Networks for Programme Production

Modern programme production tools no longer consist of specialised broadcast hardware interconnected by coaxial cables. They are now almost invariably computer applications running on PCs, and they use file-based media storage rather than tape. As a result, IT network connections are now an essential part of any production system.

Media files can be extremely large, putting patterns of demand on an IT network quite unlike conventional IT traffic. BBC R&I has for a number of years investigated the problems this brings, and worked with suppliers, manufacturers, and standards bodies to establish solutions.


Audio over IP

IT networks are usually packet switched, and their properties are significantly different from the circuit switched networks we have traditionally used to carry our signals. Being primarily designed for regular IT traffic, they do not always perform as well when faced with large media-content files. Over recent years we have bought or developed a number of highly specialised test tools, and we are continually studying the latest offerings to judge if the claims made are justified as far as media production is concerned. One of our developments is a software application that can be ported out to multiple PCs to simulate a busy production office or even an entire site. We are now investigating next-generation multicast streaming protocols, and, with HD production in mind, the performance of 10 Gbit/s IP routers.

Through this work, we ensure the BBC understands the issues surrounding network provision, and specifies appropriately from our technology supply partners. We regularly feed back the results of our tests to manufacturers, or do tests with them, to help tune products for media use. We have also found it important to take part in the work of the relevant Standardisation bodies, because of the strong influence that standards have on the design of IT equipment.

We also run a number of research and innovation projects:

PRISM

We lead the DTI collaborative project PRISM, which is applying distributed-computing 'GRID' techniques to media production. Although the project itself will finish at the end of 2008, it is part of our longer term work to try to streamline and enhance the technical processes in programme production. The other aspect of the work is to encourage standardised interfaces, so that production tools will work together even if chosen from different suppliers. PRISM will publish the interfaces it develops as a set of open specifications.

As a simple example of what PRISM is seeking to achieve, imagine creating a documentary programme from content which has been shot over a period of years on different systems. It would help if the editing system applied any necessary format conversion automatically, without the operator needing to intervene to take decisions or start the process. With GRID, the editing system could delegate the tasks of comparing formats and making the conversions, especially if the content was being retrieved from remote locations.

A more challenging example is adding a formal description of media content as it goes into repositories. Descriptive metadata is important for searching and retrieval. It is however extremely labour-intensive to create, and this is a definite disincentive. One of the partners in PRISM has considerable expertise on machine-interpretation of images, and we are very interested to find out if their techniques can be applied here. The interpretation is not entirely automatic, but needs only a small amount of prompting on context from a human operator. It is nevertheless computationally intense, and can benefit from GRID techniques. PRISM aims to demonstrate a scalable high performance system built on a standard IT core.

PRISM is working closely with BBC Northern Ireland, and will be tested in conjunction with a number of programmes that they produce.

WiFi for TV programme production

WiFi is rapidly becoming a de facto standard for connecting Media Centre computers to TVs and audio systems. This is not an application WiFi was originally designed for, but some additions to the standard have made it just about suitable for domestic use. We have been looking with a number of companies at other ways of extending the standard, to allow us to use WiFi in TV production.

WiMax

WiMax is similar to WiFi, but works at higher powers and has greater range and capacity. Its transmission in the 5.8 GHz band is licence-exempt, and we have carried out a series of tests to see if it could be used for ad-hoc contribution and distribution links. Transmissions at this frequency can be affected by buildings, so WiMax uses COFDM to benefit from reflected signals.

We arranged for a transmitter aerial to be installed on a mast on high ground in North London, and mounted a receiver aerial on a 10 m mast on a radio van. Tests at points chosen at random within 5 km of the transmitter all gave a throughput of at least 10 Mbit/s, and some achieved 20 Mbit/s. These bit rates are all adequate for high-quality contribution and distribution circuits.

We then moved to the Westminster area, where BBC News are trying to find a quick and economical way of setting up links back to their local studio. UrbanWiMax, a company that provides Internet services for business users, provided us with a temporary bidirectional link. Their WiMax network has a nominal maximum capacity of 4 Mbit/s (limited by the backbone rather than the WiMax itself), and is intended to provide spot capacity and diversity from cable connections. It covers most of the locations in Westminster that BBC News regularly use.

This is a much more built-up area, and tests with the radio van showed some locations where no signal was received. However, where a signal was obtained, in most instances it would support up to 2.7 Mbit/s video and 192 kbit/s audio streamed simultaneously, definitely acceptable for news reports where a lower picture quality is acceptable and a video bit rate of about 1 Mbit/s is usually considered adequate. We also noted that the audio quality exceeded our expectations even when reduced to 64 kbit/s.

Audio over IP

In 2004 some of the BBC's local radio stations started to exchange audio content over standard IP networks, using broadband ADSL connections. We were asked to help when it was found that some codecs were more affected by network conditions than others, and that codecs from different manufacturers did not always work together. This was worrying – we were hoping that IP technology would be an easy replacement for ISDN lines when these start to disappear.

We have therefore carried out a series of investigations, running tests on a range of commercial codecs. We are now working to establish an interoperability standard and a recommendation of good operational practices. This work is being done through the EBU, under whose authority the standard and recommendations will be published, with help from IRT in Germany and Sveriges Radio. (Sweden is already faced with losing all ISDN services in the next two years). It is intended to produce a reference codec with which to test commercial products for compliance.

Radio Systems

The BBC is a major user of radio frequency spectrum, not just for its public broadcasts but also for many internal purposes such as wireless cameras, wireless microphones, and passing signals back from outside broadcasts. Spectrum is a scarce resource, and we are constantly looking for techniques to make more efficient use of it, as these three pieces of work demonstrate.

MIMO

MIMO stands for Multiple-Input-Multiple-Output and refers to a wireless system with more than one transmitter and receiver, all operating on the same frequency but with each transmitter carrying a different signal. Each receiver picks up a mix of the transmissions, depending on propagation conditions and the placing and polarisation both of its aerials, and those at the transmitters. If the receivers can determine the mixes in the form of a mathematical matrix, their outputs can be passed through the inverse of this matrix to recover the original transmissions. In the experimental system described here, the receivers calculate the matrix by measuring the pilot tones already present in the DVB-T signals.

The increased capacity is obtained at a cost. Depending on the amount of mixing, the received signal-to-noise ratios can be worse than for a single transmitter and receiver, and this might reduce range or require more transmitter power.

MIMO

MIMO is a method for increasing the capacity of a radio link by running multiple transmissions on the same frequency. To investigate its potential BBC R&I has produced a prototype MIMO system using two transmitters and two receivers, with the transmissions based on DVB-T. An experimental pair of 50 W ERP transmitters has been installed at a site near Guildford. A survey vehicle has been equipped to investigate the coverage for both fixed and mobile reception. The transmitters can be switched remotely between dual-polarised or co-polarised transmission, to explore different configurations. We are doing this work in collaboration with OFCOM, Arqiva and National Grid Wireless within a new group set up for the purpose and chaired by the BBC, known as the Advanced Terrestrial Transmission Study Group, or ATTSG.

Initial results using 64QAM rate 2/3 modulation suggest that the coverage of dual-polar DVB-T MIMO is very nearly as good as that obtained for DVB-T itself, with a data throughput of 48 Mbit/s compared to 24 Mbit/s for the standard system.

Because MIMO is one option that is being considered for updating DVB-T, the results of this investigation are being made available to the DVB-T2 technical working group (described opposite).

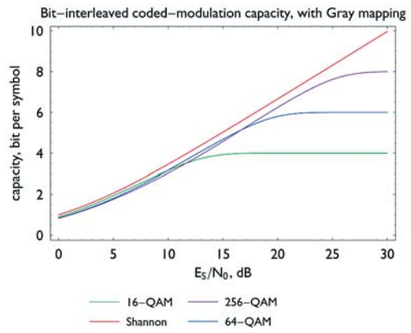
On-channel repeater

BBC R&I has developed an on-channel repeater for the DAB and DVB-T frequency bands. This device, first shown by the BBC at IBC in 2005, allows a relay station to re-transmit a signal on the same frequency as it is received. This is normally difficult because the receiving antenna almost inevitably picks up some of the signal from the transmitting antenna, causing howl-round. The on-channel repeater is particularly useful for filling 'holes' in the service area of a transmitter, or extending the range.

We have protected the key technology with a number of patents, and we have issued a licence to use the algorithm to a major transmitter manufacturer. More enquiries for licences have been received both from the UK and overseas and are currently being processed.

Trials have been carried out in collaboration with network providers in the DAB band, with additional DVB-T trials scheduled for the near future. Information regarding the behaviour of the system in complex single-frequency networks (SFNs) has allowed refinements to be made to the algorithms.

This year has seen the original system enhanced in a number of ways to improve signal-to-noise ratio and the ability to track rapidly time-varying coupling paths. So much so, in fact, that the system has been lab tested at 2.5 GHz in a PMSE (Programme Making & Special Events) radio-camera mid-point application. The results are very promising and we are close to having a solution to offer for this application. This would minimise the number of PMSE operations needing two frequencies at a time when this spectrum is likely to become increasingly expensive.



In trying to squeeze more capacity out of the precious UHF spectrum, the DVB-T2 project is bound by theoretical limits to what can be achieved. The Shannon capacity limit is well known; however, it is sometimes forgotten just how idealised it is. Once certain choices are made, such as picking a particular combination of constellation and bit mapping, more detailed application of Shannon's information theory shows that rather less capacity is then achievable, even in an ideal case. This graph serves as a benchmark for studies of error-correcting codes together with the possible addition of higher-order constellations like 256-QAM to the system.

DVB-T2

In 2006 BBC R&I submitted a paper to DVB, proposing the formation of a Study Mission to consider updating the standard for digital terrestrial television transmissions. The proposal was accepted and we were asked to lead the study, which identified several technologies that could be used to increase both efficiency and ruggedness.

We were then asked to lead a DVB technical study group to continue the technical analysis, in parallel with another group preparing the commercial requirements. The work of these groups is still underway. Currently it appears that a modest increase in capacity could be achieved through the use of advanced error correction codes, such as those used for DVB-S2, together with some changes to the underlying transmission system to eliminate other minor inefficiencies. Although a significantly greater increase in capacity (i.e. double or more) could probably be achieved through the use of MIMO this would require changes to both the transmitter aerial and the viewers' receiver aerials.

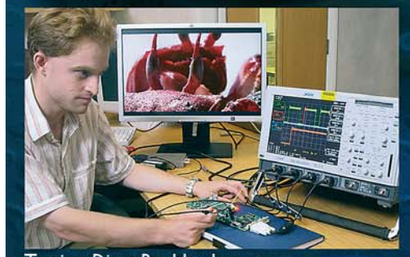
The commercial attractiveness of these options is still being studied. Existing digital viewers would need to buy new set-top boxes or digital TVs, so the introduction of a new standard might have to be incorporated into the launch of a new service, for example HD on DTT.

It is expected that a first draft of a specification for fixed and portable reception will be completed around the beginning of 2008, with a further specification for mobile receivers following later.

Video **Compression** – *Dirac* and *Dirac Pro*

Almost everywhere video is handled digitally some form of data compression is applied. Although satisfactory forms of compression exist for most applications, some are subject to restrictive or expensive licensing arrangements. This can increase our costs, and potentially the cost to our audiences in receiving our programmes. The BBC as a publicly funded body is in a unique position to develop open compression technology where it has a specific need, and to make that technology freely available. For example, the BBC's Open Archive initiatives will be making content available over the Internet, and we would like to be able to supply free software to schools and other educational bodies.

Dirac algorithm development



Testing *Dirac Pro* Hardware

Dirac Pro Hardware Products

Dirac team

Testing *Dirac Pro* hardware

Dirac

Over the past few years we have drawn on practical experience that dates back to the 1960's to develop an advanced video compression system called '*Dirac*'. Although we originally intended *Dirac* for high resolution images and high bit rates, its wavelet-based compression technique has proved suitable for applications from over 1 Gbit/s down to below 100 kbit/s. It is comparable with the latest standards H.264/MPEG-4 AVC and VC-1.

Dirac is open source, relies on no other parties' intellectual property, and can be used without payment of royalties. Its potential uses range from low resolution coders for mobile phones and Internet distribution of video clips through to HDTV and beyond with ultra-high resolution Digital Cinema. *Dirac* works under Linux and on Apple Mac PCs as well as Microsoft Windows. The ability to work on different operating systems is important to the BBC's plans for 'On Demand' TV via the iPlayer and streaming content over the Internet.

During the past year we have continued to improve *Dirac*. The algorithm has been made more efficient and easier to implement. A detailed specification has been published and open-source software made available to allow anyone to develop implementations. A second implementation, called Schrödinger has been optimised for speed although because of this it is somewhat harder to use as a basis for further development. Both implementations can decode standard definition TV in real time, with Schrödinger able to do this even on average specification PCs.

Measuring video quality

The technical quality of television pictures has been a frequent topic for discussion, even before the launch of the regular service. The debate continues, now largely over digital TV and latterly, HD.

Amongst the early broadcasts of the current HD trial were live programmes covering the FIFA World Cup from Germany. The broadcast arrangements were going to be complex using a chain of up to four MPEG-2 contribution links followed by transmission to the home using H.264 compression. Knowing that passing video signals through cascaded compression systems can cause extra picture degradation we simulated the entire chain. By experimenting with bit rate settings we were able to measure the video quality that would be achievable at home and recommend a number of improvements.

This was perhaps an extreme example, but any production chain will include a number of different compression systems between camera and broadcast, and there may also be format conversions. Because of the range of compression systems now available there is more than ever a need for a reliable and standardised method for measuring video quality.

Measuring video quality is an area we are continuing to research. In the coming year we plan to establish a test-bed to investigate and provide specialist advice on video quality within the BBC. We are continuing our programme of evaluating compression codecs and investigating issues of concatenated coding, focusing mainly on acquisition and production. We are contributing to collaborative work on this topic within the EBU.

Dirac Pro

We have now produced an implementation specifically for higher bit rates, which we have named *Dirac Pro*. It shares many features with *Dirac* and is most suitable above 100 Mbit/s.

Dirac Pro's initial application was to transport 50 frames/second (fps) HD signals on the same cables and infrastructure as conventional 25 fps HDTV. Video at 50 fps conveys a more 'fluid' motion and the BBC plans to move to this higher quality standard over the next few years. It is particularly suitable for sports coverage in HD, and could be used for the 2012 Olympic Games. *Dirac Pro* provides the 2:1 compression, sometimes known as 'Mezzanine' compression, with almost no loss in quality.

Another application of *Dirac Pro* is the transmission of HDTV signals between studios and production centres, using the existing distribution infrastructure. This requires more compression but *Dirac Pro* is sufficiently flexible to achieve this with little loss in quality. Many other applications of *Dirac Pro* are also possible, in programme production using networked infrastructure ('desktop production') and also in digital cinema production. *Dirac Pro* was successfully demonstrated to film makers in January 2007 at the Hollywood Post Alliance.

Dirac is attracting considerable interest both from within the BBC and from other organisations. It was demonstrated publicly at IBC 2006, where content from the BBC's HDTV trial was compared favourably with satellite broadcasts using H264 at the same bit rate.

We are currently formally standardising *Dirac Pro* through the SMPTE. A draft of the specification, referred to as VC-2, has been submitted and we are now waiting for it to be ratified. Establishing the standard will encourage equipment manufacturers to incorporate *Dirac Pro* into their products. An implementation of *Dirac Pro*, developed jointly with our commercial partner NuMedia Technology, will be launched at NAB 2007.

Where next?

We now regard our original implementation as a reference and have released it to several universities as a development platform. We are collaborating with them to exploit *Dirac* further and push the boundaries of video compression.

As 3D displays move closer to reality, both for the home and mobile devices, we are working with the University of Surrey to develop methods for compressing 3D video content. These techniques also help in modelling motion in conventional 2D images, and could help in improving compression there.

Brunel University are adapting *Dirac* technology to produce bitstreams that can withstand poor quality transmission systems and the effects of network congestion, avoiding the complete collapse in quality that bedevils conventional compression techniques.

As bit rates are pushed ever harder, it becomes increasingly difficult to maintain picture quality. Because the relationship between encoder control mechanisms and perceived quality is very poorly understood, encoder designers rely on ad-hoc, indirect, techniques to avoid quality collapsing when encoders are stressed. Manchester Metropolitan University have embarked with us on a project to incorporate psycho-visual modelling techniques into video encoder designs to manage video quality directly, using *Dirac* software as a test-bed.

Audio Compression

Audio bit rate reduction

A study has been made of MPEG Audio Layer II coding to find out how good it would be if an optimal coder could be developed. A 'genetic' coder was devised that could explore the myriad permutations of encoding that could be applied to each 24 ms frame of audio. The coder worked more slowly than real time but it was possible to record the results and listen at normal speed. The work was presented in a paper to the AES European Convention in 2006. We concluded that the potential for further improvement was marginal, the best coders already being close to the performance of the genetic coder.

There is always pressure to reduce the bit rates of the audio signals on DAB to make room for new features. MPEG Audio Layer II coding is adjustable only in moderately coarse steps in bit rate, and it is difficult to make reductions without compromising the audio quality. BBC R&I has continued to be closely involved in the assessment of proposed changes.

Multi-channel audio

BBC R&I took part in a major series of subjective tests organised by the European Broadcasting Union's B/MAE (Multi-channel Audio Evaluation) project group. In the first set of tests the subjective quality of multi-channel audio bit rate reduction systems such as Dolby Digital Plus, High Efficiency AAC MPEG Surround, and DTS was carefully assessed. These are systems that are, or could soon be, used for broadcast or Internet distribution of high quality surround sound, with or without accompanying video.

Early results were presented by IRT at the EBU's Forecast '06 conference. A paper has been written by BBC R&I together with colleagues from the EBU and IRT, and is to be presented at the 122nd AES convention. The conclusions reveal interesting performance evolution over the ten years since the previous comparable tests. With non-critical material, modern coders can achieve results as good as their predecessors but at a significantly lower bit rate. However, maintaining consistently high quality still requires the same, relatively high, bit rates.

Independent component analysis

Independent component analysis is a technique for splitting a sound signal into its component parts, and dealing with each one separately. As a simple example a duet might be split into the sounds of the two instruments, which in this instance would clearly be easiest from a stereo recording. We are fascinated by the applications that could be developed from this fundamental technology. A joint project is being set up with the University of Salford to examine how it might be applied in real broadcast audio environments.

Digital Rights Management

The Internet revolution encourages media businesses to find new ways to exchange content with their customers and between themselves. Digital Rights Management (DRM) is important in controlling and protecting these exchanges. However, some of the systems in use are proprietary, and as the number of connections multiplies, failure to develop interoperable solutions could be a major obstacle to the growth of the industry.

The requirements of DRM vary from limiting access, through 'copy control', to much more flexible permissions. In some cases DRM is used simply to protect the integrity of the content or authenticate authorship rather than limit distribution or collect remuneration.

BBC R&I has been working with partners in industry and academia to develop open DRM solutions. We have supported the broadcast technology providers through the DVB organisation as they specify the technologies for protecting content delivered over broadcast networks.

We also participate in the Digital Media Project (DMP) as it develops specifications and builds software prototypes from its 'Primitive DRM Tools'. These smaller DRM related functions can be used to assemble a variety of value chains according to individual business needs. The DMP aims to provide the technological means and organisational framework to allow participation in the media industry both by large content distributors and individual media creators wishing to distribute content with varying degrees of security. The DMP specifications bring a more inclusive model for all players in the value chain, from authors, performers, adapters and producers through to content providers and home users.

'The DMP aims to provide the technological means and organisational framework to allow participation in the media industry by both large content distributors and individual media creators wishing to distribute content with varying degrees of security.'

More recently we have begun working with a large group of academics and industrial partners within a mature and established project, funded partly by the European Union, that has developed a platform for cross media production and distribution; AXMEDIS.

In working with these international groups to develop and consider the issues of deploying DRM solutions we have come to a closer understanding of how our industry is changing and can change further to meet the demands of our modern world. By working with the wider industry we are better placed to control our own future and meet the needs of a new type of audience in the new digital age of broadcasting.