D12.6 A Survey of Digital Formats for Storage

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ABSTRACT	This document explains the ways in which audiovisual content can be held in computer files – the encoding of the content, including data reduction (compression) as the various file formats in use.
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1 Executive Summary

There are many ways to represent audio and video signals by ones and zeroes. The major types tend to be associated with file formats (eg .wav for audio), and so people commonly refer to audiovisual file formats.

However there are really two independent concepts at work: the encoding, and the file type – even though in practice they are encountered together.

Encoding is the method of representation of a signal, as produced by a **codec**

- The word 'Codec' is a combination of "Compressor" and "Decompressor" and describes a programme or a device capable of encoding data streams or more general transmission signals.

There is now a combination of open and proprietary codecs and file formats. This document describes the current complex situation, and tries to provide guidance for making informed choices.

In particular, we highlight the work of *MPEG*: the Motion Pictures Expert Group established in 1988 to produce standards in digital multimedia that support interoperability.

- MPEG-1 is good for preview and web encoding at bitrates from 500 Kbps to 2Mbps.
- MPEG-2 is good for broadcast encoding at bitrates from 4 to 8 Mbps. It has been used for archiving the 'semi-professional format' U-Matic, at 20 Mbps.
- MPEG-4 is good for preview encoding at bitrates from 200Kbps to 2Mbps.

*Motion JPEG 2000***,** a related standard, is the only generally-available standard to offer a lossless encoding option.

In contrast to the work of MPEG and JPEG, proprietary formats offers a different set of solutions to streaming media over the Internet.

- Proprietary formats have much quicker development cycles.
- QuickTime from Apple cooperated with the development of MPEG-4; Apple have concentrated on content creation platforms than encoding.
- QuickTime and Windows Media Player are not available on Linux, so Real Media is in a strong position to capitalise on the growing use of Linux in the European Market.
- Microsoft Windows Media Player has the highest penetration in the market (mainly due to it being delivered as part of the Windows XP).

A main consideration for any archive is whether lossy compression should be allowed. The overall recommendation is "NO" – but that is only a clear recommendation for professional quality material. It makes little sense to use allocate huge amounts of storage to video materials digitised from VHS, for instance.

Lossy compression refers to an encoding which alters the original image data upon decompression.

At present, the two most relevant compressions formats for archive encoding are MPEG-2 and MJPEG 2000. However MPEG-2 is obsolescent (it will be replaced by MPEG-4, in particular as new video material becomes High Definition rather than the current Standard Definition. All recommendations regarding MPEG-2 are short term; archives are advised to consider MPEG-4 instead.

2 What is a codec?

The word 'Codec' is a combination of "Compressor" and "Decompressor" and describes a programme or a device capable of encoding data streams or more general transmission signals. The Codes ensures that the stream or the signal is encoded for storage, transmission or encryption or decoded for viewing or manipulation in a format appropriate for the operations.

Most often Codecs are utilised for streaming video and audio transmissions. The raw encoded form of the audio and visual data should be distinguished from any metadata information or 'wrapper data' that combined make up the information content of the stream.

3 The Motion Pictures Expert Group (MPEG)

3.1 Aims

The Motion Pictures Expert Group is a working group of ISO/IEC that is in charge of developing international standards for compression, decompression, and processing coded representations of moving pictures, audio or a combination of both. The group was established in 1988 and its goal was to produce a standard in digital multimedia that would allow for interoperability.

From a manufacturers point of view this interoperability would ensure that modules from different suppliers could be integrated in a single product through clear interface agreements. From a consumer viewpoint the group would ensure that content from multiple sources would be available on players from different manufacturers.

Since it's beginning the MPEG group has managed to become the dominant force in terms of multimedia content through constant developments and progression. The MPEG working group usually holds meetings 3 times a year that are attended by over 300 experts from over 20 countries, a testimony to the wide availability and dominance of MPEG as an industry standard.

The point for the MPEG group was to develop standards-based technology in contrast to vendor-specific and proprietary technology. Rather than vendors competing for unique proprietary solutions, standards allow them to compete for the best implementation. With proprietary technology only, the limited resources of a single vendor are being applied to the problem whereas standards allow a worldwide technical community to engage in the work.

Open standards have resulted in MPEG an improved technology that is better, more interoperable and able to move the industry ahead.

The key to compression in the MPEG standard is the ability to detect and efficiently code motion in a sequence of images. Most codecs divides the video sequence into key frames, which are coded using only the information present in the key-frame image. Following frames are then coded using the difference between them and the previous key frame. Key frames, in general are critical to delivering high quality video since they allow the codec algorithm to reset from any errors and can be inserted at scene changes to allow smoother transition between two images.

In MPEG compression frames are divided into 3 categories:

- I-frames: key frames are labelled I-frames, short for intraframe coding
- P-Frames: is short for predictive frame. These are coded based on the difference between them and the previous I- or P- frame.
- B-Frames: is short for bi-directional frame. In contrast to P-frames, B-frames can predict motion that occurs in the next frame as well as the previous one.

The compression frame is set-up allows for flat areas where many of the co-efficiencies are zero to be coded more easily. In highly detailed and fast moving areas our eyes are not as sensitive to specific details and objects and the algorithm can take away information to reduce bit rates. The MPEG algorithm is based on Discrete Cosine Transform (DCT), which operates on the difference between the frames. Basically MPEG generates sets of I- B- and P- frames to make up what is called a Group of Pictures. MPEG hardware and software can then reassemble Groups of Pictures into sequential video frames for playback.

MPEG coders all use the MCPC structure and employ the 8×8:8:8 DCT. The DCT and DCT 2 is used in signal and image processing since most of the signal information tends to be concentrated in a few low-frequency components of the DCT.

When utilised in JPEG, MJPEG, MPEG and DV video compression the two-dimensional DCT 2 of *N x N* blocks is computed. N is (typically) 8 and the DCT 2 is applied to each row and column of the block. The computed result is 8 x 8 transform coefficient array in which the elements is the DC (Zero Frequency) component. Based on this computation lossy data compression is enabled since the entries with increasing vertical and horizontal index values formulates to higher vertical and horizontal spatial frequencies.

This transform process was first initiated by H.261 which was the first practical digital video coding standard. It was designed as a pioneering effort and all subsequent coding standards from MPEG to MJEP and H.262 to H.264 have been closely based on its design. The coding algorithm uses a hybrid of motion compensated inter-picture and spatial transform coding with in turn provides for scalar quantisation combined with zig-zag scanning and entropy coding.

The basic processing unit in the H.261 is called a macroblock. Each of these macroblocks consists of a 16x16 array of luma samples and two corresponding 8x8 arrays of chroma samples using 4:2:0 sampling and a YCbCr colour space. The Inter-picture prediction removes temporal redundancy and the transform coding using 8x8 DCT removes special redundancy.

The H.261 standard only specifies how to decode the video. Encoder designers were left free to design their own algorithms and to perform any pre-processing they want to their input video prior to display. One of the most used post-processing techniques of H.261-based systems is deblocking filtering. This technique reduces the block effect caused by block based motion compensation and spatial transform parts. The technique has been integrated in to the most recent standards such as the H.264.

H.264, or MPEG-4 Part 10, is a digital video codec which is noted for achieving very high data compression. It was design and developed by the ITU-T Video Coding Experts Group (VCEG) together with MPEG as the product of a collective partnership effort known as the Joint Video Team (JVT). The ITU-T H.264 standard and the MPEG-4 Part 10 standard are technically identical, and the technology is also known as Advanced Video Coding (AVC).

So in many respects the MPEG family is similar to H.261/H.264 coders, except that they operate with higher resolution frames and higher bit rates.

The main difference from H.261/H.264 is the concept of a Group of Pictures (GOP) Layer in the coding hierarchy. The layers are as follows:

- The Sequence Layer contains a complete image sequence, possibly hundreds or thousands of frames.
- The Picture Layer contains the code for a single frame, which may either be coded in absolute form or coded as the difference from a predicted frame.
- The Slice Layer contains one row of macroblocks (16×16:16:16 pels) from a frame. (48 macroblocks give a row 768 pixels wide.)
- The Macroblock Layer contains a single macroblock -- usually 4 blocks of luminance, 2 blocks of chrominance and a motion vector.
- The Block Layer contains the DCT coefficients for a single 8×8 8 8 block of pels, coded almost as in JPEG using zig-zag scanning and run-amplitude Huffman codes.

- The GOP layer displays the syntax structure of a GOP, specific prediction or intra modes invoked etc.

The first MPEG standard (MPEG-1) was approved in 1992 and produced as a standard for storage and retrieval of moving pictures and audio on storage media.

3.2 MPEG-1

As a technology MPEG is a toolset for formatting and delivering content across a wide spectrum of different communications networks. MPEG-1 as a standard was developed for compression on fixed media such as Video CDs and CD-ROMs. It has since emerged as a delivery format for basic video and audio content over Internet protocol, the transport protocol of the Internet and corporate intranets.

MPEG-1 was originally targeted to deliver compression suitable for PC multimedia use. Its main advantages are that all recent media players on most operating systems can play its format. Its typical target bit rates are around 1.5 Mbps that allows the developer to put 1 hour of video content onto a disc. Video data rates are expressed as bits per second referring to the amount of information stored per unit of time rather than bytes in computer files. MPEG-1 runs with full motion at 24-30 frames per second but constrains the frame size to 352x240. For computer applications this is sometimes relaxed to 320x240. This compression ensures that the audio and visual information crunched into acceptable data rates for streaming.

In contrast to later MPEG codecs, MPEG-1's motion estimation is computed on a frame-by-frame basis. The result is less flexibility in the motion estimation and therefore drops in quality can occur.

In comparison to other current codecs the encoding and delivery of MPEG-1 requires higher bit rates for a given quality level. With the introduction of broadband services and with the power of most corporate LANs this has no interference on the quality of streaming media but low-end web users maintaining consistent delivery proves problematic with higher quality MPEG-1.

Summary of MPEG-1:

- *It is good for bit rates 500Kbps to 2Mbps*
- *It is an appropriate standard for Video CD, video clips delivered over public internets, video to PCs over networks and news gathering from remote locations*
- *If audio is of less a concern, more bandwidth can be allocated to video and vice versa*
- *PC software MPEG decoding is possible thus removing the need for dedicated hardware at the point of delivery*
- *It is suitable for small video monitors but the quality is degraded considerably for plasma screens and video walls and cannot be considered suitable for such applications.*

3.3 MPEG-2

The architecture of MPEG-2 was fundamentally created to carry the data necessary for data broadcasting. Applications such as pre-programmed video-on-demand and basic interactivity are the targeted area for MPEG-2. The development of MPEG-2 was targeted towards higher bit rates such as in broadcast television. 2Mbps to 8 Mbps enables full screen, full motion delivered over satellites and on DVD.

The algorithm for MPEG-2 achieves higher quality due to a more flexible approach to the motion detection scheme found in MPEG-1. As explained above MPEG-1 generates the motion detection on a frame-by-frame basis whereas MPEG-2 can analyse and compensate on field basis. This more advanced method detects and corrects over several frames rather than by single frames, thus providing MPEG-2 with increases in smoothness, sharpness and enabling close to broadcast quality video with data rates around 3-6 Megabits per second, higher for true broadcast quality.

The increased depth and complexity of MPEG-2 provides avenues for interactive content to be deployed in television broadcasting. Originally MPEG-2 programme streams were used for storage systems and employed in VOD and interactive multimedia applications.

MPEG-2 programme streams are designed for high-reliability transmissions where the emphasis is on low-loss/low-error performance. An MPEG-2 programme is a set of elements generally compromised of compressed video and audio that shares a common time base. An application or device known as a multiplexer assembles the different elements in a stream. By adding clock references and time stamps to the media elements the multiplexer generates a MPEG-2 transport stream, which enables MPEG-2 streams to carry multiple programmes in the transport stream allowing for rudimentary interactivity such as VOD, billing etc.

The MPEG-2 standard supports the DVD and television industries and through vendor-specific innovation it has dramatically improved since 1994 while maintaining compatibility with the original standard. Compared to the MPEG-1 standard it has eluded adoption by the general public due it its high requirements (particularly the bandwidth required to get or play the files) and sits firmly with the television and movie industry. Today the MPEG-2 standard is the main format for broadcasting (digital television) and for the DVD industry.

Summary of MPEG-2:

- *Good at bit rates from 1.5Mbps to 80 Mbps*
- *The main format AT PRESENT for high-quality archives; it is lossy, so cannot be preferred to lossless JPEG 2000*
- *The broadcast and DVD industry, and the high-resolution computer and internet applications as well, will all move to H264 (an open standard from MPEG 4) or to Windows Media 9 (proprietary). So MPEG-2 is obsolescent*
- *Quality of encoded file continues to increase at bandwidths in excess of 5Mbps, unlike modern MPEG4-based codecs*
- *Software decoding of MPEG-2 is very CPU intensive so using dedicated hardware is advisable for the best result*

3.4 MPEG-4

MPEG-4 development began in 1993, and while most of the specifications had been released by 2000, major parts were released in 2001 and 2002. More importantly the MPEG-4 licensing terms that were released in January 2002 was a departure from previous MPEG standards. While an open standards body developed MPEG-4 some of the technology included in the specification is subject to patents. Technology developers wishing to implement MPEG-4 must license the technology from the patent holders.

MPEG-4 reaches well beyond the standard codecs we use today for streaming media. As broadband access grows MPEG-4 will be able to compete with more efficient coding algorithms from Real, Microsoft and others specialising in proprietary codecs. MPEG-4 will have advantages on the mobile market because it reaches into the low bit rates and is more readily implemented in hardware form. In addition MPEG-4 has a rich set of tools that is emerging with wide acceptance on the Internet and should result in a growing convergence of different media applications and elements in the future.

While in the proposal stage the MPEG group searched for technologies that could be built into the standard it was developing. The format that was chosen was based on Apple's QuickTime Architecture (Not the QuickTime compression but its architecture was adopted into the MPEG standard.) It included support for different media elements in the form of layers such as; text, sprites, textures, synthetic music and images that can be sent alongside the audio and video content.

In comparison with its predecessors MPEG-4 has been developed to accommodate a much higher level of interactivity with the additional media elements and layers. The delivery of these layers allows for a more flexible and efficient media creation. For instance a video sequence can have audience-specific graphics superimposed which deliverers enhanced personalisation for the user-audience.

In the MPEG-4 standard, texture mapping and coding of 2D and 3D meshes or layers can be defined according to parameters. In this way, a moving object is defined by nodes that make up the actual mesh. The position of these nodes defines motion and deformation of the object in time. A texture or even a video can be sent with the audio/visual stream and transformed by the decoder according to set parameters coded into the mesh. This provides a very effective way of delivering unique motion graphics and customisation to the end-user.

Scalability is another concern for multimedia content delivery. As multiple formats and bit rates are required by end-users, providers needed to have a better scalability tools-set to reach fragmented audiences. Since video compression scaling usually has taken the approach of lower quality at lower bit rates, end-users may see reduced spatial quality that produces a blocky effect and pixelisation due to dropped frames. MPEG-4 incorporates these scalability factors into one file for streaming. In addition, because the format defines different components of a sequence, it can scale the content based on the areas of interest or a particular application.

Due to this interoperability and flexibility MPEG-4 is targeted towards wireless application. In this market manufactures must commit compression algorithms to actual hardware because the mobile market requires the small footprint only dedicated hardware can deliver. Proprietary solutions can become obsolete when their developers introduce a new system version in comparison to MPEG-4, which is a standard rather than a proprietary technology. In this way MPEG-4 provides more flexibility for the wireless industry and less risk. With its capacity for delivering low bit rates MPEG-4 can be seen as a primer for the mobile industry because of its bps range (40Kbps to 8Mbps).

The broadcast industry is also looking hard at MPEG-4. The requirements for adopting digital television are in place and with an explosion of interactive services on sky, cable and set-top boxes. MPEG-4's advanced encoding features can provide more channels in a given bandwidth that could be explored for creating niche programming markets for cutting-edge broadcasters.

Summary of MPEG-4:

- *Good for bit rates 40Kbps to 8Mbps which gives it a wide range of possible application*
- *Appropriate for live video on corporate LAN*
- *Can deliver video to PC or to large displays such as video walls and plasma displays*
- *More efficient algorithms than previous standards making it ideal for limited bandwidth and storage applications*
- *The advanced algorithm also enables better bit rate quality performance than previous MPEGs*
- *It is suitable for a wide range of output devises, from handheld to large format displays*
- *The latest version of MPEG-4 (Part 10, also called H264 and AVC = Advanced Video Coding) is the format used for High-Definition DVD (except for the Microsoft alternative based on Windows Media 9), and is expected to replace MPEG-2 encoding for broadcasting as HD replaces SD.*

3.5 Future directions/product development cycles

Although the MPEG standard has enjoyed widespread adaptation, its development cycles have been significant in contrast to proprietary codecs such as Microsoft's Windows Media Player Codec and Real Player.

MPEG-1 and MPEG-2 development and approval processes spanned six years which is high for such a fast moving industry. Proprietary codecs offer the advantage for fast development cycles and this has resulted in wide acceptance that these technologies can achieve better quality at equal data rates than the standard MPEG-4.

In contrast proprietary codecs will most likely exhibit higher quality than any standard but the availability of interoperability has enabled MPEG to progress into the most widely know format for most applications and multimedia industries. This ease of use will benefit consumers and end-user and this is in essence the key to survival and progression in the market.

4 Proprietary streaming media formats

4.1 Overview

In contrast to the work of MPEG, proprietary formats offers a different set of solutions to streaming media over the Internet. As noted above, proprietary formats have much quicker development cycles since only one organisation or company is pushing its resources towards a set format. Development times and updates to proprietary formats enter the market place at a furious pace compared to MPEG. This pace of developments can in return generate additional problems and challenges.

The most immediate problem is that of uptake and sustainability. With several proprietary formats entering the market only a few will evolve to carry the market. The format of choice does not necessarily conform to technological sophistication, user-friendliness, and/or marketing ability but emerges from a nexus of these market forces interacting.

The sustainability of proprietary format is hard to forecast but several contenders have emerged that will be in the game for the foreseeable future. One of the main issues with proprietary media formats is the lack of interoperability between the different formats. WMP 9 did finally come out on the Mac platform but it was a long wait.

The quality of proprietary formats are at present better than MPEG since the basic premise is that specialised technology, programmed just for one player has a better chance of tweaking the algorithm for improved quality. Whether average users will be able to spot the difference in quality is dubious. In this sense it must be stated that the quality gains made by proprietary formats does not really affect average users. User satisfaction with a given format depends as much of the quality of the production and encoding as the actual player algorithm.

4.2 Market Penetration

The frontline for proprietary codecs is the availability of free downloadable media players. The market penetration of individual players gleamed from company websites are subjective and qualitative at best. The numbers in question are mainly down to convince content providers about potential reach of each player. In terms of numbers there is very little information available on whether downloads are upgrades for established users or first time downloads. Also many individual users will download a player to a multitude of devices such as laptop, home desktop, work desktop, and now several different mobile devices.

In addition most of the major players have distribution channels outside of their own websites for downloadable version of their players which in turn means that getting an accurate picture in terms of numbers is almost impossible. Even the numbers that do come up do not accurately reflect user choice or the uptake and actual use of media players on individual computers.To actually establish any real insight into market penetration of proprietary players is extremely complex but by dissecting the information available on the major proprietary players we might come closer to an approximate percentage.

4.3 Apple QuickTime

The player from Apple formed the architecture for developing MPEG-4 and Apple have made their business in this area more about providing content creation platforms than trying to dominate the format and codec market. Apple sees itself much more as a hardware provider and will probably accommodate formats that are successful at any given time[1].

In terms of numbers Apple, in 2004 claimed an estimated 250 million downloads of which 98% are PC versions. But since Apple only tracks users per platform combined with the fact that this number only takes downloads from the Apple website into account these numbers does not reflect actual uptake or use of the QuickTime player. Outside of the Apple website, QuickTime is distributed via digital cameras, editing tools such as Final Cut Pro, educational and entertainment software titles, enhanced music CDs, iTunes and AOL.

In terms of digital cameras there are more than 75 different models from a range of companies including Canon, Olympus and Kodak[2]. The proliferation of QuickTime not just from digital cameras but also from iTunes in conjunction with the success of iPods means that Apple's ability to maintain momentum in the player markets seems secure for the time being. A recent Frost & Sullivan report suggest that QuickTime is slowing gaining on the market leaders Microsoft with a reported increase towards 36.8% of the market. Again in regards to numbers any analysis must be very careful in factual reporting of users and usage of players in the market.

Last and not least the Mac computer is a very popular tool with multimedia professionals giving QuickTime a special foothold with the major producers and distributors of multimedia.

Summary of QuickTime:

- *QuickTime enjoys success across platforms*
- *The player is distributed by a variety of channels including software, digital cameras, AOL and iTunes*
- *According to their business plans Apple will be happy to accommodate most formats available rather then being proactive about developing new proprietary codecs*
- *Backward- and cross- compatibility remains strong setting a good stature for further development*

4.4 Real Player

Real are trying to enter the European market via the new fascination with Linux. Real's Helix Open-source player allows for playback of Ogg Vobis and Theora-encoded video and users are prompted to upgrade to RealPlayer for free. Since there are not currently any QuickTime or Windows Media Player for Linux, Real is in a strong position to capitalise on the growing use of Linux-based OSes in the European Market.

Real claims to have 400 million downloads each with unique email addresses of its proprietary software. According to the recent surveys there are approximately 900 million Internet users distributed all over the world with around 200 - 300 million just coming online during 2004/2005[3]. This cast some doubts on Real's claim but again several external factors

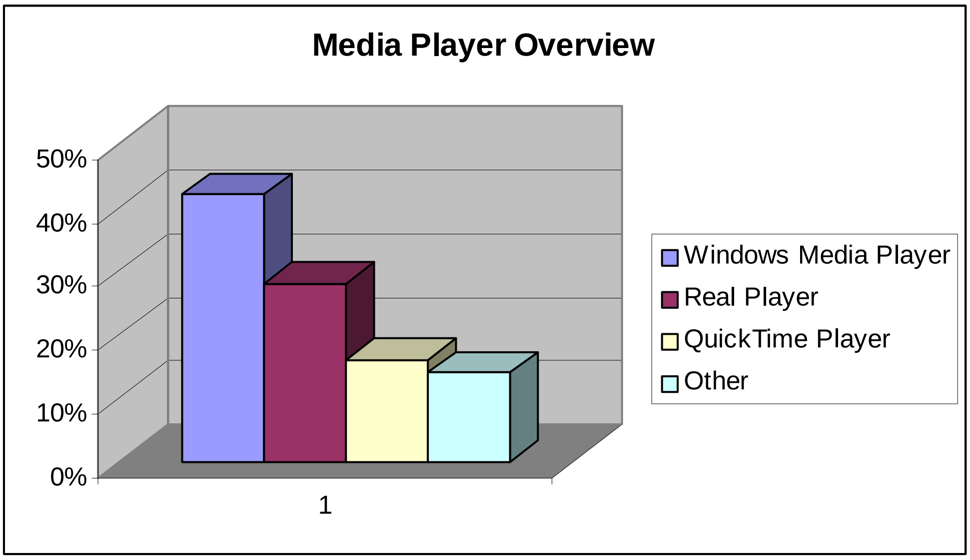
[1] Player Penetration By The Numbers by Geoff Daily, August 18th 2004 - http://www.streamingmedia.com/article.asp?id=8757&page=3&c=31

[2] NAB, LAS VEGAS—April 23, 2001—Apple http://www.apple.com/pr/library/2001/apr/23cameraquicktime.html

[3] http://www.internetworldstats.com/stats.htm - http://www.nua.ie/surveys/how_many_online/world.html

such as multiple email addresses and multiple devices could add up to a higher number of users.

Regardless of the validity of their own numbers Real is lagging behind at least Microsoft in actual eyeballs-on-player. In a resent presentation at the TERENA Networking conference in 2004, TF-NETCAST had done a study of the uptake and use of Streaming Media Players in Academic circles throughout Europe. Taking into account that the academic community in Europe is tiny compared with global number of Internet users and that this community have a good understanding of using the Internet for streaming purposes. The presentation suggested that the split in academic circles of Streaming Media Players breaks down as follows in response to the questions "What is your preferred/favourite player":



Source: Academic Streaming in Europe: Report on TF-NECAST by Alessandro Falaschi, Dan Mønster, Ivan Doležal, Michael Krsek

These numbers do indicate that Real has a larger slice of specialist markets than they are given credit for - for instance in the previously mentioned Frost & Sullivan Report and according to many industry experts.

On the mobile market Real has been pushing hard to be included as default media player on many of the major Mobile OSes.

This should give them a new lease of life since according to the recent reports they have lost ground and will most probably enter the rankings as the third largest after Windows Media Player and QuickTime. Especially since the uptake of mobile video streaming is still in its infancy.

Summary of Real Player:

- *Moving progressively towards open source software and mobile application*
- *Has a good following in certain market sectors but lacks the muscle of Microsoft*
- *Have developed a unique product for Linux and has settled into a strong position for open source developers*
- *No cross compatibility with other codecs*

4.5 Windows Media Player

The Microsoft product is currently the player with the highest penetration in the market. Mainly due to it being delivered as part of the Windows XP OS. Since Windows is running on 95% of the world's computers this was seen by many as an effective monopoly. The European Commission launched an antitrust case and won the litigation in 2004. As a result Microsoft was ordered not to bundle WMP with its XP OS and pay a record $604 million fine. Even so the easy integration of WMP with Windows XP OS ensured that it can still be seen a preferred choice for the majority of users.

With the release of WMP10 Microsoft has announced that it intends to become a major force in the distribution of digital content. Its integrated "Digital Media Mall" seeks to become the nexus between users and content providers. The move by Microsoft could ensure that WMP 10 becomes the dominant software in facilitating the connection between consumers and providers of digital content[4]. A version of the WMP 9 is available to Mac Computers but it is still unclear how much Microsoft sees WMP 10 as a cross-platform product.

One of the main features of WMP 10 is the "Digital Media Mall". The "Digital Media Mall" offers users a variety of channels connecting content and synchronise digital media products to any out-put device. This could be a very lucrative area as more and more people connect to the Internet via broadband.

The capacity of broadband enables more complexity and greater quantity of digital media content delivered over the Internet. The positioning of WMP 10 as the main connection between users and content providers signals a shrewd move to build media hubs capable of delivering the digital revolution of multimedia distribution over the Internet.

Summary of Windows Media Player:

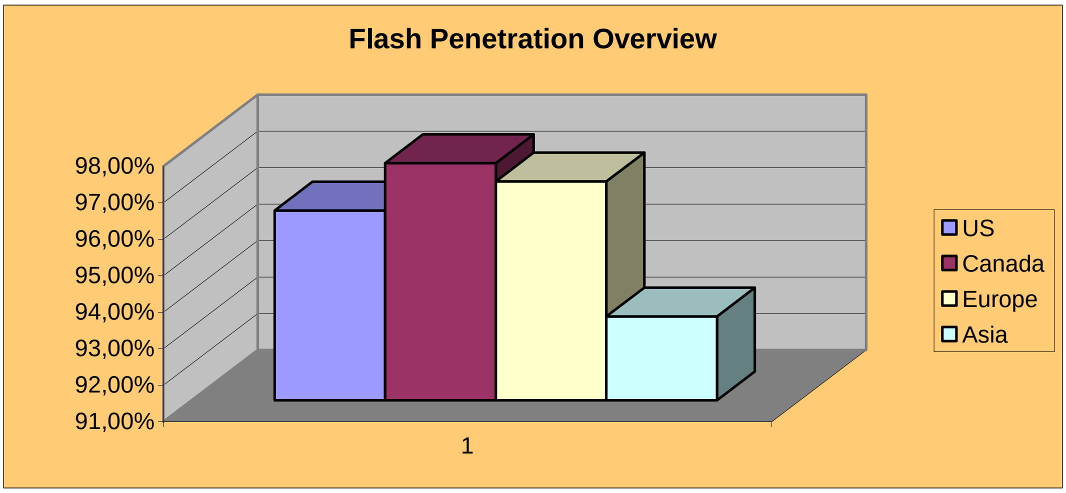
- *Has near universal penetration of the market*
- *Flawless integration with Microsoft OS*
- *Business plan to become the one-stop nexus between content providers and users with WMP 10*
- *No easy compatibility with Mac computers or other player codecs*

4.6 Macromedia Flash

Technically Flash is a browser plug-in rather than an actual player in the traditional way. The Macromedia Flash Player is a multimedia and application player. It runs SWF files that can be created by the Flash authoring tool. So even though the technical ability of flash as a player is still in its infancy its availability and current market penetration makes it an application that should be watched. With its omnipresence it is hard to ignore this application. Flash 6 and higher has some video capabilities and according to Macromedia it populates 97% (as of June 2005) of all desktops with Internet connection in Europe[5]. On a world scale the available of Flash V6 is extraordinary as you can see from the graph below.

[4] The addition of Windows Media DRM 10 and the new Media Transfer Protocol, moving songs, videos and pictures to devices will be easier for consumers and more secure for content owners than ever before." http://www.microsoft.com/presspass/press/2004/sep04/09-02wmp10launchpr.mspx

[5] http://www.macromedia.com/software/player_census/flashplayer/version_penetration.html



Again these figures does not suggest that it is being used by that many people as their main player but with the proposed Adobe acquisition of Macromedia announced earlier this year the company is positioning itself as one of the leading providers of digital content production and editing tools. Macromedia was seen as the leader in the Internet and dynamic web design area where Adobe was the leader in the digitalisation of publishing with products such as PhotoShop and Illustrator. The proposed acquisition would strengthen the position of Adobe and Macromedia as a consolidated powerhouse of digital media content production.

While the other proprietary format players are mainly interested in improving video quality via their various codecs and setting themselves up as providers of video distribution solutions, Macromedia is developing a different strategy. Macromedia's strength lies in its grip on the web developer market especially for high-end and dynamic websites. From their perspective consumers' just wants video that works every time without; having to download additional plug-ins, waiting before download and play. Combining the many other frustrations that currently plague current players in the market and Macromedia's business strategy starts to make sense. The benefits for users of Flash are minimal buffer time, the web page stays the same and users are not prompted to select several options such as Internet connection and other Player specifications before the video starts.

This benefits developers who can assume that users can and will play their video without having to open a separate player that takes them away from the actual web page. Since Flash is not platform dependent developers only have to encode the video once rather than several times for different players. And because the Flash Player is fully customisable, developers can give their customers full branding which fits well with current levels of brand-centric and advert-centric Internet marketing.

Macromedia believes that by providing the web developers with an easy tool to integrate video more firmly into actual web design and development consumers will get just that. Giving web developers more control over how they choose to deliver streaming media content gives an incentive to web developers to use Flash rather than other players in the market.

Though Macromedia themselves acknowledge that Flash video is probably less efficient than the latest Windows Media Player and Real Player the average consumer will not be able to notice the difference and with the recent launch of Flash 8 the difference should be even more negligible.

Summary of Macromedia Flash:

- *Near universal acceptance of Internet ready computers*
- *Great cross-compatibility both in terms of OSes and a variety of codecs*
- *Customisable and has the ability to be integrated into actual web development*
- *Aimed at multimedia savvy users and people with better than average IT skills*

4.7 Product development cycles

Development cycles for proprietary codecs and formats are generally much faster and this is illustrated by the flow of upgrades for Real Player, Windows Media Player and QuickTime. All the major players will try and keep backwards compatibility but the question remains if new technology comes along to replace the existing proprietary infrastructure will this compatibility remain essential to the business interests of the developers? In effect does backward compatibility make business sense for the developers at all?

This question must be raised since in terms of technology and especially in the realm of display and distribution of audio/visual content, technology has mutated several times. Analogue audio/visual storage and display technology has produced several formats with no easy compatibility[6] and the eradication of certain technologies within very short time spans.

As examples we have the 8-track, audiocassettes, Betamax, VHS and others. These examples are all of course analogue systems but even with the migration to digital formats such as DVD, there is no guaranties that this pattern will not be replicated within the digital realm.

Creating backward compatibility digitally is easy but if it does not make business sense chances are it will not happen. Many of the major players will not devote their resources to such a task regardless of whether it is analogue or digital formats.

The speed of developments in proprietary formats are determined by commercial interest which drives this trend towards non-compatibility between formats and backwards compatibility. Backwards compatibility is very critical to any form of archive since by its very nature an archive will be stored in legacy formats. Nothing short of constant updating can prevent this. Constant updating is not a viable option and hence digital formats and codecs with no compatibility are unsuitable as an archive tool in this context.

Proprietary information technologies can be seen to dynamically change every 18 months at present. In such an environment the pace with which technology develops provides a challenge for ensuring compatibility.

In the review of different formats conclusion about different market strategies from the major players have been analysed. From this analysis it is possible to see who most aggressively will develop new codecs and formats to match aspiring business interests. Some players like Flash and QuickTime are happy to sustain current formats that are available at any given time and can be seen to be very adaptable towards cross-compatibility. Also both Flash and QuickTime are very much specialist formats in the sense that their user-base are usually multimedia savvy users.

Even though Flash is present on 97% of the world's computers with Internet connection people with the ability to customise the player are usually people with a background in the production or distribution of multimedia. Also the business strategy of both Macromedia and Apple are much more focussing on these specialist parts of the IT industry rather than on the average Internet user. Both Flash and QuickTime development cycles are very slick and fast.

Real Player and Windows Media Player are aimed much more at the general Internet user in comparison to Flash and QuickTime. First of all WMP is a Microsoft product and with the majority of the world's computers running Microsoft software the integration between player and OS is flawless.

The issue here is cross-compatibility especially with Mac computers. The audience for Microsoft is the average computer users where as Mac can been as the tool for multimedia professionals and with no Mac version for WMP 10 the WMP format is exclusive to PCs. Both Real and WMP are pushing out new additions at an astonishing rate but only Real Player will try and accommodate cross-compatibility with open source OS.

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[6] In reference when mentioning compatibility it is assumed that this implies both backwards and cross compatibility unless otherwise stated.

With new platforms for multimedia delivery in the form of 3G phones, MP3 players and other technology both Real and Microsoft will be pushing out new additions and developments to their players on a regular basis.

The challenge in preserving digital video in terms of proprietary development cycles manifest itself as sociological more than technological. In the pressures to continually improve and advance proprietary technology cross- and backwards compatibility is lost.

"The dynamism of the market for information technologies and products ensures fundamental instability of hardware and software primarily because product obsolescence is often key to corporate survival in a competitive capitalist democracy. Product differentiation manifests itself at the very level of document standard. Proprietary systems provide commercial enterprises with profitable products whereas static (i.e. preservable) formats do not create a continuing need for upgrading which software and hardware companies depend upon." (Kuny:1997)

The speed of development product cycles for proprietary formats actually works against the utilisation of these for archive purposes by their very nature. Technology is not the obstacle to developing formats suited for archive purposes rather it is social mechanisms that hinder proprietary formats to be suitable for archive purposes. It is therefore to be noted that regardless of business strategies, which themselves are open to change, proprietary formats do not lend themselves well to archiving purposes in the current social climate.

4.8 Quality Evaluation

Quality evaluations of streaming media formats have long been a worry to digital archivists. How can analogue footage in terms of film quality be preserved when transferring to digital media? Can the material tolerate any losses or would the transfer need to be completely lossless even though the actual picture quality does not justify the storage needed in digital format? Quality evaluation of different formats has therefore become a tool to understand the technical requirements for transferring analogue film to digital formats.

One of the most accurate methods of analysis is based on the Genista software. Genista enables a frame by fame value of set parameters to be displayed. The data derived from the analysis is not displayed in graphic form but as graphs. It can be hard to make direct links and conclusions about specific qualities but it does deliver an indication of the overall qualities of specific formats.

For the quality evaluation and assessment of the performance of different formats the Dance Heritage Coalition released a report[7] of their findings when using the Genista Software. The issue of high quality was important since the movement capture on film would need to be transferred without loss to the digital archive to be of any value to a dance researcher. The object of their study was to find any discrepancies between the digitalised versions in terms of quality.

Condensing the information into a table will provide a detailed overview of the difference between formats. The different values represent areas where the format would be perceived to encounter obstacles in the footage. For instance in footage with fast movements and multitudes of colour in was investigated how well each format would hold up during play back.

[7] Called "The Digital Video Preservation Reformatting Project". The Dance Heritage Coalition published a 1997 report to the National Endowment for the Humanities identifying a need for preserving of dance recorded on videotape. The project progressed and developed into the Digital Video Preservation Reformatting Project. .

	MPEG-2	MPEG-4	Sorensen-3	Windows Media 9	Real Media 9
Blockiness	4 – 4 - 4	2	4 – 3 - 3	2 – 2 - 2	2 – 3 - 3
Blurriness	4	3 – 2	2	3	2
Jerkiness	4 - 5	3 – 3	3 – 4 – 2 - 3	2 – 2	3 - 3
MOS prediction*	4 – 5	3 – 3 -– 3	4 – 4 – 3 – 4 - 4	3 – 3 – 2 – 2 - 3	3
TOTAL	34/8	25/8	43/13	26/11	19/7

- The table is based on a scale from 1 – 5.
    - 5 - Exceptionally well. Would indicate that the format is completely lossless.
    - 4 - Good performance. Would indicate that the format can easily be used for digitalisation.
    - 3 - Average performance. Would indicate that the format have some issues with specific film features.
    - 2 – Mediocre performance. Would indicate that the format is ill equipped for the task.
    - 1 – Appalling performance. Would indicate that the format is not suitable for the specific task.
- The TOTAL represents the format score and the number of test it was involved in. In this sense the best formats would have a high value in the first number (A) and a low number in the second number (B). In this way certain formats underwent more tests to ensure that the results can be upheld for longer. And the total would give an indication of how good the formats are in general on the individual tests.
- Multiple numbers indicate multiple testing under different circumstances such as fast movement, colourfulness, lighting etc.
- *MOS prediction is a Mean Opinion Score that has been derived from experiments with human subjects. In this way the MOS prediction mimics human perception and observation and correlated it with video quality.

4.9 Blockiness

All discrete cosine transformed-based compression techniques (DCT) have a perceptual measure of block structures. Each block in a frame has a quantative measurement, when Blockiness occurs it is due to a strain on the format. This causes horizontal and vertical lines to appear. Blockiness can also stem from transmission errors.

4.10 Blurriness

Blur is a perceptual measure of loss in detail and in the edges of the video. Issues causing blurriness can be low-pass filtering, out of focus filming and high levels of motion. DCT based formats can also suffer from this since the technical errors would be due to the attenuation of high frequencies during either recording or encoding.

4.11 Jerkiness

Jerkiness is a perceptual measure of frozen frames. Motion in the video is conceived by users as being not smooth. Primary causes would be network congestion and/or packet loss.

Summary of qualitative evaluation

- *Most proprietary and lossy formats lose quality with high levels of motion, colourfulness and low intensity lighting.*
- *Sorensen, which Flash 8 is based on, came out as the best proprietary format*
- *Both Windows Media 9 and Real 9 came out as the worst performers in the quality evaluation*
- *MPEG-2a high level almost lossless format is good for most circumstance*
- *MPEG-4 which has better compression rates than MPEG-2did well as a lossy compression format*

5 Encoding for a high-quality archive

5.1 Overview

The main consideration for any archive encoding is to consider whether loss-less or lossy compression should be used. Both encoding methods have distinct advantages and disadvantages and the ultimate aim of the archive should be analysed to understand the best solution based on the compression available.

5.2 Lossless Compression

For many years the only compression technology that was available for data processing and in the computer fields in general was lossless. Basically, lossless compression techniques produce a smaller file for storage without changing the actual content of the file. This means that the file when uncompressed is identical to before compression. The main challenges with lossless compression of video are the processing power needed for real-time compression and the small gains in compression ratios.

Firstly it will take large amounts of processing power to convert the entire backlog of archive materials analysed by the PrestoSpace project. Computer processing power not only equates to large amounts of hardware but also to time. Processing lossless compression will usually be done in real-time so calculating the time needed to process the material for the PrestoSpace project is fairly easy. Of course the material will be processed over several locations but it provides a glimpse of the resources needed to fulfil project aims.

Secondly the compression ratios for lossless compression are related to the question of storage. In terms of ratio most lossless compression methods will yield a maximum of 7:1 compression. The challenge of converting from digital to analogue will take up huge amounts of digital storage space.

The benefits of lossless compression will definitely provide an archive with the high standards of quality needed for multimedia in the future. The tremendous benefit of having identical information before and after compression is the key to successful preservation of moving images.

5.3 Lossy Compression

Lossy compression refers to a technique where the compression of the original file alters the original image upon decompression. For most computer data applications, the complete replication of the original after compression is necessary. Anything less and the data would be considered corrupted. For video, lossy compression hopes to present the footage in such a way that the loss of certain information in each image will not affect the way in which the human eye sees the footage.

Lossy compression does have its advantages. From a practical standpoint lossy compression offers reasonably high quality results with a compression ratio of 40:1 in comparison to the lossless ratio of 7:1. In terms of the industry, lossy compression is integrated into hardware and soft ware for the video industry. On top of that most consumer digital recordings are created with lossy compression since it is build into the hardware. Because of this acceptance in the industry as a whole and in the consumer markets lossy compression enjoys a variety of technologies and standards from which to choose from.

The combination of this means that lossy compression used for video streaming can be enabled over relatively slow and limited bandwidth systems. This is in sharp contrast to lossless compression where the higher bit rates needs dedicated bandwidth and sometimes hardware in order to perform the delivery.

5.4 Formats

The two most relevant compressions formats at present are MPEG-2 and MJPEG 2000. Both are open standards and MPEG-2 has already been reviewed in the MPEG section.

MPEG-2 provides compression schemes both intra frame (inside the frame) and inter frame (between frames). These are DCT encoded and have motion compensated frame prediction. This may introduce patterns of loss in the original data. Even so its high-end quality makes it very versatile to use as an archive format. In addition MPEG-2 enjoys wide spread use and acceptance with major media organisation and is a recognised standard for both hardware and soft ware developments.

MPEG-2 is the basis for digital television and for the DVD industry. However these industries are in the middle of a ‘once in 40 years’ change of definition (lines per frame), effectively doubling the quality of TV / DVD images by moving to high definition. MPEG-2 will be dropped, as HD DVD and early forms of HD TV are already moving to MPEG-4 Part 10, also known as H264 or AVC. Archives with material in MPEG-2 encoding are faced with the need to transcode for use in HD application – which will be **all** broadcast and DVD applications within as little as five years.

MJPEG 2000 or MJPEG-2000 is a video adaptation of the popular format JPEG utilised for images. In MJPEG-2000 each video frame is compressed separately and in contrast to other MPEG formats there are no I, P or B frames. In this way MJPEG-2000 resembles analogue film more closely in the sense that single images are projected as a series, which adds up to video sequences.

Since each frame is compressed separately no frame differentiation or motion estimates occur as in other lossy compression. This means that the frame is a complete replication when uncompressed and the image suffers no loss of quality or data.

For a high quality archive these two encoding formats are the best available formats especially because they offer the high quality needed to ensure that the data contained in the archive is lossless or extreme unlikely to experience data loss after decompression.

Summary of MJPEG-2000 and MPEG 2:

- *MJPEG-2000 can produce completely lossless compression*
- *MJPEG-2000 compresses each frame individually*
- *MJPEG-2000 best compression rates are around 1:3*
- *MPEG-2 utilises lossy DCT encoding and therefore introduces loss in original data*
- *MPEG-2 is a industry standard since most major broadcasters use it at present; high definition television will not use MPEG-2 – see next comment*
- *MPEG-2 is the favoured format for DVD, but will be replace by MPEG-4 part 10 for HD DVD*
- *MPEG-2 produces better compression rates than MJPEG-2000*

5.5 Storage

Compression rates ultimately results in the amount of storage needed to convert analogue data into digital data. Based on the choice of format the calculations for determining storage can be made. In this way the bulk of storage capacity and demand will be consumed by the high quality archive encoding.

In terms of storage there are several digital storage devices; From magnetic and hard drives to a several different optical media. Optical media formats range from CD to DVD and to the emerging Blu-Ray and competing HD DVD.

From all these competing formats the most appropriate digital storage solution must be related to hard drives, large capacity magnetic tape and optical tape.

The time from CD (1982) to DVD (1997) and then to Blu-Ray (2003) and HD DVD (2004) is a relatively short period of time and yet optical storage media has managed to change dramatically. The changes have meant less compatibility across formats and across hardware especially in terms of backward compatibility. To use optical media storage for a large high quality archive would produce a multitude of conflicting formats and compatibility issues.

Most optical storage media hardware is not backwards compatible. For Blu-Ray and HD DVD chances are that they will neither be cross compatible nor backwards compatible towards DVD and CD players.
Hard drives on the other hand might have changed in terms of capacity but the technology remains very compatible over the same period 1982 – 2004. In essence the ability to migrate data from one hard drive to another has been much less problematic than with optical media storage. For hard drives there is no additional hardware needed in the sense that the hard drive is the actual hardware. In order to have the storage available for delivering a video archive the exponential growth of hard drive storage must be analysed.

Most people are familiar with Moore's Law in regards to the doubling of transistors in semiconductors every 18-months. A similar Law called Kryber's Law is less well known but should be taken into account here since it theorises that the density of information on hard drives have been growing at an even faster rate. From 1956 to now the capacity of computer storage represents a 50-million fold increase.

The basic idea is that hard drives are benefiting from an exponential increase in the density of information. This does suggest that more and more available capacity for storing a high quality archive becomes more realised as time goes on. In addition capacity cost is being driven exponentially in the other directions. Over the last 5 years the capacity of a hard drive has gone from a Maxtor 5400rpm, 61.4 gigabytes hard drive costing $398.00 to Seagate 7200rpm, 250 GB hard drive costing $129.00[8].
In this way hard drives in GB has seen an exponential increase in capacity combined with a correlating decrease in price. Currently prices are hovering around $0.80 per GB. With further developments looming on the horizon it is likely that prices decrease further while actual storage capacity manages to improve.

The main benefit with hard drives is the capacity to migrate data easily and across networks. In comparison optical storage media even though consumer uptake is greater does not offer the same benefits for a video repository the size of Presto Space. It has to be noted here that this analysis has not focussed on the environment where the storage will occur.
Any kind of storage will by definition have some kind of physical presence. In both types of storage a physical location (or several) will be needed to house the material and the cost and effectiveness of the different solutions available should be look at carefully.

It is sufficient to say that hard drives based on various tape drive systems would in Stream UK's opinion be the most viable solution in regards to compatibility, migration of data and access.

8

http://www.littletechshoppe.com/ns1625/winchest.html
http://www.tigerdirect.com/applications/SearchTools/item-details.asp?EdpNo=1265028

Summary of storage for a high-quality archive:

- *Optical storage media suffers from lack of compatibility*
- *Optical storage media changes hardware and software requirements often*
- *The future developments of new successful optical storage formats are hard to gauge*
- *There is no easy migration solution for optical storage devises*
- *Hard drive capacity and cost projections projects are very positive in regards to high-quality digital archives*
- *Hard drives provides better solutions to migration of data*

5.6 Quality assurance

Quality assurance is one of the main goals of any high-quality archive. To ensure a working model both the encoding of the content combined with the storage method needs to be integrated successfully.

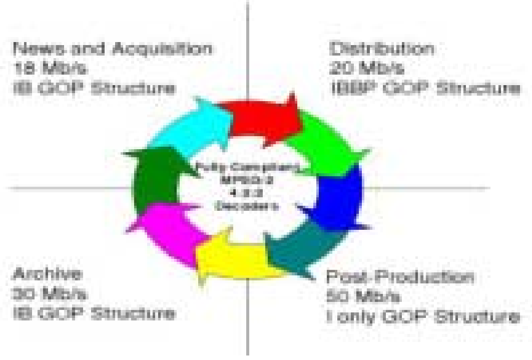
The initial encoding and conversion to digital formats will set the standard for the quality of the archive. Quality assurance will start here as well. It is therefore imperative to choose a standard that will be viable to transfer into other file formats for distribution, editing and production.

In terms of formats lossless or similar quality would be needed to sustain a high quality archive. The level of details with both MJPEG-2000 and MPEG-2suggest that both formats can convert analogue material into a digital video repository with minimal data loss. Since MJPEG-2000 is a lossless compression format the results should be like the originals and be compressed at a rate of 1:3.

With MPEG-2 the conversion may introduce patterns of data loss in relation to the original but whether the user will be able to identify the losses is also very unlikely. In terms of quality MJPEG-2000 will provide total replication of analogue material and this will be maintained after decompression. MPEG-2is widely accepted across the industry and it offers much better compression rates that again will help with the level of storage need for growing high quality archive.

MPEG-2 compression rates for archives are recommended to be in the 30 – 60 Mbps range both according to US and UK sources. In the white paper "MPEG-2 Fundamentals for Broadcast and Post-Production Engineers" (Rodriguez:1996) compression rates for MPEG-2 are broken down as:

- News and Acquisition: 18Mb/s with IB GOP structure
- Distribution: 20Mb/s with IBBP GOP structure
- Archive: 30 Mb/s with IB GOP structure
- Post-Production: 50 Mb/s with I-only GOP structure



This falls in line with Library of Congress guidelines for digital archiving, which suggests compression rates of moving image material to fall into the range of 30-60 Mb/s. MPEG-2 compression rates at between 30-60 Mb/s would guarantee broadcast levels of quality for an archive based on MPEG-2.

In terms of quality assurance for storage solutions both optical media and hard drives have excellent quality assurance. The question in terms of use comes down to compatibility more then actual differences in quality. Since the quality is based on the encoding rather than the actual storage methods.

For a long terms storage solution the more optimal storage would be hard drives because of the ease of migrating the data across to new facilities. The encoding in either MJPEG-2000 or MPEG-2 into a hard drive storage solution would provide the foundation for a robust system for digitalisation of large amounts of analogue video and a delivering a high quality archive.

Summary of quality assurance:

- *MJPEG-2000 supports completely lossless compression and can provide for the best quality assurance*
- *MPEG-2 may introduce patterns of data loss but is essentially lossless*
- *MJPEG-2000 will need more storage than MPEG-2 since the latter has better compression rates*

6 Encoding for previews and online distribution

6.1 Overview

Once the encoding and storing of a digital high-quality archive has been develop the files need the ability to be distributed and previewed by people interested in the archive. From lossless and high quality images the preview and online distribution of any materials will have to be reformatted towards lower quality. The lower quality will enable easier access for users to the material stored in the archive.

In this way it is necessary to assume that users will access the archive with a range of different software, from different geographical locations and with different connections speeds. In future multitudes of different devices might also be included in the equation in users accessing the archive. This could include mobile phones and other portable devices.

Because of the multitude of possible user requirements the preview and online distribution encoding will have to take these variables into account. The subject of actually searching and indexing vast quantities of video material might also have an impact on users accessing the archive. In this report the subject of indexing and establishing metadata for the archive will not be investigated. Instead it has been noted and will be taken into account when forming the analysis of suitable encoding for previews and online distribution.

6.2 Formats

The formats available for previews and online distribution are many and varied. The main characteristic that can be applied to this would be lossy compression. This would make it much more feasible to stream the material to the user from the archive. In terms of lossy compression there is multiple formats to choose from. Previously in this report proprietary formats were analysed and before that the whole family of MPEG.

Since the previews and the online distribution does not have to have the same quality as the files stored on the archive the doors open to use more compression efficient and lossy compression algorithms that can more easily distribute and preview the archive content.

If the archive is encoded in either MJPEG-2000 or MPEG-2 transcoding of these formats are very CPU intensive and would need dedicated hardware for the best results making both formats unsuitable for previews and online distribution.

The whole range of lossy compression formats can be viewed as suitable for delivery of online distribution and previews. Conclusions on what format is most suitable as a long-term solution as a preview format for a digital video repository should be made on the basis of compatibility and availability.

	Availability and penetration	*Compatibility*	*Pros*	*Cons*
Windows Media Player	Great availability and penetration among PC users. No availability for Mac users with the new Windows Media 10 format.	No cross compatibility with other formats. . Backwards compatibility might be discarded based on market circumstances. .	Easy integration and development with Windows	Propriety format
Real Player	Good availability on both the PC platform and Mac platform. Penetration is average.	No cross compatibility with other formats. . Backwards compatibility might be discarded based on market circumstances.	Supports open source platform	Behind QuickTime and Windows Media Player
Flash 8	High availability for both PC and Mac.	Great compatibility with other formats. Backwards compatibility might be discarded based on market circumstances.	Customisable	Relatively new to the market
QuickTime	Great availability for on Mac, not so good for a PC.	Great compatibility with other formats. Backwards compatibility might be discarded based on market circumstances.	Industry accepted	Long delays in cross platform developments
MPEG	High availability for both PC and Mac.	Great compatibility with other formats. Backwards compatibility ensured	Industry accepted. Open standard Long development times	

In order to find the most suitable formats users search, access and delivery has to be taken into account. These variables will need to be applied to online distribution as well before looking at the connection between the high-quality format and the review and distribution formats.

In general a mixture of options could allow for better user satisfaction in accessing the data. With most of the proprietary formats able to connect with the MPEG standard the preview option and online distribution could be based on supplying a basic format that can be encoded into several codecs based on what the user has available.

In terms of encoding levels most Internet users will be able to access around 300k streams. This is not dependent on the choice of format but rather what their connection speed is. The level of encoding can be set by intelligent streams to recognise the users connection speed and choose the best possible connection.

Anything above 300k can be done to enhance the preview in terms of quality but the encoding should probably not exceed 750k since this would have an impact on most current Internet users.

Summary of formats for preview and online distribution:

- *Proprietary formats could develop compatibility issues*
- *MPEG offers the best solution for long-term compatibility*
- *MPEG will be less efficient in generating video and audio quality*
- *Preview and online distribution formats needs to be compatible with main archive*
- *Encoding should be done to around 300k. This can be increased based on connection speeds but should probably not exceed 750k since it would be wasting bandwidth for just previews.*

6.3 Storage

Storage for the preview and online distribution is very much dependent on the actual method of searching through the archive.

In the case of search per key frames no additional storage will be needed. In this case the preview will actually be based on a transcoding of the main archive. If the main catalogue is encoded in a lossless compression format such as MJPEG-2000 or MPEG-2the transcoding to preview and online distribution could potentially be done with a multitude of other formats such as Windows Media Player, Real Player, Flash and QuickTime.

A separate storage area could be dedicated to previews and online distribution based on a certain format that would then be accessible by users. This area would then sit on top of the actual archive and would needed to be updated regularly to ensure that in covered the entire archive at any one time.

The storage needed for this would be approximately 1:40 of the actual archive. This rate is based on lossy compression rates from most formats. Such a solution would need to ensure that there would be compatibility with the main archive and that this could be maintained.

The suggested methods will very much depend on how the search and metadata function will work in relation to the main archive.

Summary of storage for encoding for previews and online distribution

- *Storage would be minimised if preview and online distribution can be generated from the actual archive*
- *Integrated storage would require integration with search and metadata functions*
- *A separate storage area for previews and online distribution can be generated to sit on top of the main archive as a separate entity*
- *A separate preview storage area would be 1:40 of the original archive*

7 Storage requirements

7.1 Overview

Storage requirements for a large-scale video repository would be dependent on what formats where chosen to carry the bulk of the archive.

As mentioned in the encoding for a high quality archive lossless compression would be the most relevant for the PrestoSpace project since it is about the preservation of our filmic cultural heritage. In terms of previews and online distribution it might be possible to generate the previews and online distribution from the main repository.
The general numbers involved in terms of physical storage will run into several petabytes. Such storage solutions exist in commercial form and several companies offer storage solutions with this kind of capacity.

7.2 Storage requirements for a high-quality archive

Because of the vast amount of data involved in the high quality archive, data could be placed on tape based hard drive. Several solutions are already in the market place and can be upgraded to contain in the excess of 25 PB (petabyte) of compressed data and approximately 10 PB of native storage. 1 PB is one thousand terabytes.

Such systems are based on magnetic tape or optical tape able to hold up to 250 TB per square metre at present. There are two basic technological tape formats: linear (serpentine and Parallel) and Helical. Helical is the more recent addition and has much better performance data in terms of capacity and delivery. Of Helical tape formats SAIT (super advanced Intelligent Tape) holds the most promise for large-scale digital storage and is the only one worth mentioning as a possible solution. SAIT is cost effective and is setting new bench marks for capacity and performance in a half-inch, single-reel form factor design position. Each cassette is capable of storing up to 500GB of uncompressed data on a single-reel, half-inch tape cartridge and featuring a sustained native transfer rate of up to 30MB per second uncompressed. First generation SAIT drives incorporated into automation solutions will provide uncompressed capacities ranging from 10TB in a space-efficient configuration to more than 500TB in a 1,000-cartridge freestanding library.

These massive storage solutions can be connected via SAN (storage area network). SANs are high-speed networks managed to provide connection between storage elements and servers. Its communications infrastructure providing physical connections organised by a management layer that organises the ability of multiple servers to connect to the same storage device.

The connections are made available as fibre optic channels allowing for bandwidth of 2Gbits/sec and above.

The benefits of these systems would be:

- *Ability to migrate data across networks*
- *Replication of data across networks*
- *Internet enabled access and retrieval*
- *Data back up to multiple formats*
- *Ability to bolt on storage capacity*

In terms of pure hard drive solutions Capricorn Technologies have developed a Linux JBOD solution for mass storage. The currently prices for this Linux based petabyte storage solutions runs to around $2 per GB. The best example of this storage solution was developed for the Internet Archive based in San Francisco[9]. Its machine "Wayback Machine" contains approximately 1 petabyte of data and is growing at a rate of 20 terabytes per month.

Currently most storage solutions of that magnitude are designed for content management, data backup and enterprise storage solutions. The density on the tapes is looking to reach 250 terabytes of native capacity per square metre of floor space. The native data transfer rates for these repositories can be extended to 2.88 GB per second. This would enable fast and efficient back up of the data stored.

Specialised software developed for such high-density storage is designed to maximise performance by automatically transferring data from the hard drive to tape to achieve a cost effective storage balance.

Considerations for the development of large-scale media repositories based on tape based hard drives:

- *Storage density on hard drives increases between 60% and 100% annually*
- *Storage pricing for hard drives falls between 35% and 40% annually*
- *Storage performance in terms of access and management increases less than 10% annually*
- *The cost of managing storage is 3 to 10 times the cost of the hardware*

As the cost of hardware for storage decreases exponentially in contrast to the capacity and density of storage the cost of managing data storage rises. Data management, access and retrieval become priorities when media repositories move towards petabyte size.
Any digital repository will require active management in order to avoid problems due to media degradation and failure.

The only approach to this generic problem is for the repository manager to put in place policies for periodically migrating content and to make sure that there is ample redundancy via routine backups, off-site backup, and the use of mirrored sites or other types of redundancy options. Management will need to ensure that there is always another digital space where users can find the digital object.

A network of interoperating digital library repositories would be the best safety feature against redundancy. From a digital preservation perspective, redundancy of content is perhaps the most critical consideration. Even with data management incorporating RAID technology and daily backups it is advised to replicate all content in a mirrored server configuration. This form of configuration would not only provide increased redundancy but also enable higher access availability of the content. This mirrored server configuration offers the possibility of preview access for users.

[9] http://linuxdevices.com/news/NS2659179152.html accessed 25th October 2005

7.3 Storage requirements for preview quality distribution

The development of a separate archive for online distribution and previews should be based on lossy compression formats to ensure the minimal strain on the system in regards to quick access. The interface between user and the archive should have a separate area for searching and viewing the material.

The separate preview archive would demand 1:40 of the total archive storage. According to calculations (See PrestoSpace Deliverables) the current archive would be lingering around 4 Petabyte. At a compression rate around 1:40 this preview archive would take up around 100TB. This would need to be encoded at a lossy compression format separately from the actual archive and updated in parallel with the main archive.

An archive of 100TB can easily be stored on dedicated hard drives. As mentioned in the high quality storage solutions the "Wayback Machine" in San Francisco holds 1.5 Petabytes of data based on a Linux model.

A second option would be to search the main archive directly and then have software encode the selected files into multiple formats based on user connection and player availability. This would integrate a search function with transcoder software and would delivery a preview system with minimal storage requirements. In addition it would run into having extended search times based on the scale of the high quality archive. This would need dedicated search development and metadata handling and falls outside the scope of this survey.

Summary of storage requirements for preview quality distribution

Developed as a separate archive it would need:

- *Updating in parallel with the main archive*
- *Approximately 1/40 of the main archive storage space*
- *Encoding to a lossy format*
- *MPEG-4 encoding would enable previews on the majority of computers*

Benefits of a preview archive:

- *Search and access can be performed with speed due to smaller storage size*
- *Functioning as a front-end for user interaction with minimal access to the main archive*
- *Can be based on JBOD technology making access and updating very simple*

8 Delivery/access requirements

8.1 Overview

During the last chapter two distinct solutions have emerged for accessing the archive. It can be done either via an additional preview archive or as a software solution that interfaces with the main archive. The delivery and access requirements are radically different for these two solutions.

8.2 Delivery/access requirements: High quality archive

In the case of accessing the high quality archive two concepts can be applied to managing access and delivery. One: direct access and two: mitigated access. Direct access would imply that users connect directly and interact via software with the archive. Mitigated access would imply that a separate entity mitigates access and delivery and access between users and the archive. In this case a preview archive would mitigate actual access to the main archive.

8.3 Delivery of high quality archive

In both cases the easiest way of delivery and access would be online. It would allow for multitude of users, global presence and the ability to deliver material via the same channel. With recent advances in broadband connections delivery of 25 Mbps is feasible and would allow for real time MPEG-2delivery. Currently such delivery speeds would be facilitated within a LAN. With new additions to delivery speed over broadband connections it could be possible to server users with the highest connection speeds currently available.

Other methods of delivering content from the high quality archive would need to include non-digital methods of delivery. The last method to consider is Copper software from Digital Rapids. Here video is sent in packages over UDP. Each packet can be sent without waiting for an acknowledgment from the receiver. Each packet contains some information about the entire file so in case of loss another package is dispatched. In this way packages can be received in any order and be pieced together upon reception.

Summary of delivery of high quality archive:

- *Normal mail delivery of optical disks with the high quality material*
- *Real time delivery over the Internet via 5 Mbps streams only available for high-end connections.*
- *Content can be delivered as individual wrappers send over UDP*
- *LAN configuration can enable full broadcast of MPEG-2files*

8.4 Access to a high quality archive

Access to the main archive will need high-speed connection to push data to and from the archive. However, providing widely distributed users access to a very large video repository poses several challenges. Delivery for video playback requires stringent real-time scheduling and significant network bandwidth with conventional wide area networks offering neither. The size of the objects needed to be accessed also features and will expand the increase in access time.

The high-band width delivery constrains of digital video delivery are best addressed by LAN based file servers. These can be located close to playback clients in order to maximise potential gains in speed and access. In contrast the cost effectiveness of large petabyte sized storage devices and the desire to share video widely motivate the use of a central repository.

Combining the cost effectiveness of a central storage solution with a distributed network of servers can maintain high performance and scalability. This would provide caching mechanisms to the data on the main storage system.

The servers would be allowed to cache frequently and accessed data from the central source. The multiple caches would then be distributed across the network of servers. For users this would mean that access to commonly accessed content enables the system to respond quickly. In this way commonly search features would be available quicker than more obscure material or material that is very seldom accessed.

Furthermore users such as programme providers and scholars and even the majority of users might know ahead of time what material they would like to gain access to. This kind of predicative information can be feed to the network. Then the network would be able to respond in time to an access request.

Summary of access to high quality archive:

- *Combining distributed network of servers with centralised storage facility*
- *LAN server network would allow for caching of mostly commonly accessed material*
- *Users behaviour should be taken into account in terms of access*

8.5 Preview Quality

The quality of preview formats should enable users view the requested content over a broadband connection. This would include preview formats to go as low as 300k. Anything above that can be requested but it should be noted that for streaming of content 300k encoding rates will probably be the lowest the archive should go. This level of encoding would provide users with a quality for previewing that is acceptable by current standards.

As mentioned, proprietary formats could offer better quality over MPEG than other open formats for previewing the archive. It must also be noted again that the compatibility of proprietary formats cannot be guaranteed far into the future.

The non-proprietary option would be delivery in MPEG-4. The open standard would enable most players to play the file. There would be some degradation in terms of quality compared to the proprietary codecs but this would be negligible for most users.

In terms of choosing a particular media format for preview this might not be necessary. Both transcoding software and hardware of broadcast standard can output to multiple formats and in this way it is possible for users to perhaps choose their required formats.

Summary of Preview Quality:

- *Encoding rates should be set at 300k and above*
- *All proprietary formats would deliver solid preview performance*
- *MPEG-4 would be the best open format standard*
- *MPEG-4 playback on proprietary media players would suffer some degradation in comparison to proprietary codecs*

9 Transcoding from the high quality archive to preview formats

9.1 Overview

Transcoding from the high quality archive to preview and online distribution will depend on several factors in terms of digital media formats. The high archive will need to be stored in a format that can be accessed and transcoded to a multitude of different formats. This would open up the repository to a more diverse user group.

Options for the high quality archive includes MPEG-2and MJPEG-2000. These formats would lend themselves well to transcoding into several other lossy formats for preview and online distribution. The transcoding to preview can be done by banks of transcoders working in tandem with requests and search functions within the repository or by multiple software transcoders working in conjunction with servers.

In terms of transcoding software and hardware MPEG-2as an accepted industry standard has a range of different options available for transcoding. Several configurations will make it possible for multiple and real-time transcoding. Most formats and codec will be compatible with MPEG 2. Making it a versatile format to transcode from.

MPEG-2in paticualr has been an industry standard , the hardware and software for transcoding is numerous and readily available. Because of this transcoding solutions for MPEG-2can be assembled from off-the-shelf components in contrast to more specialised formats that might need high cost customised solutions.

A multiple transcoding solution would be to run banks of decoders/encoders to transcode files into the requested file formats. The more open and compatible the original file format in the high-quality archive is the greater the increase in transcoding successfully to a range of other formats regardless if the delivery format is proprietary or not.

Transcoding software solutions offers better integration with a range of different servers and content networks. It would also be easier to upgrade transcoding software rather than transcoding hardware.

Summary of transcoding from a high quality archive to preview formats:

- *The transcoding to preview can be done by banks of transcoders working in tandem with requests and search functions within the repository or by multiple software transcoders working in conjunction with servers*
- *MPEG-2and MJPEG-2000 are both high quality formats that will handle most transcoding requests and translate them into a range of preview formats*
- *MPEG-2 transcoding can be done with off the shelf components due to it being an industry accepted standard*
- *Transcoding software offers better integration with delivery network*
- *Transcoding software offers the ability for upgrading the system periodically*
- *Transcoding hardware solutions offer dedicated hardware to run requests from users*

9.2 Assessing needs

Transcoding requirements for delivering the high quality archive into preview formats will be determined by the number of user requests and size of the requests. Transcoding can be done either on a software basis or a hardware basis. Either solution will have negatives and positives attached to it. Below, a set of parameters for the solution has been outlined that enables an objective analysis of the transcoding to preview formats.

The transcoding solution will need to be able to:

- *Handle multiple request and transcode requested material in batches*
- *Transcode from the archive into multiple formats*
- *Transcode time should be real-time or better*
- *Be compatible with most industry standards*
- *Connect and interface with server technology*

9.3 Transcoding software

The software needed for delivering the preview archive would need to be able to transcode to a multitude of formats and be able to perform multiple transcoding jobs and if possible transcode faster than real-time. Transcoding software takes advantage of new ultra-fast processors to convert digital video into a range of digital media formats.

Currently there are a number of options including Telestream's FlipFactory and Anystream, which are perhaps the two most well known brands. These transcoding software solutions can convert universally between codecs and formats. In addition transcoding software can convert in batch or on-demand. The difference with software transcoding is that it does not have to use hardware accelerators, which enables it to sit on top of any broadcast server, streaming server or customised content distribution system.

Transcoding software has certain network capabilities that makes it very useful for transcoding of media files towards online distribution. Most can send and receive media via FTP, HTTP or SMTP and will generate redirector links for most major streaming formats in metafile format such as .ram/.smil/.asx. Most industrial strength software transcoders can deliver across DV, MPEG 2, MPEG 1, Real, Windows Media and Sorensen media formats.

Transcoding software can plug-in for all of the major media servers and transcoder modules enabling broadcasters to submit transcoded media processed by the software directly to servers. Thus integrating transcoding with asset management, content indexing and other media production functions.

Summary of transcoding software:

- *Ability to transfer files via FTP, HTTP and SMTP*
- *Does not need any hardware accelerators*
- *Can sit on top of broadcast servers, streaming servers or customised content distribution systems*
- *Can transcode to multiple formats from any high quality archive*

Software based preview access and distribution

- *No additional storage requirements*
- *Management of several transcoders connected to the SAN*
- *Multiple formats output to end-user*
- *Specialised software to deal with multiple requests and manage transcoding*

10 Delivery infrastructures

10.1 Overview

The public enthusiasm for video and audio content has progressed the uptake of broadband services globally. This has pushed current Internet infrastructure to near capacity.

New methods of delivering are starting to emerge that will be able to handle the growth of video and audio content delivery. CDNs (content delivery networks) have progressively become the means to delivery the extra capacity needed. The Internet is made up of a massive number of independent networks sharing information in a decentralised environment.

Over time formations of bottlenecks around peering points have formed where frequently accessed information is stored. Congestion at these bottlenecks will increase as the amount of audio, video and streaming media is delivered over the existing infrastructure. Rather than building a new Internet infrastructure CDNs deliver more bandwidth and speed over the existing infrastructure by bypassing congested peering points and storing content on servers at the edge of the network.

Frequently accessed content is then replicated on the fringe servers and cached at the edge of the Internet. In effect users request are accessed on local cache servers located physically closer to the user rather than the request being forced to being retrieved from the originating server.

Caching systems and content delivery systems are distinct and complementary systems. With CDNs are networks of caching servers linked together and functioning as a distinct system.

In addition content delivery technology also directs incoming requests to the optimal server on the network. In this way CDNs offer significant improvements in access performance and content availability for users.

CDNs replicate, distribute and store content on local servers. The stored content can then be distributed from the originating server to the network edge via the Internet. CDNs also update, store and serve replica copies to users at the edge of the Internet. Some systems cache the content under the direction of a centralised control system. Alternatively the centralised system direct user request for content to specific servers. These servers then retrieve the content on a request basis.

Intelligent storage is one of the most important aspects of CDNs. The content delivery systems create networks of intelligent storage devices, which are located at the edge of the network. The value of intelligent storage will increase in parallel with the deployment of video and audio content for broadband services. CDNs storage will enable better performance and transmission. Such systems would lend themselves well to serve as storage infrastructures for preview and could deliver online distribution of previews over the Internet to users outside the LAN.

Summary of content delivery systems as a storage infrastructure for preview and online distribution:

- *Caching content in close proximity to user locality*
- *Bandwidth optimisation by increasing the link between user and content server: caching systems can double the bandwidth link*
- *Caching of content locally enabling low-cost local bandwidth and content delivery*
- *Optimisation of delivery through better management of high bandwidth content*

10.2 Load balancing

With bandwidth heavy applications such as streaming video and audio content it is not just enough just to get better cable connections or bigger servers. It is also necessary to maintain the infrastructure within the CDN. This will enable better traffic handling across the network and produce better performance in requesting and delivering content to users. This in turn would prevent the network from being saturated by user requests for previews and content delivery.

Network load balancing enhances both the availability and scalability of the CDN. This in turn will enable the servers and transcoders to deliver content to the end-user.

Within the CDN the content is replicated out to the servers. In such a network it becomes important to direct the user to the most appropriate or best suited streaming server. Choosing the appropriate server can mean several things, including:

- The least loaded server in terms of network, disk or CPU
- The server closest to the end-user

The closest server can also be defined along a set of parameters including:

- Geographical location
- Network IP subnet hops
- Latency or ping times

In addition the presence of requested data from the user can also be factored into the criteria to determine the most appropriate server to deliver the content. It can be less appropriate to send a request to an idle server, which would have to cache and send the request to a server that is lightly loaded, but already has the content cached.

Any load balancing system can incorporate access control or load limiting functionality. This would include:

- Limiting use by IP address
- Aggregate egress bandwidth
- The number of concurrent users
- Limiting the number of users across the entire network
- Limiting the number of concurrent viewers per servers

These techniques can prevent the network from becoming saturated and should be planned in advance. The network administrator can make adjustments on the fly to load balance the server network but this should only really be done when critical need arises.

10.3 Network and bandwidth issues

With a CDN there is a need to control network resources in order to improve the utilisation of the network. This can help reduce cost and optimise the user experience. Several hardware and software options are available to control network and bandwidth issues.

Firewalls and caching proxy servers will preserve bandwidth by caching content and can be the first line of defence against any malicious activity on the network. Network email servers and gateways can also reduce internal bottlenecks by dividing out bandwidth between; email, address books, mailing lists, virus scanning and content delivery.

If these operations become muddled together or if the specialised servers are removed the network would become congested. Bandwidth would be consumed by redundant and low priority data traversing the network links. High priority traffic would become bogged down with lower priority network traffic draining all bandwidth with in the network. In this way content delivery regardless of format choice would be unsatisfactory for the end-user. Especially with the requirements needed for delivery of video and audio content it is necessary to develop an effective network infrastructure.

Many networks that have not installed any streaming media infrastructure will experience that low priority media streams may saturate network links needed for making higher priority streams available. Users may then traverse expensive wide area network links to access content that could have been delivered across the local area network at a fraction of the cost. Making certain servers overloaded while others sit idle waiting for user requests.

An effective CDN infrastructure will enable network administrators to monitor usage and manage network resources are allocated accordingly. The infrastructure will revolve around a core set of functions:

- Content replication
- Load balancing
- User requirements
- Historical reporting
- Network Monitoring
- Streaming services
- Content management

These functions would be able to resolve most network and bandwidth issues that might arise.

10.4 Quality assurance and monitoring

Assessing quality and reliability of the content delivery is vital for any network and for any content owner using networks as a distribution channel. The data can either be processed through internal resources or can be outsourced to a third party with external measuring and monitoring service.

The quality assurance and monitoring should reflect end-user experience as much as possible. This will provide the content provider with some accurate measurements about their service. Monitoring can provide

- Accurate end-to-end measurements on delivery quality. Based on this educated decisions on delivery-hosting solutions can be made
- Real-time notification. This can pre-empt complaints from users

Specialised software can be used to mimic the behaviour of end-users by connecting to the network and viewing the content for a specific period. This form of quality assurance is known as “synthetic transaction”. The software runs on a host of agent computers. These host computers should be in a variety of location and have a variety of connections and settings.

There is number of different ways to measure quality metrics. Below are some of the most commonly used metrics which are relevant for a range of content delivery options. In addition all media formats can be tested against these metrics since they all refer to actual user experience.

Connection success rate (CSR)

This metric represents the number of times a connection was established with the server as a total of attempted connection. It is a good indicator of users ability to access the content. Connection failure can arise from several factors:

- Connection problem – there is no available path through the Internet from the user to the address specified
- Server problem – the server is not accepting connection or not responding
- Logic problem - the requested content was not found on the server or the server did not allow access to the content

Bit rate monitoring

When data is transfered across the Internet it should arrive in the actual rate that the content was encoded in. The monitoring should be based on bit rate during Play Time, Buffer Time and Rebuffer Time. These metrics fall under the category of Time Profiles.

Time profile metrics

These metrics most closely resembles the end-user experience. It gives an indication of how long a user will have to wait before the delivery begins and how often it was interrupted?

Connect time

This is the measurement of time elapsed between the initial request for data by the media player and the start of buffering. Including DNS lookup (Domain Name System), resolution, metafile actions and resolution, server/player initial connection and the transportation of the first byte of data to the media player.

Buffer time

Buffer time is the measurement of time used to build the initial data for the delivery. This is determined by bit rate, the bandwidth available between user and server, the consistency of the bandwidth available and server and user settings. There will always be some buffering because it is an integrated part of the protocol of delivery. Properly configured servers and CDNs can keep buffering time to well under 10 seconds and with the current generation of servers data bursting can keep this time interval under a second.

Rebuffering

This is when playback is halted to reassemble the delivery. Based on a decrease in the incoming bit rate. This would indicate inconsistent connectivity.

Rebuffer time

This equals the collective time of rebuffering that impacts the experience of the user severely. Properly configured server systems and networks should have not had any rebuffering times.

Summary of quality assurance and monitoring:

- *This can be an in-house function or out-sourced to a third party*
- *The main indicator of quality would be the experience of the end-user*
- *With properly configured networks and servers:*
    - *Buffering time should be less than 10 seconds and preferably less.*
    - *Connection should be maintain throughout delivery*
- *Monitoring should include:*
    - *Connection success rate (CSR)*
    - *Time Profile Metrics*
    - *Connect Time*
    - *Buffer Time*
    - *Rebuffering*
    - *Rebuffer time*

10.5 Redundancy

Overview

Refers to peripherals, computer systems and network devices that take on the processing or transmission load when other units fail.

Server redundancy

Server redundancy is the need to load balance requests coming into the network.
In general server redundancy levels can be improved by content replication and improvements to the network infrastructure.

In content replication the content is distributed across the network to increase scalability, redundancy and deliver improvements to the streaming of content to the end users.
Scalability is produced by replicating the content across multiple servers capable of handling a finite number of user requests and views. As additional capacity is required additional dedicated servers can be brought online. When this happens the network can be segmented to increase bandwidth and enable further replication to the additional servers.

By replicating the content across multiple servers redundancy can happen without the failure of the entire network. This means there is no impact on the end-user. Server redundancy requires coordination of the CDN load balancing to direct users away from filed hardware.

Client side redundancy

Client redundancy is facilitated by the client-server architecture. In contrast to servers, clients are basic workstations that run applications. Clients connect to the server network for resources such as files, devices and even at times processing power. If the client receives several entries it will try each of the servers pointed to by these entries in order of their priorities. Client side redundancy is usually performed by play-lists in the case of content delivery.

Network redundancy and the BGP protocol

The BGP is an acronym of Border Gateway Protocol, which is an autonomous system routing protocol. A network or a group of networks under a common administration and with common routing policies are considered to be an autonomous system. The BGP is used to exchange routing information for the Internet enabling Internet service providers (ISPs) and their customers to connect. When BGP is used between autonomous systems such as different networks it is known as External BGP and when the ISP is using the BGP to exchange routes within the AS it is referred to as Interior BGP.

BGP is then the network protocol that chooses how to send information through the Internet based upon the fewest number of available network hops.

Network redundancy is then achieved by connecting network location to two different Internet service providers. This process is called multihoming. When multihoming the network to two different ISPs, BGP runs the Internet router(s) and provides redundancy and network optimisation by selecting which ISP offers the best path to a resource.

Proprietary solutions

The CDN market has gone through significant changes over the last couple of years with increase in demand for CDN solutions and services.
Content delivery networks emerged in the late 1990s as effective ways of delivering rich content over the Internet. Today the market is mainly owned by a handful of Content Delivery Service Providers (CDSPs). These providers basically service the needs of Content Owners and providers and using mainly proprietary technology. The market leaders are Akamai and Exodus.

Several traditional carriers and service providers are delivering services similar to the CDSPs using technology available from CDN infrastructure vendors. Most of the need for content distributions comes from large enterprises needing to deliver content across their Intranets and Extranets. The Enterprise CDNs (ECDNs) are either built into an infrastructure and operated by the enterprise or the CDN is delivered and managed by a CDSP.

These solutions mainly refer to Internet based content delivery for end-users that are more consumer-oriented. In addition there is LAN solutions available for distributing the content across a local area network that will improve efficiency of delivery.

Streaming video looks great on a LAN because it is possible even with 300K simultaneous streams to consume a minimum of the build in bandwidth. With 10 simultaneous streams running at 300k the total bandwidth consumption would be 3% on a 100Mbps network or 0.3% on a 1 Gigabit network. These numbers illustrate the benefits of delivering the content over a local area network rather than over the Internet.

In comparison, delivering the same 300k content on a Wide Area Network the likelihood is that a 256Kbps link will shut down under the weight of just one stream.

Currently corporate networks of 100 Mbps and 1 Gigabit connections are common which enables the streaming of both MPEG 1 and MPEG-2and will provide quality results with streams as high as 1.5 – 6 Mbps MPEG-2streams.

	Bandwidth range			
Application	28 – 56 Kbps	200 – 512 Kbps	1.5 – 6 Mbps	6 Mbps and above
Consumer	Low-end consumer web browsing not applicable for high-end content delivery.	First consumer broadband levels. Internet surfing and delivery of lossy formats.	2nd generation broadband. . Internet TV, full screen streaming. Low end MPEG 1 and 2 - delivery.	3rd Generation broadband. Internet2 Full motion video on demand, delivered via broadband. TV and VOD services. Lossless compression formats.
Corporate	NA	Main streaming applications. . LAN, remote LAN access via cable modems and xDSL services. Lossy formats delivery.	LAN, requires high speed switched local area network. . Streaming of MPEG 1, 2 and MJPEG-2000.	Full motion video on demand, delivered via broadband. TV and VOD services. Lossless compression formats.

This table provides and idea of how LANs shape up for content delivery. Content deliveries within LANs are governed by the internal connections. The most popular type of network connections is Ethernet. Ethernet networks have speeds of 10Mbps, 100Mbps, or 1Gbps. A 10Mbps Ethernet network transmits data at 10 million bits per second. A 100Mbps Ethernet network transmits data at 100 million bits per second. A 1Gbps Ethernet network transmits data at 1000 million bits per second. The majority of networks today operate at 100Mbps. 1Gbps networks, howeverare becoming more common as technology and bandwidth demand increases.

Depending on these connections LANs are able to sustain high-level delivery of lossy and lossless compression formats. In this way a properly configured LAN can delivery content from the high quality archive as well as delivery of preview formats to a multitude of users with in the LAN.

Proprietary solutions can then include both LAN delivery and CDN delivery. CDN delivery can support preview formats encoded for 300k to Internet users but would struggle in delivering higher quality content. LANs can deliver both lossless formats in addition to lossy formats for preview purposes.

Summary of proprietary solutions:

- *CDNs are capable of delivering preview quality videos for consumers over the Internet*
- *LANs are capable of delivering preview quality videos and high quality videos to users on the LAN*

11 Costs of building an architecture

11.1 Overview

The cost of building the architecture can be broken into distinct sections:

- Storage Area Network
  - Storage
  - Network infrastructure
- Local Area Network
  - Transcoding
  - Servers
- Content Delivery Network
  - Streaming servers

Storage Area Network

The actual storage can be built using raid disks or utilising custom build systems from a range of vendors. The cost of the total system can be deducted from the cost of 1GB. This will not only provide initial costs but also future costs based on the expansion of the repository.

The current cost of Raid Disk space is £2 per GB based on a JBOD configuration in a Linux infrastructure. A 1-petabyte unit is currently selling for £2,000,000. Additional capacity can easily be added to individual storage units in the long term and the data can be migrated. Several units can be connected in a SAN.

Custom build storage solutions with approximately 10 PB of native storage can be purchased from several vendors for around £5,000,000 per unit. The more expensive configurations will enable high-speed access via fibre channels. The price for optimal systems can run up to £20 per GB in the current market place. Several of these units can be connected in a SAN.

In addition to the actual storage the access and retrieval of data needs to be configured to enable the vast flow of data to be available to users. Without access and retrieval the data stored is useless. The development of a Storage Area Network (SAN) is necessary to facilitate the process of accessing and retrieving data. In a SAN data is stored based on how frequently information is accessed. Less frequently accessed information can be stored on lower-tier disks within the SAN, while data that is used more often is kept on higher performance Fibre Channel disks. What a SAN does is make the connectivity easier by allowing physical access from any server to any device. There are no distance restrictions within a SAN and thereby less cabling is needed in order to connect multiple hosts and devices together in a SAN.

The connections between components can run on speeds of 10Mbps to 10 GB per second depending on port and channel configurations. With most of the customised solutions these configurations can be built into the system.

Summary of SAN cost

- Data storage – £2-15 per GB depending of option taken
- SAN infrastructure – Add 20% to the cost of each GB

Local Area Network

With new 10 Gigabit connections available the infrastructure the delivery infrastructure for LANs can be approved dramatically. Such backbone networks will be able to sustain MPEG-2and MJPEP 2K streams within the LAN. In addition any lossy compression format delivery within a 10 Gigabit LAN would only take up 0.03% if encoded at 300k.

As mentioned previously a preview archive could be cached onto the LAN to provide users with access. Preview compression is 1:40 of the total archive. With a basic high-quality archive running into 2 Petabyte the preview archive would be totalling around 53,500 GB. Each server in the LAN will be able to cache and stored 500GB. The total number of servers need would total around 150 to be able to load balance the preview archive. High-end servers costs between £1500 – 2000 per unit. Considerable discounts are available for bulk purchase.

In addition the LAN network needs transcoders to update the preview archive from the high-quality archive. This can be done with several connections out from the SAN. To enable high transfer rates four 10 GB links will go out to four servers that run transcoding software. These will update the LAN serves with the new archive material in the chosen preview format.

Summary of Local Area Network

- Each server in the LAN will be caching around 500GB
- The example of a 2 Petabyte archive would need 150 servers caching 500GB each to develop the preview archive. Each server cost of £1500 - £2000 per unit
- Transcoding software with the ability to transcode in batches
- The software should run on other dedicated servers to process requests and link directly with the SAN

11.2 Content Delivery Network

This part of the network would serve users outside the LAN. It can deliver 300k streams to Internet users and would be the online distribution channel for the LAN content. This delivery network would be based on the demand.

A CDN consists of a network of geographically distributed servers with a suite of services and applications built around managing various aspects of delivering digital media online.

There are four common methods of developing a CDN infrastructure for streaming media. Hardware-based multicasting, software-based grid delivery, and hardware-based caching devices. The benefits gain from a CDN are to cut WAN load, increase start-up speed, localize delivery, centralize management, and provide user monitoring.

11.3 Single-Site Streaming

This simple method involves only one location with significant LAN bandwidth. With single site streaming a single streaming server can be enhanced with multiple or faster network cards and the server connected to the core backbone. Resources used on a streaming server are relatively low, and many concurrent sessions can be supported.

11.4 Multi-Site Software Streaming

This method is good for increased usage that occurs in a location remote from the streaming server. The main problem with this method lies in aggregate use of the wide-area bandwidth. In general CDN's tend to purchase bandwidth based on average usage rather than coping with the often-temporary peaks caused by bandwidth-hungry video.

11.5 Grid Delivery Multicasting

This method increases streaming capacity by utilizing the mass of idle PCs on a network in a method called grid-delivery multicasting. Grid-delivery multicasting provides a cost-effective solution by allowing companies to take advantage of existing computing and network capacity to deliver digital content. Distribution starts at one central server, but each user's PC that receives the file can become a server and service other requests on the network. After one user receives a file, subsequent requests for the file on that LAN would be served locally from previous recipients, preserving WAN bandwidth.

Another method is to rely on outsourcing the delivery outside the LAN to a secure CDN. This would move the cost of maintaining and updating such networks to a third-party.

Outsourced Content Delivery Networks

The last option is simply to outsource streaming to a secure CDN. These vendors have extensive global networks, some using physical servers around the world and others utilising peer-to-peer arrangements, which can easily handle live and on-demand streaming to a huge amount of concurrent users. CDNs also have a high degree of built-in redundancy that increases delivery reliability. The management portals of such vendors typically provide easy access to extensive usage reports in order to better understand viewer behaviour.

11.6 Building versus Outsourcing

The benefit of building an infrastructure is that the owner will maintain control over the network and any modifications to the SAN, LAN and CDN can be coordinated internally. Certain aspects of the combined infrastructure will lend itself well to being controlled and administrated by archive owners since it fits their current business model. The SAN is a digital version of a video archive and within most archives there will be enough knowledge and know-how to build and maintain such a system.

The same goes for the LAN. The LAN is basically the internal distribution network and administration facility for the SAN. These two structures can be superimposed onto any current video archive. Building and maintaining the SAN can be done in conjunction with partners but ownership on a day-to-day basis should fall within the PrestoSpace consortium. Since the LAN and the SAN will need to be closely integrated, it stands to reason that both these infrastructures will benefit from being under the ownership of the PrestoSpace umbrella.

The control and administration related to these two media assets are the core of the digital archive and should be controlled and administrated as such. Access, maintenance and expansion are the key objective for the LAN and the SAN and should consider one entity for the purpose of these processes. Outsourcing the LAN and the SAN is of course completely feasible complete with control and maintenance. The key part is to note the role of ownership, control, maintenance and administration of such assets.

The delivery network on the other hand is not something that archive owners traditional have had full ownership over. The dynamics and pressure that drives CDN are very different to the LAN and SAN assets.

Building and maintaining a CDN will be resource intensive for any archive. Delivery of content is not usually within the resource typically allocated to archive owners. In this way it will be an added cost to build up, alongside the CDN, a human resource and skills repository. With a multitude of large-scale delivery networks emerging it is possible to outsource building, maintenance and control over this part of the architecture to a third-party. The essential media assets stored and administrated in the SAN and LAN whereas the actual delivery is not essential assets.

12 Case Studies

12.1 CNN video formats for digital delivery network

The global media corporation CNN decided to transfer their video archive from analogue to digital in the early 1990s. Material goes back 22 years and is mainly stored on tape. This mean transferring approximately 150,000 hours of tape into a digital media format and finding a suitable storage solution that would suit the specific needs of the organisation. The project aimed to maintain the existing workflow at CNN. Maintaining the workflow meant that the work dynamics of CNN was not disrupted or would have to be revised. As of summer 2005 approximately 200.000 hours have been ingested and converted to digital media.

From a News Organisations point of view access and the ability to edit digital files in real time from multiple locations was essential. Editors and producers needing to access old footage and edit it before inserting chosen pieces into a live broadcast meant that a digital archive would need to be able to handle not only previews but also to deliver broadcast standard files for editing and quick delivery. This meant real-time delivery of video files to editors and producers across the CNN network.

The encoding format chosen is MPEG-2but because of supplier problems DV25 was used as a temporary replacement until the supplier problems could be sorted out. DV25 is the format for consumer DV cameras. It’s a raw format that can be translated into several digital formats without loosing quality. In the CNN architecture it is stored with 4 uncompressed channels of audio and 6 lines of uncompressed VBI. One hour of DV25 at this compression equates to 14.4GB of disk storage space. This format is used for archiving tape footage and is stored on large-scale media servers. This is what is considered hi-resolution media from which programmes can be edited and produced for broadcast.

In order for editors and producers to access this footage across CNN a smaller preview and editing format was needed. The DV25 format was running at 230 MB per minute, which means that it would be unsuitable for preview and editing outside the main LAN. Even inside the LAN this high-resolution format would encounter processing problems on desktop machines. Rather CNN choose MPEG-1 I-frame only for desktop viewing and editing. This format was encoded to ensure that 1 hour of footage would equal 1 GB of storage space. With this MPEG-1 format editors and producers could access and edit footage directly across the organisation. Once an edited file was done it could be broadcast from the main repository based on the editing data from the MPEG 1 format.

The MPEG 1 I-frame only format means that each frame is a key frame. In this way editing can be done more seamlessly. The MPEG 1 format preview and editing video was stored separately to the high-resolution DV25 formats. The CNN system was divided up between a High-resolution repository from where the actual footage chosen was delivered from and the preview and editing repository. The preview and editing repository based on the MPEG 1 format enabled desktops connected to the CNN network to preview and edit footage. Editing metadata is then transfered to the high-resolution repository that sends out the footage based on the metadata from the MPEG 1 edit.

Two locations were selected for the running of the operation: New York and Atlanta. The system deployment in New York consisted of 2x 14 TB High Resolution cores and 2x 2 TB Low resolution cores. In Atlanta the system had even more high-resolution capacity: 2x 28 TB High resolution cores and 2x 2 TB low-resolution cores.

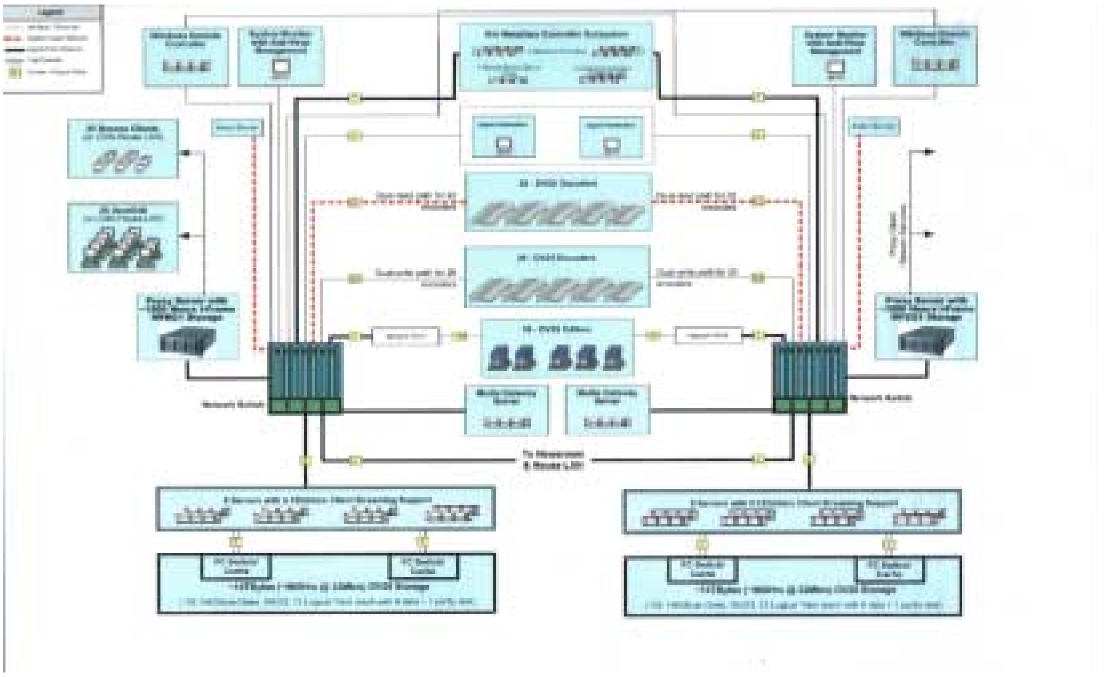
Two encoder/decoder banks enable ingest and play-out services in both locations. The decoder banks sits between the two cores at each installation and service both cores. They service all needs for transcoding and encoding within the local system.

The challenges that stands out for CNN is the ability to maintain backwards compatibility in terms of:

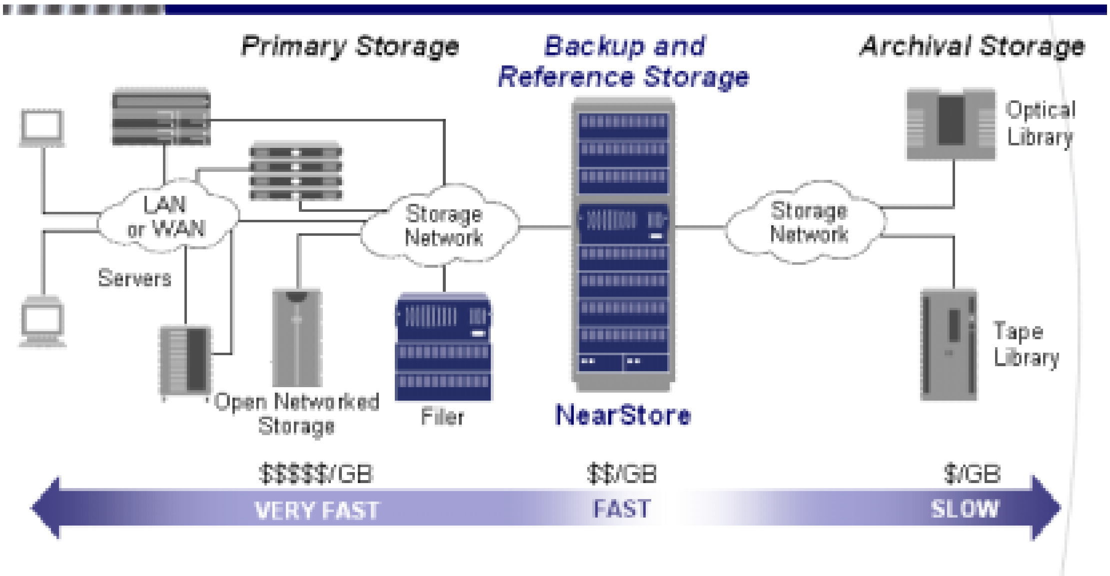
- OS
- Applications
- Configurations
- Hardware
- System Architectures
- Bus Architectures

In addition the ability to maintain forward compatibility in terms of media formats is one of the challenges that CNN faces along with all other video archive owners. This means trying to anticipate which media formats will dominate in the future and what kind of compatibility is available with already chosen formats.

12.2 Diagram #1 CNN system diagram



12.3 SAN and LAN diagram #2



13 Technical glossary

ATM	Asynchronous Transfer Mode
AVC	Advanced Video Coding
B-Frames	Bi-directional frame
BGP	Border gateway protocol
CD	Compact optical Disk
CDN	Content Delivery Network/System
CD-ROM	Compact optical disk carrying data in Read only Memory format
CPU	Central Processing Unit
CSR	Connection success rate
DCT	Discrete Cosine Transform
DVD	Digital Versatile optical Disk
ES	MPEG Elementary Stream
ECDN	Enterprise Content Delivery Network
FTP	File Transfer Protocol
GB	Gigabyte (1024MB)
GOP	Group of Pictures
H.261	First digital video codec
H.264	The latest digital codec of the H.26. Family
I-Frames	Intraframe coding
IP	Internet Protocol
ISP	Internet Service Provider
JBOD	Just a bunch of disks
JVT	Joint Video Team
LAN	Local Area Network
Lossless Compression	Refers to compression with no loss in the original data
Lossy Compression	Refers to compression with patterns of loss in the original data
Mbps	Megabits per Second
MBps	Megabytes per second
MCPC	Multi Channel Per Carrier
MPEG	Motion picture expert group
MPEG1	A standard for storage and retrieval of video clips
MPEG2	A standards for production and distribution of high-quality full screen video
MPEG4	A standard for mobile and streaming delivery of video
MJPEG-2000	Lossless video format based on the JPEG image format
OS	Operating system
PB	Petabyte
P-Frames	Predictive frame
RAID	Redundant Array of Inexpensive Disks
RAM	Random Access Memory
SAN	Storage area network
SMTP	Simple Mail Transfer Protocol
UDP	Universal Datagram Protocol (reliable transport service for IP)
VCEG	Video Coding Experts Group
VOD	Video on demand
WAN	Wide Area Network
WMP	Windows Media Player

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