

Do's and don'ts of video conferencing - Experience from LIVE-NET

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Report to AGOCCG
December 1994

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ABSTRACT

LIVE-NET started in 1987 as a collaborative project between London University and British Telecom to provide interactive video teaching for inter-collegiate courses held within the University.

LIVE-NET has been used for teaching academic subjects ranging from theoretical physics - "Quantum Electrodynamics" to classics - "The Dialogues of Plato" as well as for meetings and satellite broadcasts.

LIVE-NET has had experience of using both analogue and digital networks. The original LIVE-NET system was based on a switched star analogue video network connecting seven sites of the University. In the summer of 1994 LIVE-NET moved over to a hybrid system consisting of analogue links within University College with gateways to external digital networks.

Since 1987 LIVE-NET has gained a large amount of experience using video networks for interactive communication applications. This has ranged from straightforward teaching applications to multi site satellite conferences.

LIVE-NET is controlled by a central computer which is responsible for scheduling sessions and remotely controlling equipment such as the video switches, CODECs and the Laser Videodisc Recorder.

LIVE-NET

London University is a collegiate University with colleges spread over the Greater London area ranging from Royal Holloway and Bedford New College (RHBNC) at Egham (South-West London) to The Whittington Hospital at the Archway in North London and Queen Mary & Westfield College in the East.

By the mid 1980's the colleges of the University were offering students access to courses based in schools other than the one where they were enrolled. Although this increased the range of subjects each College could offer, it required the students to travel across London to attend classes. An administrative nightmare ensued. The time tabling of classes in order to allow the students to travel between sites significantly reduced the time available to attend class.

An interactive video link provided the solution, and research in partnership with British Telecom (BT) followed. The system was based on the technology that BT had developed for the switched star cable television network that was at the time being installed in the City of Westminster.

The system consisted of a star network connecting seven University locations with a video crosspoint switch located in Senate House. Video switching was also provided at some of the remote sites so the network could be extended locally. Connection between the remote sites and the hub was provided by fibre optic cables which carried four near broadcast quality analogue signals and a fifth data channel. Control of the system was provided by a computer located at the hub of the network in Senate House. [Figure 1]

The Westminster cable system used multi-mode fibre operating at 850nm which had an attenuation of 3.5dB/km and a bandwidth of greater than 600Mhz/km. This enabled a transmission distance of 4km to be achieved before the picture quality degraded. Whilst this was acceptable for the shorter links the links to Imperial College, Queen Mary and Westfield College and Royal Holloway and Bedford New

College used monomode fibres at 1300nm. The longest link, 42km to QMW used a repeater at 25km. The longest possible link using this technology was quoted as ~70km.

It was originally envisioned that LIVE-NET would be used mainly for teaching science courses. Whilst LIVE-NET was (and still is) used for teaching postgraduate theoretical physics the system tends to be heavily used for teaching arts and medicine.

LIVE-NET 2

During the summer of 1994 LIVE-NET moved over to a hybrid network consisting of analogue links within University College London and gateways to external digital networks.

The analogue section of the network connects the main campus of University College London (UCL) with the Whittington and Middlesex Hospitals. On the Middlesex site the link extends to the Audio Visual Centre television studio, the Multimedia research laboratory, clinical operating theatres and the X-ray and Urology departments. The analogue section of the system provides near broadcast standard video and is heavily used for teaching within the medical schools of the college, currently running at 600 hours per annum. [Figure 2]

The digital section of the network can access Integrated Services Digital Network (ISDN), SuperJANET or the Internet. ISDN can be accessed at any rate from 128kbps to 384kbps. A British Telecom VC7000 videophone can be linked into LIVE-NET via its external connections so that any site on the analogue side of the network can access its 128kbps CODEC. Higher data rates can use an Ascend inverse multiplexer connected to a GPT H261 Coder/Decoder (CODEC).

Access to other Colleges in the University is now via dial up ISDN lines rather than the dedicated analogue fibres used in LIVE-NET 1. This has been used to

hold courses on Classics, Particle Physics and European History. Usage is currently about 300 hours teaching per annum.

SuperJANET can be used to connect to any of the 13 other SuperJANET ATM video sites in the UK. Transmission of video is via a 2Mbps Permanent Virtual Circuit (PVC) on the 155Mbps SuperJANET network. [Figure 3]

SuperJANET has been used for medical sessions involving Cambridge, Manchester, Newcastle and Edinburgh. During 1995 it is planned to run a series of lectures on Human Computer Interaction between UCL and Imperial College over the SuperJANET network.

Technology

The original LIVE-NET system was based on an early technology domestic cable TV distribution system. With this sort of network it makes economic sense to send as many channels as possible down each fibre. At the time of its development during the mid 80's the maximum bit rate that could be carried on optical fibre was ~140Mbps. This is equivalent to a single high quality uncompressed digital video signal. Unless complex and hence expensive equipment were used to compress the digital signal there would have been a practical limit of one video channel per fibre. As a result an analogue frequency modulation system was used which enabled four high quality analogue signals and a fifth data channel to be carried on one optical fibre.

Due to drift in the transmission and reception equipment this did not prove to be too successful in practice. In particular the fifth data channel on the longest link (RHBNC to Senate House 42km with a repeater at 25km) was never very reliable as a result of which one of the video channels had to be used to carry data.

The analogue section of LIVE-NET 2 is based on a single channel contribution network using RS1000 standard equipment. This technology was developed for

surveillance and security systems (such as those used in city centres) where only a single channel needs to be transmitted per fibre. RS100 provides a slightly better quality video signal and eliminates the problems of equipment drift which occurred with the previous equipment.

Some of the fibres in the new system are used to carry data at the G703 standard (as used by LIVE-NET 1). Since the fibres used to transmit data are not shared with other signals reliability is expected to be far higher than with the previous system.

The cost of fibre is not a large factor in determining the overall cost of a fibre based video distribution system. With present day technology four single channel fibres are as cheap as a single multiplexed four channel fibre. Multiplexing becomes cheaper than using single fibres when transmitting between 6 and eight channels.

Digital Video

Digital video systems work by taking an analogue signal, converting it to digital form with an analogue to digital (A/D) converter, compressing the signal by removing redundant information and finally transmitting it over a digital network where the signal is decompressed. This is the derivation of the word CODEC, CODer/DECoder.

The key parameter characterising digital video is the data rate which is measured in bits per second (bps). Transmission rates range from 64kbps (64 thousand bps) to 140Mbps (140 million bps). The quality of the received video is dependent on the data rate.

Effects of compression

The BBC uses a data rate of 140Mbps on digital transmission links which gives results which are as good as and in some cases better than analogue links.

Channel 4 uses moderate compression of the data stream to produce a bit rate of 35Mbps. This gives results which are visually as good as 140Mbps albeit with a slight delay between the transmitted and received signals due to the compression/decompression process.

Below ~35Mbps the loss in picture quality due to the reduction of data rates start to become noticeable.

The quality of the received signal is characterised by its resolution and delay. Increasing bit rates from 128kbps to ~700kbps results in an increase in the definition of the received picture whilst above this rate the picture quality remains the same but the delay in reconstruction is reduced due to the smaller amount of processing needed.

SuperJanet, the successor to the Joint Academic Network (JANET), carries video at 2Mbps. Rapid changes of picture content such as occur when switching between video sources cause slight delays and loss of definition whilst the picture is being updated. Overall quality is roughly equivalent to a good domestic VHS video recorder. This has been found to be acceptable for most meetings, lectures and seminars.

Transmission at 384kbps (six 64kbps ISDN channels) provides a clear and stable picture for scenes with minimal changes in picture content. However when there are major changes in the transmitted picture the quality of the received picture degrades, there is loss of resolution and noticeable blurring.

At 128kbps (as used by the BT VC7000 video phone) picture quality is noticeably jerky and resolution bad with quite noticeable delays in movement. Due to the jerky nature of the video signal there is a noticeable loss in synchronisation between the received audio and movement of the speakers lips. During sessions run by LIVE-NET at 128kbps it was necessary to keep pictures from the overhead camera and slides still for an appreciable time in order to allow the picture to

stabilise. If both sides attempted to speak at the same they would experience difficulty in the audio in the form of clipping.

The bandwidth of a digital video signal is split into two sections, one for the video and the other for the accompanying audio. The data rate for audio must be at least 48kbps to achieve an acceptable quality. For a 128kbps channel this results in only $(128 - 48) = 80$ kbps being available for the video. If the data rate is doubled to 256kbs the bandwidth available for the video signal nearly quadruples resulting in a dramatic increase in picture quality.

Codec tests

In November 1993 four suppliers selling digital video conferencing equipment, BT, PictureTel, CLI and V-TEL took part in a series of tests of their equipment to help in the selection of a CODEC for LIVE-NET 2. The CODEC supplied by BT was actually manufactured by GPT.

Tests consisted of playing a previously recorded Hi Band Umatic SP tape through the CODECs at 128kbps, 384kbps and finally at 2Mbps. The still images on the tape consisted of text, handwriting, line drawings, well defined colour graphics (maps and charts) and poorly defined graphics (leaves and earth samples). Moving images on the tape consisted of surgery and radiological clips, 'talking heads', classroom shots and sports.

The output from the CODECs were viewed in parallel on four specially matched monitors and recorded individually on a separate Umatic recorder. To prevent bias the outputs of the four CODECs were sent to monitors which labelled A, B, C and D rather than being labelled with the manufacturers name. An audio tape was then played individually through each CODEC at 384kbps as a test of their audio performance.

Five test sessions were held with between five and ten people the same group of

users or potential users attending each session. Panel members were classified as 'real end users' if they had used or wanted to use LIVE-NET and 'interested parties' otherwise.

The panel members preferred the CLI CODEC to the BT CODEC by a 2:1 ratio. Nobody expressed a preference for the PictureTel or V-TEL CODECs.

The CLI CODEC seemed to be preferred by those (who formed a majority of the panel) who cited picture brightness and a good representation of the edges, details and accurate colour reproduction of still images as reasons for their choice. These users tended to say that their LIVE-NET material was at least equally visual and verbal. Some of the qualitative comments in favour of the CLI CODEC were :-

“better sharpness of image and good colour”

“better definition at 384”

“sharper and clearer for still subjects”

“better for detailed still pictures at low speeds [128kbps]”

“slightly better for stills”

“better for X-rays”

“allows background to be still while foreground moves”

“better for movement”

“better on sound”

“best on sound”

There were also comments against the CLI CODEC, however for those who preferred this device these were not too important :-

“image persistence problems”

“takes the longest time to get into synchronisation upon changes of scene”

“considerable time lag, particularly at lower rates”

“jerky movement”

“less good at showing lecturers”

BT seemed to be preferred by those for whom personal presentation is important. For these people it is important that the system produces a smooth moving image with good reproduction of facial expressions and synchronisation between sound and lip movements. Some of the qualitative comments in favour of the BT CODEC were :-

“Better graphics”

“motion is better”

“better movement at 384”

“better for movement and synchrony”

“overall at the highest bit rate, BT was the best in all respects”

“clearer definition of people lecturing”

“better for movement in close-up and mid/long shots and in general for images of people”

The rating of sessions on a verbal/visual balance by the various groups are given here. The first group preferred the BT CODEC whilst the others chose the CLI.

More verbal than visual :-

Ancient Greek philosophy, ancient warfare and administration

Equally verbal and visual :-

Geology, microscopy, global environmental change, medicine, computer science, book preservation and library user education

More visual than verbal :-

Mathematical physics

Strongly visual :-

Radiology and surgery

Most of the differences between the two groups were relatively small, different

people would often cite the same reasons for preferring different CODECs. Some qualitative comments indicating the reasons for the preferences given :-

“Couldn't tell the difference between monitors”

“Difference between A and D is marginal”

“At the highest bit-rates there was little difference”

“Close between A and D”

“Very difficult to decide”

“It is hard to choose between A and D”

Any differences would be unlikely to greatly effect teaching :-

“All in all the differences in performance were inconsequential in most teaching settings

The H261 standard for data compression ensures interoperability between equipment from different manufacturers. It is however a lowest common denominator since it has been frozen in time to allow manufacturers to conform to it and therefore does not allow the use of the most up to date algorithms or equipment. Proprietary algorithms such as used by PictureTel can increase the quality of the picture but at the loss of inter-operability.

Comparison between analogue and digital

Generally speaking analogue transmission can provide better quality video than digital. However against this is the higher cost of and inflexibility of analogue systems. Analogue systems need dedicated circuits whilst a high speed network such as SuperJANET can quite easily carry digital video and computer data by reserving a Permanent Virtual Circuit (PVC) to carry the video signal. There is potential for local campus networks which can be used to carry video without using all the bandwidth available.

Whilst it is possible to re-generate a digital signal which has been transmitted across a noisy link this is not possible for analogue signals. Digital transmission methods can also carry error protection information within the transmitted data so even if a signal is corrupted it can be corrected.

Since the cost of an ISDN call is directly proportional to the data rate a call at 384kbps will cost three times as much as one at 128kbps and a ISDN 30 call will cost fifteen times as much. Thus it is possible to choose the quality of a digital circuit as a function of its cost. See Appendix A for more details.

There is a choice to be made between permanent leased lines and the use of dial up facilities. The rental cost of leased lines are high, BT charges £16000 per annum for rental of the LIVE-NET 2 lines, but there is no hourly usage rate. However since leased lines only provide point to point links they are less flexible than dial up.

System control

LIVE-NET is controlled by a computer which provides a booking system for the sessions and controls the video crosspoint switches and other equipment. Since the system had to have multi user access and be able to provide low level access to external devices it was decided to use a computer which ran the UNIX operating system.

In 1991 the original computer (a BT 68020 box) was damaged by a mains transient and proved to be impossible to repair. Since the system was UNIX based and written mainly in C it was possible to get the LIVE-NET programs up and running on the new computer (a SUN IPC) in under two days. Most of this time was spent tracing a bug in one of the programs which relied on a peculiarity of the hardware architecture of the 68020.

The original version of the LIVE-NET software was written by two postgraduate

computer science students between 1987 and March 1989. Nine months later in November 1989 another programmer was employed to work on maintaining, debugging and enhancing the system.

Instead of using a single large monolithic program to control LIVE-NET, the system was split into three separate smaller programs each of which control their own part of the system [see figure 4]. The programs communicate with each other by passing messages between themselves. `switch` controls the video crosspoint switches and keeps track of the current configuration of the system. `dbp` looks after the bookings database and is responsible for scheduling sessions. When a session is due to start or finish `dbp` communicates with `switch` telling it what crosspoints to set on the video switches. `livenet` is a screen based interface to the other two programs which is used to insert or modify sessions or manually make network connections.

Rather than develop a new control system SuperJANET uses a modified version of the LIVE-NET interface, booking and switching programs.

The paradigm used when designing the LIVE-NET software was of a simply connected star network with video switches connected to the control computer either directly or via the fifth data channel. To the computer this would appear as a direct connection.

In early 1990 the data links were disconnected from the computer and used to provide the Livenet Data Network (LDN). This was the first network to provide IP connectivity within London University and acted as the basis for the Janet Internet Protocol Service (JIPS).

To provide control of the remote switches a Packet Assembler Disassembler (PAD) connected to the JANET X-25 network was wired to the serial lines of the control computer. Each of the remote video switches was connected locally to a PAD. Changes had to be made to the control program to make it call the remote PAD

and set up a connection between the LIVE-NET computer and the remote switch.

LIVE-NET 2 is not connected to JANET and has to control CODECS, Ascends and the LVR as well as the video switches. Further modifications were made to the control program to allow it to access the network interface of the computer. This allows equipment connected to the Internet to be controlled. Equipment can either be connected to another computer (with a small control program running on that machine) or a terminal server.

Since the Internet is a global network there is no reason why LIVE-NET can not control equipment beyond the bounds of Greater London. Today London, tomorrow the world !!

Apart from the section of code which opens a connection to the equipment whether directly from a serial port, via an X-25 PAD or an Internet connection the changes were transparent to the rest of the program

As well as the three main control programs several other programs were written for use with LIVE-NET. These included programs to control the Laser Video Disc Recorder (LVR), report generation programs to produce statistics of system usage and list the sessions for given dates and programs to provide low level control of other parts of the LIVE-NET control system.

The main report generation program produces a schedule of the sessions for a given time period (Appendix B). This program translates the location names given in the booking form to a more useful form. The printed output is sent to the site representatives as a record of the sessions for their site and also serves as a central reference. In practice it is far quicker to look up a session in a printed listing than to retrieve it from the computer.

Experiences, good practice

It was found from practice that it was better to use rooms which were solely dedicated to videoconferencing rather than multi use lecture/seminar rooms. Since the equipment in dedicated rooms is permanently set up sound levels and camera positions will always be correct which obviates the need for testing at the beginning of each session.

Most sites involved in LIVE-NET 2 only have one CODEC and Ascend so when using ISDN they can only receive digital video from one site. This is acceptable for two site sessions but for sessions involving three or more sites some form of switching must be provided. It is possible to automatically switch video signals using a Multi Point Control Unit (MCU). When using an MCU the sites involved call the MCU which detects the site with the loudest sound level and transmits its video signal to the other sites. The current 'transmitting' site receives the signal from the previous transmitting site. Each site is fed with a sound mix from the all other sites.

MCUs can also be manually controlled in which case a chairman decides which site is to be seen by the others. This is similar to using the chairman control program in LIVE-NET.

Due to the cost of over £40k LIVE-NET 2 does not have an MCU. If an MCU was needed for a session it would be necessary to book time on one provided by an external service provider, such as BT. For a 384kbps session the cost of booking an MCU is over five times greater than the line charge, £225 per hour as opposed to £43.20 per hour [see Appendix A]. Because of the expense MCU's have only been used for a few LIVE-NET 2 sessions eg. the Photobiology conference sessions held in September 1994.

It is possible to run three site lecture type sessions over ISDN without using an

MCU by using the two Ascends at UCL and combining the video signals from the two non lecturing sites into one and sending it to the lecturers site. The combination is performed with a 'quad split' which takes four video inputs and produces a single video output with each of the inputs occupying a separate quadrant of output. This type of set up would perhaps not be acceptable for a meeting or seminar but it does seem to work quite well for a straightforward lecture.

As with other video networks the majority of the technical problems encountered with LIVE-NET are caused by sound balancing and the prevention of audio feedback.

LIVE-NET uses a Shure automatic microphone system (AMS) which is fed into a frequency shifter. The AMS will switch when the volume detected by the microphone reaches a preset level. This helps prevent ambient noise from reaching remote sites since the system will only switch when someone speaks

Since LIVE-NET uses microphones sitting in front of, but pointing away from, loudspeakers of the video monitors audio feedback or howlround can occur. The use of a frequency shifter in the audio path increases the sound level before howlround starts. Although the frequency shifters introduce artifacts in the audio signal (a sort of 'cyclic ringing') just before feedback starts their use is considered acceptable in view of the extra gain in headroom they provide.

Whilst it is fairly straightforward to adjust the sound levels for two site sessions adjustment for sessions involving three or more sites prove more difficult. This was due to the difficulty in balancing sound levels, the sound input level to the system at the sites would normally be different which meant the audio level of the video monitors at each site had to be individually adjusted.

It was originally intended to use the AMS to provide automatic switching or control of the camera so as to achieve eye contact between the speaker and other

participants. This would have been achieved by using the control signals from the AMS to switch the video signal from multiple cameras or by using a pan/tilt head attached to a single camera to physically move it. In practice did not prove to be necessary to use such a system. For teaching sessions a fixed camera pointing towards the lecturer could be used whilst students could be viewed as a group with a fixed wide angle camera.

In the case of meetings some form of control was needed. This was provided by a combination of hardware and software. Multiple cameras at a site could be controlled with pan tilt heads and selected with a video switch box.

To enable multi site meetings to be run with the limited number of inter site video channels available quad splitters were used to display four pictures on a single monitor. Two monitors could be used to display the pictures from up to eight sites. A program running on the LIVE-NET computer would then be used to control which picture would appear full screen on the centre monitor at each of the sites. This would normally be the person who was talking at the time.

This relied on having a nominated chairman at one of the sites selecting the picture to appear full screen. In practise this was acceptable during the formal sections of a meeting such as when a person was making a report since the system only needed to be switched infrequently. During discussion periods the constant switching required proved to be distracting and often the full screen picture was left on the chairman.

Some form of automatic switching of images such as provided by a Multipoint Control Unit (MCU) when using ISDN would have been preferable.

The quality of the analogue and SuperJANET links are fixed whereas with ISDN it is possible to select the desired quality of the received picture. However since the cost of an ISDN call is directly proportional to the data rate there is a conflict between maximising picture quality and minimising cost. The cost of a one hour

call between UCL and another London college is £4.80 at 128kbps and £14.40 at 384kbps. A 2Mbps ISDN call (ISDN 30, equivalent to SuperJANET) would cost £72 per hour. One of the LIVE-NET lecture series started off using 128kbps but at the lecturers request switched over to 384kbps after the second lecture due to the poor picture and sound quality incurred whilst trying to lecture. All the other lecture series currently run over LIVE-NET with ISDN are at 384kbps, the maximum data rate possible with our equipment. The Ascends can run at up to 512kbps but the six ISDN 2 lines available at Gower Street are split between the two Ascends limiting the maximum baud rate to 384kbps.

LIVE-NET has been asked to run several ad-hoc one off ISDN sessions by external organisations. Whilst we are willing to help when possible we do insist on testing the link a day or two beforehand. We have had trouble linking our equipment to remote sites despite nominal compatibility. For example we have had trouble getting our CODEC and Ascend to call Japan whilst there have been no problems with the VC7000 videophone.

Users views of LIVE-NET

Questionnaires were distributed to staff and students in order to determine users reaction to LIVE-NET. The responses tended to be shared between lecturers and students. The only reasons which weren't shared tended to be specific to each group. LIVE-NET saves students from having to travel whereas lecturers normally use facilities at the college where they are located.

"More lectures should be given by LIVE-NET instead of making students go up to London each week"

There were also complaints from students about the lecturers use of visual aids

"The lecturers should be made aware that students require **more** time in which to study and write notes from visual aids."

"There should be a standardised format for the presentation of visual text which makes sure it is visible **or** lecturers should distribute bibliographies"

Some lecturers don't like or trust the technology involved in LIVE-NET and are adverse to learning to use the equipment as they felt they were there to lecture - not to operate equipment. Some preferred a technician to operate equipment for them. Since the cameras used by LIVE-NET are fixed lecturers are restricted to sitting or standing in one position. Lecturers who are used to walking about tended to find this restrictive and unnatural.

However lecturers can reach a far wider and larger audience with LIVE-NET than otherwise. They are able to show slides, video tape, pictures from the overhead camera (which unlike an overhead projector can be zoomed in and out) and use the LVR for previously prepared stills or video clips. Other lecture rooms do not have all these facilities and some, like the LVR, are unique to LIVE-NET.

Some students feel intimidated by the setup. They feel they couldn't ask questions and are very shy of the camera, however other students are able to participate without any problems.

Use of satellites

LIVE-NET is able to receive and transmit satellite broadcasts. Reception of signals is via a 1.8m steerable dish or a 1.0m fixed dish. The dishes used to be mounted on the roof of the Senate House library but were moved to the Middlesex Hospital during the summer of 1994.

The first LIVE-NET satellite broadcasts were via the specialised services payload on the European Space Agency experimental Olympus satellite. Transmissions to Olympus were made from the Imperial College satellite uplink station at Silwood Park in ascot. This was connected to LIVE-NET by a fibre optic spur from Royal Holloway and Bedford New College.

After Olympus went out of service LIVE-NET used the Super Beam payload of the Eutelsat II F-3 satellite with the support of the British National Space Centre.

Depending on what is required LIVE-NET can now use commercial services to broadcast from any satellite which is reachable from the UK.

Sessions involving satellites ranged in complexity from the reception of broadcasts viewed by a group of people in a lecture theatre to the transmission of lectures with participation from the receiving sites through an audio conferencing bridge.

Reception of satellite broadcasts was normally straightforward and the sessions could be run automatically. The only intervention needed was point the dish towards the satellite and tune the receiver to the correct frequency before the broadcast.

The most frequent although not the most complicated satellite broadcasts run by LIVE-NET were a series from the Polytechnic of Central London (now the University of Westminster), "Digital Signal Processing Perspectives".

These sessions were transmitted to university sites throughout Europe who participated via an audio conferencing bridge was used so that the reception sites which were located throughout Europe could participate. When a remote site was speaking the signal to the satellite was switched from PCL to a picture of the participant which had previously been recorded on the LVR. An Amiga computer was used to produce overlay captions for these pictures.

Laser Video Disc Recorder

A Sony LVR-6000 Laser Video Disc Recorder is connected to LIVE-NET. This can store 36,250 high quality still video images, 24 minutes of moving video or a combination of both on one side of a 12 inch WORM disc (Write Once, Read Many).

Control is by the machines front panel, a hand held remote control which emulates the front panel or a serial port for computer control. The machine can play forwards (or backwards) from still to 20 times normal speed and also perform other functions such as playing a pre-programmed sequence of frames. The maximum frame to frame seek time is approximately one half second.

The LVR was originally directly connected to the LIVE-NET computer which was in the same room. It is now located separately but is still controlled by the same machine using a connection on the Internet.

A control program was written for the LVR which can emulate the front panel of the machine or act as a sophisticated slide viewer capable of displaying still frames or moving video clips. The slide viewer works by reading a previously prepared file which lists the numbers of the frames to be displayed. Each entry is either a single frame number for still pictures or two frame numbers (the start and stop points) for a video clip. Since the LVR is essentially a random access device the entries in the file do not have to be in the same order as the actual frames on the disc.

There is also a keyword retrieval program which can locate and display the frames that match an arbitrary boolean expression based on a description of the frames held in a database. The time taken to locate and display the first frame is less than the seek time of the LVR.

The LVR has been used during satellite broadcasts, lectures and research. During satellite broadcasts the LVR is used to produce a countdown timer to mark the start and end of the transmission and display pictures of people who participate by telephone (ie. audio only).

When a lecturer wanted to use the LVR they would record the images they wanted on the machine several days before. During the lecture they would select the image they wanted to display using the control program and switch between

the lecturers camera and the LVR with a video switch box.

Whilst it would have been possible for lecturers to show slides using a slide video converter or illustrations with an overhead camera without using the LVR it was much more convenient being able to prepare illustrations beforehand, especially when there were a large number, since it eliminated the time taken in setting up the material and they could be reused if a lecture was repeated.

TVEI

The LVR has been used in conjunction with a live satellite uplink and the VC700 videophone for teaching A level electronics to isolated schools in Wales, the Technical Vocational Educational Initiative.

During each broadcast the lecturer at the TVEI centre in Gwynedd would use a VC7000 videophone to contact the VC7000 in Senate House and a computer terminal connected to the LVR via the Internet. The terminal was used to select previously recorded pictures from the LVR and switch the feed to the satellite uplink in Plymouth between the VC7000 and the LVR. Using a local satellite receiver the lecturer could see the signal being broadcast and switch it between himself and the LVR with the terminal.

A few days before each session the TVEI centre would send the pictures for the next broadcast to Senate House via the Internet where they would be reconstructed and saved on the LVR. There were problems transferring pictures using this method, each picture took several minutes to transfer and the quality of the reconstructed image was never quite as good as the original. For the final broadcasts a diskette was sent from Wales and an Amiga computer used to record the images on the LVR.

Initially two links to London were used, an ISDN line for the VC7000 and a normal analogue phone line with a modem for controlling the LVR and image

selection. Unfortunately since the modem connection went via the UCL dial up service which had an inactivity timer the connection would be closed after approximately six minutes of non use. This made sense for normal users but caused problems for the TVEI broadcasts since there would quite often be pauses longer than this between commands being sent to the LVR. The problem was solved by using the data ports on the VC7000 which allowed 9600bps data from the terminal controlling the LVR to be transmitted over the ISDN line to the LIVE-NET computer. The bandwidth was only used when data was being transmitted.

Types of sessions

Due to the equipment available, the crosspoint video switches and four video channels being sent to each site there was great flexibility in setting up sessions for LIVE-NET 1. This could range from the simple playout of a video tape from Senate House to a single remote site to multi site seminars where each site could see each other.

The ideal session would have all participating sites able to see and hear each other. In practice it was not always possible or desirable to connect all sites together. Since there were only four video trunk channels going to each site a maximum of five sites could participate in a fully interconnected session. There were further limits to how sessions could be set up due to the need to run sessions in parallel and the availability of equipment at each site.

Three main types were run on LIVE-NET, lectures, fully connected seminars/meetings and multiplexed seminar meetings.

When the system is configured for a lecture the signal from the main, or transmitting site, is sent to the receiving sites whilst all the receiving sites are sent to the transmitting site. This means the transmitting site can see and hear all the receiving sites whilst the receiving sites can only see the transmitting site

and not each other. This configuration allows the lecturer to see and hear remote students and lets the students ask questions, however students at two different remote sites can not see or hear each other. This configuration proved to be quite successful in practice. Its only drawback being that the lecturer had to repeat questions so that students at all the remote sites could hear what was asked.

A seminar or meeting requires a much greater degree of participation between sites than a lecture. Because of this all the sites are connected to each other. This was the most expensive type of session in terms of resources used, a five site session would use all the trunk channels to the remote sites and need four video monitors at each site.

As a compromise quad splits were used to combine the video from up to four sites into a single picture which would be sent to each site. Two quad splits could be used which allowed up to eight sessions to participate in a meeting. Normally a control program would be used to select which picture would appear full screen at each site. As discussed previously there were problems with this.

In practice the set up of sessions tended to be more complicated than indicated. Some sessions had to be recorded and modifications made to the connections to allow for situations when not all the trunk channels to a site would be available either due other sessions running in parallel or trunk channels being taken out of service.

Do's and Don'ts

The problems associated with running a video conferencing system such as LIVE-NET can be divided into three (overlapping) categories, infrastructure, presentation and production.

A video conferencing system must be interactive. This depends firstly on its technical design and secondly on how the system is used in practice. Lecturing via

interactive video is a challenge and requires new teaching techniques to be developed if the medium is to be used to its best advantage. In this area it may be necessary to consider that all lecturing staff should undergo some level of media training.

It is wrong to assume that video conferencing is the same as lecturing, the technology is often unfamiliar to new users and in some case may be perceived as threatening so consideration must be given to training new users of the system. The style of presentation when using a video conferencing system is often different from a straightforward lecture so the lecturer must give some thought to changing his or her style. For example the screen format is virtually identical to A4 landscape so it makes sense to produce diagrams in this format rather than the more normal portrait format.

The booking and switching system which operates a video conferencing network should preferably be fully automatic with the ability to insert bookings up to a year in advance. This has the dual benefits of not requiring operator intervention and allows bookings to be made for times when staff would not normally be available. Some form of remote switching for multi site conferences should also be provided so that the person speaking can be seen at all the sites. This can be automatic as when using an MCU or manual as provided by LIVE-NETs lnchair program.

Ideally rooms used for video conferencing should be reserved for this purpose. If this is done then proper lighting can be installed which does not shine on the video monitors and is the correct colour temperature. The lighting on the faces of lecturers is very important. The ability to change camera views and close up from time to time adds interest to the viewing. A sole use room also has the benefit that equipment once properly installed and adjusted can be left in place and doesn't require setting up at the start of each new session.

Whilst it is possible to use a single fixed camera for a simple lecture far better

results can be obtained if multiple cameras are used or the camera can be remotely controlled by the lecturer (pan/tilt and zoom). For meetings involving more than perhaps two or three people it is convenient to have multiple remotely controlled cameras focused on different people within the group.

It is also important that lecturers practice their delivery style and play it back to themselves to control bad mannerisms.

Facilities available at lecturing site should at the very least include an overhead camera (OHC) with remotely controlled zoom and focus (if not automatic) and ideally a slide/video converter and a video tape player. An OHC is far more flexible than an overhead projector, it can be used for normal paper as well as OHP transparencies and also for samples or artifacts.

Changing from point to point conferences to multi site conferences can cause problems especially with sound and the number of video channels available at each site. The use of frequency shifters or echo cancellers can be used to alleviate if not eliminate sound problems. Quad splits can be used to multiplex four video pictures into one if there are problems with video channel capacity. There is a loss of resolution when using a quad but in practice this has been found to be acceptable.

It is vital that consideration is given to the provision of technical support to maintain the highest standards of video and audio performance of the equipment used. A good picture cannot be produced from low quality or badly performing equipment.

In summary due to audio feedback, echoing and the necessity of adjusting volume levels far more technical difficulties occur with the audio side of a video conferencing system than the video side.

Appendix A - cost of ISDN calls

The cost of an ISDN call is proportional to the bandwidth and the length of the call. If an MCU used to control a multi site call the booking charge for the device must be added to the cost.

The booking charge for an MCU depends on the data rate, the number of sites (or ports) using the MCU and the total number of port hours per month. This varies from £40 per port hour (70+ port hours per month at 128kbps) to £75 per port hour (1-19 port hours per month at 384kbps). Added to this is a one-off registration fee of £75 per site.

The table below shows the cost for one hour sessions at four different data rates. The first three sessions are for local call charges which would be charged between two London University colleges. The second session is a three site booking which uses the two Ascends and a quad split at UCL to combine the pictures. The third session uses an MCU for switching video.

Number of sites	Remote site	128kbps	256kbps	384kbps	ISDN 30
2	Local	£4.16	£8.32	£12.48	£124.80
3	LIVE-NET	£8.32	£16.64	£24.96	£249.60
3	MCU	£177.48	£219.96	£262.44	N/A
2	Europe	£100.48	£200.96	£301.44	£1507.20
2	USA	£134.68	£269.36	£404.04	£2020.20
2	Australia	£222.68	£445.36	£668.04	£3340.20
2	Japan	£353.88	£707.76	£1061.64	£5308.20

The cost of booking a satellite transponder and corresponding uplink is approximately £1250 to £1500 per hour. This gives a broadcast quality signal

albeit only one way. Since the cost of an international ISDN 30 call is at least £1500 per hour under certain circumstances a satellite circuit can be cheaper. If confidential matters are to be discussed encryption may be provided on a satellite circuit a cost of £200 per hour. Encryption is not needed for ISDN calls since it is not a broadcast medium.

Since LIVE-NET has a direct fibre connection to the BT tower from where video signals can be sent to uplink stations satellite broadcasts are relatively straightforward.

LIVE-NET does not have access to ISDN 30 these figures have been included for comparison purposes only.

Appendix B - LIVE-NET UPDATE

This appendix contains a sample copy of the LIVE-NET update. (see separate file update.ps) This lists all the sessions for a given range of dates in a format which was designed for quick reference.

The information for each booking in the update is extracted from the bookings database and converted to a more understandable form before it is printed. Taking the example of booking 5698 (see Appendix D) the first location in the booking form is taken to be the transmitting site and is transliterated from 'rhb.comp' to 'RHBNC Computer Centre (Room C07)'. The rest of the locations (apart from those which refer to devices rather than rooms) are listed as receiving sites. Lines in the Notes section of the booking form which start with "School:" or "Note:" are printed on separate lines below the Contact field.

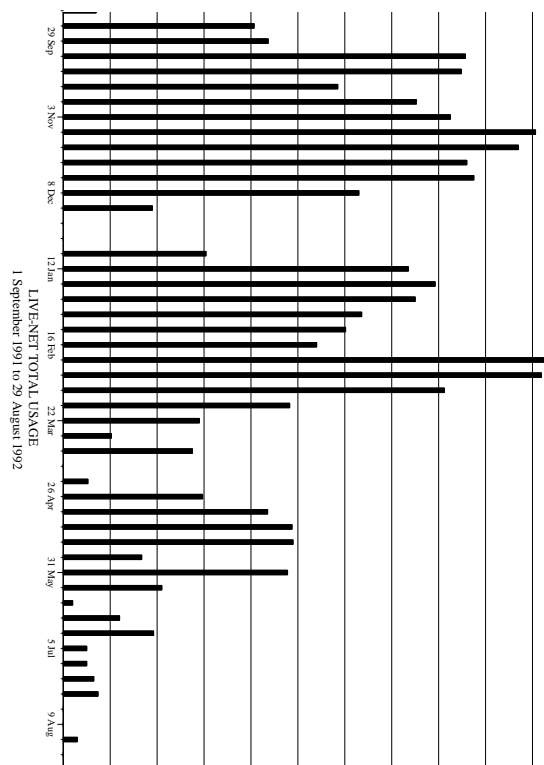
The 'DATA LINK' sessions in the update were used to switch a video channel between Senate House and RHBNC in place of the fifth data channel which never worked correctly. Since the link needed to operate continuously each session was set up to start immediately after the previous session had finished.

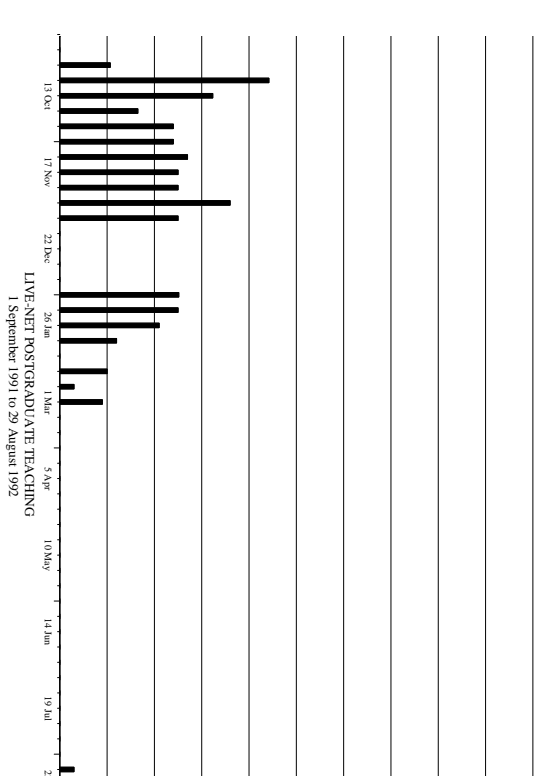
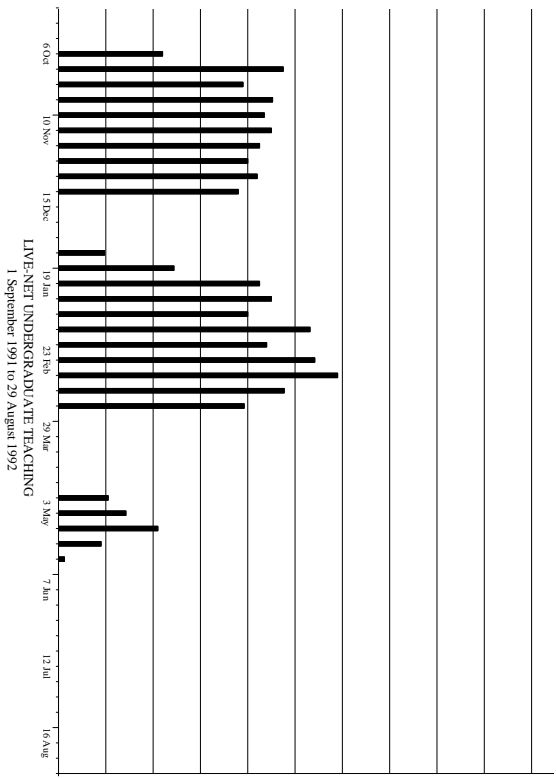
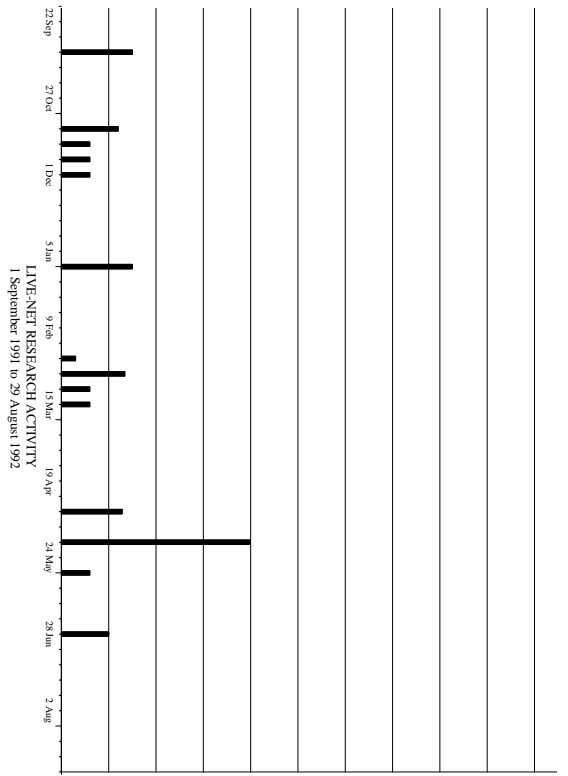
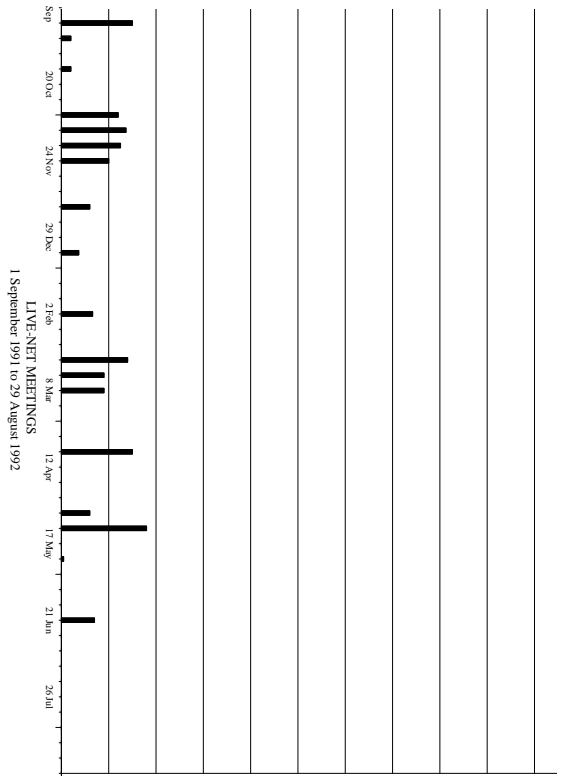
A modified version of the program has been produced which highlights the sessions for each of the individual sites. This is used by the site managers to provide a quick reference to the sessions that are to be transmitted from or sent to their site.

Appendix C - LIVE-NET usage

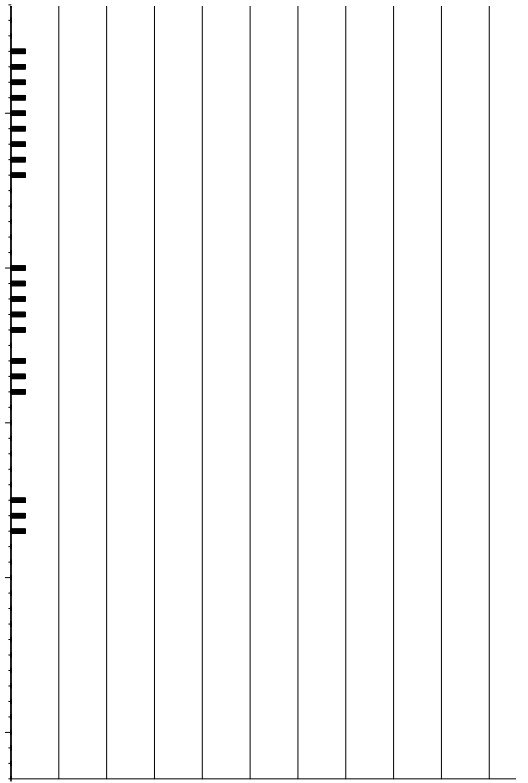
During 1993 when discussions were being held on the replacement for LIVE-NET the following graphs were produced to show a more accurate view of the usage of the system. All the sessions in the bookings databases were placed into one of ten categories and then the hours of usage per week for each category calculated. The figures are in terms of site hours rather than session hours, thus a two hour session involving three sites will count as six hours rather than two. Figures for the 1992/1993 academic year were also produced but since they were partially based on future sessions they are not reproduced here.

As expected for an academic video conferencing system LIVE-NET was most heavily used during term time. Teaching was wholly during term time, trailing off towards the end of the final term when students had exams. Non academic categories of use such as meetings and demonstrations showed a more even pattern of usage.

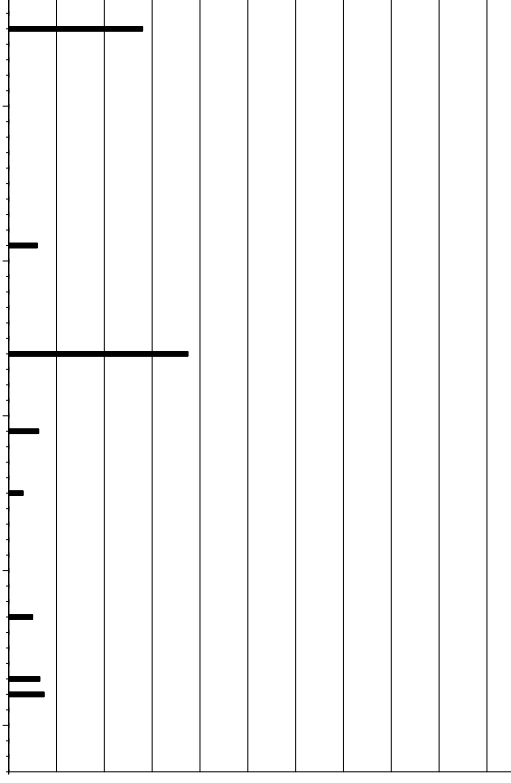




LIVENET COMBINED UNDERGRAD AND POSTGRAD TEACHING
1 September 1991 to 29 August 1992



LIVENET MISCELLANEOUS
1 September 1991 to 29 August 1992



Appendix D - How LIVE-NET works

The main interface presented by `livenet` is a form containing the information relating to a booking. A typical form is shown below.

```
Booking Number: [05698]      Date: [07/10/93] (dd/mm/yy)      Start Time: [17:00]
                                                                End   Time: [18:00]
                                                                Sw on Time: [16:45]
                                                                Sw off Time: [18:15]
                               Open/Closed: [o] (o/c)
Series:  [BIOLOGY - PRE-TERM MEETING] ]
Session: [ ] ]
Contact: [Prof W G Chaloner] ]
Locns:  [rhb.comp   ] [imp.main   ] [kcl.semr   ] [ucl.gower  ] [snt.rmb    ]
        [snt.quadb  ] [kcl.mon    ] [kcl.local  ] [kcl.recd   ] [snt.clock  ]
        [ ] [ ] [ ] [ ] [ ]
        [ ] [ ] [ ] [ ] [ ]
Notes:  [School: RHBNC - Dept. of Biology] ]
        [Note: sites to be confirmed] ]
        [ ] ]
        [ ] ]
```

The booking number is unique to each individual session and is allocated by the system in sequence. Date is the day the session is due to start. In the upper right corner are the start and end times of the session and the times at which the session actually switches. Normally a session will be scheduled to switch on a few minutes before the advertised start time (to allow for pre session tests, setting up of equipment etc) and will switch off a few minutes after the advertised end time (to allow for possible session overrun, discussion periods etc).

The session times used with LIVE-NET 2 tend to be more exact since the colleges have to pay for the time used and are therefore less keen to allow sessions to have extra time.

Open/Closed indicates if a session, once started, will allow other sites to connect to them. Normally sessions would be run as open however confidential sessions are run in closed mode. The series, session and contact fields contain optional information which though not needed to run the session is used for administrative purposes.

The notes field was originally used solely for optional administrative information.

It is now used to hold information which is to be printed on the livenet update and commands to control the Codecs, Ascends and the VC700 videotelephone.

The locns fields contain a list of the rooms or equipment used in the session. In the example given ucl.gower is the UCL television studio in Gower Street and snt.clock is an Amiga computer used to produce a real time analogue clock. The first three characters of the field indicate where the location is, rhb for Royal Holloway and Bedford College, kcl for Kings College London, snt for Senate House etc.

Associated with the booking form of a session is a channel map which lists the connections to be made between the locations given. Channel maps can be generated automatically for certain types of sessions, entered by hand or by a combination of these two methods.

```
rhb.comp 1 > imp.main 1 kcl.semr 1 ucl.gower 1 snt.rmb 1
imp.main 1 > rhb.comp 1 kcl.semr 2 ucl.gower 2 snt.rmb 2
kcl.semr 1 > snt.quadb 1 imp.main 2 ucl.gower 3 kcl.mon 1
           kcl.local 1 kcl.recd 3
ucl.gower 1 > snt.quadb 2 imp.main 3 kcl.semr 3
snt.rmb 1 > snt.quadb 3 imp.main 4 kcl.semr 4 ucl.gower 4
snt.clock 1 > snt.quadb 4
snt.quadb 3 > snt.rmb 3
snt.quadb 5 > rhb.comp 3
```

When a session starts the channel map is used to set crosspoints on the video switches. The crosspoints set are chosen to minimise the use of the trunk channels between sites. For the channel map given rhb.comp 1 is sent down a single trunk channel to the switch at Senate House and then to the other sites rather than using four separate trunk channels.

Once a session is inserted into the system it will start and finish at the set times

without any further intervention. The start time can be immediately (in which case the switch on time is left blank) or any arbitrary time in the future.