European Digital Cinema Forum

A White Paper on High Frame Rates from the EDCF Technical Support Group

Background

The initial requirement from DCI was to support a 2K frame Rate of 24 frames per second or 48 frames per second (thereafter called fps). For 4K systems the frame rate was set at 24 fps only.

As a result of lobbying from IMAGO (the European Federation of Cinematographers) and the EDCF with support from many in Europe a SMPTE study was performed on the need for frame rates additional to 24fps and 48 fps. This study then migrated into workgroups studying mainstream 2D frame rates and specialist archive frame rates. The additional 2D frame rates established were 25, 30, 50 and 60 fps.

These optional additional frame rates are supported by many of the servers and projectors in the market but not all.

3D systems were initially specified to use the existing 2K 48 Fps infrastructure with very minor modifications but 24fps per eye 3D is not very satisfactory. Even after the success of Avatar James Cameron was still unhappy with the judder in 3D presentations caused by the low frame rate. He then instigated a series of private experiments with certain of the manufacturers to explore 48 fps per eye and 60 fps per eye.

His material has been demonstrated at several trade shows at both 48 fps per eye and 60 fps per eye. Also, Peter Jackson is shooting the Hobbit at 48 fps per eye. 48 fps is seen as a compromise which allows easier generation of 24 fps per eye to be compatible with existing installations.

Following on from the Cameron initiative, SMPTE has initiated a study group to access the need for high frame rate 3D. If this group identifies the need, a working group will be formed to actually generate the standards documents needed to provide a uniform approach in Industry and thereby compatibility between vendors.

Current Situation as at 7th January 2012

- Series I projectors will not support high frame rate 3D
- Early servers / media blocks (mb) will not support high frame rate 3D
- Some server's / mb may be upgradeable by adding a high speed interface card and high speed discs to feed internal media blocks. (imb),(check with the manufacturer)
- TI based Series II projectors will support high frame rate 3D but will need an imb and firmware / software updates. (Firmware = programmable hardware).
- Sony SXRD projectors will support high frame rate 3D but will need upgrades to their imb.
- Interim internal media blocks will use external storage; future internal media blocks may have limited onboard storage.

- If the venue has a library system this could connect directly to the imb but the IT system would need to be well designed to avoid data drop outs. (Store and forward is not speed dependant, direct connection is)
- It is believed that Cameron will release Avatar 2 to several hundred high frame rate screens the rest will be 24fps per eye.

Summary

Newer installations with TI based series II projectors and recent servers should be able to be upgraded by adding a high speed interface to the server and an imb to the projector.(manufacturer dependant)

Sony systems will need imb upgrades

SMPTE will need to assess the data requirements for high frame rate 3D and until this is done it is difficult for manufacturers to make concrete statements about upgradeability.

Background Technical information (for the brave)

As mentioned above, DCI mandated the use of 24 and 48 fps for 2D Digital Cinema.

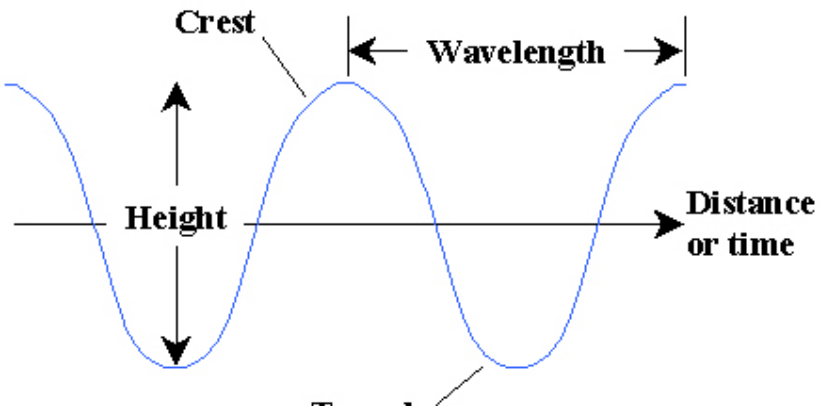
When the additional frame rates were standardised a method had to be found to pass the higher speed data between the server and the projector.

This was made possible by using a compromise needed for 4K which substitutes a (RGB) connection between the Media Block and the projector for a (Y.Pb.Pr) connection.

R.G.B. means Red, Green and Blue. Mixed together in the right percentages Red Green and Blue can result in white.

Y is the term for brightness information and Pb, Pr, mean in effect processed blue and processed red. Y.Pb.Pr. can be mathematically turned back to RGB with minimal visible quality loss but needs less bandwidth for storage and transmission which is why all TV systems use Y.Pb.Pr. Using this format facilitated 3D operation and additional frame rates for 2D.

Bandwidth is the term used to describe the equivalent analogue frequency band. Band being, for example, 25 black white cycles per second to 30 million cycles per second. 1 cycle per second could be displayed as below if the period is 1 second. (This is actually 2cycles)



Analogue Sine Wave 2 Cycles White Black White Black

(Trough represents Black and the peak represents white)

The Digital Images are scanned from top left to bottom right then back to the top again. If you were to look at the scanned image during the scan you will see something like the picture above though the wavelength depends on the resolution of the object in the scene so the waveform will be much more complex.

Digital systems are sampled from the analogue original and the mathematical rule is that the frequency you sample at must be more than twice the maximum frequency of the analogue signal. Without going into the details, the 30 million cycles per second maximum is sampled at 74.25 million times a second for each colour (2 x + safety factor). This then becomes the speed of interconnection and in digital cinema Series I systems two links or cables are used with a digital speed of 1.5 thousand million samples a second.(1.5 Gbps)

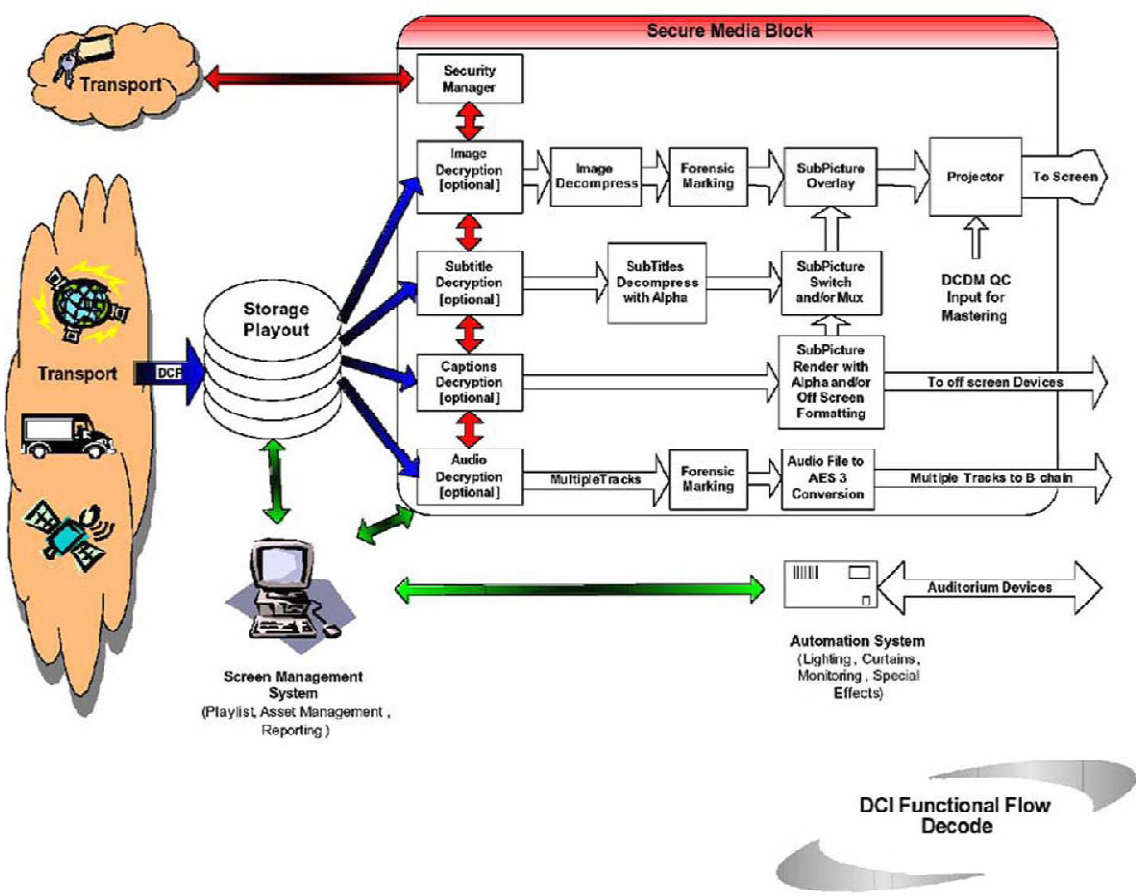
Images are also sampled temporally. In cinema, 24 samples per second are captured (24 fps). This is very low and in fact slower than many objects move in daily life. This low sample rate causes the reversing wagon wheel effect in cinema - the object moves faster than the sampling law allows and an alias or reverse image is generated.

Increasing the frame rate to 60 samples per second per eye significantly improves the temporal sample rate and minimises, but does not eliminate, temporal alias. What it also achieves is more realism in the scene. It is Ironic that the artefacts caused by too low a frame rate are the core of the “Film Look” but now S3D needs more realism which calls for higher frame rates.

In their requirements document for digital cinema, DCI laid out a functional block diagram for the projection box, it is illustrated below.

For most Cinemas the projection box has a playout server and a projector. With the exception of Sony installations, in most installations today the server is separate from the projector and is connected to the projector by two cables. These cables carry HDSDI (High Definition Serial Digital Interface). The signals are encrypted for security as HDSDI is a professional TV standard and without encryption it would be possible to record from the server.

Now we get to a specifically digital cinema term - “Secure Media Block”. Digital cinema packages or DCP’s are a group of picture, sound and auxiliary service files, encrypted for security, wrapped up and delivered to the Cinema for playout. DCI were very concerned about the security of their digital movies as the quality is close to the post production masters. Anyone hacking into the system would have at their disposal a top quality pirate duplication source.



DCI Projection Booth Block Diagram

This concern led to the need to encrypt the files and also make it impossible for pirates to get inside and pull out the picture for recording. The server designs use a lot of IT based components but from the early days they also used specialist hardware circuit boards with a tamper resistant protective covering. They are called Gore Boards after the Gore-Tex covering over the component to detect tampering. At this point these special digital cinema servers were renamed Media Blocks.

Initially, due to the difficulties of hardening the electronics to the Xenon lamp's strike pulse (the lamp strike pulse is like a small electromagnetic pulse generated by a nuclear explosion) the Media blocks were separate from the projector. Systems which worked with Series I projectors used separate media blocks with a Dual HDSDI cable connection. The base files were decrypted in the media block then re-encrypted to send through the connecting cables. The projectors then decrypted the signal in a physically secure environment. If this environment is mechanically disturbed the decryption keys can be dumped which prevents playback with an open case.

The Dual HDSDI link is limited in bandwidth and, as is mentioned before, will only support additional frames rated up to 60fps 2D by using Y.Pb.Pr. encoding over the media block to projector cables.

To support 3D, the Left and Right signals are transported in the DCP as a time sequential pair, the media block unpacks them into left on one cable and right on the other, again the signal is now Y.Pb.Pr. rather than R.G.B..

There is an added complication with 3D in that, to prevent flicker, the images are displayed multiple times as they would be with a 2 or 3 bladed shutter in a film projector. This is called double flash or triple flash and has no bearing on the interface speed as the flashing is done deep inside the projector electronics. When you hear that the projector can support 144 frames per second this is not true, it is supporting 24 fps left + 24 Fps right with a flash or refresh rate up to 144 flashes per second.

So the Dual HDSDI interface used in series one projectors and external media blocks means that they cannot be upgraded with DCI security to support any more than the SMPTE additional frame rates (Up to 60fps 2D). Therefore Series I projectors will never support high frame rate 3D.Some early servers may be upgradeable to supply data to internal media blocks.

Sony

Sony projectors have an imager with 4096 pixels in the horizontal direction and 2160 in the vertical direction. From a signal processing point of view the imager is divided into 4 x 2K tiles. (2K = 2048 Horizontal columns x 1080 Vertical Pixel rows). As this would require eight HDSDI connecting cables to connect to an external media block, Sony chose from the beginning to put their media block inside the projector case. This is called an integrated media block (imb). This allows several short distance unencrypted high speed interfaces between the secure media block and the projector electronics all in a box sealed for security. Sony projectors can already support additional frame rates up to 60Fps as Sony achieve 3D by splitting the imager feed into two segments, upper and lower, which can already display 3D at 60 fps. This does not however mean that the projector is high frame rate ready as there will be upgrades needed to the IMB to support the various aspects of a higher frame rate.

Series II Projectors

Unlike TI based Series I projectors from Barco, Christie and NEC, the Series II projectors have the capability of integrating the media block inside the projector case. This improves the security and also facilitates higher speed connections between the media block and the projector electronics.

The Series II projectors also have much higher speed signal processing than the Series I projectors. In fact all the series II projectors have 4K ready processors to allow for later upgrading from 2K to 4K. Modern digital processing electronics hardware is programmable in a similar way to software. This means that the projectors could be configured to support different formats or frame rates as long as the absolute processing power is not exceeded. The projector manufacturers are able to support higher frame rates by reprogramming the electronics to support 2K 3D at up to 60fps per eye. This does not mean that the projector will do this today but an upgrade path is possible. The lens systems are similar on time sequential systems. (Please refer to the EDCF 3D guide for illustrations of these processes).

Integrated Media Blocks

Most of the existing media block suppliers will produce integrated media blocks; at least one TI based projector vendor will produce their own IMB.

Example DOREMI INTEGRATED MEDIA BLOCK

As mentioned above, the original servers are connected to the projectors with two encrypted HDSDI cables.

To allow for a faster connection to the projector electronics the IMB uses several very high speed, but very short, data buses to connect from the IMB to the Projector. The first generation IMBs do not have storage on board so they need a high speed connection to an external server or storage system. Future generation IMBs may use next generation portable computer hard drives for integrated storage.

The picture data in the DCP is quite heavily compressed using JPEG2000; this is similar to the compression in your stills camera. DCI specified the compression system and also the amount of compression for digital cinema. Compression is a highly tuned mathematical system which analyses the picture content and looks for redundant data which is present in just about all pictures. This allows the picture data to be placed into a smaller space.

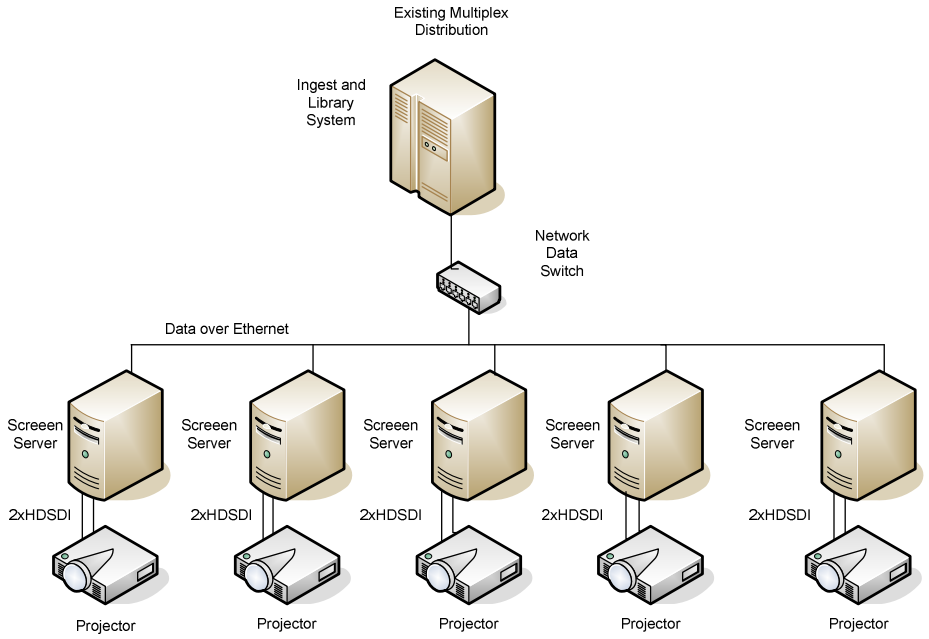
DCI chose, through a series of evaluations and manufacturer discussions, a maximum picture data rate of 250 Mbps (million digital bits per second) to serve 2K at 24 or 48 Fps and 4K at 24 Fps only. This translates into 125 Mbps per eye at 2K 3D.

Although the High Frame rate Group has been initiated in SMPTE , there has been no open and substantive work on the required data rate for high frame rate 3D yet.

At the demonstration in St Petersburg at Kino Expo 2011, 48 Fps per eye and 60 Fps per eye were shown. 48 Fps used a data rate of 400 Mbps and 60 Fps used a data rate of 500 Mbps. It is not yet known what the optimum data rate is but these figures may be realistic. In this case the server has to supply the media block at something like 550Mbps. This is not possible with current servers though it may be possible to modify the existing server by removing the media block and replacing it

with a high speed interface card. There may also be a need to upgrade to faster and larger discs because the storage requirement also jumps.

At the moment there are no documents specifying the data rate for compression or the high speed interface between the server and IMB. In the Doremi case above, they extend an internal computer bus called PCI Express with a special connector; other manufacturers may chose a different way.



The Drawing above shows an existing system.

Upgrading

Note that Sony systems will only need an IMB upgrade.

To upgrade TI based systems to higher frame rate 3D a Series II projector is essential.

An IMB needs to be added to the projector by plugging an IMB card as illustrated above into the appropriate slot and upgrading the projector firmware and software to recognise the new card and its capabilities.

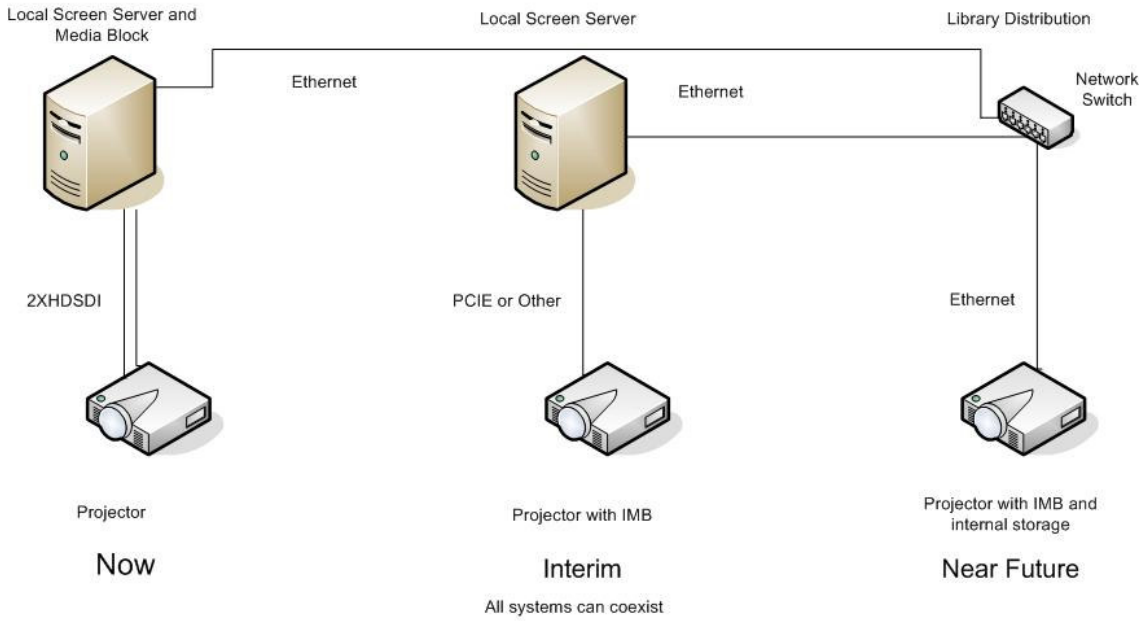
The screen server manufacturer needs to be contacted to see what, if any, of the existing system can be reused. Depending on the manufacturer and the age of the server, it may be possible to update by adding a PCI express interface card and cable together with software.

It may also be necessary to update to faster and larger discs for local storage.

Some servers may not have sufficient data bus bandwidth to support 550 Mbps if this becomes the specified data rate for 60 fps per eye. Contact the manufacturer.

The Library system will be unaffected although it may be necessary to increase the storage capacity in line with the larger data requirement.

The Drawing below shows the update.



Integration of old and new

In future systems with Generation two IMBs with onboard storage, the ingest and library system can be connected directly to the IMBs network terminals.

Digital cinema uses a store and forward system; this means that the compressed data flow can be moved at faster or slower than real time. At the output of the IMB it has to be real time uncompressed in synchronism with the sound and auxiliary services.

3D Systems

A poll of the major 3D systems manufacturers indicates that there should not be a problem with existing installations. They will most likely need a software / firmware update but the core systems should work at higher frame rates. It is not yet decided what the final flash rate recommendation will be.

Peter Wilson V1.1 09/01/2012