2IMMERSE project guide

Contents

1. Introduction

This document has been produced to summarise the availability of the 2IMMERSE results based on the recommendations of the Project Reviewers and the Project Officer after the final review of the 2-IMMERSE H2020 project in February 2019.

In particular this document addresses the following topics:
   i.   How the concept of "immersion" evolved in the project;
   ii. what is the synthesis from the use cases in terms of lessons learned, design principles identified, validation results?;
   iii. what are the plans for continuing the promotion of the results by the consortium?;
   iv. what are the implications for standards both old and new ones?.

The sections of the document correspond to the topics as raised.

2. The immersiveness of 2-IMMERSE

In 2015 when the 2-IMMERSE project was proposed to the H2020 research program the consortium offered to *"create and pilot new media services built on research and development related to the production of, access to and engagement with rich content across the screens of multiple devices (multi-screen experiences). The project will innovate around the delivery of experiences that are created to be multi-screen in production yet delivered to be flexible across single and multiple-screens and responsive to the preferences of individual audience members"*.

In this context the project used the term "immersion" as defined in the dictionary as "deep mental involvement in something". The 2-IMMERSE project sought to develop experiences that were more engaging than conventional linear broadcasts and that commanded more of the users' attention (thus deepening the sense of immersion), and the project worked with a number of avenues to deliver this:

the first was using multiple screens;
the second was enabling personalisation;
the third was encouraging interaction with the content; and
the fourth was including social media services (sharing, contributing and communicating).

Thus 2-IMMERSE set out to develop more compelling and immersive entertainment experiences based on the multi-screen concept from the start.

The current use of the expression "immersive" to describe experiences has evolved to be associated with Virtual Reality experiences using 3D headsets and similar devices. Unfortunately this misses the point that other experiences, like good books, compelling stories, great movies and even engrossing tasks can become immersive and people can be totally involved and absorbed in the activities without disappearing into a virtual world.

2-IMMERSE, from its outset, was always aiming to achieve immersion through the mechanisms mentioned above to make traditional TV more interesting, involving and more personal.

The success of 2-IMMERSE is that it has no only shown that there is interest and enjoyment to be had from the extended service concepts developed in the project, but also that these services can be built in a pragmatic way using existing and emerging standards to support customer and audience retention and growth into the future for immersive television productions.

3. Guidance for using 2-IMMERSE results (lessons learnt)

3.1 Context for the 2-IMMERSE guidance

The main result of the 2-IMMERSE project is a reusable platform for developing multi-screen experiences. This platform was evolved and validated during the project life via a series of innovative service prototypes that considered different usages, contexts and content to prove that value could be added to TV based entertainment and the same technologies could also be effectively used for education.

3.2 Service prototype design approach

2-IMMERSE's key focus was to develop a robust and scalable multiscreen platform architecture which could be showcased and tested through a number of sports and theatre use cases. As such, the multiscreen user experience developed across the use cases had to serve as a demonstration of key platform capabilities whilst being easy to use for one-time operation in user trials.

The development of the initial UX designs came from a team of experienced UX/UI design experts working on the project. 2-IMMERSE followed established user-centred design processes to develop first stage prototypes, which were then tested in field trials to inform the technical design priorities for the platform. The aim of a user-centred design process is to ensure that the design of a product or service remains focused upon who will use it, in what context, and with what aim. The UX/UI designers worked with a number of key user groups in mind included; content producers, broadcasters, orchestrators (such as a teacher or landlord) and audience members.

The UX/UI design insights gained from adopting this approach were used to iteratively develop and refine the initial proof of concepts to a state that they were ready to be trialled 'in the wild'. It was agreed that once we had developed the design to a point that it could be trialled, we would not look to further iteratively develop the UX/UI through formal lab and contextual user tests and evaluation procedures. Of course, for a product that was to be launched it would be standard practice to further iteratively develop the UX /UI through such user tests and evaluations.

3.3 Service prototype evaluation methodology

The use cases in 2-IMMERSE were all distinct, and were evaluated in different ways to gain insights from the perspectives of platform capabilities, production tools and the audience experience. This was immensely useful for the project team as 2-IMMERSE primarily sought to build, test and prove a ubiquitous capable and relevant platform that supports greater immersion through the use of multiple screens, personalisation, and interaction with content and other people.

2-IMMERSE sought to get the maximum value from the project by experimenting across genres, device configurations and social spaces to validate the platform across many unique use cases. This approach was optimal for supporting the 'platform focused' goals of the project.

2-IMMERSE primarily used qualitative evaluation methods for the small-scale trials, including interviews with stakeholders and end-users, and contextual observation in the field, to test and qualify key aspects of the design and implementation of the platform. This evaluation provided sufficient insights and evidence to the project team and stakeholders alike to suggest that object based broadcasting (OBB) has many potential benefits which warrant further exploration beyond the conclusion of the 2-IMMERSE project.

Quantitative evaluation, while a more formal and rigorous evaluation of the trials, would have required running trials at significantly larger scale for a longer period of time with more instrumentation and supporting post-trial analysis. It would not have been possible to undertake significant quantitative evaluation given the project's scope, time and resources constraints.

3.4 2-IMMERSE experience for your Guidance

The following recommendations are based on the project team's insights and lessons learned. The intention is to use these as guidance for the development of further multiscreen experiences which utilise an object based broadcasting approach. The adoption of these recommendations would mean that the learning curve to being able to produce object based broadcasting programming would be significantly reduced.

There are multiple aspects to the 2IMMERSE results and you can ideally access them in line with the stage you are at in considering Object Based Broadcasting and the degree of technical information you want to see.

- For high level overviews and the introduction to our trials and services please have a look at our videos

- For the detailed descriptions of our implementations and results please have look at our published deliverables
- For the open source software and components produced by the 2IMMERSE project please look at our GitHub repository.

The following 13 recommendations are the ones we selected from our results and deliverables to give you the most assistance when considering adopting Object based broadcasting to offer enhanced personalised multi-screen services.

3.4.1   Adopt a Micro Services Approach

The micro service infrastructure that we used for the delivery of object based multi-screen presentations was good. Because micro services can be a little complex you are invited to re-use the open source platform we used.

During the development process of our platform we used the industry standard approach based on micro services believing this would bring the affordances of scalability, re-usability and extensibility that the project sought. Our experience within the project has borne this out. We have been able to extend and reuse components and have achieved significant re-use between different use cases. We are pleased that we adopted the micro services approach. However, trying to adapt our service stack to various deployment scenarios, we realized that it could be tricky to find the right order and settings for each scenario. Building Distributed Media Applications (DMApps) can also be challenging in such a context, as we have multiple services that can work together, each with its own API and set of capabilities. To address this we developed some documentation to help.

We recommend that you should adopt a micro service approach if you want to achieve scalability, extensibility and reusability of components. You can use the extensive platform that we developed, based on open source software and including some component developed by 2-IMMERSE. Please access the "Get Started" GitHub repository which includes everything you need to deploy a standalone 2-IMMERSE platform within a few minutes. It also contains a 2-IMMERSE overview, documentation and examples of DMApps to help you get started.

3.4.2   Ensure the visual quality and aesthetics of the presentation

Value the quality of the presentation you develop if you want to influence the TV industry. 2-IMMERSE found it important to demonstrate how OBB can support the visual quality needed to deliver the look and feel of well-established content brands. As the TV production and broadcasting industry places significant value on presentation, OBB needs to at the very least replicate the aesthetic quality of existing productions. This includes on-screen graphics, animations, transitions, etc. If it is not possible to offer equivalence, then consider hybrid options that mix together OBB and traditionally rendered effects.

We recommend that you should work hard to ensure the visual quality and aesthetics of an OBB presentation that is not inferior to the standard currently delivered via traditional production methods. Although OBB offers many new and exciting opportunities to producers and broadcasters, it should not be undertaken at the expense of compromising the visual look and feel or editorial narratives of established practices.

3.4.3   Be sensitive to the needs of the brand

The project sought to better understand the tussle between offering users control over layout and retaining such control by producers. In the first service prototypes we were advocating a feature, dubbed a component switcher, which would allow the user to decide which feature should appear in which portion of which screen. We never fully implemented the component switcher, but it is

instructive to contrast the appetite for this design idea in the first service prototype with those that emerged for MotoGP at Home, the Football and Theatre in Schools service prototypes. In the latter examples, which were more design-led, the approach adopted was to use templates, where users could select from a range of pre-determined layouts but could not build their own layout from scratch.

Our reflection is that for most branded and treasured content the sensitivity from rights holders about how the content will appear will mean that templated solutions will be preferred. Templated solutions allow users to select from a range of options that have all been crafted by professionals sensitive to the needs of the brand, and our experience is that this will be more likely to be allowed by the rights holders. As we worked with our content partners it became clear that the way the content looks now, in established frames on TV or mobile, is not an accident. Media professionals have been working to optimise the ways in which they present their content and tell stories with it for years, sometimes decades; this history should be embraced and adopted.

We recommend that you should work with the existing mores and tropes used in traditional production. Working with the established design approaches will make your interactive design ideas easier to sell to rights holders, will require a less onerous change in the overall production effort, and will be more easily assimilated by your end users already familiar with the look and feel of the existing designs.

3.4.4 Do not disrupt the story

Theatre, MotoGP and Football all showcase great drama and tell good stories. In the design of multi-screen experiences it is possible to lose sight of the story in a forest of options, interactions and added extras. Be careful, the story really is the thing. Do not disrupt the story in fundamental ways. If the heart of the story is the commentary be very careful as you consider options that may interrupt this. When offering optional replays consider how you will allow the main story to remain present. In MotoGP we made the live feed a picture-in-picture as the replay was playing. In the football prototypes we never allowed the replay to usurp the main broadcast feed on the shared TV; it could sit alongside it or appear on a companion device but the main live feed was never deposed and the live commentary was always dominant. In Theatre we did not have replays to contend with but we consciously forced the presentation of the live play to be the biggest item on the shared screen and, like a theatre production, each extract could not be interrupted. In this way the film retained its primacy over other content forms and helped to keep the story the main focus of the experience.

We recommend that you should think about where the story is being driven from and be very wary of allowing interactions that would significantly limit, obstruct or demote that storytelling feature.

3.4.5 Design rules are guided by the content

When it comes to design rules for multi-screen experiences we are not able to offer prescriptive advice about font sizes, the number of items in menus or where to place interactive menus, nor about how many features is too many. Each case is different, and must be approached as such.

The way MotoGP is presented on screens today is already data and graphics heavy. Football employs fewer graphics and theatre is presented with no additional graphics or data at all except in the closing credits. Design rules are not common across genres but rather are guided by the brand and the form of content in question.

Do not expect simple one-size-fits-all content rules. We recommend that you should not expect the relatively "busy" nature of a screen design used in one genre to be appropriate for another content

genre. Reflect on the style and emphasis used for traditional broadcasts in your genre and develop your content appropriate designs from there.

3.4.6   Develop a strategy for using Object Based Broadcasting

We explored many ideas in the design phase for how OBB could offer new opportunities for presentation and interaction. Some of these ideas were developed and implemented so that we could assess and identify which features were most attractive and which had the greatest impact with audiences, broadcasters and producers. The different features implemented varied significantly in both impact and cost. For example, users reported that alternative video views (particularly the onboard bike cams in MotoGP) had the greatest impact, but it should be acknowledged that this feature is expensive to produce and requires the most capable target devices. As a consequence, the addressable base for such features will be small. As you develop ideas for multi-screen experience these complexities need to be acknowledged and you will need to negotiate through them and, inevitably, to make compromises.

Be clear about the objectives you have for using object based broadcasting.

We recommend that you should develop a cogent strategy based on a clear rationale for using the the OBB approach. There are several possible rationales that could shape your response including:

- Maximum addressable market strategy; where you design using technologically simple features that require only modest capabilities in the end-clients and which are those most likely to be achievable across a range of end target devices.
- An inclusion strategy; where you choose to focus on improving the inclusive design of your content. In this case subtitles, text description, responsive design and onscreen signing options may be paramount and targeted even though such features may not work on simpler devices.
- Premium experience strategy; where you focus on delivering the most impactful experience possible, accepting that doing so is likely to limit your addressable market. Developing such an option may help position the experience as a premium or 'halo' product that will showcase differentiation, drive interest in your product and brand, and increase uptake.

3.4.7   Personalise the Audio experience too

Personalised audio experiences have a very high impact. Audio is an object too; as user experience designers consider options for interactivity and choice, it is possible to overlook audio, but doing so would be a mistake. Using audio as an object is impactful and relatively low cost. In the MotoGP trials the ability to change the relative volume of the commentary and the ambient crowd noise was the feature gaining the second highest number of spontaneous recalls from users.

Audio does not require high bandwidth and is relatively easy to decode and render, and so can easily form a component of a maximum addressable market strategy.

Providing control over some aspects of the audio mix can also offer accessibility enhancement for those with hearing difficulties. We recommend that you should ask at many points of your design journey, How am I using audio?

3.4.8   Audio in Multi-Screen environments

One issue that 2IMMERSE identified, but for which we do not have a clear answer, is how to deal with audio presentation when multiple screen devices are capable of delivering audio. In replays for

Football and MotoGP and in the Theatre At Home and Theatre In Schools service prototypes we enabled features that would play video with audio on the companion device.

During the live event both Football and MotoGP adopted a stance of muting audio from the replay so the narrative from the live broadcast was never lost. However, post event we did enable the audio from both the main screen TV and the companion device to play out concurrently, which on occasion did cause confusion and frustration as neither could be heard clearly. This multiple audio approach was not ideal, but since the large screen is a shared experience and the companion screen a personal device neither did it seem right to silence the audio on the main screen – others may be watching and listening to it.

We advise you to consider the impact of second screen audio and to look for compromises or good design rules that may help you and others navigate this issue.

3.4.9   Constraints on Audio or Video chat

In the Theatre At Home service prototype we attempted to allow people in different homes to enjoy watching theatre together in a virtual theatre box and to use video chat during the interval and before and after the play itself. This remains a seductive idea but it proved difficult to implement well at low cost. Mainstream video chat implementations have focused on optimising the experience for single person devices in which audio can be handled quite well. In our use case, where the ideal was to place the audio and video on the main screen, it was much harder to capture both audio and video well. Built-in devices are optimised for a presumed user orientation which may not apply in these shared screen experiences. Harnessing efficient beam forming and echo cancellation is essential to develop good audio chat in an arbitrary environment. Be aware that if you try and implement audio and video chat this is a complex task. However, watch developments with smart speakers closely as the efficient functioning of these devices depends on addressing such audio challenges.

Audio for communications between open spaces remains difficult to implement well, but the technology employed by smart speakers may help.

We recommend that you should be very careful if considering including an audio or video chat feature in your experience. Current chat implementations, attractive as they may seem, may not be optimised for a TV-based set-up.

3.4.10   On-Boarding is key

It is relatively easy to imagine a user within a multi-screen experience and to conceive the ways that they will interact with the media objects made available to them. It was always harder to envisage how they joined a multi-screen experience in the first place.

Within the project defining the process by which people and devices are on-boarded (brought into a multi-screen experience) received considerable attention and by the end of our work we had defined a robust and extensible method for on-boarding.

Three iterations of on-boarding development yielded a standards-based approach that works for all the use cases developed in 2-IMMERSE and there appears to be no reason why it should not also work for other use-cases.

We have built into the on-boarding process ways of defining the type of screen (shared screen, e.g. TV, tablet or phone) and the role of the user (teacher, student, venue manager) as they are added to the experience. This became critical for us towards the end of the project where in the Football

FanZone development we have five potential large screen roles and in Theatre in Schools where we had three roles for the tablets.

We recommend that you should think carefully about how devices and people become associated with a multi-screen experience. The 2-IMMERSE "on-boarding" implementation works well and you are welcome to re-use it.

3.4.11 Simplify work flows

It is comparatively easy to see OBB experiences from the perspective of the end user, but it is critical that you recognise that OBB also requires changes to production workflows. The best implementations of object based productions we can imagine will demand a clear separation of the underlying video and the graphics, audio and alternative video that may augment them. Production workflows must be able to deliver both clean assets, video, graphics and audio as well as the existing dirty feed that has all graphics and audio burned in. Achieving these different outcomes should not require distinct workflows from the perspective of the operator. Ideally single actions should trigger two outcomes; one for the existing broadcast world and one for an object based broadcast.

We recommend that you should work with partners in the production chain to enable this twin output solution. Chyron Hego, in this project, have set out on this journey by developing an adaptation to their PRIME graphics authoring tools that will output graphics suited for embedding in a video stream and also to output HTML5-based code describing the graphics that can be rendered over a clean feed using a client-side browser plug-in.

3.4.12 Manage Bandwidth

2IMMERSE discovered during the Theatre At Home trials that, due to the nature of TCP, traffic patterns could emerge that would favour one service or content stream at the expense of others, effectively starving certain features of our multi-screen experience of bandwidth. To unlock the largest addressable market possible it is important to manage intelligently the use of the available bandwidth in order that, even in situations where bandwidth may be limited, users are provided with the best possible experience.

2IMMERSE has implemented a bandwidth orchestration tool that allows content producers and broadcasters to specify how the experience should respond to situations where bandwidth is limited.

We recommend that you should use a bandwidth management and orchestration approach to ensure the experience for the user remains optimal even as the supply of bandwidth may become limited. You can reference and use the 2IMMERSE bandwidth orchestration tool.

3.4.13 Synchronisation is Essential

Multi-screen experiences can be rendered unattractive or even incomprehensible when the presentation of objects is not correctly synchronised. There are many reasons that screens can become out of sync and we have worked within the project to provide mechanisms that will allow screens to be synchronised frame accurately within a room or across multiple sites. It is extremely important from a production perspective that the directorial intent for content presentation is maintained as, without this assurance, OBB presentation would not be considered fit for purpose.

Synchronisation is essential, and you can use the 2IMMERSE open source synchronisation code.

You should be aware of the risk the lack of screen synchronisation creates. You must either design your experience such that it is not a critical facet of the experience or implement a facility to ensure screens are always in sync.

The 2IMMERSE network based synchronisation service is available as an open source component.

4. 2-IMMERSE open source release plans

The 2IMMERSE plan is to grow the community of developers and practitioners using the open source release of the 2-IMMERSE software and to migrate from publishing as a means of disseminating results towards adopting an open development model (ODM).

Secondly, since the 2-IMMERSE project has implications for the way we produce and consume media, we will use the open development model to work towards consolidating upon and eventually standardising industry formats (based around the capabilities of HbbTV2.0) that permit archiving, sales and re-distribution of object-based multi-screen content to different EU broadcasters.

Interoperability is an area for future standardisation and the goal of the consortium-wide exploitation is to help the community make progress together towards standardisation and to help interface 2-IMMERSE software with industrial systems.

4.1 Open source ecosystem

Openness of software projects can range from closed at one end, as a "publishing mechanism" in the middle, to a fully "open development method (ODM)" at the other end.

There is a strong case for following a truly open development method in order build a successful community. ODM is therefore a model to aspire to in the long run, but it starts with publishing closed source software under an open source license, primarily to disseminate results.

4.2 The 2-IMMERSE open source roadmap.

The initial goal of open source publishing is to make the code open to inspection and peer review, increasing the number of people looking at it and harnessing a wider range of insight and expertise from outside the original consortium of partners.

A pre-requisite is to define a governance model which involves formalising contribution arrangements in a concise way and capturing this knowledge to help newcomers. The 2-IMMERSE governance model is expected to evolve as outlined below:

Consortium governance -> Open source publishing -> Benevolent leadership -> Consensus-based democracy -> Open Development Method (ODM) / meritocratic governance model.

The goal is to change the decision-making process from a centralised model to one where more people are willing to contribute to the goals of the project. Having attracted a larger group of developers and users interested in the value of the software, the challenge shifts to community management and ensuring the quality of contributions, whilst retaining contributors through continued engagement and support. Cultivating the community of users is an ongoing activity.

A document describing the governance roadmap is available in the https://github.com/2-IMMERSE/get-started.git repository.

The 'get-started' repository is being augmented with further documentation, tutorials and deployment configurations to help attract and retain a bigger community.

4.3 Community Management

We expect community management to be active, informal, and low-key. The job of the community managers is to proactively encourage contributions and ensure their quality.

The BBC are responsible for administrating the 2-IMMERSE Github organisation on behalf of the consortium, with additional consortium partners having administrative ("Owner") permissions. GitHub recommend giving "Owner" permissions to a small group of people who will manage the organization account.

Initially people outside the 2-IMMERSE GitHub organisation will have read-only access to the repositories and are required to submit pull requests to contribute their changes as is the convention with open source contributions.

4.4 2-IMMERSE at TVX 2019

A significant event that relates to promotion of the 2IMMERSE results is TVX 2019 hosted by BBC in Salford, UK from 5-7 June. https://tvx.acm.org/2019/

BBC, in conjunction with other ex-consortium partners will be demonstrating the open source software stack, promoting the open source community and communicating progress towards successful adoption. It is an opportunity to evangelise the benefits and to spread the word about the ecosystem of contributors with a view to attracting more users.

5. 2-IMMERSE implications for standards

What are the implications for standards both old and new ones?

The 2-IMMERSE project defined how novel multiscreen experiences for consumers can be realized. It has evaluated the impacts on the architecture of such a platform, how it changes production tools and workflows and how various types of end consumer devices can be targeted for a 2-IMMERSE experience. In short, the project believes that there is no general lack of open standards to realise and deploy immersive multiscreen services. Though, for some issues there is potential for improvements in standards but in the first place it is a matter of content providers making use of existing technology and that includes existing standards. The following highlights a specific across the 2-IMMERSE architecture and platform, and references are made where these can be found in the 2-IMMERSE documentation.

5.1 Consumer device specific aspects

At the consumer side 2-IMMERSE made use of off-the-shelf devices, like tablets, smart phones but also evaluated other platforms like AR-glasses (which only slowly find their way into consumer stores). Those devices run operating systems that are driven by the de-facto standards Android and iOS, however, 2-IMMERSE was mainly using Web technologies which are standardized in W3C. Existing browser implementations on the selected mobile devices have proven suitable to run all the scenarios defined for the 2-IMMERSE platform. Also, these platforms are relatively open for content providers via the manufacturer's application stores, i.e. getting started with 2-IMMERSE-like offerings on those devices is not prevented by missing standards. A description of the client implementation can be found in the various deliverables of WP2, specifically in D2.3, D2.4 and D2.5.

For TVsets including STB, many European broadcasters (and those in many other areas of the world too) are pushing the HbbTV specification as the platform to deliver their Internet based services. HbbTV v2 adds required features for the 2-IMMERSE architecture for device discovery and media synchronisation of multiple A/V and data streams. The lifetime of 2-IMMERSE was ideal to support the introduction of first devices and services by exploiting know-how and technology. The MotoGP showcase has been shown on one of the first available HbbTV 2 devices in the market. The evaluation report of this validation activity is available in D2.5 and aspects on standardisation in D6.3.

While there are limitations on existing devices, e.g. the support of multiple video decodes to allow for PIP scenarios, this is not a standards problem. HbbTV defines since its first version how terminals can support and signal the availability of such decodes, but so-far manufacturers don't see additional commercial value that justifies the implementation efforts. It is up to the content providers to convince manufacturers of that feature and its value for both sides the consumer and the broadcaster. Beside that HbbTV members including BBC and IRT are active on improving the specification, especially to keep it up-to-date with emerging or missing web technology, like W3C MSE/EME, WAVE/MPEG CMAF or new codecs like AV1.

5.2 Architecture aspects

2-IMMERSE evaluated a number of existing open and de-facto standards for its architecture. For instance, a list of candidate technology for the initial 2-IMMERSE platform, mostly based on standards, can be found in D2.1. One draft specification, namely MPEG-MORE, included a number of concepts that were either already considered in 2-IMMERSE or were adopted later as they provided the solution for issues experienced in the early trials, e.g. bandwidth orchestration. Detailed analysis of MPEG-MORE and its relation to 2-IMMERSE can be found in D6.2 and D6.3.

At the end of the project, 2-IMMERSE extracted a Reference Architecture (RA) for Distributed Media Application (DMApp) systems from the analysis of representative DMApp platforms including the 2-IMMERSE service prototypes (see 2.6). The RA defines a taxonomy of the main concepts, their responsibilities, and their relationships, thereby fixing the nomenclature of the domain. It also provides a generalisation of the functionality required for multi-device object-based media orchestration as behavioural patterns and architectural abstractions/elements. These behavioural patterns were identified from grouping and generalising common functionality and then associating these with architectural elements. These elements, their functions and their interactions form an abstract architecture pattern for the DMApp domain. This pattern is free from technology choices, specific standards and deployment strategies. It is a useful template for synthesising concrete architectures that are tailored to suit an organisation's requirements and implementation strategies.

The RA provides an abstract API specification for each architectural element, thereby standardising which functionality is encapsulated within each element and how that functionality can be invoked. Future DMApp platform-building exercises can therefore use the RA as an initial blue-print and specialise it to suit their requirements and constraints.

It is expected that RA-compliant DMApp systems will be broadly compatible, potentially leading to scenarios where a Timeline Orchestrator from one DMApp system replacing the same element in another DMApp system. The Orchestration elements are sufficiently self-contained as to create the opportunity for third parties to provide alternative implementations. Further standardisation of the Orchestration elements will be required, in this case, to ensure strict functionality adherence and interoperability.

The RA can be used by partners and third parties as a starting point to define new or may adapt existing specifications, e.g. for the next generation of BTSport's delivery platform to broadcast Football, MotoGP and other events in an object-based manner.

5.3 Platform aspects

2-IMMERSE has chosen a micro-service-based architecture and Docker-based containerisation to realise the services. This allowed us to easily move our platform services across PaaS and IaaS layers without changing the microservice design, as well as our use of de-facto standard industry tools and services and practices. The 2-IMMERSE platform microservices are:

- Encapsulated using Docker as the de-facto containerisation standard, thus are portable to any major cloud infrastructure.
- Self-contained: i.e., they are not tightly coupled with any particular platform and use services that can be hosted on any cloud infrastructure, e.g. Consul, MongoDB, that also eases migration to another platform as exercised within 2-IMMERSE.
- Installed using docker-compose scripts, which simplifies deployment to different infrastructure

The containerisation technology is defined and standardised by the Open Container Initiative by major companies in the cloud business including CISCO. This activity will even improve and further mature the technology.

Please refer to the deliverables of WP2 for further details and its evolution through the project.

5.4 Production tools and workflow aspects

The TV production industry relies upon a host of technical standards to enable interoperability within the complex workflows which exist for both broadcast and offline production. The industry is also beginning to transition to all-IP production environments, and new standards are developing as the supporting technology evolves.

2-IMMERSE made use of certain broadcast production standards and specifications during the development of its service prototypes:

- For the live end-to-end tests of object-based broadcasting for football carried out at Wembley Stadium, the components deployed on site needed to receive live camera feeds in HD-SDI format from the BT Sport production truck. Technical specifications, picture and sound quality requirements and delivery requirements for BT Sport programmes are defined in conjunction with the Digital Production Partnership (DPP), a UK trade body which promotes common standards among its members. BT Sport's DPP specification was referenced in deliverable D2.1 and informed the design of our solution for the live end-to-end tests at Wembley, which was described in detail in deliverable D4.6.
- For the MotoGP and Football service prototypes, supplementary data feeds provided by Opta Sports were integrated to enhance the personalised multi-screen experience. Again, this required an understanding of a third party specification which is widely used within the industry.

Looking forward with the benefit of the insights gained during the 2-IMMERSE project, there is scope for certain broadcast standards and specifications to recognise object-based broadcasting use cases, as the need grows for interoperability between broadcast professionals implementing object-based approaches. The international industry forum AMWA (the Advanced Media Workflow Association) has developed the Networked Media Open Specifications (NMOS) to enable better integration between software systems and devices in the move towards all-IP production. It is feasible that live production elements of the 2-IMMERSE Reference Architecture could be implemented using AMWA

NMOS Interface Specifications, and that an AMWA Application Specification could potentially be created to address object-based broadcasting requirements.

6. Publication of this report and relevant material

The recommendations coming from the lessons learned, the design principles identified, and the validation results are published on the 2-IMMERSE website to assist the uptake and use of the project results. www.2immerse.eu/guidance

These recommendations encourage people to use the project website to find the results at different levels in line with the stage "customers" are at in considering Object Based Broadcasting and the degree of technical information they want to see.

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For the detailed descriptions of our implementations and results please have look at our published deliverables

For the open source software and components produced by the 2IMMERSE project please look at our GitHub repository.

The impact on standards is available on the project website www.2immerse.eu/standards