5G FOR BROADCASTERS – NEW OPPORTUNITIES FOR DISTRIBUTION AND CONTENT

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ABSTRACT

This paper describes trials carried out by the BBC and associated partners in the areas of distribution and content generation using 5G technologies and examines the future role that 5G could have in broadcasting.

The 5G RuralFirst project represents the first public trial of 4G/5G technology for live broadcast radio – a medium for which delivery to mobile devices and vehicles is particularly important. It provides insights on the requirements for a useable and attractive service and the technical results are being used to inform inputs into standards for future mobile developments.

The 5G Smart Tourism project examined the types of media experiences that 5G could make practical as new enhanced network capabilities become available to broadcasters.

The results of these projects are presented and the emerging requirements for future 5G deployments are explored.

INTRODUCTION

As the Internet becomes increasingly important to deliver the BBC's programmes and services, it is vital that everyone in the UK has good access, regardless of where they live, to enable them to receive existing TV and radio services and also to benefit from opportunities for new experiences.

5G is the latest mobile technology development and promises significant improvements in quality of service, spectrum efficiency and seamless connectivity. Practical concerns remain on the economics of rural deployment and the precise benefits that 5G will offer to broadcasters for programme distribution and content production.

A number of mobile technologies have previously been proposed for delivery of broadcast content to mobiles, including DVB-H and DVB-NGH. However, these have not been universally supported in handsets and the networks to support reliable delivery have not been deployed. 5G technologies are expected to be universally supported in mobile terminals and thus provide broadcasters with an important new opportunity to deliver future services.

5G also has potential to transform the types of services that broadcasters can deliver. Emerging technologies such as Mobile Edge Compute (MEC), network slicing and heterogenous network orchestration have the potential to support Virtual Reality (VR), object-based broadcasting and a move from traditional broadcast services towards wholly IP delivery that enables new content and user experiences.

This paper details initial trials undertaken by BBC R&D as part of collaborative projects with industry and academia. The projects have explored areas of distribution and content to help understand the benefits of 5G to broadcasters. While the trials explore the benefits that full 5G could bring, the current lack of commercial equipment means that certain elements had to be implemented using pre-5G and Wi-Fi technologies supplemented by an enhanced modem developed in-house. The individual capabilities of all these would be brought together within a future 5G system.

5G RURALFIRST

Overview

As part of the 5G RuralFirst project (1), we have been working on a 5G Broadcast Radio trial, testing 4G/5G broadcast to deliver live radio services directly to members of the public. This work represents the first public trial of this technology targeting radio and builds on our previous demonstrations of 4G broadcast (2). The delivery of radio is of particular interest in the context of 5G since radio is a naturally mobile medium and a significant proportion of listening is in vehicles and on the move.

5G RuralFirst is one of six projects funded under the UK Government’s 5G Phase 1 testbeds and trials programme (3) and aims to demonstrate new approaches to the deployment of connectivity in rural areas, which traditionally suffer from poor coverage and low bandwidth on both fixed and mobile networks. The project targets a number of use-cases ranging from farming and fishing to Internet of Things (IoT) applications.

Traditional unicast distribution of broadcast content to mobile devices on 3G and 4G networks has a number of limitations. In urban and suburban areas, unicast is wasteful of resources as multiple copies of the same data are sent to each terminal, which ultimately leads to network congestion and a poor user experience. In rural environments, it is not usually cost effective to deploy a dense network of mobile base stations, so the coverage tends to be uplink limited. As a consequence, the cell sizes supported for unicast delivery are typically smaller than for broadcast delivery using the downlink alone.

The aim of the trial is to investigate the role that 5G could have in delivering BBC services to areas that have traditionally been hard to reach and to understand the benefits 5G could bring beyond super-fast connections in densely populated areas.

The 5G Broadcast Radio trial comprises two parts; a public trial based on commercially-available 4G equipment and the in-house development of a standalone ‘5G broadcast’ modem that implements the latest mobile broadcast features that won’t be available in commercial handsets until they support 5G.

The Public Trial

Figure 1 – Location of Stronsay, Orkney

The public trial is based on the island of Stronsay in Orkney, off the coast of Scotland. It was chosen because it currently suffers from limited fixed broadband, little or no mobile signal and poor digital radio (DAB) coverage.

Thirteen live radio stations are being transmitted, including the local service BBC Radio Orkney, over a 4G broadcast mode (eMBMS). In addition, participants are offered conventional mobile Internet access. This allows us to demonstrate the benefits of broadcast for live services alongside unicast for catch-up and on-demand.

Although our implementation relies on 4G technologies, by using our own dedicated frequency allocation and providing SIM cards at no charge to the users, we have been able to emulate the types of broadcast features we would need to rely on in 5G broadcast such as stand-alone transmissions and free-to-air reception.

A broadcast-capable mobile network has been built from the ground up, giving complete control over transmission settings and allowing them to be varied to assess performance in different situations. Participants are provided with a broadcast-enabled smartphone with a ‘BBC 5G Radio’ App to access the live radio services.

At the time of writing, the trial is on-going with further detailed data analysis still to be done. An extension to the project has been approved and, as well as collecting further data on system performance with different transmission parameters, the aim is to connect to the project’s 5G core and explore opportunities in programme contribution & production.

Base station engineering

A Software Defined Radio (SDR) architecture was selected for the experimental base station to maximise flexibility and to provide an upgrade path for emerging 5G New Radio (NR) technologies. The RF engineering, however, presented some significant challenges, particularly for the intended rural application.

It is desirable to maximize the cell size in rural broadband to reduce the infrastructure costs and the link budget for the uplink proved particularly important. For LTE systems, the handset power is limited to 23 dBm Total Radiated Power (TRP) and terminals typically detach from the cell at a carrier to noise ratio of 0 dB. Good SDR noise performance is thus vital to achieve sufficient sensitivity and range.

A further issue is the performance of the duplex filters and the isolation between the transmitter and receiver ports. Careful design is required to ensure broadband noise from the power amplifier does not degrade the uplink receiver noise floor. Low insertion loss is important to retain uplink noise performance. A cavity filter with 100 dB isolation and 0.5 dB insertion loss was specified for the trial.

Laboratory tests revealed the SDR had a noise figure of 7 dB, which together with the duplexer insertion loss and feeder loss raised the noise floor to -99 dBm / 5 MHz. The associated link budget revealed that the maximum path loss would be limited to 128 dB on the uplink compared to 142 dB on the downlink. These figures were confirmed by laboratory tests using the arrangement below.

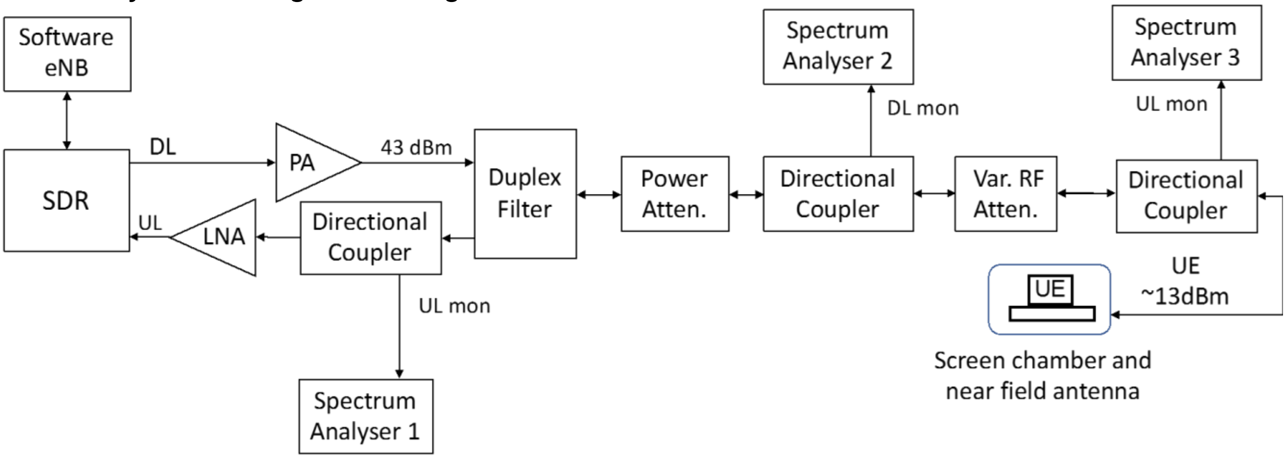

Figure 2 – Laboratory test arrangement for conducted RF tests

A 6 dB reduction in maximum path loss corresponds to a halving of the mobile cell size which is undesirable for rural deployments. A high-performance Low Noise Amplifier (LNA) was selected with a low noise figure (0.5 dB) and 16 dB gain. This improved the overall system noise figure to 1dB, thus reducing the discrepancy between the uplink and downlink budgets. The lab testing can be seen in Figure 3 below.

Figure 3 – Lab testing of the base station and the broadcast-capable handsets

Deployment

An omni-directional antenna was installed at Stronsay Junior High school by project partners CloudNet who also provided the Internet backhaul using a wireless link from the neighbouring island of Shapinsay. The school was an ideal site given its location on a hill at the centre of the island. Initial coverage predictions indicated that the majority of the island could be covered by a single base station.

The base station equipment itself was installed in the loft space close to the antenna to minimise the length of RF feeders and related signal losses. It consisted of an eNodeB, a stand-alone mobile core network and the necessary broadcast core network components. The live audio streams were delivered over MPEG-DASH direct from Audio Factory (4), the BBC's production audio streaming system, over the backhaul. In addition, components were added to enable remote monitoring and configuration.

Community engagement was vital to the success of a public trial such as this. We therefore worked closely with partner Orkney Islands Council in the initial discussions around the choice of Stronsay as a location, organised meetings with the local community council and hosted a public meeting to explain the trial as well as 5G more generally. The trial was launched in mid-February and, ahead of this, a publicity campaign was carried out to recruit potential members of the public to take part. They were then shortlisted and invited to meet us at drop-in sessions to sign-up and collect their phones.

Application development

A 'BBC 5G Radio' Android application was created to allow trialists to consume the live BBC radio services over broadcast. It implements a simple user interface for discovering and controlling the playback of streams and supports background audio to enable multitasking between applications whilst still listening to the radio.

The app gathers data about the quality of the service being provided and users' consumption patterns. Client-side telemetry reports playback events such as streams starting, stopping, buffering or failing. Information about the user's geolocation, signal strength and quality are transmitted with these in order to understand the performance characteristics of the network in different parts of the island.

There are also inbuilt mechanisms to communicate with the trialists; a server-driven messaging channel to inform them about developments and a send-email action to encourage qualitative feedback.

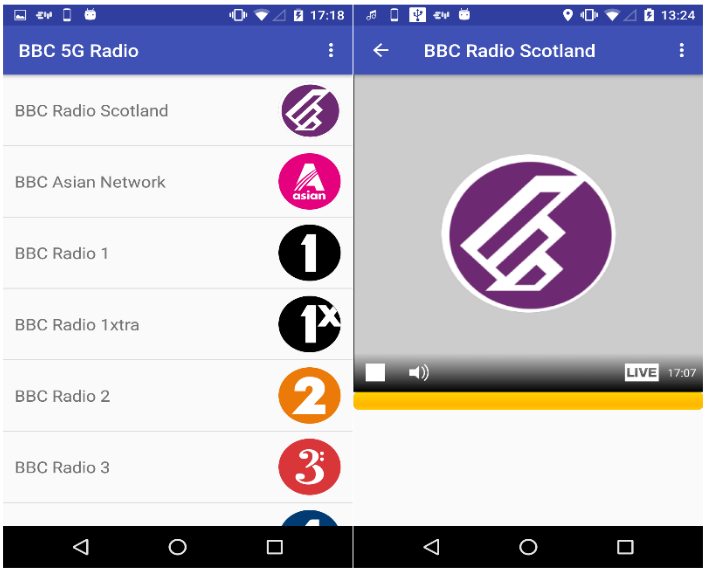

Figure 4 – The 5G Radio app

It was important to demonstrate the playback of the broadcast streams using existing BBC infrastructure where possible. The BBC Standard Media Player (SMP) is a shared library for consuming MPEG-DASH content on the Android platform. For use in the 5G Radio app, it had to be extended to handle broadcast streams via a third-party 5G broadcast component that surfaces the service as a locally-hosted MPEG-DASH stream. The modified SMP was also subsequently integrated into a custom BBC Sounds build to validate that there were no architectural or technical barriers to its adoption in production applications and to demonstrate the possibilities of broadcast and unicast working together seamlessly to deliver live and on-demand audio respectively.

Results

During the trial, quantitative and qualitative data are being collected via the recording of technical telemetry information from the handsets and a cycle of audience research respectively.

A database server and a related web application were developed and used to collate the detailed telemetry data reported by the handsets as people listened to the radio services. This enables us, for example, to build-up an anonymised, crowd-sourced coverage map across the whole island and to assess the performance of different transmission parameters on the quality of service. Crucially, it allows us to make an analysis over a much longer time period and over a wider area than drive testing alone would allow and, because the data is coming from real-life handsets, gives us a much more accurate picture of how the technology works in practice. Some example initial data is shown in Figure 5.

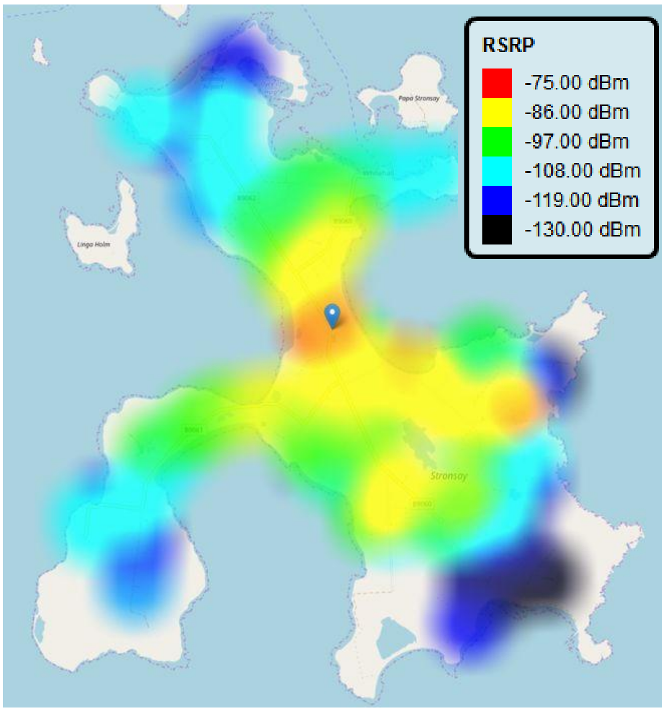

Figure 5 – An anonymised, crowd-sourced coverage map of received power (RSRP) from the base station (blue location pin)

Across the sixteen active handsets over the first five weeks of the trial, average broadcast listening was measured at just over two hours per day, which would be the equivalent of around 1.5 GB of data over a month (had the radio services been delivered by conventional unicast rather than broadcast). This a very significant proportion of the average monthly mobile data per active connection in the UK of around 1.9 GB per month (5) and would leave little allowance for other uses.

In terms of the audience research, pre-trial it was clear that Internet use was already a part of daily lives for the trialists, but that online activities are currently limited by low speed and unreliable Internet connections. Almost all trialists listen to radio services daily, but face challenges in terms of the reception quality and reliability of reception available.

There has generally been a very positive response to the trial service and its impact, amidst a backdrop of dissatisfaction with existing Internet and radio options. Almost all (around 9 in 10) were satisfied with the trial Internet service, with a similar number feeling that it has lived up to their expectations. While signal strength varies in relation to proximity to the antenna, over half of participants described the trial phone Internet as faster than previous options, with around two thirds feeling that it is more reliable.

Furthermore, there is widespread satisfaction with the quality of signal and the range of listening options provided by the 5G Radio application. While listening habits broadly reflect trialists' existing service preferences, there is evidence of a broader repertoire of stations being listened to via the trial app. There is increased use of digital-only stations (e.g. Radio 1Xtra, Radio 4 Extra), with the limited reliability of DAB previously forestalling use. Those preferring the trial radio app to previous alternatives cited its greater reliability (‘less wiggling of aerials’), the flexibility to listen on the move and the variety of stations.

5G Broadcast Modem

In order to go beyond what is possible with currently-available commercial equipment, we have developed a complete LTE-based (FeMBMS) hardware implementation of a broadcast transmitter and receiver that is compliant with Release 14/15 of the 3GPP specifications (6) including the Cell Acquisition Sub-frame (CAS) and the ability to dedicate 100% of the available capacity for broadcast. We use the transparent mode to carry IP programme streams directly across the RF link.

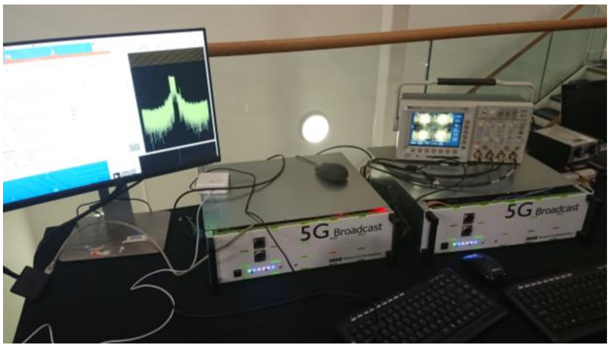

Figure 6 – The 5G Broadcast hardware modem

All the signal processing is running on a Field Programmable Gate Array (FPGA) using firmware developed in house. This means our solution is very power efficient compared to a software approach and allows us to incorporate real time diagnostic and debugging functionality. This capability allows, for example, the testing in real equipment whether the performance of different aspects of the signal (such as the CAS) is sufficient. It also enables us to test modifications to the signal to see whether improvements can be made to broadcast that might be included into future releases of 5G standards such as physical layer Time Interleaving, improved Reference Symbol (pilot) patterns and MIMO.

Future Work

The extension to the 5G RuralFirst project has the potential to allow further optimisation of the technical parameters of the 5G Broadcast Radio Trial. In particular, the long duration of the MPEG-DASH audio segments, while optimised for unicast Internet delivery, results in start delays for the broadcast services that the audience research suggests is a significant concern for users. We also intend to better characterise the delays between the 5G broadcast services and analogue radio and to use the telemetry data to better understand the precise modulation and coding settings needed to deliver a reliable service at a given signal strength. The overheads of delivery of streams over 4G/5G broadcast are another area requiring additional analysis in order to refine the bit-rate of the broadcast bearers. Finally, the potential benefits from the broadcast coverage not being uplink limited are also to be fully determined.

The outcome of this work will steer our inputs into further standardisation work around 5G Broadcast systems in 3GPP Release 16 and beyond.

5G SMART TOURISM

Overview of the Application

Through the 5G Smart Tourism project (7), we examined how 5G might change the types of media experiences that would be practical on a mobile device and how they might enable the BBC to inform, educate and entertain in new ways. Working with the Roman Baths, in Bath (8), Aardman Animations (9), Bristol University (10) and CCS (11), we built and trialled an Android smartphone application that used the ‘Magic Window’ paradigm to show the user a ‘Virtual Reality’ (VR) alternative view of their physical location. The scenes displayed were historical reconstructions of important moments in the Baths’ history.

This approach has much in common with augmented reality, although showing a VR view rather than adding overlays to the live video from the user’s phone has advantages:

- There is no need for highly-accurate tracking of the device, it only needs to be good enough to let the user understand the relationship between the real world and the image on their screen;
- There is no need for the user to have a good image from their phone’s camera. They can use the app when they do not have a good view of the scene (e.g. when people are standing in front of them or when the scene is poorly-lit), and they can hold the device at a comfortable position, rather than having to frame an appropriate view.

The video that provided the VR view was streamed on request over the 5G network; it was not installed on the smartphone.

Using aligned-to-the-real-world 3D graphics, the app tells the story of three periods: the mythical discovery of the hot springs by King Bladud, the Baths falling into disrepair when the Romans left and the Victorian renovations. Each period was recreated by Aardman as an animated 3D scene that plays for several minutes, with interactive elements to encourage exploration. Each scene was designed to be viewed from a particular location in the Baths and was triggered when the user pointed their phone’s camera at a picture mounted at that location. The position and orientation of the user’s phone with respect to the trigger picture was used to set the initial orientation of the scene, and sensors on the phone tracked its pose from then on.

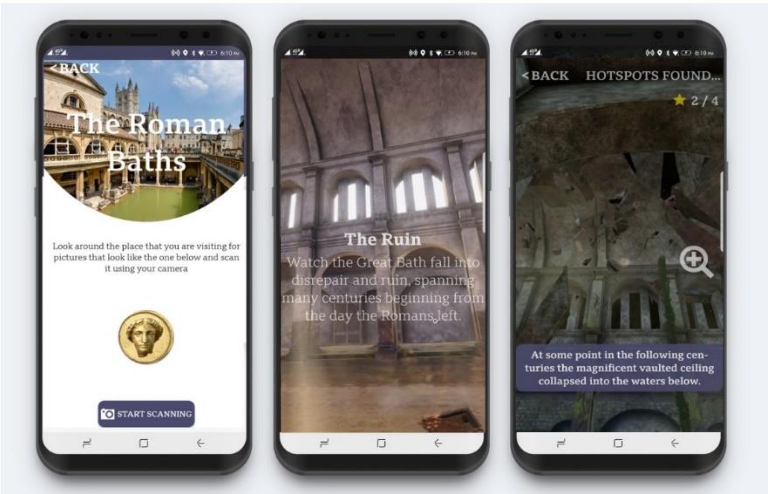

Figure 7 – Screenshots of the app

Trials

We undertook two sets of trials examining two different video content delivery methods. The first trial focused on delivering the scenes as pre-rendered 360° video (4k x 2k resolution) and the second trial tested the delivery of live, remote-rendered video.

For the 360° video, the scenes were encoded using H264 at several bit rates in the range 5-40 Mbit/s to allow an investigation of the trade-off between picture quality and loading/buffering time. A bit-rate of 10 Mbit/s was selected as it offered good visual quality with rapid loading time and no buffering on the project network with twenty simultaneous users on the same Wi-Fi access point.

The video was hosted on MEC (Mobile Edge Compute) servers in the 5G network, set up by the Smart Internet lab at Bristol University. The network was linked to the Baths using the UK's first 60 GHz mesh network, provided by CCS. The final link to the handsets used Wi-Fi, as 5G-enabled smartphones were not yet available. Technical data such as the loading/buffering times were logged, and user feedback was gathered via questionnaires and interviews.

For the second trial, a 'remote-rendering' version of the app was tested alongside the 360° version. To enable remote-rendering, the smartphone's physical pose was sent to a MEC server which used that information to render a 'live' view of the historical scene before streaming it back to the smartphone for display.

The key technological requirement for remote-rendering was to keep the delay between a user moving their smartphone and the view on their screen updating to a minimum. The same 60 GHz network described above was again provided between the Baths and Bristol's rendering servers. The final 'hop' between the 5G network and the smartphones used Wi-Fi, as in the first trials, although the 360° video version served to a subset of users was delivered over LTE-A, extending the range of technologies tested.

Figure 8 – Alignment between the modelled scene and the real world (close-up of trigger picture on left)

Bristol University provisioned ten virtual graphics-rendering PCs using OpenStack optimised for fast memory and GPU access. A cloud-based application assigned renderers to smartphones on demand.

Using Google's ARCore SDK and the trigger picture mounted on a stand, each smartphone could locate itself in the Roman Baths and then send its pose and control data to Bristol's graphics-drawing PCs. A Unity-based application on these PCs drew the appropriate VR view and a server application based on the NVIDIA Capture SDK (12) captured the framebuffer, encoded it as H264 video and streamed it back to the smartphone using the SRT protocol (13). This video was then decoded and displayed on the smartphone.

Overview of the trials

Key information about the trials is summarised in Table 1 below.

Date	10th/17th Dec 2018	15th March 2019	
Render technology	360° video	360° video	Remote Rendering
Wireless technology	60 GHz mesh; Wi-Fi to mobile devices	60 GHz mesh; LTE-A to mobile devices	60 GHz mesh; Wi-Fi to mobile devices
Video rate per user	10 Mbit/s	10 Mbit/s	5 Mbit/s
Total number of users	120 (60 on each evening, in 3 groups of 20)	31	22
Simultaneous users	20	10	10

Table 1 – Key information regarding the 5G Smart Tourism trials

The network was able to deliver throughputs greater than 600 Mbps with latencies less than 10 ms to handsets in the Roman Baths. The CCS nodes provided the trunk link between the Roman Baths and the Guildhall to the 5G network, which validated the IP/Ethernet end-to-end interoperability requirements. The live trial generated a large amount of high bandwidth video traffic which the 60 GHz mesh was able to deliver and latency over the mesh was maintained at less than 1 ms which is an important 5G performance indicator, setting it apart from existing 4G and LTE.

Figure 9 shows the median time for the three different (4K, 10 Mb/s) 360° video streams to start playing once triggered. The width of the coloured bar is the middle 50% of the data (the data between the 25th and 75th percentiles). The whiskers are set to 1.5x the width of that box centred on the median. Any point beyond them is considered an outlier.

The median start time for each 4K stream was around 1 s from the initial network request to the start of playback. There are a few outliers with start times of several seconds; analysis of the timing data and observation of the visitor movements suggested that these were due to users wandering out of network coverage when launching a video resulting in long delays or a complete failure to load.

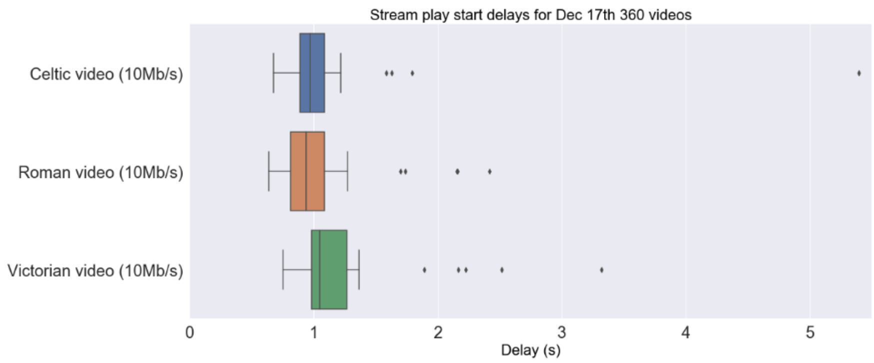

Figure 9 – Delay from requesting video from the server to play starting, for 360° video, showing median times, quartiles and outliers

To check whether the roughly 1 s delay to load a video was considered acceptable by the users, the in-app questionnaire included the question “How did you find the delay in starting the historical reconstructions after scanning the picture with the phone?”. 24 out of the 40 trialists rated the delay as “fine” (the top scoring option) with a further 13 indicating the one-from-top option, i.e. 92 % of users were satisfied with this response time.

For the remote-rendered video, the phone-movement to screen update delay was ~200 ms. User feedback confirmed that this is acceptable for a hand-held VR experience, but it would be too long for a headset-based application.

CONCLUSION

While it is clear than 5G services will become a reality, there is still much work to do to understand the full implications of the technology to broadcasters. 5G is at an early stage of standardisation and deployment, so there are exciting opportunities to influence its development to suit broadcasters.

From a distribution perspective, the 5G RuralFirst project has demonstrated that 4G/5G broadcast modes can deliver a service that is popular and highly regarded by users. Triallist feedback indicates a clear benefit to having a choice of broadcast radio services conveniently available through a smartphone application.

While 5G is likely to have an impact on all aspects of media delivery, it will have a particularly important role to play in the delivery of radio services given the high proportion of listening on mobile devices, both handheld and within vehicles. Such devices are expected to adopt 5G technologies in the near future.

The development of the 5G Broadcast Modem enables us to experiment with features not currently available in commercial equipment and to go beyond current 3GPP Release 14/15 specifications. We shall be testing new features and enhancements relating to 5G Broadcast modes and are currently involved in standardisation activities within 3GPP Release 16.

Further larger scale trials are planned to evaluate how the technology trialled on Stronsay would scale, exploring new broadcast mode features and quantify the benefits.

The 5G Smart Tourism project has demonstrated the possibilities of a 5G-specification network for unicast delivery of high bit-rate and low-latency video using edge computing. We have demonstrated an example of the type of media experience that such technology enables for the user. Understanding the cost and practicality of deploying edge computing nodes in a real-life 5G network will require further work with mobile network operators.

The trials have demonstrated the opportunities that 5G could enable for distribution and content. 5G promises to support a range of applications with different requirements (such as low-latency, high bit-rate, high reliability, efficient broadcast coverage) running across a common set of infrastructure with universal support in user terminals. However, details relating to the costs to broadcasters and the associated business models will require further investigation.

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