NetMuse: a very-high-performance wide-area network for Music

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Abstract

The paper introduces NetMuse, a project which links all university Music departments in Scotland by means of an innovative ATM-based multimedia network. It covers (1) the problem of network bottlenecks in relation to music and audio, (2) the prerequisites for a high-quality music network, (3) the ATM-based strategy used in NetMuse and the specifics of its implementation, and (4) applications and materials developed under NetMuse. (5) the NetMuse staff training and development programme, and (6) an outline of NetMuse's future potential.

1. The Problem of Network Bottlenecks

Many recent developments in the field of networking applications have had an impact on Music, but, as with high-resolution graphics and video, users have become painfully aware (as they wonder whether or not to click on that tempting multi-megabyte sound file icon which has popped up in their Web browser) of limited bandwidth as a constraint upon network-based musical activity. The limitations exist in three main ways: (i) the amount of data associated with the audio file may be so great that a conventional file transfer could cause difficulties at the client end; (ii) the large amount of data takes much longer than the real-music-time to transfer; and (iii) there is no prospect of maintaining a steady flow of data, and hence no prospect of real-time playing across the net.

These constraints inhibit networked audio and music applications, and distort their planning and design to an unacceptable extent. A good example is RealAudio, which can only sustain a sound-quality acceptable for speech rather than music and cannot give guaranteed quality-of-service.

2. Requirements for a high-quality networked music service

The prerequisites for a high-performance music service are the same as for a general, "superhighway", multimedia-capable network service: (i) a very-high-speed backbone for consolidated traffic, (ii) a high-speed local loop to which the individual user may connect, (iii) services capable of servicing multiple bits and passing multiple-audio-channel information, glitch free, to the backbone, and (iv) the integration of the music service with all other services.

Special devices, such as codecs for inputting and outputting time-based materials directly to and from the high-performance net, are also necessary, as is a server which is optimized for time-based materials and which also has direct access to the net.

Recently, an opportunity has arisen to bring all these elements together in order to run a wide-area trial, based on all the higher education music departments in Scotland. This project, called NetMuse, is funded by the Scottish Higher Education Funding Council (SHEFC) under its Use of MANs Initiative (UMI). The five participating institutions are the University of Glasgow (lead site), the University of Edinburgh, Napier University, the Royal Scottish Academy of Music and Drama and the University of Strathclyde. The project is organized into three "strands": (i) Enhancement of Hardware; (ii) Application/Materials and Software; and (iii) Staff Development and Training.

3. Strand 1 - Enhancement of Hardware

The NetMuse hardware builds on an infrastructure of Metropolitan Area Networks (MANs) which now cover all the main conurbations in Scotland. They are academic networks, based on 155 Mbps ATM technology, managed by the academic community and funded by SHEFC. Commissioned in 1995, with interMAN links following in 1996, they provide a very-high-performance network capable of transmitting sustained high-quality audio and video, as well as "conventional" network traffic. The MANs link to campus networks which maintain the same level of network performance. All the participating institutions lie in the central belt of Scotland and are served either by the ClydeNET or EasternMAN. The additional NetMuse hardware funded by the SHEFC UMI brings the same high-performance into every music department right down to individual workstations. Each departmental location therefore has its own ATM switch which attaches to the campus net and to a set of workstations, servers and codecs which support direct video and audio i/o. Fig 1 shows the overall network topology, and fig 2 shows the typical departmental ATM provision.

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The workstations currently attached include SGI Indys, Apple Power Macintoshes and Intel Pentiums. The codecs (Nemesys AVA-300s and ATV-300s) are controlled by the SGI Indys. The two servers are SGI Challenge II, one sited in Edinburgh and the other sited in Glasgow. A total of about 20 Gb of fast-wide disk storage, plus a further 20 Gb of fast-wide RAID storage is attached. One server functions as a WebServer: should it receive a call for a soundfile, it fulfills the request by calling the sound from the second server which is optimized for storing and outputting sound to the network. The initial calls were handled as conventional, but very fast file-transfers to the client machine, but are now handled as live "plays" via either the requesting workstation’s DACs or an ATV-300.

A good deal of the underlying technology for handling sound is dependent on the outcome of a research project in the University of Glasgow Centre for Music Technology. It is the acronym of MultiMe (Multi-Participant Interactive Music Services), and has been funded under the Multimedia Networked Applications programme of the Engineering and Physical Sciences Research Council (EPSRC). It is clear that high-quality interactive music-based services such as those outlined below are amongst those with the strictest requirements in terms of granularity of synchronization and quality-of-service constraints. Such services underline a vast range of potential applications, from distance music teaching and learning, through distributed "orchestras" and single-user interactive composition, to a distributed recording and processing studio. They are clearly distinguished by their demands from the more widely investigated multi-party audio applications such as audio conferencing. In particular, simple delay constraints are insufficient, as one must also deal with maintaining the relative timing of the channels right down to the phase relationship in order to maintain spatial imaging [Arnold et al., 1995].

Among NetMuse targets are transmission of multichannel audio files, remote, interactive processing of audio files, making specialist lab-based processing equipment available as networked resources, providing effective access to rational...
supercomputing resources, transferring large-scale graphics files (such as musical scores), providing video-conference services in a musical context (such as distributed master classes), and providing a very-high-performance Web service for multimedia course materials.

4. Strand 2 - Application/Materials and Software

The major effort under Strand 2 has been the development of a series of demonstration packages which cover aspects of higher musical education in a variety of fields and using a variety of distinct styles, but all dependent on the NetMuse high-capacity network.

The topics agreed for the trials included a good number which were not currently widely or well covered in Scottish music departments, including - rather surprisingly - Scottish Contemporary Music and Scottish Traditional Music. The other topics are: English Medieval Music, La Création du Monde by Darius Milhaud and Aspects of Popular Music and Jazz.

The delivery styles range from the fully-authored, hypertexted, multimedia presentation, similar to one of the ways to the Voyager-type CD-ROM, of the Medieval Music package, through a detailed study of an individual work (La Création du Monde) using methodology which can be readily reapplied when making studies of other works, through provision of an "uninterpreted" information resource (Scottish Contemporary Music), to highly interactive, compositionally orientated, skills-based Popular Music and Jazz packages. There has been no restriction on the size or number of music examples, either audio or graphic. The aim is to test the performance of servers and network. Even so, since the main backbone is common to all MAN users, experiments with MPEG-2 compression have been conducted.

The basic delivery strategy is to use the Web, that is, running classical IP over ATM, but triggering native ATM sound transmissions when appropriate. This minimizes, though does not completely remove, the problems of developing packages to run on different platforms using a variety of browsers.

Since the soundfiles associated with these educational materials often comprise complete pieces, and graphics files complete musical scores, the NetMuse materials are currently only accessible by members of the NetMuse group. There are also issues associated with intellectual property rights which make it unlikely that NetMuse can become "open" in the near future.

5. Strand 3 - Staff Development and Training

There are many reservations on wide take-up of computer-based learning (CBL) in Music. In the first place, many academic musicians have little time to invest in the acquisition of a wide-range of additional skills. Then there is the uncomfortable reality that development of computer-based teaching and learning materials is still a slow process, so that it requires a substantial effort to make a big impact on the overall content of any particular course. Finally, unless the design of materials takes careful account of how they are to be integrated into the course, they are likely to be underused, with the consequence that the development resources invested will have been wasted.

The NetMuse Strand 3 programme tried to address some of these issues. In the first place, the academic staff who attended four day-long sessions had their time paid for by the project, so that their home department could finance any necessary replacement teaching. The sessions themselves took place well away from participants' everyday environment. Many commented how welcome it was to be able to tackle a new field in a non-threatening, non-threatening situation.

All sessions were founded on the notion that it would be easier and more interesting for the participants if all exemplification related directly to real musical, or music-educational, situations.

The first session introduced the concept of using networked resources within teaching and learning, demonstrated a range of possible sources and uses, introduced some special NetMuse materials and outlined the basic aims and objectives of the NetMuse project. A good deal of time was allowed for individual Web searches, so that the Web's strengths and weaknesses became very clear.

The second session was devoted to learning how to develop a simple multimedia presentation. Demonstrations of digitizing and simple editing of graphics and sounds were given. All the materials needed were provided (the topic was Verdi), but the participants had to assemble them using HTML. All participants accomplished the set tasks, and then sense of achievement was palpable.

The third session, presented in collaboration with the Computers and Teaching Initiative in Music (CTIM) and the Teaching and Learning Technology Programme (TLTP), comprised a presentation of all the music-educational and other musical software which could be assembled and provided a forum to discuss integration strategies.
The fourth and final session was the most challenging, since participants were invited to bring along "their favourite lecture" and redevelop it as a multimedia, independent-learning resource.

If we began by thinking that Strand 3 was a relatively minor aspect of the project as a whole, our minds were changed by the enthusiastic reactions we received from the participants, who comprised the vast majority of music academics in higher education in Scotland.

6. Future Plans

It is hoped that the immediate future of the NetMuse resource will revolve around further expansion of content within the topic areas outlined above, moves into new topical areas, more experimentation on live interaction involving both audio and video, particularly as they relate to performance and composition, and a production cycle which is more closely responsive to the course development and research needs of the NetMuse partners. In order for the trial to evolve into a full-scale service, many more ATM-enabled workstations will have to be added at all sites (at present, only four workstations per site have this capability). It looks as though the most cost effective way to achieve this is by attaching secondary 25Mbs switches to a spare port on the existing departmental switches. These switches have up to twenty 25Mbs ports, enough to provide for an entire nb of machines at a cost not significantly different from that of ethernet provision.

Now that all the interMAN links have been commissioned, there is an opportunity to have inspections from the other two MANs join the NetMuse club, although the high level of initial investment will make this objective difficult to attain.

Recently, the Departments of Music and of Theatre, Film and Television Studies at Glasgow University were contracted by the nationwide Arts and Humanities Data Service (funded by the Joint Information Systems Committee (JISC)) to supply a data service for the performing arts, including time-based manifestations such as performances of music and video materials. We expect to apply the experience gained under NetMuse to aspects of the design of this new service.

The technology which has so far been put in place provides a model for a generalised music distribution system, which, at a price, could be scaled up to cover cities, countries and continents. Many commercial agencies, including the intellectual property agencies, are looking at the pioneers of issues to which this possibility gives rise. While the current generation of ATM switches offer a maximum of 622 Mbps, experimental switches already exist which operate in the multiple-gigabit range, with terabit performance being actively researched [Turner, 1996].

It is not so much a question of whether such music services will be implemented, as when. The electronic dynamics will be critical, of course, but there is some reason to hope and plan for a situation where the critical mass of dispersed niche markets will not need to be particularly great in order to have a healthy existence - unlike the present circumstance, where manufacturing, marketing and distribution costs combine to exclude a vast quantity of music of intrinsic merit and interest.

Experiments are being made into the viability of implementing a large-scale trial of a generalised music distribution system, with not only interdisciplinary academic input, but also with the active support and participation of commercially oriented partners.

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8. References

The NetMuse Web page is at: http://www.muse.gla.ac.uk/HTMLFolder/Research/NetMuse.html


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