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ACTION AT A DISTANCE - DEMANDING APPLICATIONS

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1. Introduction

Many seminars, like this one, conclude that bandwidth will soon be free, processing power be infiniite, and unlimited power will become available to the desktop. I am delighted to hear these predictions, and cannot wait to be in the world where they are true. Unfortunately, this wonderful Utopia has not reached my institution yet, and I doubt that it will be attained in the near future; it would require a revolution in the way the current industry is structured, and in the way we spend our resources. Our first aim is usually to continue to provide our current facilities at a cheaper price; it is a very severe challenge to industry to provide advanced facilities at a price we can afford, without undermining the whole of their present revenue base.

Another set of statements are that with the Wide Area Networks (WANs) just coming in, all our Local Area Network (LAN) applications will run over the WANs with the same ease and speed as they do locally. Aspects of these statements are true - but substantial work is required before they really apply. Many years ago, we started running applications over single LANs such as Ethernets; as soon as we outgrew single Ethernets (which happened only too fast), we found limitations in the devices connecting LANs together. Over the years we have speeded up our Inter-LAN gateways and routers, put in high speed backbone LANs, put in switched LAN hubs, and considerably honed our network monitoring and management tools; now we can get reasonable LAN performance at a price - but only if we keep a watchful eye on our LAN configurations with good monitoring tools, and are prepared to pay for our good local performance.

Our medium speed WANs can now perform with a reliability and consistency that mirrors those of LANs at higher speeds. I now expect to be able to transfer large files and to get reasonable performance for terminal and information retrieval applications. However even here, as soon as time-critical services are invoked, the current packet-switched systems can become overloaded - with a resultant inadequate performance. National communication channels are being upgraded, and in a more limited form international ones. However we do not get all the performance gains we would like; increase of communication bandwidth requires corresponding changes in the protocols used to get full benefit from the increased bandwidths. For example, in medium speed networks, end-end windowing and flow control can provide reasonable performance. Moreover the large amount of data in the network can cause large fluctuations in certain components if error or failure conditions occur elsewhere. Again various fair-share or metered measures can take place at boundaries of autonomous domains - but the relevant procedures are still in the piloting stage, and we do not yet see fully deployed systems.

As we move into the more time critical applications - voice, video and transaction processing - the situation gets more serious. Many portions of the Internet depend on collaborative behaviour; unfriendly acts or stupid behaviour can have far-reaching impacts. Many Europeans would consider the DS3 or DS4 bandwidths currently used on the US Internet a goal to be achieved within five years - yet at the last IETF meeting single transmissions of conferences were often inaudible. We quite understand why this occurred, and can avoid the same errors next time - but others keep cropping up. The PNOs are not surprised at the difficulties encountered in the Internet; many have long argued that this packet-switched technology is quite inappropriate for real-time traffic. They have usually put in much firmer controls to ensure that the user can get the performance for which any contract was given. In the pure circuit switched world, this requires substantial reservation of dedicated capacity - both in switching and transmission. In the packet-switched world it required strong hop-by-hop flow control, and substantial buffering. At any given performance level, the looser controls of the Internet have usually out-performed those of the PNOs - but the difficulty of guaranteeing performance has made the relevant charging more tricky.

Recently, the differences have been narrowed. Frame Relay can provide the light-weight protocols of the Internet on top of the conventional X.25 network access. SMDS provides IP access over higher speed, shared-access services; finally Asynchronous Transfer Mode (ATM) switching should provide the short packets (cells) needed for efficient synchronous traffic together with the packet switching used by the Internet world - albeit with very short (53 byte) packets. In practice, the saga is not yet over. For any given speed range, the straight IP access seems the more performant; their end-to-end procedures are normally invoked in any case, irrespective of the error-control procedures provided for network access.

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2. Some Demanding applications

2.1 A few types of applications

We are currently trying to provide a number of applications for which the capabilities are still very limited:

I. Unicast: Directory Services, Database Access, World Wide Web Access, Video on Demand;

II. Multiway : audio conferencing, video conferencing, shared workspace;

III. Near-Broadcast: Seminars, lectures, special events with audio, video and shared workspace.

These services have very different properties. In the Unicast ones, a single user is interested in the service. In the multicast ones, the data may be destined to many people, but in a controlled way with topological control, related to the source of the data, to limit the access by the source. In others the data may be required by many more recipients limited only by charging considerations and the number of people wishing to access the data at the same time.

2.2 Unicast Applications

The **Directory Services** activity is very distributed. A given inquiry may refer to many databases; it is important that individual searches are reasonably fast, and that there is not too long a delay in the transaction being relayed if this is needed. If the service is only for a human to find an address, then a delay may be tolerable; if it is to obtain a security certificate or to find a specific address in a message agent, then the impact of delays may be to hold up the whole of a complex procedure each time such a call is made. This can make the use of the Directory unworkable. This is the current situation in the Global Directory Service - so that most organisations keep substantial local caches; which can be a nightmare to keep current.

The **database access service** is often less demanding on the communications facility. As long as we are not dealing with a distributed database, there is often only a single transaction at stake. These days the data requested may be voluminous. In the typical library application, the publishers currently provide their data mainly in bit-map form; the inefficiency of this form of storage can easily result In 1- 10 MB of data being retrieved for a single article. With high definition colour, the data retrieved may well be an order of magnitude higher.

The **World Wide Web** (WWW) is, of course, just such a distributed database. This creates colossal amounts of traffic for several reasons. The data is very distributed; the hypermedia aspects of the WWW makes wandering from one database to another normal. The WWW has standardised the storing of not only text and image data, but also live audio and video; thus the amount of information retrieved can be very large. The very standardisation has made it very easy to move between databases. There are various proposals to cache WWW databases in National or Regional caches; this would move the pressure points from disorganised international channels to specific ones to which high speed data access can be made available. We expect that this will be an important development once the high speed networks really become operational. Certainly UKERNA is considering funding just such sorts of initiatives.

2.3 Multicast Applications

The three conferencing applications (video, audio and shared workspace) are similar in their needs for data dissemination to a controlled number of participants - but otherwise make very different demands on the underlying networks. The multi-way dissemination is best provided by some form of multicast at the network level. This is currently not available in the newer PNO-supplied services; many of us are having to provide the facility outside the network. In other ways the three forms of data are different from each other, and have very different properties. **Audio** is a medium where there is a fair amount of redundancy - so that some loss can be tolerated; however if delays exceed a few hundred millisecs, it can become very difficult to use the data. Real loss of the order of 10-20% of speech is just about tolerable; losses of this order of compressed speech can become very difficult to compensate. There are various schemes of multiple coding which allow protection against data loss. If these schemes do not work, the audio data may as well be discarded by the recipient. **Video** has different properties. It stresses the communications networks more in total traffic; full video digital television (uncompressed) can require 120 Mbps. Coding can bring this down to between 50 Kbps and 50 Mbps - depending on the quality required. Discarding appropriate data may make it impractical to achieve full motion, though usually it is still possible to reconstruct images even if there is substantial loss - though the picture may become less smooth. It is still possible to derive digital video; though the frame-rate may have to be reduced considerably. This may result in a jerky picture - but one which is still quite comprehensible. It is this difference between the nature of the video and the audio that explains why so many of us do not like the CCITT standards for combining audio and video in single data streams.

Shared Workspace is an all-embracing term. It may mean just the overhead transparencies or the notes being used; it may be something like the image on a ultrasonic scan, the results of some complex tests in video form, or the results of a computation. The distribution of a shared workspace may make even greater demands than normal video - consider, for example, the results of a computer aided tomography or a nuclear magnetic resonance scan. Sometimes it is very important that these be transmitted without loss; in other applications, this is a very undemanding application.

2.3. Broadcast applications

In the conferencing application, there are usually mechanisms for constraining the number of people participating in a conference. In broadcast applications, on the other hand, the members of the audience may be much larger, and the controls weaker. One example of such an application is the current trend in the Internet to advertise and distribute lectures, conferences or other big events such as a space shuttle landing. Now any Internet user (and there are many tens of million), might try to view the event. In the television environment, a separate network is provided for this application; dedicated channels are provided either as specific frequency allocation (or other division) on the ether or local cable TV. In the Internet version, the same facility is provided - but over the shared communications channels. There can be impacts both from the transmitted and return information. On transmitted information, there is danger that additional unanticipated receivers may demand communication capacity at the expense of others. In interactive broadcast applications, there is danger that any members of the audience may provide feedback at the same instance to a specific node - overloading the communications near that node, and causing interference with other users in the vicinity.

The **video-on-demand** application has some characteristics that could place even greater strains on the communications system. Now any use should be able to request the communications at will - and there would not even be the current limitations on the Internet that it should be one of the advertised events, or of the entertainment world where it is one of the several hundred cable TV channels. It is not clear that this application could be managed at all except in a local environment, where the distribution system can be sized (and charged) to accommodate such demands between a video server and a local area high capacity system.

3. Recent UCL Experiences the newer Services over High-speed Pilots

3.1 The Internet MBONE

In the early versions of the Internet MBONE, any multicast applications were transmitted to all sites capable of receiving multicast information. This caused serious congestion in networks - even when they had no interest in the multicast activity. Later versions had *pruning* of the multicast trees; this implies that only where there are current recipients of the information, will the current multicast tree be set up. Pruning improved the situation arising from completely unwanted communications - but has not addressed the more serious question of overloading communications channels because some recipients have requested the information, so that the intervening communications becomes over-loaded. Internet protocol designers have developed mechanisms for resource allocation at nodes, which should be able to allocate resources on a policy basis. It is not clear yet, however, whether these can be implemented on the large scale needed without considerable degradation of performance in the nodes.

3.2 Local House Distribution

There is a common problem in the use of the word *local area network* (LAN). One use is for communications inside a building or a site which does not have to traverse public Rights of Way; this is the terminology we will use. Another is for communications in a limited area - e.g. a single cable television system; for this we will use the terminology of *Metropolitan Area Network* (MAN) - even though it may apply outside a metropolis. We have had difficulties even on local distribution of multicast audio-visual information because of its volume. We have had to segment Ethernets into switchable hubs, and to introduce higher speed LANs, e.g. local ATM networks and FDDI networks, to cope with the volumes. While there have been some problems with achieving the requisite performance, these have been surmountable.

3.3 Use of SMDS

UCL has use of the SMDS service under SuperJanet. The way this has been implemented has caused little problem. It is used as an IP network with limited access speeds. The equipment comes from one manufacturer, it is configured for point-point working, and we have had no problems with our usage.

As part of our work with the European PNO pilot, we do have SMDS access with interworking units. Here special engineering has had to be made for the routing. This requires special attention, but works well most of the time. In fact it has worked so well for the current limited traffic and environment, that the operator of the MBONE in one country has requested that all its MBONE traffic to the UK be routed, on an experimental basis, over this channel (and UCL-CS). This requests raises questions of policy, resources and technology at many levels - international telecommunication operator, national telecommunication operator, national research network operator; UCL Information Services, and UCL Department of Computer Science. It is being discussed with the relevant authorities at all the requisite levels, and no decision has yet been made.

3.4 Use of the ATM Pilots

UCL has access to SuperJanet via ATM switches both to a plesiosochronous digital hierarchy (PDH) and a synchronous digital hierarchy (SDH) network operated by BT. The switch on the PDH network supports also a codec running a constant bit rate (CBR) service, while the UCL traffic is variable bit rate (VBR). We have found the service using the combination of particular switch used and CBR requirement very difficult to use; even small amounts of VBR traffic disturbs the CBR service. The use of a different switch with the SDH network has caused less problems with the VBR traffic - but there is no CBR traffic on that switch. however, there are problems that the UCL switches have limited traffic shaping, while the SuperJanet network is only able to do traffic policing on the maximum applied traffic per Virtual Path (VP). There are no facilities for policing an average traffic from the switch - averaged over a number of VPs. This means that we have to put considerable emphasis on traffic shaping in the applications; this is not required, of course, on LAN applications. When these precautions are taken, the high speed services operate well with little problem and low error rates - even internationally.

The present Call set-up facilities on the ATM pilot are very limited, and multicast is not provided inside the network. This means that the exact destinations for VPs and the bandwidth required on them, must be requested individually on an end-end basis. To use such facilities for the multicast types of application of Section 2.2 requires considerable network management and multicasting on customers' premises to implement the multicast needed for even limited conferences. It would be quite impractical to use this type of approach to achieve the near broadcast capability of Sections 2.3.

Some of our applications still have to use a variety of networks - ATM, SMDS, N-ISDN and conventional packet-switched Internet. Because we use IP across all these networks, we have little problem in gluing them together - though sometimes there is rather poor performance due partly to the duplication of function at different levels. This approach obviates the problems we otherwise encounter because of the different protocol structures used by the applications providers using networks in their native mode. As two examples, it can be very difficult to use ISDN workstations in such systems - because of the way they use lower level protocols; codecs using H.221 can be very hard to connect into conventional workstations.

4. Conclusions

We have many applications which are difficult to accommodate on the current WANs, though they operate reasonably over LANs. Normally these applications can be made to operate in a small scale over MANs and WANs; larger scale deployment require resolution of a number of technical and managerial problems which we are starting to understand - but have not yet resolved. Where we have had access to the relevant facilities, we have shown that these demanding applications operate well on an international scale.

I am particularly concerned that in the half dozen UCL-CS projects using the ISDN (at higher than 64 Kbps) and higher speed WANs, almost all have mainly academic and research institute involvement. Two involve network operators directly; one has involved another industrial organisation and the ISDN. The reason for the lack of industrial participation is the current level and structure of European PNO charging, and the lack of commitment by the commercial companies to invest to obtain their experience in the face of these levels of charges. I hope that these problems will be resolved as a result of the forthcoming sets of European Union collaborative projects, which are expected to start in the autumn of 1995