Laurence Murphy, Nigel Linge, Andrew Daly

DELIVERING 4K TELEVISION TO THE HOME

Broadcast television in the UK has evolved significantly from the early black and white analogue VHF service of the forties and fifties. Today, viewers are increasingly watching television via the Internet on their portable devices or Smart TVs and using merged media access methods like Netflix and SKYGO. But what next? Laurence Murphy, Nigel Linge and Andrew Dal explore the exciting developments already underway and examine the ramifications of 4K and 8K.

After the early black and white VHF service, the next big advance came in 1964 with the launch of analogue UHF services, shortly followed by colour transmission and then in the 1980s satellite and cable television arrived. We moved to high definition pictures in 2005/6, and by October 2012 the digital switchover had been completed. Having gone through so many changes over the past decades, we now find ourselves once again on the brink of a new and significant development in television with the advent of ultra high definition (UHD).

High definition (HD) transmission in Europe currently offers a picture resolution of 1920 pixels x 1080 pixels transmitted at 25 or 50 frames per second. Meanwhile two new standards for UHD are being considered. The first of these, 4K, uses a resolution of 3840 × 2160 pixels (approximately four times the resolution of full HD) and is likely to be accompanied by an increase in frame rate in Europe to 100 frames per second. The second, 8K, has a resolution of 7680 × 4380 pixels (approximately 16 times the resolution of full HD) and is expected to increase the frame rate even further; eventually reaching 120 frames per second with enhanced 22:2 surround sound.

The big loser in this move to UHD is 3D. In 2011/12 the industry was considering supporting 3D as the next significant widespread step in the evolution of television. However, a lack of confidence in its market penetration and a limited scope for programme production has led the sports broadcaster ESPN to announce the cancellation of their 3D channel and in July 2013 the BBC confirmed that they had no plans to use 3D technology after the end of a two year trial. Last year FIFA confirmed that coverage of the Football World Cup in Brazil 2014 would be prioritised for 2D, not 3D, but that would include 4K acquisition and transmission.

The demise of 3D as a mainstream service has most definitely left the industry looking for a new premium service for which distributors and broadcasters can grow market potential. In that respect, 4K appears to be it but the challenges, as always, are how to: produce content that truly exploits its capabilities that viewers want to watch, provide the means by which UHD can be displayed and crucially, determine how UHD services can be delivered to our homes.

THE PRACTICALITIES OF DELIVERING 4K AND BEYOND

The resolution of a digital television picture is determined by the number of picture elements or pixels that make up each frame. Current HD uses over two million pixels organised as an array of 1920 pixels horizontally by 1080 pixels vertically (16:9 aspect ratio). Each of these pixels is then converted into a digital number which represents its colour and luminance properties. Up to 24 bits can be used to represent each pixel which results in almost 50 million bits of digital information for one HD frame. Movement in a television picture, like that in cinema, is achieved by transmitting a series of frames at regular intervals. The number of frames transmitted per second is therefore important for this ensures that movement is naturally and faithfully reproduced; a higher frame rate being needed for rapid action.

There are two basic methods for transmitting each television frame, interlaced (i) and progressive (p). With interlaced transmission, the image is scanned line by line in two passes to make one frame. Field one comprises the odd lines and field two the even lines. Whilst this reduces the amount of data that needs to be transmitted it can result in picture blurring when fast moving action is being shown. The time delay between the odd field and the even field also injects errors into the process. This problem is overcome, albeit with a resulting higher data rate, with progressive transmission in which each frame is scanned and transmitted in its entirety.

A 1080i HD TV transmission at 25 frames per second generates a huge data rate requirement of 622Mbit/s. However, this figure ignores one very important aspect of a moving picture and that is the amount of redundant information it contains. Except for where there is rapid movement or a sudden scene change, there can be a lot of commonality between one frame of a television picture and the next. An object that does not move from one frame to the next need not be transmitted each time a frame is sent. Recognising this and encoding a picture so that only movement is transmitted is the essence of the video codec (COder / DECoder).

A codec must therefore analyse the frames comprising a television picture and identify those elements which are common within a frame (spatial redundancy) and those that are common between frames (temporal redundancy). Often referred to as video compression, the use of a video codec massively reduces the amount of data that needs to be transmitted. The codec relies on the creation of reference frames, the integration of error correction and in the case of moving elements, motion prediction. One of the most commonly used codecs for the transmission of HD is H.264 / MPEG4 AVC (Moving Picture Experts Group Advanced Video Coding) which was developed by the International Telecommunications Union (ITU) in 2003 [1]. Using this standard, the data requirements for the transmission of a HD television are significantly reduced down to between 3 and 17Mbit/s.

During the London 2012 Olympics, the BBC in partnership with Nippon Hoso Kyokai (NHK) (the Japan Broadcasting Corporation) transmitted coverage of the games in 8K to theatres located in BBC Broadcasting House, the National Media Museum in Bradford and BBC Pacific Quay Studios in Glasgow with two International sites, one in the USA and the other in Japan. Three 8K TV cameras were deployed within the Olympic Park and the resulting 24Gbit/s uncompressed digital data streams were sent over fibre optic cable links to BBC Television Centre. From there the data was encoded using H.264 to produce two Internet Protocol data streams that resulted in a combined data stream of 350Mbit/s which was carried over the SuperJANET national network to Bradford and Glasgow.

These data rates and dedicated network connections are both unrealistic for the delivery of UHD TV to our homes but a new codec has been developed that could change that. A successor to H.264 is the ITU's H.265 HEVC (High Efficiency Video Coding) standard [2]. Finalised in June 2013, it is predicted to offer data compression rates double those of H.264 which could result in a data requirement for the transmission of 4K UHD television as low as 9Mbit/s; that is at rates lower than those currently being used for the transmission of HD TV using H.264.

The RED Epic-M and EPic-X cameras have a 5K resolution

VIEWING PARADIGMS

The delivery of 4K UHD TV to our homes will change how we watch programmes and bring with it new viewing paradigms which broadly fit into the following categories.

"Sit-back" viewing will allow conventional viewing to be experienced in more detail. This is the most obvious implementation of 4K technology, and will give a greater sense of realism to the images viewed on conventional stand- or wall-mounted televisions.

Interestingly, the increased resolution of 4K also makes viewing more comfortable at closer distances because of the smaller pixel size. Therefore, you don't need a massive 80 inch screen or to live in a mansion to enjoy 4K.

"Lean forward" viewing is the complement to "sit-back" viewing whereby content is consumed on a device with a screen significantly smaller than a television, such as a tablet or laptop. Such devices would be well suited to displaying 4K content, since the viewing distance would usually be small enough for the eye to resolve the increase in resolution, despite the small screen size.

Quadrant focus allows areas of the screen to display a level of information which was previously unavailable. For example, the user will be able to focus on a particular quadrant of the screen and expand/zoom the image out to examine a part of the picture in more detail. This action would not be possible on a standard or high definition television as the resultant picture would become too blurry to be of use.

THE DELIVERY OPTIONS

There are three prime ways in which television can be delivered to our homes: terrestrial transmission through an aerial, satellite transmission and via the Internet. The development of the H.265 codec offers the potential to deliver 4K to our homes using all three of these delivery methods.

Terrestrial - Freeview HD became the first operational service in the world to deliver HD using Digital Video Broadcasting – Terrestrial Second Generation (DVB-T2) when it launched in December 2009. It encodes the picture using H.264 and delivers an HD channel within a 3 to 17Mbit/s data stream. Radio frequency capacity in the UK currently exists for the transmission of five HD terrestrial channels and as a result of the completion of the digital switchover, telecommunications regulator Ofcom has announced the possibility of releasing spectrum for the provision of a further 10 HD channels.

South Korea is leading the way for terrestrial 4K transmission with a recent demonstration at the 23rd Korea International Broadcast, Audio and Lighting Equipment Show in May 2013 by the Korean Broadcasting System and LG. This system used H.265 over DVB-T2 to deliver 4K UHD at 60 frames per second within a 35Mbit/s data stream.

Manufacturer	Model	Scree size (diagonal)
Sony	KD-84X9005 KD-65X9000A KD-55X9000A	84 inches 65 inches 55 inches
LG	84LM9600 66LA9700 55LA9700	84 inches 65 inches 55 inches
Samsung	S9 UE65F9000 UE55F9000	85 inches 65 inches 55 inches
Toshiba	REGZA L9300 series	84 inches 65 inches 58 inches
Sharp	Aquos LC-70UD1	70 inch
Panasonic	OLED	56 inch

Table 1: *Example range of 4K UHD TVs now on the market.*

It is unlikely that Ofcom will allow the creation of another HD dedicated multiplex for transmission of HD, let alone a 4K multiplex. What is highly likely is that the adoption of H.265 across all the multiplexes, with the resulting efficiencies and bandwidth economies - may allow for the future delivery of 4K by terrestrial in the UK.

Satellite - Within the UK there are already over seventy HD 1080i TV channels available via satellite.

In April 2013 European based satellite operator SES successfully transmitted 4K television via the Astra satellite using H.265 with a data rate of 20Mbit/s using the Digital Video Broadcasting Satellite Second Generation (DVB-S2) transmission standard. Meanwhile, Japan's Ministry of Internal Affairs and Communication aims to become by July 2014 the World's first country to be broadcasting in 4K using their CS satellite system. The plan is that this will be followed in 2016 by a trial of 8K broadcasts by NHK.

The availability of transmission capacity therefore makes satellite an obvious choice to enable 4K distribution.

Internet (Broadband) - In June 2013 Japanese telecommunications company NTT West completed the world's first trial of streaming 4K UHD TV over the Internet at 1080p using H.265. Whilst average domestic broadband access speeds in Japan are higher than those in the UK, the performance of the H.265 codec does make the delivery of 4K in the UK a real possibility for many households.

According to Ofcom, the average UK broadband speed reached 12Mbit/s in November 2012 with 13% of residential broadband connections being on superfast services that offered an average download rate of 44.6Mbit/s. The growth in superfast services has been driven by the deployment of Fibre to the-Cabinet technologies - although the limitation remains the fact that existing copper is used to provide the final connection to the customer. Whilst delivering fibre all the way to each customer's home may offer a solution, and indeed volume distribution of 4K and 8K may become a driver for it, no telecommunications

Director Peter Jackson chose 5k for The Hobbit:an unexpected journey, shooting up to 120 frames per second.

company has yet developed a business case that can justify the estimated £30billion cost of nationwide deployment.

There are techniques, however, which can be used to squeeze even higher capacities out of the UK's copper access network. The most promising is ITU standard G.993.5 which adopts a technique similar to that used within noise cancelling headphones, where digital signal processing within the street cabinet is used to massively reduce cross-talk over the local copper pairs. Known as vectoring, this technique makes the prospect of 100Mbit/s download capacities a reality for many homes in the UK over the existing copper infrastructure [3]. Thereafter ITU's emerging G.Fast standard, which takes advantage of fibre being deployed beyond the street cabinet to the distribution point, can offer significantly higher bandwidth over short copper lengths as demonstrated in July 2013 by Telekom Austria working in partnership with Alcatel Lucent where 1.1Gbit/s was achieved over a 70m good quality copper line and 800Mbit/s over 100m, dropping to 500Mbit/s over 60m when lower grade lines were tested.

Technology therefore exists to enable a broadband connection to handle the delivery of multiple 4K UHD TV streams to our homes and indeed the future delivery of 8K. However, the broadband connection is only one link in the delivery chain and the large scale distribution of 4K and 8K will have implications for Internet Service Provider networks too.

One further development in Internet access is that of 4G mobile networks. The recent demonstration by EE of a 94Mbit/s download capability via their live 4G network also opens up the possibility of the mobile phone network as a future delivery mechanism for 4K.

When considering the delivery of 4K UHD TV over terrestrial, satellite and the Internet, it has been assumed that the prime delivery mechanism is one of real time streaming. However, a second option is to download 4K content for delayed viewing as currently used, for example, in the terrestrial topup tv service. Downloading of content can be automatically managed by a set top box during the off peak period, which reduces the load on the network, requires less transmission capacity and minimises the investment that operators must make in additional equipment and/or spectrum.

PROGRAMMES AND TELEVISIONS

The momentum behind a move to 4K is most definitely gathering pace. The BBC's Natural History Unit are filming *Survival,* an epic six part series, in 4K UHD. Peter Jackson's *The Hobbit: An Unexpected Journey* was actually shot in 5K and many USA film studios are investing in the restoration of their 35mm back catalogues into 4K.

Today's film, television and media industry has an expanding range of camera technology available for this new UHD format. For example, the RED Epic-M and Epic-X cameras[1] have a 5K resolution (5120 x 2700) and were used to shoot the Hobbit trilogy, Canon's EOS C500[2] operates at 4K and Sony's F65[3] operates at 8K resolution.

Sony's 4K Ultra HD Media Player already comes preloaded with 10 feature films in true 4K and its soon-to-be-launched Video Unlimited 4K will offer the World's first and only network video service that gives access to a library of full-length 4K UHD feature films and TV shows, expected to extend to over 100 titles by the end of 2013. Each of these can be downloaded and stored on the Media Player's 2TB hard disk. Netflix are already experimenting with 4K streamed delivery over their backbone as illustrated at the National Association of Broadcasters Show in Las Vegas earlier this year.

At the 2013 Consumer Electronics Show held in Las Vegas, 4K UHD TVs dominated the show. Some commentators likened 4K to the step change that people experienced moving from standard definition to high definition. The higher number of pixels within a 4K UHD picture does naturally facilitate even larger screens and these were well represented by a range of 84 inch televisions. However, there is a growing acceptance that screens between 55 and 65 inches across the diagonal will become the mass market product. The ideal viewing distance for this size is between 1.5 and 2m which is the same as that recommended for a smaller 35 inch HD TV. Sitting closer to a larger screen is comfortable because the pixels on a 4K UHD TV are four times smaller than on a HD TV and therefore harder to discern which leads to a more immersive experience. Most of the major television and media manufactures are now offering products within this range of screen sizes as shown in Table 1. Industry research specialists NPD DisplaySearch are predicting that 500,000 4K TVs will be sold worldwide this year rising to over 7 million by 2016. However, as always with new technology, prices begin very high before mass market sales drive them down. As a typical example, Sony's 55 inch 4K UHD TV is currently retailing at £4,000 in the UK.

AUTHORS' CONCLUSIONS

The development and launch of 4K UHD TV is most definitely gathering pace with broadcasters gearing up to produce programmes in 4K, camera and television manufacturers releasing a growing range of products and the distribution companies testing H.265 encoded transmissions over terrestrial, satellite and Internet delivery platforms. However, there is still a long way to go before a widespread 4K UHD television service becomes a reality for the masses. Nevertheless this is a very rapidly moving landscape that is expected to evolve significantly as we move towards the end of 2013 and into 2014.

As with many developments in television, sport acts as a catalyst and no doubt the 2016 Olympics are likely to be a big moment for UHD. Equally, the gaming and home cinema markets are also important and they too may be the catalyst which propels 4K as a premium sought after technology. The industry has learned the hard way with 3D and they know that without the public's engagement no matter how radical or interesting the technology, user acceptance and economic drivers will ultimately be the factors that curtail its implementation.

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ABBREVIATIONS

DVB-T2	Digital Video Broadcasting – Terrestrial Second Generation
HD	High Definition
ITU	International Telecommunications Union
NHK	Nippon Hoso Kyokai
UHD	Ultra High Definition

FOOTNOTES

[1] See http://www.red.com/products

[2] See http://www.canon.co.uk/For_Home/Product_Finder/Digital_Cinema/Cinema_EOS_Cameras/EOS_C500_PL/

[3] See http://www.sony.co.uk/pro/product/broadcast-products-camcorders-digital-motion-picture-camera/f65/overvie

ABOUT THE AUTHORS

LAURENCE MURPHY

Laurence Murphy is Senior Lecturer in Media Technology and leads the BSc Media Technology Degree programme at MediaCityUK, University of Salford. He is an active researcher in high definition advanced television systems for 4K, 8K & 3D and is currently engaged in PhD research into changing media technologies and their impact on the broadcasters, the viewers and the manufacturers. He is also an active camera and engineering consultant for a number of broadcast companies and manufacturers.

NIGEL LINGE

Nigel Linge is Professor of Telecommunications at the University of Salford. He specialises in computer networks and their applications and has research interests that cover location and context based services, communication protocols, the delivery of multimedia applications, network design and the use of networks for sensing. In addition, he takes a keen interest in telecommunications heritage and is actively engaged in public engagement. He is a member of the ITP.

ANDREW DALY

Andrew Daly is a Lead Consultant at Analysys Mason. He joined Analysys Mason in 2007 and specialises in the areas of broadband costing, technology and policy development. Andrew's expertise includes network cost modelling, regulatory analysis, government policy development, and the capabilities of next-generation fixed and wireless access networks. Andrew advises regulators, local authorities, governments and operators on topics such as fibre-to-the-cabinet and fibre-to-the-home deployments, and the roll-out of 4G wireless technologies.