can be integrated with the protocols defined in the DVB CSS specification.

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[9] https://www.w3.org/TR/resource-timing/

[10] https://w3c.github.io/resource-timing/

[11] https://dl.acm.org/citation.cfm?doid=2940136.2940144

5.1.6.2   Recommendations

The implementation of 2-IMMERSE platform is largely based on W3C specifications, however the adoption of HbbTV 2.0 including DVB CSS for media synchronisation and DIAL for device discovery required 2-IMMERSE to implement native extensions to enable those features.

W3C already includes APIs, namely the Web Timing and Presentation APIs, which would allow to adopt both, DVB CSS and DIAL in web browsers. A future strategy of broadcasters and other content providers with a strong demand in HbbTV 2.0 should be to push those integrations in web browsers through work in W3C groups like the Web and TV Interest Group.

6 Conclusion

This final report of WP6 documents how important has been the exploitation of the results of 2-IMMERSE. Many presentations, including a very successful stand at IBC 2018 and workshops across the broadcasting industry, raised strong interest in how the scenarios as well as the technology can be transferred to production. The technical achievements convinced not only sports-oriented broadcasters like BT Sport but also the schools and theatres for our Theatre showcases, still a new field for broadcasting technology. The project also created a significant number of opportunities for follow-ups for all partners.

Also, the broader media production community benefits from 2-IMMERSE, especially with release of the core platform under an open source license. It includes rich documentation and tutorials and commitments from partners to act as community managers for the published software components, which is how we address the question of how sustainable the results of this project will be. The software is accompanied with the release of the Reference Architecture that will assist interested parties in creating their own multi device application platforms, whether or not they start from the 2-IMMERSE open source software.

A number of awards for its academic publications and from the industry-based jury at the HbbTV symposium shows that also the wider world recognised and appreciates the results of the project. Developments and testing in cooperation with manufacturers of HbbTV devices and broadcasters helped to promote the HbbTV 2.0 specification. Two vendors brought devices with full HbbTV 2.0 implementations to market in 2018. The ARD has started on-air trials for hybrid media delivery, i.e. sending audio via broadband for broadcast services. Both developments were supported by showcases and software modules created in 2-IMMERSE.

Besides HbbTV 2.0 and related DVB specifications, 2-IMMERSE analysed other technical specifications like MPEG MORE and MPEG SAND and where sensible adopted solutions in its architecture. Conclusions for these specifications are documented and can be used as a starting point in future standardisation work.

Appendix A – IBC 2018 Flyer

Open-source Platform for Multi-screen Entertainment

2IMMERSE

www.2immerse.eu

2-IMMERSE is an EU co-funded innovation project which has developed and is launching a new open-source platform for Object Based Multiscreen Entertainment.

The open-source platform is based on reusable components that will accelerate the development of new immersive multi-screen experiences, encourage the take-up of the HbbTV 2 specification and contribute towards its evolution.

Programme exemplars based on high-value content forms including; MotoGP, the Emirates FA Cup final and award winning Theatre productions have been created to define and demonstrate the core platform capabilities.

Visit the **2-IMMERSE Showcase in Hall 8 F46** to see:

- **Demonstrations** of how Object-based Broadcasting can transform watching multi-screen Sports and Theatre.

- **Production Tools** that enable the authoring of live object-based multi-screen TV programmes.

- **Platform** for distributing multi-screen presentations in a resilient, scalable and extensible manner.

- **Open-source Software** the project will release later this year.

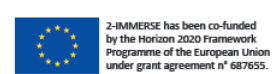- **Reference Architecture** to guide the development of live multi-screen TV services.

Main 2-IMMERSE Showcase - Hall 8 Stand F46 (Future Zone)

IBC Conference Presentation - Sunday 16th Sept at 16:45 in the Forum

Hall 10 F51 (IRT) - MotoGP demonstrator on an HbbTV 2 TV display

Hall 7 C21 (ChyronHego) - Broadcast tools for object-based production

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BBC
British Broadcasting Corporation

Illuminations
Illuminations

IRT
Institut für Rundfunktechnik

CHYRONHEGO
ChyronHego

BT
British Telecommunications plc

CWI
Centrum voor Wiskunde en Informatica

CISCO
Cisco

2-IMMERSE has been co-funded by the Horizon 2020 Framework Programme of the European Union under grant agreement n° 687655.

The **2-IMMERSE Object-based Broadcasting Platform** enables TV programming to be customised to suit the capabilities of available client devices and network bandwidth. Content can be adapted for a range of different environments allowing, for example, the presentation of football in a public fan-zone space to be quite different to the presentation in a home.

Object based broadcasting is enabled through a **Distributed Media Application** (DMApp), a set of software components orchestrated across the participating devices by a cloud service platform. The DMApp components typically render media, support user interaction and/or implement application logic.

The common client software environment we have adopted to support this is HTML/CSS/JavaScript, and in particular HbbTV 2. The service platform we use is a containerised platform managed using Rancher.

DMApp Orchestration Services

| Timeline | Layout | Bandwidth Orchestration |

Runtime Services

| Cloud Sync | Websocket | Data Playback | Shared State |

Support Services

| Production Tools | Authentication | Logging |
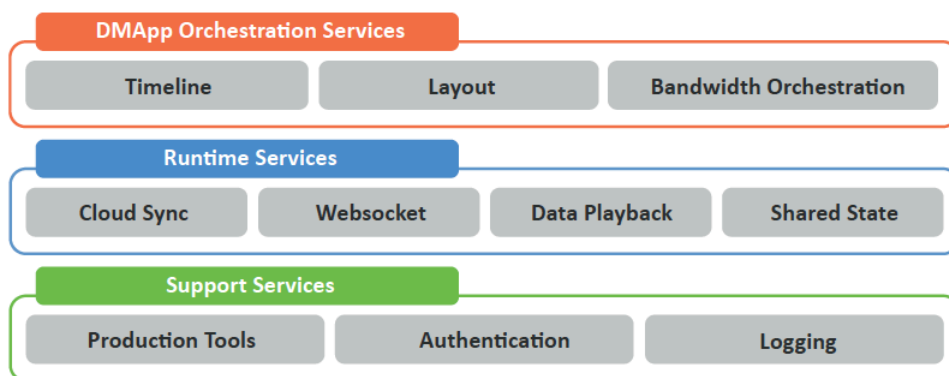
Orchestration, putting the right components in the right part of the right screen at the right time, is the key and distinctive task for the 2-IMMERSE DMApp. Orchestration involves three key services:

A **Timeline Service** that deals with temporal orchestration by interpreting an XML timeline document that controls the temporal composition of the media items and components.

A **Layout Service** that determines the optimum layout of components using authored layout requirements, user preferences, and the set of participating devices and their capabilities.

A **Bandwidth Orchestration Service** that will, where necessary, reallocate bandwidth to optimise the overall quality of experience by monitoring the bandwidth consumption of ABR audio and video components using the generalised architecture and protocols defined in MPEG SAND.

The 2-IMMERSE platform is broadly compatible with the MPEG MORE draft specification which provides a generalised architectural framework for object-based media orchestration. The temporal and synchronisation architecture adopted by MPEG MORE is DVB CSS, which is the basis of the 2-IMMERSE approach to synchronisation.