FUTURE MODELS FOR LIVE EVENT BROADCASTING

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ABSTRACT

A move to IP throughout the content creation and distribution chain will help broadcasters exploit next-generation technologies such as 4G broadcast, virtual reality and immersive viewing spaces to provide audiences with richer and more compelling experiences. At the 2014 Commonwealth Games, BBC R&D applied its work on IP Studio and Object-Based Broadcasting to demonstrate an extensive end-to-end platform for live event broadcasting. This paper reviews this trial, and outlines recent work on proving the concepts demonstrated at scale through collaboration with industry partners and with programme makers. It further outlines an approach that allows production facilities to generate time aware media objects that can support next-generation consumer platforms.

INTRODUCTION

Profound change to the way media is produced, distributed and consumed is upon us. For live events, this offers new opportunities to provide audiences with richer and more compelling experiences. Next-generation technologies such as 4G broadcast, virtual reality and immersive viewing and listening spaces will allow audiences to enjoy an event as much as those at the venue (or possibly better than being there). Furthermore, the consumer will have a more personalised relationship with the production, receiving the content and data of interest to them, while still benefitting from a properly authored experience.

In the last few years, BBC R&D has been researching these themes, considering some of the potential changes to the nature of the content and the means to produce them, the means to deliver them and the means for the audience to enjoy them. Collectively, these advances can be thought of as parts of a New Broadcasting System.

The kinds of user experiences we have been researching fall into three categories:

- **Dynamic, responsive & personal content.** While linear, scheduled programmes will continue, the content will exist in a form that is capable of being recapped and presented in a way that responds to the audience member, their time and context and the devices(s) they are using.
- **Audience as explorers.** It will be possible to capture a ‘digital space’ and give audiences the ability to explore that environment. New ‘media playgrounds’ emerge.
- **Co-creators & collaborators.** As production tools move into the Internet, it will be possible for everyone to access production environments. Broadcasters can

embrace this to widen our audience's involvement in our content.

Object-Based Broadcasting

A key concept in the realisation of these kinds of user experience is the handling of the constituent parts of the media as objects, where the individual media assets (whether live or recorded) may be addressed separately. Metadata describes the relationships and associations between various objects, to describe the editorial intent. At the point of consumption these objects can be assembled to create an overall user experience. The precise combination of objects can be flexible, and responsive to user, environmental and platform specific factors.

The characteristics and potential benefits of Object-Based Broadcasting and a case study is further described in (1)

This approach is applicable not only as part of an audience-facing delivery and presentation platform, but also upstream within a production environment. As part of its research into the New Broadcasting System, the BBC R&D IP Studio project (2)(3) has specifically been investigating how production media objects should be handled.

2014 COMMONWEALTH GAMES

To investigate the approach of the IP Studio project at scale, BBC R&D demonstrated a live ultra-high definition (UHD) outside broadcast made using end-to-end IP for the duration of the 2014 Commonwealth Games in Glasgow.

Live video and audio were delivered from three games venues to a public exhibition at the Glasgow Science Centre and broadcast via the department's trial of UHD distribution. As shown in Figure 1, this provided a test of a live production distributed across three UK cities and synchronised wherever it was needed for viewing and broadcast distribution. This enabled facilities and staff to be located according to operational need, and reduced the numbers required at each competition venue. For example, the audio production and commentary position were located in London.

Four UHD cameras operating at 3840 x 2160p50 were used to provide coverage of the games' opening ceremony, rhythmic and artistic gymnastics heats and finals, and boxing and netball finals. This was separate to the main HD programming provided by the host broadcaster, SVGTV.

Extensive use was made of BBC R&D's software framework developed by the IP Studio project. Each camera was connected to a local IP Studio video **capture node** via a quad 3G HD-SDI link. Each capture node was configured to provide two multicast RTP flows using H.264 I-frame only compression: a primary UHD flow at 800 to 1200 Mb/s, and a down-converted HD proxy flow at 100 Mb/s. Audio capture nodes produced uncompressed audio flows from the host audio feeds supplemented with additional local microphones.

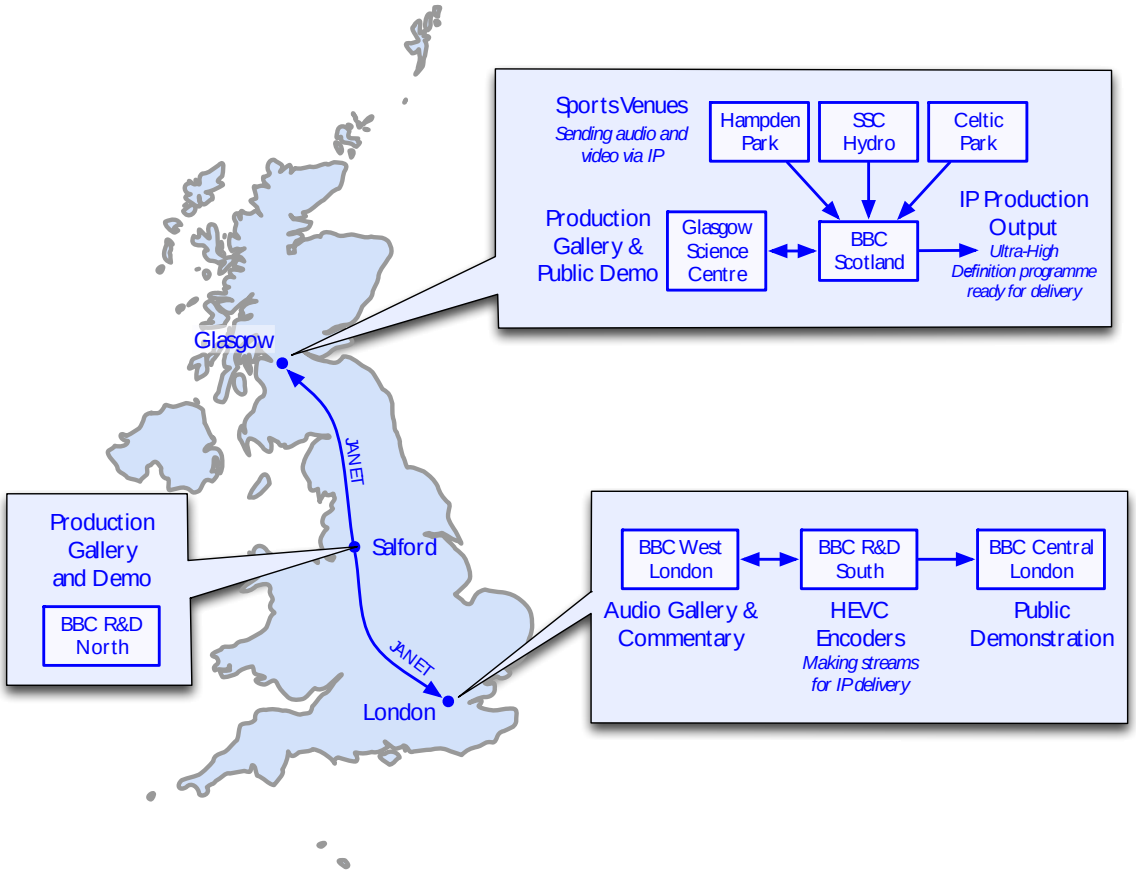

Figure 1 - End-to-end IP production for 2014 Commonwealth Games

In each production gallery (Figure 2), staff selected and viewed the required flows on **multiviewer nodes**, and used browser-based user interfaces to configure and monitor the production's operation. The director operated a software **vision mixer node** through a touch-screen.

Figure 2 – Glasgow production gallery, showing touch-screen vision mixer

To demonstrate the possibility of a multi-resolution or multi-format architecture, only the proxy (HD) flows were used in the production galleries, and operations on the primary (UHD) flows were performed in a technical area at BBC Scotland. The cut decisions taken by the director were "live-conformed" with frame-accuracy, to produce the main programme output as a new multicast UHD flow, which was received in the demonstration and distribution areas.

The programme output was then broadcast using both DVB-T2 and DVB-DASH at 35 Mb/s Main Profile HEVC to a number of prototype UHD receiver implementations as part of R&D's trials of UHD distribution (4), also used for coverage of the 2014 World Cup. These were carried out in collaboration with Arqiva and BT.

At times where no live event was happening, a previously created programme flow was replayed from an IP Studio **sequence store** at BBC Scotland. Sequence stores were also used to hold the individual camera and microphone flows, both temporarily at the capture location, and longer-term at BBC Scotland.

Network connectivity within each city made use of dark fibre provided by Virgin Media Business and the host broadcaster, and between the cities via Cisco 100 Gb/s interfaces onto the Janet6 academic network. Source-specific multicast was used both within and between cities; however each city had its own PTP distribution and grandmaster clock, with GPS used to synchronise the cities.

The IP Studio platform and network connectivity allowed BBC R&D to demonstrate new content experiences in the Glasgow Science Centre:

- **Venue Explorer** (5)(6) allowed the viewer to interactively explore a UHD panoramic view of the athletics stadium and zoom into see more detail, sending only the pixels from the area of interest, and adapting the audio and graphics to suit the area of interest (Figure 3).
- A **live 360-degree** demonstration (Figure 4) streamed video from a 360-degree camera mounted close to the gymnastics performance area, together with spatial audio from around the stadium to provide the viewer an immersive experience via a VR headset.
- A **high frame rate** demonstration (7) used a 4k HFR camera (typically normally used for slow-motion playback) with a Barco projector capable of 100 frames per second to allow visitors to see the improvements in motion portrayal that could be achieved at higher frame rates.
- A **live 4G broadcast** demonstration streamed event coverage using MPEG-DASH and LTE eMBMS, a mode defined by the LTE specification for one-to-many service for 4G mobiles. This was carried out as part of the UK's first technical trial of eMBMS, in collaboration with EE, Huawei, and Qualcomm, and informs part of R&D's wider work on broadcast to mobiles (8).

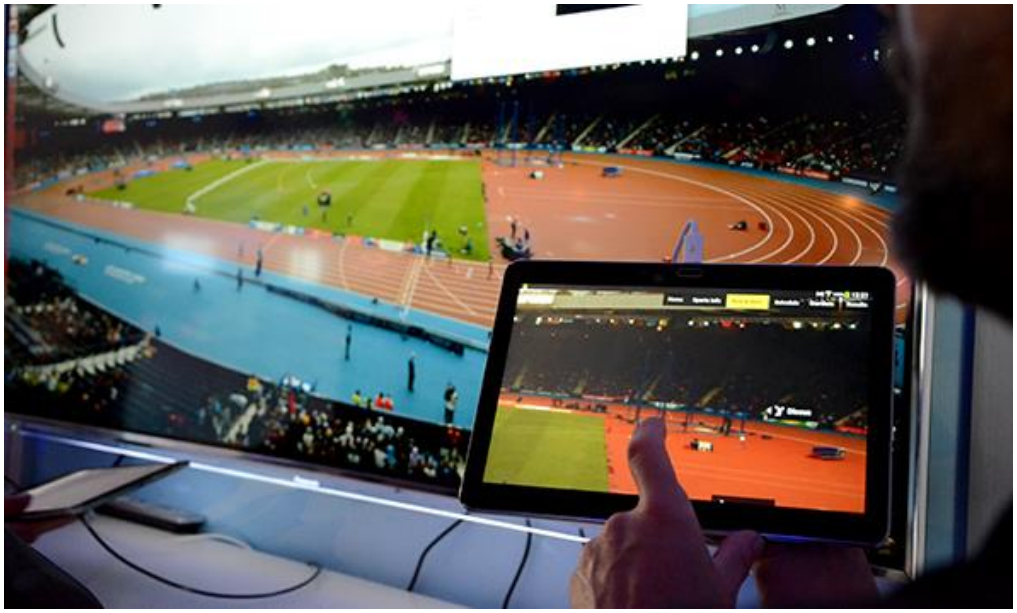

Figure 3 – Venue Explorer

Figure 4 - Live 360-degree viewing

Further information on the Commonwealth Games trial can be found at (9).

MODELS FOR DEPLOYMENT

The Commonwealth Games trial showed an architecture in which both the production control surfaces and processing were geographically distributed. However, IP also enables other architectures, such as virtualised facilities located in a central data centre and controlled remotely from production sites, an approach now being adopted by the BBC for local radio (11). Factors that should be considered in choosing a deployment architecture include:

- The number and location of production facilities
- Cost, speed and resilience of network connectivity
- Latency requirements, for gallery operations, and for the programme output
- Whether the facilities are temporary (e.g. for an event) or permanent
- Patterns of usage though the day; for example, news production makes most demand around the time of evening bulletins
- Availability of, and requirement to use, existing infrastructure

INTEROPERABILITY

The trial demonstrated how an all-IP approach could make live event broadcasting more flexible for the programme maker and more exciting for the audience. For this to become a reality beyond the research environment, it is essential that interoperability can be achieved for IP-based production and broadcast equipment. BBC R&D has identified the following areas as of particular importance:

- **Essence formats.** SDI's rigid payload structure has previously made uncompressed video the norm within facilities, but IP allows formats to be chosen to suit network 'sweet-spots' and to meet differing production scenarios. These can encompass lossless or visually lossless compression supporting low latency operation, as well as multi-format operations such as the primary-and-proxy approach used for the Commonwealth Games.
- **Transport protocols.** Multicast RTP is typically suitable for low-latency use for a live production facility. However, other transport protocols, for example HTTP, better suit access to stored content, so the choice of protocol must be decoupled from the essence format.
- **Identity.** The "flows-and-grains" approach described in (3) provides a flexible means to uniquely identify any element of production content, both in a live or recorded context, in a way that can be mapped to different transport protocols.
- **Flow packages.** Flows can be grouped together into 'flow packages' that identify bundles of co-timed content of editorial value to a production. Unlike traditional editing 'clips' these are not tied to a particular file-based approach, but provide the downstream systems creating new user experiences with a means of finding and accessing content at a suitable granularity (see Figure 5).
- **Network based timing.** The Commonwealth Games trial demonstrated synchronisation of a significant wide area production using grain-based timestamps and PTP. Interoperability will be achieved through standardisation of time labelling and the PTP parameters that should be supported by the network infrastructure, for example that specified by SMPTE's PTP profile (10).
- **Automated configuration.** Networked devices must be usable without manual intervention. This becomes particularly important where devices are created on-demand through virtualisation. This requires an interoperable approach for registration of devices and their resources, and for how control applications find this information.

- **Security.** Transport protocols, flow package access APIs, timing infrastructure and configuration interfaces are all vulnerable to attack, so interoperability specifications must consider security aspects.

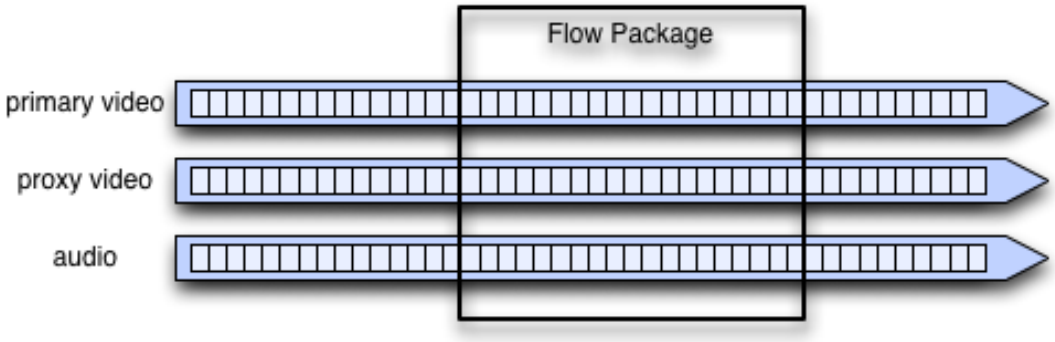

Figure 5 – Example of a flow package

As the broadcast industry starts to adopt IP, we are increasingly seeing multiple incompatible specifications. There remains the need for genuinely open specifications that are supported by multiple manufacturers. BBC R&D is active in promoting the above model for interoperability within the industry, for example the Joint Task Force for Professional Networked Streamed Media (12).

FURTHER EXAMPLES AND TRIALS

Audio objects and spatial data, multiple rendering

Through collaborative research projects S3A (13) and ICoSOLE (14), BBC R&D is investigating the application of IP-based systems to object-based audio production. Audio objects describe their own spatial position and level in the mix, making the content independent of the speaker configuration. The rendering of the mix to the speaker configuration is performed in the listening environment rather than as part of the production process. Importantly, this also allows adjustments to be made at the point of consumption, for example to adjust the relative level of music and dialogue.

As part of the Sound Now and Next event (15), a specially commissioned 3D object-based audio drama was played out from BBC R&D's North Lab in Salford and streamed in real time over an IP network to Broadcasting House in London. The 64 audio objects, comprising audio and associated metadata, were rendered locally to a speaker system consisting of 17 loudspeakers surrounding the audience, arranged in 3 layers, augmented by two subwoofers (Figure 6). A web-based graphical control application was used in the auditorium to modify the mix.

Figure 6 - BBC Sound Now & Next

BBC Northern Ireland remote production trial

A trial with BBC Northern Ireland is providing experience of IP based production on existing BBC infrastructure, using PTP network clocks on an enterprise scale for synchronisation of media in a distributed production environment. As well as offering a cost-effective solution for live coverage from a remote site, this work will help to inform future directions for infrastructure provision and network architectures.

NewsLabs

Working with BBC NewsLabs (16), the IP Studio team is exploring how flow packages can be used in conjunction with web-based linked data technologies to build richer user experiences. Each flow package can be linked semantically with other content and concepts through its unique identifier. Next generation production tools for journalists provide ways of surfacing content based on topics and tags, assembling flow packages into sequences. Flow packages can be generated on the fly from incoming live content, enabling fast turnaround and repurposing of the media across multiple platforms.

CONCLUSIONS

This paper has presented models for future live event broadcasting which offer new user experiences for the audience and take advantage of the ubiquity and flexibility of IP networking approaches.

The public demonstrations staged by BBC R&D at the 2014 Commonwealth Games showed that a large-scale live sports production across multiple locations is possible at UHD resolutions, using IP and an open approach.

Although standardisation efforts have been underway for some time, the number of different incompatible approaches in the marketplace is increasing, which will clearly

present barriers to adoption by the user community. The need to agree and adopt common approaches is becoming ever greater.

It is important that the broadcast industry grasps the opportunity to fully leverage the power of the Internet in mapping out common approaches to the replacement of current infrastructures. In so doing we unlock the capability to produce vibrant and compelling user experiences that will remain relevant in a fast-changing media landscape.

REFERENCES

1. Shotton, M. et al, 2014, Object-based broadcasting - curation, responsiveness and user experience, , Proceedings of the International Broadcasting Convention, September 2014, www.bbc.co.uk/rd/publications/whitepaper285
2. BBC R&D, IP Studio project, www.bbc.co.uk/rd/projects/ip-studio
3. Brightwell P. et al, 2013, The IBC Studio, Proceedings of the International Broadcasting Convention, September 2013, www.bbc.co.uk/rd/publications/whitepaper268
4. Layton, P., 2014, BBC R&D Ultra-High Definition Trials, BBC R&D blog post, 20 June 2014, www.bbc.co.uk/rd/blog/2014/06/bbc-r-d-ultra-high-definition-trials
5. BBC R&D Venue Explorer project www.bbc.co.uk/rd/projects/venue-explorer
6. Gregory-Clarke, R. et al, 2014, Immersive Live Event Experiences - Interactive UHDTV on Mobile Devices, BBC R&D White Paper WHP284, September 2014, www.bbc.co.uk/rd/publications/whitepaper284
7. Pindoria, M., 2014, BBC R&D blog post, 28 August 2014, www.bbc.co.uk/rd/blog/2014/08/higher-frame-rate-television-for-future-broadcasts-at-the-commonwealth-games-but-i-already-have-a-100hz-tv
8. BBC R&D 4G Broadcast project, www.bbc.co.uk/rd/projects/4g-broadcast
9. Rawcliffe, A., 2015, Covering the Glasgow 2014 Commonwealth Games using IP Studio, BBC R&D White Paper WHP289, March 2015, www.bbc.co.uk/rd/publications/whitepaper289
10. SMPTE, 2015, ST 2059-2:2015, SMPTE Profile for use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications
11. BBC Media Centre, 2014, BBC introduces ‘virtual’ Local Radio stations, www.bbc.co.uk/mediacentre/latestnews/2014/virtual-local-radio-stations
12. EBU/SMPTE/VSF Joint Task Force on Profesional Networked Stream, www.videoservicesforum.org/jt-nm
13. S3a Future Spatial Audio project, www.s3a-spatialaudio.org
14. ICoSOLE project, icosole.eu
15. BBC Sound Now and Next, May 2015, www.bbc.co.uk/rd/events/sound2015
16. Shearer, M., 2013, BBC News Lab: Linked data, BBC Internet blog 28 January 2013, www.bbc.co.uk/blogs/internet/entries/63841314-c3c6-33d2-a7b8-f58ca040a65b