4G BROADCAST: CAN LTE EMBMS HELP ADDRESS THE DEMAND FOR MOBILE VIDEO?

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ABSTRACT

At a time of increasing demand for video on mobile devices, it is vital to use the resources on existing mobile networks as efficiently as possible.

4G Broadcast (LTE eMBMS) offers the possibility of addressing issues of congestion and peak demand for popular content by sending a single stream once for reception by multiple users within a cell. This capability could be enabled in localised areas of peak demand, within existing 4G networks, and switched on as required, to allow the network to be dynamically optimised for the current traffic conditions.

BBC Research & Development has been investigating how 4G Broadcast technology might be used to improve the delivery of streamed content to mobile devices. We have demonstrated two example use cases – firstly as part of an app tailored to a specific event (for example at a sports venue), and secondly by connecting the technology seamlessly to BBC iPlayer (the BBC's Internet streaming service that offers both live and catch-up content) to allow viewers to continue watching popular content in congested areas, without the experience being spoilt by buffering.

This paper will explain the work BBC Research & Development has been carrying out on 4G Broadcast and present the results of recent trial work.

INTRODUCTION

In recent years, the proliferation of highly capable smartphones means many more people are now interested in watching video on their mobile phones, and there is therefore a corresponding increase in the amount of content available for such devices, both as short-form clips as well as long-form programmes and live streams. Although much of this viewing is done whilst the device is connected to a WiFi network (either at home or in the office etc.), there is also demand for this content directly over the mobile broadband networks – and the user is probably agnostic to the nature of the connection, being more concerned about both reliability and cost (or limits from data allowances).

Most industry analysts expect that the demand for mobile data will continue to increase significantly, and that a large portion of this will be driven by demand for video. The concept of the "busy hour" is already well known within the industry when mobile networks are at their most congested at places of peak demand (e.g. busy railway stations during commuting hours), and increasing numbers of people requesting popular video content can only exacerbate this situation. There is clear evidence that, for example during key sporting events such as the Wimbledon tennis championship, demand for live video content to mobile devices has increased dramatically; on 7th July 2013, when Andy Murray became the first British man to win the Wimbledon title since 1936, 64% of total requests to the BBC Sport site were from handheld devices (1). 4G Broadcast also has the potential to address spikes in demand over the mobile network when a new show or film is first released.

In all these cases, where large numbers of people are trying to watch the same content, at the same time, within the same geographic area, using a mobile broadband network, currently the network will attempt to stream numerous identical copies of the content, using a unicast mechanism. 4G Broadcast offers the opportunity to replace this with just one single stream for all users in one area, which not only has the potential to be significantly more efficient, but should also allow all users to be assured a consistent good quality experience, without the risk of buffering due to network congestion (in areas of good coverage).

This paper concentrates on the technical aspects of 4G Broadcast and does not address wider business or cost issues (for example the impact of 4G Broadcast on data allowances) or rights considerations.

WHAT IS 4G BROADCAST?

The term ‘4G Broadcast’ is used within this paper to refer to Long Term Evolution (LTE) enhanced Multimedia Broadcast/Multicast Service (eMBMS), the broadcast mode defined by the 3rd Generation Partnership Project (3GPP) in their 4G standards. Use of the term means eMBMS, as currently specified, namely within 3GPP Releases 9, 10 and 11.

Choosing this term was done for two reasons; firstly the aim was to use a name that would be accessible to a wider, non-technical audience; secondly other commonly used terms within industry such as ‘LTE Broadcast’ are not always used consistently and are sometimes used to refer to potential future developments of the specification.

There is typically benefit to be had from the broadcast mode when 2-3 users want to watch the same content concurrently, although the exact point at which it is more efficient to switch from unicast to broadcast will be dependent on the precise propagation conditions and how far the users are from a given cell tower.

Technology

eMBMS (2) shares the physical layer OFDM modulation scheme with LTE, allowing a certain proportion (up to 60%) of the LTE sub-frames to be assigned to the broadcast mode. These sub-frames are designed such that they do not adversely impact handsets that do not support them.

The symbols of these frames are defined to use a longer Guard Interval than conventional LTE, allowing a path difference of up to around 5 km within a synchronised Single Frequency Network (SFN) across multiple cells – another potential source of efficiency gain. As such, eMBMS is primarily targeting delivery to mobile devices and is therefore not suitable as a replacement for systems such as DVB-T (3) or DVB-T2 (4).

Whereas with conventional unicast LTE, a handset has the option to request retransmission of data it is unable to decode, the broadcast mode is a one-way transmission. As a result, and to add time diversity, an additional Application Layer Forward Error Correction (AL-FEC) scheme is added in the form of Raptor codes.

MPEG Dynamic Adaptive Streaming over HTTP (MPEG-DASH) is the dominant delivery format over eMBMS. It is a segmented video format that splits the video/audio stream into a number of chunks which are delivered as individual files. These files have unique filenames which are reassembled at the receiver into a continuous stream. A manifest file is used to signal to the receiver the video and audio format used and the naming convention for the segment filenames. MPEG-DASH is particularly suited to Internet delivery where it can traverse firewalls in the same way as normal web traffic and lends itself to caching and efficient delivery over Content Delivery Networks (CDNs). It is also adaptive with the client able to choose from a number of different representations at different bit-rates as the network connection dictates.

It should be noted that for use by eMBMS, DASH is not in fact used in a dynamic or adaptive fashion, nor is it delivered over HTTP. Instead, a single representation is delivered over a fixed bitrate broadcast bearer using a data carousel.

For delivery over eMBMS, the individual video and audio segments are packaged into a data carousel using the FLUTE protocol. This packaging, and the application of the AL-FEC, is the task of a new entity within the mobile core network called the Broadcast Multicast Service Centre (BM-SC)

In terms of media delivery, both streaming and file transfer are defined within eMBMS. However, the use of MPEG-DASH over the file transfer mechanism appears to dominate and has the advantage of integrating well with unicast delivery.

How Could 4G Broadcast Be Useful?

Figure 1 shows situations where eMBMS might be useful. The vertical axis shows the two main categories of consumption; linear/live programmes vs. on-demand. The horizontal access indicates location. If a user is at home and wishes to consume either form of content it is likely that they will be able to stream over a local WiFi connection (on the assumption that a sufficiently good fixed broadband connection is available).

Away from home and with on-demand content, a user has the option of downloading in advance before leaving home (side-loading) or streaming over conventional 3G/4G networks where data allowances and capacity allow.

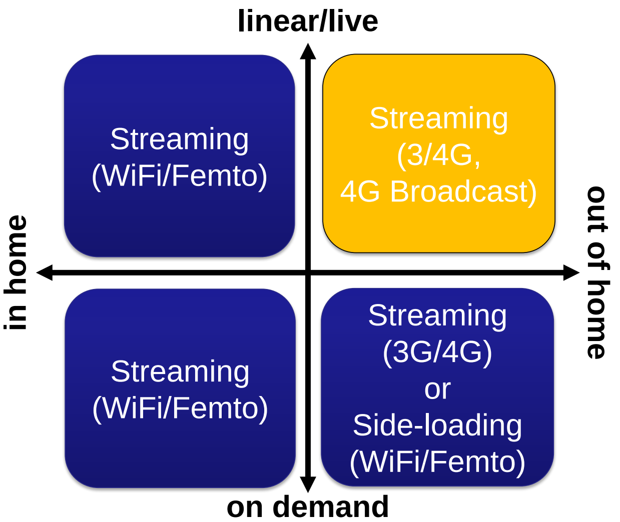

Figure 1 – Application Areas for Delivery to Mobile Devices

Linear or live content, by definition needs to be consumed now, whether it be a live sports event or on-demand content that has a linear-type consumption pattern such as demand immediately after a popular new show is released on-line. It is in this area where 4G Broadcast could best play a role in delivering this content most efficiently and with the best quality to mobile devices.

THE COMMONWEALTH GAMES TRIAL

In the summer of 2014, a trial of 4G Broadcast was carried out as part of BBC R&D's wider public showcase around the Commonwealth Games at the Glasgow Science Centre.

The trial was a collaboration, with BBC R&D providing content and an application, EE providing a network and dedicated spectrum, Huawei supplying equipment and Qualcomm providing software and middleware. The handsets were Galaxy S5s supplied by Samsung. These were off-the-shelf handsets (since they already support eMBMS within the hardware) but with dedicated firmware to enable reception of the broadcast streams.

A 2.6 GHz frequency allocation with a 15 MHz bandwidth was used to provide a private LTE network from a dedicated eNodeB (base station) transmitting the broadcast signals within the confines of the exhibition hall.

Three streams were made available of the BBC's TV channels carrying live action from The Games. The target screen size was 5.1" which meant that standard definition resolution was sufficient and an average video bitrate of 1.3 Mbit/s was used with an MPEG-DASH segment length of 1s. The use of short segments reduces the impact of error extension and ensures that, in the event a segment cannot be recovered at the receiver, the impact to the viewer is minimised.

TRIAL ARCHITECTURE

Figure 2 shows the architecture put in place for the trial.

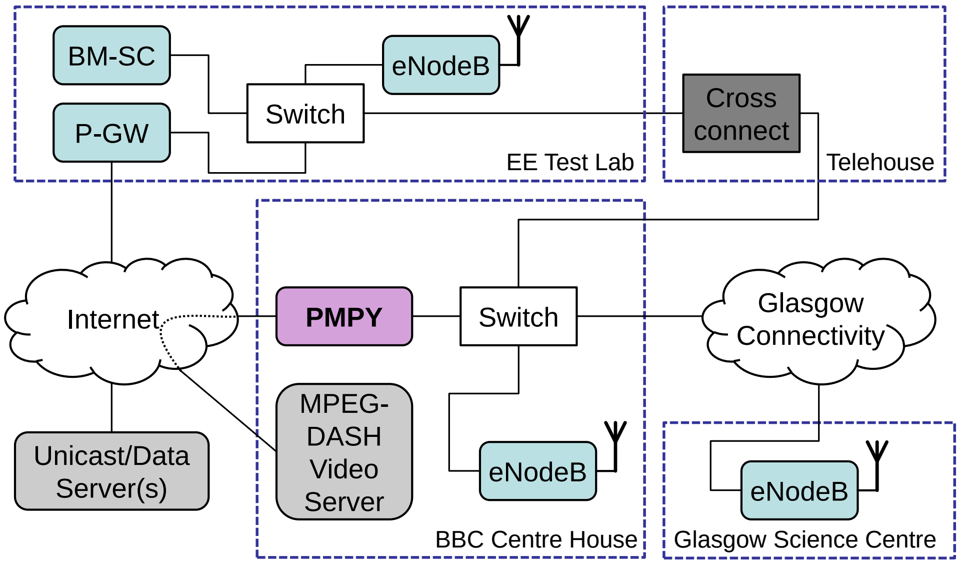

Figure 2 – The Architecture (simplified) for the 4G Broadcast Trial

The flow of the audio/video content through the system begins at BBC Centre House in West London, where direct feeds from the BBC's playout centre were encoded and formatted as MPEG-DASH streams. These were then transported to EE's test lab, via Telehouse in London over a dedicated link put in place for the trial. Here the BM-SC carried out the eMBMS encapsulation as well as applying the AL-FEC. A Packet Data Network Gateway (P-GW) was also present to allow conventional unicast Internet access on the trial LTE network.

From the EE Test Lab, the encapsulated content then returned to BBC Centre House, before being sent up to the Glasgow Science Centre via the dedicated connectivity put into place for the showcase for transmission within the exhibition hall.

As well as an eNodeB within the Glasgow Science Centre, there were also eNodeBs present within the EE Test Lab and at BBC Centre House to enable detailed testing to be carried out.

One particular node of note in the diagram is the ‘PMPY’ or Push Me Pull You. The task of this was to act as an interface between a standard MPEG-DASH server and the BM-SC. MPEG-DASH streaming is normally driven by the client, which, based on the current time of day, requests or *pulls* a segment with a particular index sitting on the HTTP server. However, BM-SC implementations typically expect segments to be *pushed* to them as soon as they are available. The task of the PMPY was therefore to act as a conventional MPEG-DASH client to *pull* segments from the server and *push* them to the BM-SC. In practice this consisted of a computer running the Linux operating system and some software developed specifically for the trial. The PMPY also served as a useful monitoring and logging point for the duration of trial.

THE USER EXPERIENCE

Two potential ways of utilising 4G Broadcast were presented to the public. The first was a dedicated events-based application specific to the Commonwealth Games as shown in Figure 3 below.

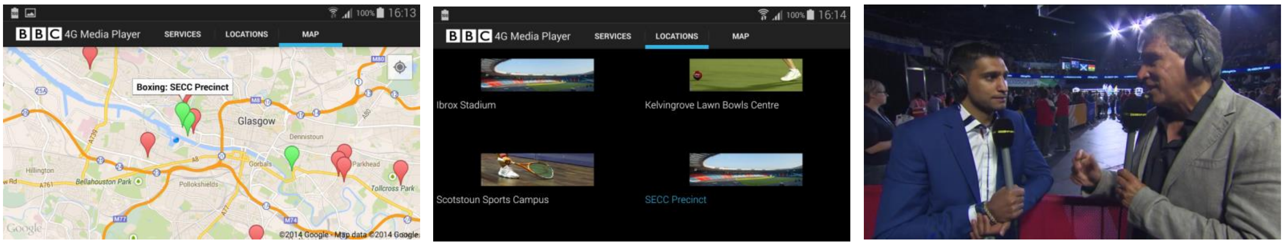

Figure 3 – The 4G Broadcast Application

This allowed the user to navigate around the different sports venues using a map with pins appearing green when a live stream was available from that location. Clicking on the venue brought up information about the event currently in progress and allowed the user to see the live feed. In this application of the technology, users would be aware that in some sense the 4G Broadcast enabled a special service for an event.

It was necessary to bring a number of data feeds together to drive the application as Figure 4 shows. Data concerning the venue names and locations, the sports events taking place at each one, the TV schedule and the mapping of TV channels onto those being broadcast over eMBMS were all combined into a single file using some software written in Ruby and stored on a web server for the application to interrogate.

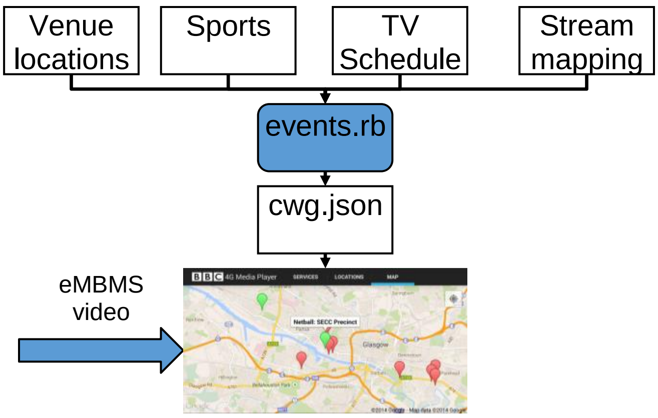

Figure 4 – Data Sources for the Application

The second approach was to show eMBMS as an underlying technology that could enhance reception of mobile video on an existing service. To demonstrate this, the 4G Broadcast streams were connected to the BBC iPlayer, the BBC's Internet streaming service that offers both live and catch-up content. This is shown in Figure 5. In this way, the user was taken seamlessly to the 4G Broadcast stream when it was available while still having catch-up content available over unicast streaming.

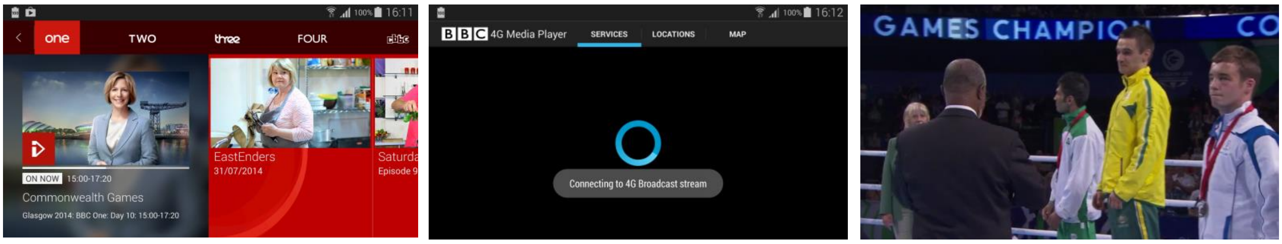

Figure 5 – 4G Broadcast and the BBC iPlayer

LESSONS LEARNT

Public reaction to the demonstration was very positive with many praising the quality and consistency of the 4G Broadcast pictures. There was also a good awareness of issues such as data caps and congestion that can effect unicast streaming on current mobile networks in certain situations and therefore the potential advantages of 4G Broadcast.

Early on in the project, we realised the need for the PMPY entity to act as the interface between the mobile network and BBC R&D's standard MPEG-DASH servers. Unlike the vast majority of interfaces within 3GPP, this interconnection is not currently specified and, although it seems that most manufacturers use similar protocols, this is something that could perhaps benefit from standardisation within 3GPP in order to simplify integration with different operators and vendors.

Another potential issue with the current eMBMS standard is the lack of support for statistical multiplexing. On conventional broadcast services, the BBC shares bitrate across multiple services. This means that if there is content on one channel that is simpler to encode, some instantaneous capacity can be released for another channel to use in the event that it is showing something that is more challenging. This approach results in an improved overall picture quality.

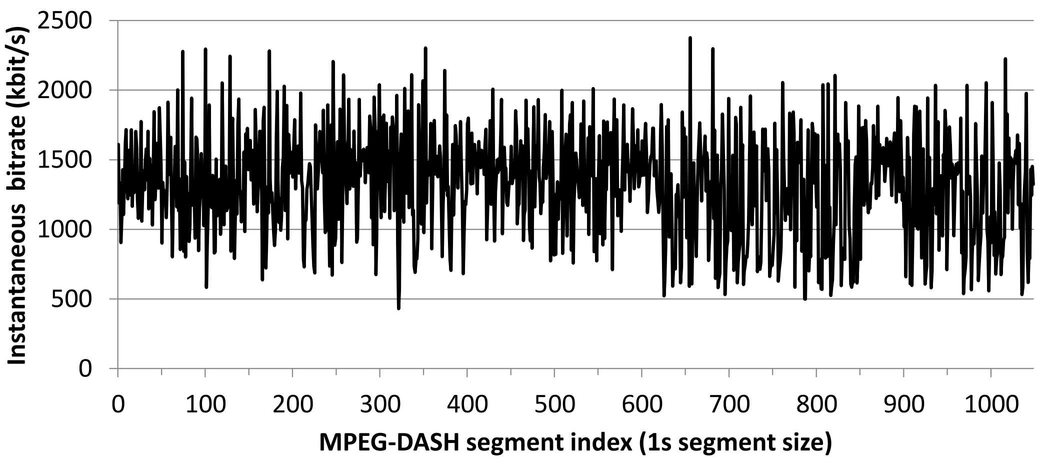

Figure 6 – An Example of the Variation in MPEG-DASH Segment Sizes

Figure 6 above is indicative of the sort of variation in bit-rate seen from one configuration of the MPEG-DASH encoder used for the trial over the course of around 15 minutes. While it would be possible to constrain this further, it would result in a reduction in picture quality. Since the broadcast bearer is a fixed bitrate pipe specified per service, there are two main options. The first is to over-specify the bit-rate to cope with peaks in capacity; the second is to accept increased delay through the system. Neither of these is optimal and support for statistical multiplexing across services is something that could be very beneficial.

Finally, the end-to-end delay through the system is something that needs further characterisation. Since MPEG-DASH relies on a sequence of files, there is the risk that the presence of buffering at multiple handover points through the chain serves to introduce significant delay. This is not so much of an issue away from a sporting event but could impact the use of the technology to show live video of an event inside the stadium where the images on screen could lag behind the live action at the event.

SEAMLESS SWITCHING AND HYBRID NETWORKS

The ability to switch seamlessly between broadcast and unicast streams would mean that a user could benefit from 4G Broadcast automatically when moving into areas where it is available. BBC R&D has investigated whether this switching could be carried out in the application, without the need for standardisation.

The use of MPEG-DASH simplifies the implementation of this switching since each segment is uniquely identified by its number. At any given time, the client can calculate the expected segment number based on the difference between the current time and the known start time of the stream divided by the segment duration. Introducing some buffering allows the application to determine if a given segment is received correctly over the broadcast mechanism and, if not, it can attempt retrieval over a unicast connection before it is required to be played out. This is illustrated in Figure 7 below. Inevitably this type of approach introduces some delay but was demonstrated to be work successfully.

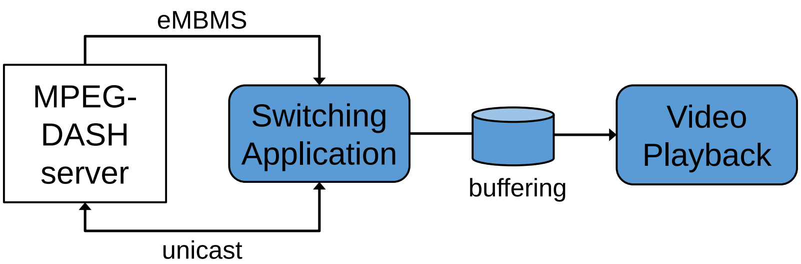

Figure 7 – Application-based Seamless Switching

The 3GPP Release 12 specification is to include a feature known as MBMS Operation On Demand (MooD). As well as offering a standardised means of implementing this switching functionality, it will allow the network to determine the number of users receiving a particular stream over unicast. Once this reaches a given threshold, the users can automatically be moved over to a broadcast version of the same content, effectively offloading the multiple requests onto a single multicast stream. This would ensure that the resources of the mobile network are always used in the most efficient way possible.

The availability of these types of features, enables a hybrid, dynamic network to be built where eMBMS is deployed in the operator's busiest areas and enabled for the most appropriate content at the most appropriate time.

It is this flexibility that has the potential to differentiate 4G Broadcast from previous mobile TV standards such as DVB-H, DMB or MediaFlo that required a new network to be built everywhere that coverage was required.

4G BROADCAST AT THE FA CUP FINAL

Working with the partners from the Commonwealth Games, with the addition of EVS and Intellicore, we participated in a trial at the FA Cup Final at Wembley Stadium in London in May 2015.

As well as the live BBC One feed of the Cup Final, we used BBC R&D's Stagebox technology to deliver an additional two live camera feeds from the outside broadcast area via an IP link. These were then broadcast along with highlights packages. In addition, EVS supplied multi-angle replays to a 'replay zone', allowing users to interactively select the angle of view for incidents of interest during the game.

Figure 8 – The BBC Sport App at the Cup Final

All of this content, with the addition of real-time statistics, was brought together in a dedicated application written by Intellicore. This ran on a number of specially enabled tablets given out to invited guests.

BBC R&D also worked with BBC Sport to seamlessly connect the broadcast streams into the live coverage area within a modified version of the existing BBC Sport application, shown in Figure 8.

This proved the ability of 4G Broadcast to deliver high-quality content in situations where congestion might not typically allow it and showed the benefits for the user in bringing unicast and broadcast content together in a seamless fashion to give the best possible experience.

WHAT NEXT?

This paper has specifically concentrated on today's 4G Broadcast, and we would expect to continue to work with the mobile operators and others in the industry in the future to explore further how best to make use of this technology, and whether to support more frequent use at appropriate events.

However, it is also worth considering how the technology itself could be enhanced. In addition to some further developments already being planned for current releases of 3GPP standards (e.g. MooD), discussions have started within 3GPP about the possibility of developing eMBMS technology further. Improvements being considered include allowing sharing of a single broadcast across multiple mobile operators, perhaps making full use of a standalone block of spectrum, as well as introducing longer Guard Intervals to improve coverage across larger areas. It is not yet clear whether some of these features will be fully incorporated within further releases of 4G specifications, or whether some of them will need to wait for the next generation mobile broadband specification (5G), for which the requirements are now beginning to be captured.

One requirement that could be useful, and significantly help both improve the overall efficiency of use of the network, as well as providing for a better experience for viewers, would be the ability of a service operator to use the broadcast mechanism to push popular content to be transparently cached on devices, where this is enabled by the user. This could be done, for example, at times of the day when the network is lightly loaded.

As well as improving the physical layer capabilities, a key requirement from a broadcaster's perspective is that 5G technology should allow for free-to-air delivery (for example of a public service broadcaster's content), without the viewer incurring additional costs.

BBC [R&D] are members of the 5G Innovation Centre at the University of Surrey, and will be contributing to discussions about requirements for 5G technology, to ensure that broadcasters' needs in this area are represented.

CONCLUSIONS

Our trial work indicates that 4G Broadcast is capable of delivering a high standard of video and audio to mobile devices with a defined quality of experience, even in crowded environments. Bringing broadcast and unicast together in a single application enables the user to benefit from the strengths of both distribution techniques, while the flexibility to switch seamlessly between broadcast and unicast could allow 4G Broadcast to form part of a hybrid network with it enabled at the busiest locations at the busiest times.

Looking to the future and towards 5G, we have learnt that a number of features could be added or enhanced, such as the introduction of support for free-to-air and stand-alone transmissions, statistical multiplexing between services and more flexible scheduling of broadcasts combined with the ability to seamlessly switch between broadcast and unicast.

Despite the potential of perceived 'infinite' capacity from 5G standards, the realities of a practical rollout are likely to mean that such capability will not be available everywhere and a properly integrated, flexible broadcast mode is therefore likely to be an important factor in delivering the high quality content that users demand wherever they happen to be.

REFERENCES

1. http://www.bbc.co.uk/mediacentre/latestnews/2013/bbc-wimbledon-stats

2. ETSI TS 136 211, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation

3. ETSI EN 300 744, Framing structure, channel coding and modulation for digital terrestrial television

4. ETSI EN 302 755, Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)