CANADIAN INSTITUTE FOR TELECOMMUNICATIONS RESEARCH
INSTITUT CANADIEN DE RECHERCHE EN TÉLÉCOMMUNICATIONS

Canadian Broadband
Applications Research Program

Research Proposal

Canadian Broadband
Applications Research Program

Research Proposal

Table of Contents

Executive Summary

In this proposal we outline a two-year research program in the area of broadband network applications with the objective of stimulating the development in Canada of innovative broadband services and applications over ATM networks. Such research is needed to help Canada gain a leadership role in exploiting the enormous potential of the Information Superhighway (IS) to create new businesses and enhance productivity of existing private and public enterprises. The Superhighway is emerging rapidly from the confluence of an array of technologies incorporating computers, telecommunications, television, cinema, publishing and consumer electronics, and offers exceptional opportunities to develop applications that access, distribute and process information or entertainment in novel ways.

The research program is motivated by a vision of the future in which an electronic marketplace/city square will allow easy access to a broad range of information services, enable commercial transactions of many forms and broaden modes of social interactions. The marketplace/city square will be accessible from the home, the office and, indeed, by individuals on the move. This ubiquity will afford such remarkable economies of scale that entire new service industries will emerge and thrive. The services and applications offered by this new industrial sector will drive the evolution of the (IS).

Based on this perspective, we envision the IS to be a coherent, massively distributed, information infrastructure (as opposed to a network infrastructure) designed to support a retail, open environment for rapid applications development and deployment. This will allow information providers to focus on content for their customers and provide end-users with simple, personalized and pro-active access to a wide variety of applications.

The program is designed to promote research excellence and relevance in Canadian universities in an area crucial to Canada's future. It is organized into five Major Projects: Broadband Services, Broadband Networked Learning Environments, Workplace of the Future, Multi-media Tele-Medicine over ATM Networks, and Distributed Multi-media Digital Libraries. These cover the most attractive areas for exploiting broadband applications in the next three to five years. Our methodology favours the generation of new knowledge through rapid prototyping of system demonstrators and evaluating results over experimental broadband ATM test beds. In this way we maximize value to both industry and the user community. The program will also exploit synergy across Major Projects to attain architectural coherence. Mechanisms will be put in place to facilitate interactions, on a continuing basis, to share research results and experiences with

respect to robustness, scalability, user community interaction and technology transfer.

Our strategy is to creatively exploit new and diverse applications that drive technological inventions and innovations, and to anticipate and solve downstream engineering problems. The research focus is on the understanding of applications and services and on the key/enabling technologies that will make them ubiquitous. The general approach is to frame and address the research in the context of specific applications and of the communities of interests that use them.

The research program has been organized by the Canadian Institute for Telecommunications Research (CITR), a Network of Centres of Excellence (NCE) established by the Federal Government, in collaboration with ASI of BC, CRIM, ITRC, TRIO and TR Labs, major Canadian organizations that have mandates to fund or organize industrially-oriented, university-based research programs in information technology.

Newbridge Networks Corp. is providing ATM switching and related equipment valued at nearly three and one half million dollars. More than two and one-half million dollars have been obtained from various other federal and provincial sources of funding and this proposal is seeking a similar amount from NSERC. The research involves a number of important collaborations with industry, government laboratories and user groups. Five major regional ATM networks have agreed to provide broadband connectivity between researchers, and CANARIE has agreed to provide connectivity between the gateways of the regional networks.

The initiative is the first within the Canadian university sector to research a multiplicity of broadband applications within a single program and is designed to exploit synergy between applications. It will create a significant shared knowledge base and provide a stimulating exposure of ATM technology and applications to a large number of postgraduate students. As well, entrepreneurial researchers and students will acquire the breadth and depth of knowledge to create wealth by developing new businesses. More than 60 professors and about twice as many graduate students at 20 universities across Canada will participate in the program.

1 Introduction

In this proposal we outline a two-year research program in the area of broadband network applications with the objective of stimulating the development in Canada of innovative broadband services and applications over ATM networks. Such research is needed to help Canada gain a leadership role in exploiting the enormous potential of the Information Superhighway (IS) to create new businesses and enhance productivity of existing private and public enterprises. The Superhighway is emerging rapidly from the confluence of an array of technologies incorporating computers, telecommunications, television, cinema, publishing and consumer electronics, and offers exceptional opportunities to develop applications that access, distribute and process information or entertainment in novel ways.

The program is designed to promote research excellence and relevance in Canadian universities in an area crucial to Canada's future. It is organized into five Major Projects: Broadband Services, Broadband Networked Learning Environments, Workplace of the Future, Multi-media Tele-Medicine over ATM Networks, and Distributed Multi-media Digital Libraries. Each of the Major Projects addresses an application of economic value to Canada, and together they cover the most attractive areas for exploiting broadband applications in the next three to five years. Our methodology favours the generation of new knowledge through rapid prototyping of system demonstrators and evaluating results over experimental broadband ATM test beds in collaboration with a user community. In this way we maximize value to both industry and the user community.

Our initiative is the first within the Canadian university sector to research a multiplicity of broadband applications within a single program. We intend to exploit the synergy between different application areas by initiating a high degree of sharing of conceptual and technological frameworks, of technologies and systems and of applications experiences. Our management structure will coordinate the activities of the various Major Projects in developing requirements specifications and reference architectures based on the analysis of experiences in the diverse application areas. This will create a shared knowledge base and provide a stimulating exposure of ATM technology and applications to a large number of postgraduate students. As well, entrepreneurial researchers and students will acquire the breadth and depth of knowledge to create wealth by developing new businesses. More than 60 professors and about twice as many graduate students at 20 universities across Canada will participate in the program.

This document constitutes the free form material required by the Strategic Grants program of

NSERC. We first present a detailed program description (Section 2) and then describe key elements of program organization, management and administration (Section 3). In Section 4, we outline our relationships with industry and various user communities, while in Section 5 we review the impact of the program on the development of highly qualified personnel . Appendix I lists the equipment donated by Newbridge and indicates how it will distributed among the participating universities.

2 Technical Program

2.0 Introduction

The research program is motivated by a vision of the future in which an electronic marketplace/city square will allow easy access to a broad range of information services, enable commercial transactions of many forms and broaden modes of social interactions. The marketplace/city square will be accessible from the home, the office and, indeed, by individuals on the move. This ubiquity will afford such remarkable economies of scale that entire new service industries will emerge and thrive. The services and applications offered by this new industrial sector will drive the evolution of the (IS).

Based on this perspective, we envision the IS to be a coherent, massively distributed, information infrastructure (as opposed to a network infrastructure) designed to support a retail, open environment for rapid applications development and deployment. This will allow information providers to focus on content for their customers and provide end-users with simple, personalized and pro-active access to a wide variety of applications.

Our strategy for the research program is to creatively exploit new and diverse applications to drive technological inventions and innovations, and to anticipate and solve downstream engineering problems. The research focus is on the understanding of applications and services and on the key/enabling technologies that will make them ubiquitous. The primary approach to new knowledge generation and/or validation is through rapid prototyping/demonstration and evaluation on experimental ATM test beds.

Major investments are being made in national broadband infrastructures around the world. In the next 4-7 years, a vibrant, global retail marketplace in applications will emerge. The Computer Systems Policy Project in the USA. has estimated that the National Information Infrastructure (NII) will "create as much as $300 billion annually in new sales across a range of industries". The Economic Strategy Institute of USA. has concluded that accelerated deployment of NII would increase productivity by 20 to 40 percent by the year 2007.

Most of these new sales and productivity improvements will be the result of rapid development and deployment of new applications and services. The key enablers are:

- a service layer (sometimes referred to as middleware) incorporating an Application Programmers Interface (API).
- an Application Development Environment ADE) incorporating a service layer and tools.

- application evolution via user feedback and participation.

In a useful analogy with the personal computer industry, R.E. Kahn, President of CNRI (Collaborative National Research Initiatives) in the United States, has pointed out that most applications on microcomputers require significant common functionality, and it was only through the advent of operating systems and standardized user interfaces that the applications business exploded on personal computers and workstations. A well-developed ADE is analogous to a super operating system for the IS. There are substantial research challenges to meet this goal.

A shared goal of the CBAR program is to come up with an application development environment, comprised of an API and a set of tools. The Major Project on Broadband Services is motivated by the need to extend the network infrastructure to incorporate a service layer (sometimes referred to as middleware) , which interacts with system components such as document management, QoS negotiation, database, continuous-media file server, media stream synchronization, QoS management, conversational session management, and transport (see Figure 1). Since applications are end-to-end, the service layer permeates across servers, networks and end-user devices. Since its purpose is to develop technologies that facilitate the rapid development and deployment of a large class of applications, its output will be utilized by all the Major Projects.

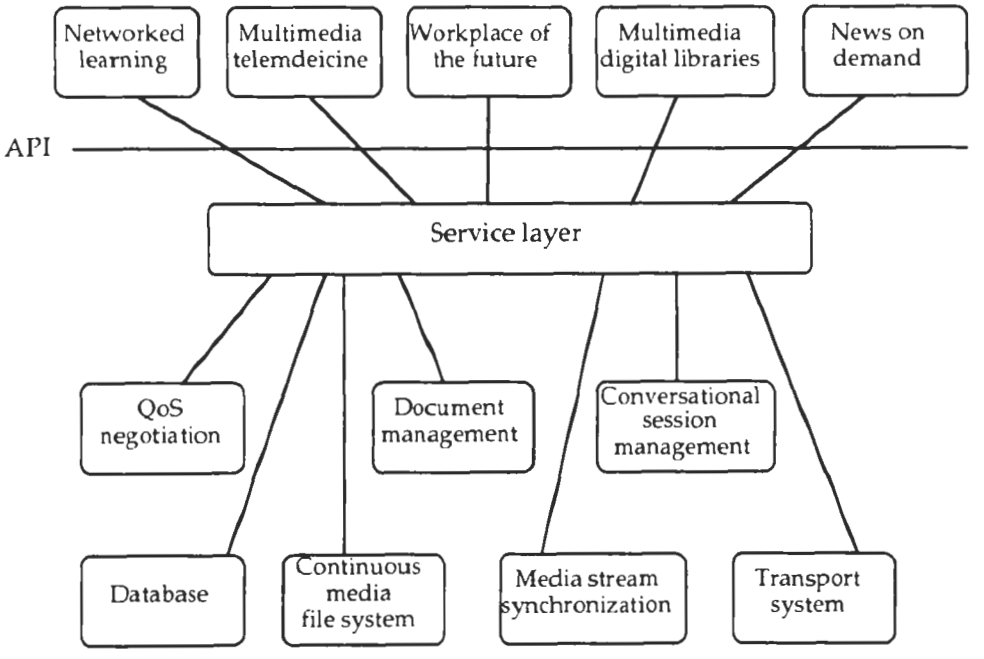

Figure 1

The research program deals with a number of important application areas that offer opportunities to enhance productivity and create new businesses. The research thrust in Tele-learning explores new methods of delivering courseware which limit education costs while improving the learning experience. The importance of the area is evident since Canada spends more than $55 billion dollars annually on education, of which nearly 35% is spent on post-secondary education and corporate training. Although technology alone can not solve all the problems, the research can provide strategic technologies, tools and insights in the effectiveness of given techniques. Interactive multimedia learning tools have frequently been shown to a offer a richer, more stimulating educational experience than traditional teaching methodologies. An Industry Canada report entitled *Educational Opportunities on Canada's Information Highway* stated "students working on interactive media tasks were focused on learning (84% work on task) whether the teacher was present or not".

A second research thrust is directed at the delivery of high quality, timely and cost-effective health care to all parts of Canada. Currently we spend more than is $67 billion annually on health care and the total is growing rapidly. The situation in the United States is even more critical since they spend nearly 50% more per capita than we do. Studies in the United States have estimated that broadband network applications can reduce health costs by $36-100 billion each year while improving quality and increasing access. Our research in Tele-medicine is motivated by these factors, and we have chosen to focus on 'consultation at a distance' and 'the sharing of virtual health records', areas with strong potential for productivity gain. For example, the Institute of Medicine in the United States has concluded that computerized health records are critical since, at the present time, 11% of all laboratory tests must be re-ordered because of lost results, and at least one medical record is unavailable during a patient's visit 30% of the time.

The Major Project on the Workplace of the Future is motivated by the need to develop new modes of working that will improve the productivity and increase the global competitiveness. The research plan involves the development of computer-based tools to model and simulate the flow of information and the communication processes in enterprises that possess a distributed, networked environment. Testing will be carried out over test-beds representing various workplace scenarios such as manufacturing, routine office functions and creative research activities.

Finally, the research in Digital Libraries is directed at applications involving on-demand, cost-effective access to information by a multiplicity of user groups. It has applications and impact on formal and informal education and on cost-effective on-demand access to information and

knowledge. Broadband on-line information applications offer exciting opportunities for entrepreneurs including many that will use the Internet in the not too distant future.

The research program is highly multi-disciplinary with the participation of researchers from departments of Computer Science, Electrical Engineering, Distance Learning, Medicine, Kinesiology, Mechanical Engineering, Plant Biology and Music. Mechanisms are in place to exploit the synergy between the Major Projects and create architectural coherence across applications. A technology co-ordination strategy has been put in place for developing a reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API followed by the refinement of application requirements and confirmation of the API . A core element common to all Major Projects is *information access and sharing on demand.* Research results on technologies such as browsing, user agents, navigation, content based indexing and retrieval etc, will be shared at an early stage. Further, the various test beds will share experiences and use common software where possible. Cross fertilization of ideas and experiences on key issues such as robustness, scalability and technology transfer strategies will be encouraged, supported and managed.

A summary of the Major Projects is outlined in the table below. A detailed description of the research program is presented in the following sections.

Applications	Major Project Leader
Broadband Services	Johnny Wong (Waterloo)
Broadband Networked Learning Environments	Tom Calvert (SFU)
Workplace of the Future	Brian Gaines (Calgary)
Multimedia Telemedicine over ATM Networks	Nicolas Georganas (Ottawa)
Distributed Multimedia Digital Libraries	Renato De Mori (McGill)

2.1 Broadband Services
Major Project Leader: J.W. Wong (University of Waterloo)
Co-Leader: K. Lyons (IBM Canada Ltd)

2.1.1 Objectives

The Broadband Services major project is focused on the enabling technology required for the development of distributed multimedia applications, and the ATM-based implementation of these applications. The objectives are:

- to define an application programmer interface (API) that is suitable for a broad range of distributed multimedia applications.
- to investigate the software infrastructure required for the development of broadband applications that are efficient and flexible.

The software infrastructure includes the service layer which implements the API and the system components, as shown in Figure 1. Our results are expected to facilitate rapid application deployment, as well as to impact the design of continuous-media file servers, multimedia databases, and telecommunications software. A multimedia news on demand service, allowing users to browse and search a database of current-affairs items stored in remote servers, has been selected as a target application to focus the research. In addition to research output on long-term issues, a key deliverable is the integration of results from the constituent projects into a working prototype. Versions of this prototype will be demonstrated annually.

2.1.2 Background and rationale

Advances in computer technology have led to the development of powerful workstations with audio/video capabilities, and server machines with high capacity storage devices. Similarly, advancements in networking technology promise the availability of high-speed ATM-based networks that are characterized by bandwidth-on-demand. These developments have spurred interests in the development of distributed multimedia applications. Deployment of such applications can be enhanced by the availability of service enabling software that hides the details of the underlying network infrastructure from the application developer. Research is also required to fully understand the communication requirements of these applications and the corresponding implications for ATM network design.

Distributed multimedia applications can be classified as presentational, conversational, or having aspects of both. Presentational applications take the form of multimedia documents

featuring continuous (voice and video) and/or discrete (text and image) data, stored in one or more server computers. These documents are accessed by users over a broadband network. Example applications include electronic news, digital libraries, and networked learning. Conversational applications, on the other hand, involve real-time multimedia communications, typically among people. Examples include video conferencing, consultation, and remote, computer-mediated collaboration. A "kiosk" application, where a user interacts via video conferencing with a staff member of a service organization and accesses multimedia documents at the same time, has aspects of both.

In the last few years, investigations of systems that support the retrieval of multimedia documents at remote servers have received much attention (selected references are listed in Section 4 [1-15]). A similar observation can also be made for conversational systems (see [16] and references therein). Most studies, however, are concerned with specific aspects of the required software infrastructure only, eg, video servers [4-7], real-time transport service [8], user interaction, temporal synchronization [14,15], multimedia databases [1-3], video/image encoding [9-11], quality-of-service management [12,13], and conferencing session management [16]. The Broadband Services major project is different in the sense that strong researchers with expertise in all these areas participated in the project as a team from the very beginning. Their complementary expertise often leads to the identification of issues that might have been overlooked if expertise is only available for one aspect of the overall system.

It has been recognized that the ability to demonstrate research results will enhance the significance of the research output. The project team also feels that developing a target application will provide a vehicle to focus the research, and opportunities to evaluate how well the different system components work together. Multimedia news has been selected as our target application. Demonstration of versions of this application on an ATM test bed is planned annually. This would provide a further focus for the deliverables of the constituent projects.

2.1.3 Research plan

Broadband Services is a major project within the Canadian Institute for Telecommunications Research, and started in September 1993. The research program is multi-faceted, yet complementary with respect to the development of enabling technology for distributed multimedia applications. The initial emphasis is on presentational applications. The research challenges include the support of large user populations, large volumes of multimedia data, client equipment with different capabilities, and multiple applications on a broadband network. An important deliverable is an application programmer interface (API) suitable for a broad

range of presentational applications. Under the CBAR program, our technology will be extended to include a conversational capability, with the corresponding prototype developments. This capability is suitable for applications that require conferencing and/or a shared view of multimedia documents among users.

The research program is divided into five areas. Two are directly related to multimedia databases: (i) multimedia data management which addresses issues such as logical modeling, query language design, and support of content-based search, and (ii) a high performance continuous-media file service that provides efficient access to multimedia documents over a broadband network. The remaining areas deal with issues that are important for providing service flexibility. These include (i) scalable video encoding, where the research is directed at encoding and storing video efficiently to accommodate different levels of resolution, so that we can support client equipment with different capabilities and users with different quality of service (QoS) requirements, (ii) QoS negotiation and adaptation where we investigate the impact of dynamically changing QoS at the transport service on the design of applications, and (iii) design of software control systems to synchronize multiple data streams for presentation at the client, and to coordinate real-time communication among people with any required access to multimedia documents.

The Year 1 program is focused the establishment of a reference architecture, the identification of application requirements, and the definition of an API for the application areas within the CBAR program. A first version of the service layer will be implemented using system components developed by the constituent projects, supplemented by off-the-shelf technology where appropriate. A multimedia news application will also be demonstrated. The Year 2 program will see an evaluation of the initial developments, leading to improved implementations of the service layer and system components. The other major projects in the CBAR program will demonstrate applications in their respective areas using technology developed by Broadband Services.

The research plans of the constituent projects are described below.

Project 1: Multimedia Data Management
Principal Investigator: M.T. Ozsu (University of Alberta)
Co-Investigator: D. Szafron (University of Alberta)

The topics under investigation are (i) logical modeling of multimedia objects, (ii) design of query primitives, (iii) multimedia data distribution, and (iv) content-based indexing of image objects. The long term goal is to develop an object-oriented database management system that is suitable for distributed multimedia applications. Before this database is available, a commercial

product ObjectStore will be used in our development of the multimedia news target application.

In logical modeling, SGML/HyTime [17] have been used to define our multimedia document structure. Both SGML and HyTime are ISO standards. A document type definition (DTD) for the multimedia news document class has been completed. Issues to be investigated include: (i) methodology for dealing with multiple DTD's and (ii) modeling of presentation types with respect to temporal synchronization. As to the storage scheme, we plan to follow an approach which stores the text portion of the document and the mark-up separately. This would facilitate document retrieval. Under the CBAR program, we will interact with the other major projects to come up with a standard document architecture, and if SGML/HyTime is not chosen, we will adapt our DTD's to the agreed upon standard.

A visual querying facility, which allows a user to browse a list of documents, filter the documents according to given attributes, search documents for specific information, view document and follow hyperlinks to related documents, define presentation layout, and add annotations, is currently under development. Our approach is based on an object SQL (structured query language). The appropriate query primitives and language constructs that are needed to access a multimedia database will be determined and incorporated into this query language. The issue of logical distribution of multimedia objects will also be investigated. Of interest are mechanisms that would insulate the user from the distribution considerations in data access, eg, distributed query execution/optimization methods and transparent language capabilities.

As to content-based indexing of images, research focus is on techniques that will allow one to index contents of images that can be recognized by current and evolving image recognition technology. The mandate here is "if imaging systems can recognize parts of images, then we should be able to index and query on them."

Project 2: Distributed Continuous-Media File Service
Principal Investigator: **G. Neufeld (University of British Columbia)**
Co-Investigators: **N. Hutchinson (University of British Columbia)**
R. Ng (University of British Columbia)
M. Ito (University of British Columbia)

A prototype distributed file system that supports the time-sensitive nature of continuous-media data will be developed. This file system will provide high aggregate throughput of at least 622 Mb/s and linearly scalable to Gigabit rates, support many (500) client streams simultaneously, and support high-volume high-transfer rate disk storage (100 Gigabytes). Specific requirements of distributed multimedia applications will also be taken into consideration. For example, the file server will be designed to support (i) the delivery of short-term video clips rather than large

video documents (eg, a movie), (ii) media streams that may not be integrated, and (iii) the possibility of frequent updates, eg, news update in a multimedia news application.

The architecture of the file server is based on a set of processor nodes connected to a local ATM network. Each node provides a certain amount of disk bandwidth. More nodes can be added, resulting in a linear bandwidth increase. To achieve high-bandwidth from the disk to the network, a light-weight real-time micro-kernel developed at UBC is used at the processor nodes. High-performance transport service is provided by the use of a real-time protocol (XTP) on the ATM network. A Phase 1 prototype has been developed. Its design will be evaluated with a view to improving performance. Design points to be visited include disk scheduling and data layout policies, support of stream synchronization, node functionality balance, and performance of nodes. The results of the evaluation will lead to the design and implementation of our Phase 2 prototype.

Buffering is critical in a continuous-media file service since buffer overflow will result in lost data and buffer underflow will result in artifacts seen by the client. In general, each media stream may have a different bit rate. Also, the network itself adds to the jitter which is countered to using buffering. An effective buffering scheme, which addresses these concerns, will be developed.

Extension of our software technology to include a conversational capability will put further demand on the transport service, due to the low latency requirement of communication among people. Protocol support for real-time communication in an ATM network, including multicast, will be investigated and incorporated into our prototype.

Project 3: Scalable Video Encoding for Database Storage
Principal Investigator: E. Dubois (INRS Telecommunications)
Co-Investigators: J. Konrad (INRS Telecommunications)
S. Panchanathan (University of Ottawa)

We focus on video coding systems where it is possible to flexibly transmit a portion of an encoded video signal at a lower rate and/or display it at a lower visual quality. The transmission rates under consideration range from 1-20 Mbps, with resolution ranging from VHS quality to High-Definition TV. We consider both the optimization and evaluation of the scalable encoding methods proposed in the MPEG-2 standard, and the development of novel encoding methods that are amenable to efficient scalable representations. The two main aspects under study are the conversion between different levels of resolution, and methods for hierarchical coding.

A complete software MPEG-2 encoding and decoding system, include the spatial scalable

extension, has been developed. MPEG-2 is not very efficient with respect to spatial scalable coding, and it only provides two possible resolutions. More efficient scalable coders with a more continuously variable range of resolutions will be developed. Of particular interest are representations that can be simply converted to the standard MPEG-2 format, and consequently be decodable by the multiplicity of MPEG-2 hardware decoders that should be available on the market in the near future.

The scalable encoding of still images will also be investigated. This includes techniques to reduce or eliminate the bit rate overhead involved in achieving spatial scalability, and an investigation of color scalability.

For scalable video and image encoding, the design and performance evaluation of techniques to store the encoded data on a continuous-media file server will be considered. Our objective is to exploit the format of the encoded data, and design a storage method such that video or image documents at different levels of resolution can be retrieved efficiently.

Project 4: Quality of Service Negotiation and Adaptation
Principal Investigator: G.v. Bochmann (Université de Montréal)
Co-Investigators: R. Dssouli (Université de Montréal)
J. Gecsei (Université de Montréal)
B. Kerhervé (Université du Québec à Montréal)

The goal of this project is to design distributed multimedia applications that can adapt to changing QoS conditions in the underlying transport service, and to develop methods for managing resources needed for QoS adaptation. These requirements are particularly relevant when there is a slow or unreliable link in the transfer path. A negotiation protocol between the application processes, the database servers and the underlying transport service, will be developed. This protocol allows the dynamic re-negotiation of QoS parameters as a function of user requirements and the QoS actually available from the network. It also facilitates the support of users requesting video/image documents at different levels of resolution, and of real-time communication among people. The latter requires a protocol that could be used in the context of multipoint communications. Our implementation will include a user interface which supports the paradigm of "QoS selection by example". Specifically, a user can view example presentations at different levels of quality (with corresponding cost information) before making a selection.

Our research in QoS negotiation has identified the need for an accurate performance model to predict the actual QoS parameters received by the user as a function of the internal performance parameters that are selected by the QoS negotiation protocol. Such a model will be developed. We will experiment with measurement tools that estimate the internal performance parameters

in real time. Re-negotiation may be initiated when our model indicates that the QoS requirements of the user are not satisfied any more.

The interplay between data distribution and QoS parameters requested by the user will be investigated. Of interest is the case where a given document may exist in different locations, with possibly different QoS attributes. We will design a scheme to manage the data distribution and establish appropriate access paths in response to user queries. In addition, a design methodology for application evolution, in the presence of new adaptation scenarios, or better QoS levels, will be investigated and applied to our multimedia news prototype.

Project 5: Synchronization of Multimedia Data for Presentational Applications
Principal Investigator: N.D. Georganas (University of Ottawa)

This project is concerned with the temporal and spatial synchronization of different media streams over an ATM network. In a presentational application, these streams correspond to components of a multimedia document that are stored in distributed servers. Both intra-stream and inter-stream synchronization will be considered. We have completed the design and implementation of a synchronization system which places a scheduler at the client workstation. Final synchronization recovery is performed at the client before the playback of the multiple data streams. An important design objective is to keep buffering at the client to a minimum. The effectiveness of our synchronizer for MPEG-2 and JPEG streams will be tested. Performance evaluation of our synchronizer using analytic modeling will also be performed.

Many emerging applications are aiming at systems which place less functionality on the client. A distributed synchronization control scheme, where the scheduler function is provided by a distributed process at the media servers, will be developed. Specifically, the presentation scenario is sent to all media servers involved in the requested document. A scheduling dialogue then starts among these servers, resulting in a "good" schedule to transfer media streams to the client workstation. Included in the research plan is an investigation of real-time scheduling algorithms where end-to-end media delivery deadlines are distributed to intermediate nodes along a connection. The design of a recovery buffer at the client workstation to compensate for any mismatch among the arriving media streams will also be considered. The effectiveness of the distributed synchronization architecture, as well as the dimensioning of the recovery buffer at the client, will be investigated.

Our work will be extended to include a conversational capability. This will add complexity to the synchronization problem because of the need to synchronize the encoded video/audio in a conversational application, as well as the media streams corresponding to a multimedia document. In addition, a session control scheme which coordinates real-time communication

among people with any required access to multimedia documents, will be designed and implemented.

Project 6: Project Integration and Application Development
Principal Investigator: J.W. Wong (University of Waterloo)
Co-Investigators: M. Shepherd (Dalhousie University)
C. Watters (Acadia University)

The objective of project integration to coordinate the milestones of the constituent projects, such that the objectives of the Broadband Services major project are achieved. In collaboration with the other major projects in the CBAR program, a reference architecture for distributed multimedia applications will be developed. This reference architecture defines the required systems components and interfaces between components, An API suitable for the various application areas will be defined, and a common document architecture will be determined.

Within Broadband Services, a project integration team with representation (research staff or graduate students) from all constituent projects has been established. This team is responsible for integrating research results into a working prototype.

Phase 1 of our multimedia news application has been developed and demonstrated in March 1995. This application draws on broadcast news from a radio and a TV station (the CBC), and from a newspaper publisher (the University of Waterloo Gazette). The user component contains a news browser and QoS negotiation by example. Phase 2 will see the addition of individual profiles through selection of topics and categories of interest, tools for annotation and real time creation of multimedia news documents, and a conversational capability. Our Phase 1 prototype runs on an RS6000 server and an RS6000 client (both running AIX) interconnected by an ATM switch from Newbridge. We will interact with the other major projects in the CBAR program to come up with a common hardware/operating systems platform for future application developments, and if necessary, port our technology to this platform. We plan to demonstrate our Phase 2 multimedia news application, together with our initial implementation of the service layer, at the end of year 1 of the CBAR program.

In year 2, we will refine our implementation of the service layer and the various system components, and work with the other major projects to develop applications in their respective areas using our technology. These applications will be demonstrated at the end of the two-year program.

Integration of research results often leads to insight on the potential system bottlenecks. Such information is very useful, especially when one considers scalable and robust systems for large scale deployment of broadband applications. We will investigate alternative system and

network architectures that are suitable for large scale deployment. Our approach is to come up with "balanced" configurations of server machines, delivery network, and client workstations, and use analytic modeling or simulation to evaluate their performance with respect to supporting large user populations and large volumes of multimedia data.

Included in the research plan is an investigation of agents from an information retrieval perspective. The agents under consideration will access multiple databases from different sources and media, retrieve items based on event, time, place, or person, and draw links between them to impose some order. This type of agents will be demonstrated as part of our multimedia news prototype.

2.1.4 References

[1] N. Dimitrova and G. Golshani, EVA: "A query language for multimedia information systems", Proc. Int. Workshop on Multimedia Information Systems, Tempe, Arizona, February 1992, 1-20.

[2] E. Oomoto and K. Tanaka, "OVID: Design and implementation of a video-object database system", IEEE Transactions on Knowledge and Data Management, 5 (4), August 1993, 629–643.

[3] B. Thuraisingham, "On developing multimedia database management systems using the object-oriented approach", Multimedia Review, 3 (2), 1992, 11–19.

[4] P. Venkat Rangan and Harrick M. Vin, "Efficient Storage Techniques for Digital Continuous Multimedia Data", IEEE Transactions on Knowledge and Data Engineering, Special Issue on Multimedia Information Systems, August 1993.

[5] P. Venkat Rangan and Harrick M. Vin, and Srinivas Ramanthan, "Designing an On-Demand Multimedia Service", IEEE Communications Magazine, 30 (7), July 1992, 56-65.

[6] D. P. Anderson, Y. Osawa and R. Govindan, "A File System for Continuous Media", ACM Transactions on Computer Systems, 10 (4), November 1992.

[7] J. Hartman and J. Ousterhout, "Zebra: A Striped Network File System", University of California, Berkeley Technical Report No. UCB/CSD 92/683, 1992.

[8] I. Miloucheva, "XTP and ST-II Protocol Facilities for Providing the Quality of Service Parameters of Connection-Mode Transport Services", Research Note TUB-PRZ-W-1029, Technical University of Berlin, November 1992.

[9] M. Vetterli and K.M. Uz, "Multiresolution coding techniques for digital television: a review (invited paper)", Multidimensional Systems and Signal Processing, vol. 3, 1992, 161-187.

[10] T. Hanamura, W. Kameyama and H. Tominaga, "Hierarchical coding scheme of video signals with scalability and compatibility", Signal Processing: Image Communication, vol. 5, 1993, 159-184,.

[11] M. Antonini, M. Barlaud, P. Mathieu and I. Daubechies, "Image compression using the wavelet transform", IEEE Trans. Image Processing, vol. 1, April 1992, 205-220.

[12] A. Campbell, G. Coulson, F. Garcia D. Hutchison, "Towards an integrated Quality of Service Architecture (QOS-A) for Distributed Multimedia Communications", Proc. 4th IFIP Conference on High Performance Networking, Liege, Belgium, edited by A. Danthine and O. Spaniol, December 1992.

[13] Y. Baguette, L. Leonard, G. Leduc, A. Danthine and O. Bonaventure "OSI 95 High

Performance OSI Protocols with Multimedia Support on HSLAN's and B-ISDN. The enhanced Transport Facilities and Functions. Liege, December 1992. Esprit Project 5341/Sector OBS"

[14] "Multimedia Communications", Special Issue of the IEEE Communications Magazine, 30 (5), May 1992.

[15] R. Steinmetz and C. Engler, "Human Perception of Media Synchronization", IBM European Networking Center, Technical Report 43.9310, 1993.

[16] J.F. Koegel Buford, "Multimedia Systems", Addison Wesley, New York, 1994.

[17] ISO standards ISO 8879 and ISO/IEC 10744.

2.1.5 Milestones

3 months

All projects
- Confirmation of reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API.

6 months

Project 1
- Specification of the query language features for accessing multimedia data completed; reporting on the requirement and evaluation metrics of content-based indexing techniques.

Project 2
- Test suite creation for the evaluation of our Phase 1 prototype continuous-media file server completed; analysis of existing buffering algorithm completed.

Project 3
- Demonstration of results on optimization of parameters of MPEG-2 scalable implementation; demonstration of a non-linear interpolative vector quantization based spatial scalable still picture system.

Project 4
- Demonstration of a QoS negotiation protocol, including the initiation of re-negotiation based on prediction by a performance model and measurement data.

Project 5
- Completion of performance analysis of client-based scheduler; completion of implementation and performance evaluation of the distributed scheduler.

Project 6
- Refinement of application requirements and confirmation of the API.

12 months

Project 1
- Incorporation of query language features into our object SQL completed; definition and implementation of a logical model of multimedia documents completed.

Project 2
- Completion of design and implementation of our Phase 2 prototype continuous-media file service, including the integration of our real-time kernel and the

development of an effective buffering scheme; initial results on protocol support for conversational applications.

Project 3
- Demonstration of improved scalable system with better conditional coding, including off-line transcoding to MPEG-2; demonstration of color scalability.

Project 4
- Completion of design of a scheme for data distribution and an database access protocol which takes QoS parameters into account; initial results on extension of QoS negotiation protocol to the context of conversational applications.

Project 5
- Implementation of real-time scheduling algorithms where media delivery deadlines are distributed to nodes along a connection completed; initial implementation of an extension of synchronization control to support conversational applications.

Project 6
- Demonstration of initial implementation of service layer and Phase 2 multimedia news application; completion of design of our information retrieval agent.

18 months

Project 1
- Implementation of an object model for our database management system completed; preliminary results on logical distribution of multimedia objects.

Project 2
- Evaluation of the Phase 2 prototype continuous-media file server completed, with a view to supporting large user populations and large volumes of multimedia data.

Project 3
- Reporting on the design and performance evaluation of techniques to store scalable video or image data on a continuous-media file server.

Project 4
- Refinement of performance model and measurement tools required for QoS negotiation and adaptation completed; investigation of design methodology for application evolution completed.

Project 5
- Extension of synchronization control to the context of conversational applications completed, including the dimensioning of the recovery buffer at the client.

Project 6
- Implementation of the service layer completed.

24 months

Project 1
- Reporting of results on logical distribution of multimedia objects, including distributed query execution/optimization methods and transparent language capabilities.

Project 2
- Reporting on the design and implementation of a high-performance distributed continuous-media file service; reporting on protocol support for conversational

applications on an ATM network.

Project 3
- Demonstration of efficient scalable video coding system with finer grain scalability and variable rate coding.

Project 4
- Extension of QoS negotiation protocol to the context of conversational applications completed.

Project 5
- Demonstration of a session control scheme for presentational/conversational applications.

Project 6
- Demonstration of applications in the various areas using the API; demonstration over a wide-area ATM network; reporting on large scale system and network architectures; reporting on the design and implementation of information retrieval agents.
- Completion of a final report for the two-year research program.

2.1.6 Equipment

CITR has set up ATM test beds at the University of British Columbia (UBC), Université de Montréal, and the University of Waterloo. These are local ATM networks consisting of a six-port switch from Newbridge, and client and server machines from IBM. Due to budgetary considerations, similar switching equipment has not been acquired for the University of Ottawa, the University of Alberta, and Dalhousie University.

The details of the ATM switching equipment requested under this research program are given in Appendix 1.I. This would result in test beds being installed at all locations, as well as extended configurations at UBC, Montreal, and Waterloo. Connectivity to wide area network will be pursued where available, and the anticipated topology is shown in Figure 2.

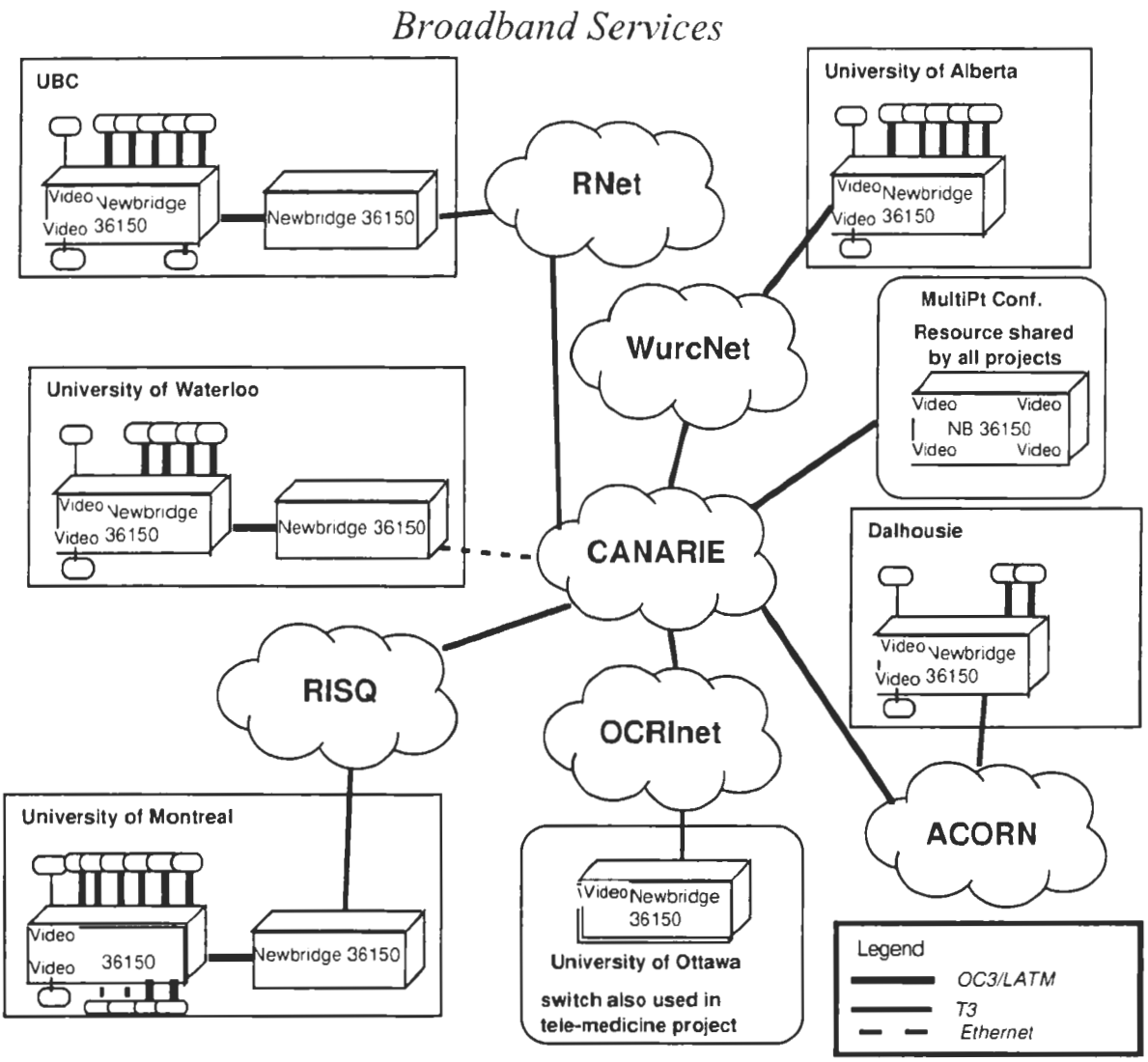

Figure 2

For wide-area connectivity, we plan to connect the test beds at Ottawa, UBC, Alberta, and Montreal to OCRInet, Rnet, WurcNET, and RISQ respectively. These networks are interconnected by CANARIE links. We hope that wide area connectivity will soon be possible for Waterloo and Halifax.

The availability of ATM test equipment at all locations will greatly enhance research progress. The Broadband Services major project is organized such that the components of the software infrastructure required are developed by different constituent projects. For each constituent project, it is crucial that an ATM test bed is available locally to test the system component being developed. Since we have adopted a client server model for our distributed applications, our test bed must consist of servers and client machines. We thus request OC3 and LATM

interface cards for client and server connections.

The Broadband Services major project is concerned with distributed multimedia presentational applications. The requested JPEG cards will provide a facility for presenting a video document, with synchronized audio, to the end user. These cards will also be used to implement the conversational capability outlined in our Year 2 program. A related usage of these JPEG cards is video conferencing. The Broadband Services major project has recently used a video conferencing facility based on the request JPEG cards for an Area Committee meeting. The conference was set up at the CRC and MPR-Teltech, interconnected by a CANARIE link. We found that video conferencing is a very effective way of conducting meetings and research discussions, and plan to use our ATM test bed for this purpose in the future.

At UBC, Montréal, and Waterloo, two LATM cards are requested to connect the requested switch to an existing switch. This would create a more realistic networking environment to test our software, eg, performance issues between the two switches could be addressed. Also, at Montreal, two Ethernet cards are requested to extend the test bed to include LAN's. This would create a heterogeneous network, a desirable networking environment to test the quality of service adaptation protocols. T3 cards are requested at each location for wide area connectivity. This would permit the demonstration of our prototype over a wide-area ATM network, as well as providing a video conferencing facility. Finally, 16-port switches are requested for Ottawa and Montreal because each of these switches is shared between two major projects.

2.2 Networked Learning Environments
Major Project Leader: Tom Calvert (Simon Fraser University)
Co-Leader: John Dunn (BC Tel Education Centre)

2.2.1 Objectives

The overall goal of this work is to investigate the technical systems needed to support telelearning environments that are as good as, or better than, traditional classrooms for learning. Telelearning, as we use the term, involves the use of networked multimedia workstations to create learning environments. These technologies remove the requirement that teacher and student, or student and learning resources must be present at a particular place or at the same time. Within this, our research will focus on the specific opportunities for use of interactive multimedia on ATM networks. We will also participate in the definition of the architecture and API for scalable and robust system being developed in the parallel Major Project on Broadband Services.

The research objectives are to conceptualize, design, implement and evaluate:

- a human interface design that provides an instructor/student and student/student environment that motivates effective learning experiences for a variety of subjects - specific research will focus on the metaphor of the interface.
- a general purpose platform that incorporates such an interface and supports the delivery of a wide range of courses on networked multimedia workstations - specific research will focus on how the architecture and API from the Broadband Services Major Project are best applied to telelearning.
- tools to support learning models based on collaborative or knowledge building approaches - specific research will focus on how broadband technology can best be used in these tools.
- generic tools to support authoring and allow customization of the instructional environment for different types of course content - specific research will focus on how course content should be structured to take advantage of broadband networks.
- specialized tools needed to offer specific course components such as laboratories - specific research will focus on the need for physical skills and real time sound.
- environments that accommodate synchronous and asynchronous learning styles with the greatest sense of presence for both teachers and students - specific research will focus on the reactive shared classroom.

The target for application of these telelearning developments will be post-secondary education

on-campus and at a distance. Another important application of these developments is in the workplace. Continuing education, training and updating of skills will be essential for the knowledge worker who has to operate in an environment of rapid change and increasing global competition.

Field test sites will involve the distance education offerings of Simon Fraser University, the courses being developed by SkillNet for a number of BC companies, a skills component involving BCIT, and course offerings given by Carleton University and University of Toronto to industrial clients or other post-secondary institutions (eg, University of Ottawa).

Some of the work proposed here complements that in the TeleLearning Network of Centres of Excellence. The value added by this CITR/Newbridge sponsored project is the opportunity to extend network learning experiments to an ATM based broadband environment.

2.2.2 Background and rationale

Although relatively primitive, functional examples of telelearning applications already exist, ranging from university programs where courses are delivered asynchronously to students via computer networking [9], to a synchronous learning style (ie, greatest presence between teacher and students) using reactive shared classroom [3]. Most of these examples, however, are either deployed on a small scale, eg, a local area network with a small number of workstations, or on systems that does not provide quality of service (QoS) guarantees, eg, the World Wide Web. The welding of broadband ATM networks and emerging multimedia technologies offers opportunities for large scale deployment of telelearning applications with QoS guarantees. In addition, the ability of these technologies to support sophisticated simulation and information retrieval techniques will allow students access to learning experiences with a richness in content and stimulation unknown to this point. Much research is needed to understand how one can exploit ATM and multimedia technology for telelearning applications.

Current telelearning technologies have an exciting potential to impact on the nature of student understanding since they can support a number of advanced models of learning including collaborative learning and knowledge building. Effective tools to support these learning models are needed. Although some tools are available, the issue of how ATM broadband technologies can best be exploited in these tools has received little attention.

Several factors will impact the success of a telelearning environment. First, a good human interface could lead to effective learning experiences for the students. Secondly, easy-to-use authoring tools will encourage more teachers to adopt telelearning. Ideally, these tools should

allow for customization of the instructional environment for different types of course content, and for the development of specific course components such as laboratories. Finally, the system and network technologies that support the telelearning applications must be efficient and flexible, so that course material can be retrieved from a range of end-user workstations and with good response time performance, and that the interactive nature of human-to-human communication is not affected in collaborative learning or remote consultation. A design that incorporates all the above factors will enhance success in large-scale deployment of telelearning applications.

The investigators have extensive experience in prototyping or using telelearning systems. Specifically, the VIEW-*U* prototype was developed by SFU, as part of the CANARIE funded COECEE project, in collaboration with MPR Teltech, Stentor, the Open Learning Agency of B.C., and Science World. This prototype is designed to deliver course material over heterogeneous networks with speeds ranging from 14.4 Kb/s dial-up to 155 Mb/s ATM broadband. In another effort, the Reactive *Shared Classroom* developed under the Ontario Telepresence Project [3] has been used to deliver lectures to students at a remote location. The proposed research will build on the above experiences.

2.2.3 Research plan

Overview

The research focus of this major project is on design - design of the pedagogies that work best with ATM and multimedia. The proposed research addresses the development of tools and applications on ATM and multimedia technologies to create a virtual campus which provides a networked learning environment for post-secondary education on campus, at a distance, or in the work place (referred to as *VIRTUAL-U*).

Projects 1 and 2 involve development of tools to support the use of networked multimedia workstations to create the *VIRTUAL-U* network learning environment; this will initially be built using the VIEW-U prototype and WWW tools such as Netscape but will be transferred to the Broadband Services architecture when it is available to achieve high performance as a conversational system. In addition to the general purpose platform, discipline independent tools to support advanced models of learning and to manage, structure and evaluate courses are being developed. In project 3, which involves BCIT, SFU, UBC and UVic, specific tools to support the special needs of courses with a physical skills and real-time performance component will be studied and developed. These tools will be incorporated into the VIRTUAL-U platform for field test and evaluation in Project 5. The parallel work on the *Reactive Shared*

Classroom at Carleton and Toronto complements the Virtual-U development and a major goal is to investigate how the workstation based environment of projects 1, 2, and 3 can be integrated with the interactive video environment of project 4 in a classroom setting. Evaluation is a very important component of the proposal - in addition to experiments focused on the delivery of post-secondary courses we will determine optimal strategies for telelearning delivery of education and training to different workplace environments in Project 5.

Project 1: Networked Learning Platform Development: Virtual-U
Principal Investigator: **Tom Calvert (Simon Fraser University)**
Co-Investigators: **Vladimir Cuperman (Simon Fraser University)**
Jacques Vaisey (Simon Fraser University)
Wo-Shun Luk (Simon Fraser University)
Jiawei Han (Simon Fraser University)
Ze-Nian Li (Simon Fraser University)

The primary focus of this project is the provision of an evolving platform (VIRTUAL-U) which initially will be based on the VIEW-U prototype and other evolving WWW tools such as Netscape. The research team will interact with the other major projects within the CBAR program to define the reference architecture and API, and with Broadband Services in particular, to develop the technologies that would best meet the specific requirements of networked learning. Specifically, they will provide input to the Broadband Services major project on the confirmation of reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API. As soon as possible the reference architecture being developed in the Broadband Services Major Project will be adopted . A secondary focus is on design and evaluation of an effective user interface, based initially on a spatial metaphor.

The system will provide a general purpose platform to support a variety of approaches to networked learning. The network architecture will use systems and devices as appropriate (multimedia, workstations, CD-ROM, heterogeneous networks, etc.) to support access to text, image and video items, to provide e-mail and conferencing (video, audio & text) and to provide internet access. The principal area of application will be credit and non-credit post-secondary courses delivered, on-campus, at a distance and in the workplace. Note that Project 2 (below) will work in parallel to provide discipline independent tools to support advanced models of learning (specifically collaborative learning and knowledge building) and to manage, structure and evaluate courses.

An interdisciplinary team will work iteratively on (a) conceptualization and problem definition, (b) system design and implementation, and (c) evaluation and field test. This team will work with the other projects within Networked Learning to develop the application requirements; an

obvious requirement is the integration of text based interaction with images, video, sound, multipoint e-mail, and group communication.
The design of human interfaces which provide an instructor/student and student/student environment that motivates effective learning experiences for a variety of subjects is central to telelearning research [1,5]. The research focus is on the design and evaluation of interfaces with metaphors and interaction techniques appropriate to different user populations in networked learning environments.

Included in the research plan is the development of techniques for efficient data acquisition, storage, indexing, and content-based search for networked learning applications [6]. This work will be coordinated with M.T. Ozsu's Project (Project 1) and G. Neufeld's Project (Project 2) within Broadband Services. We will also investigate data-mining and knowledge fusion for multimedia telelearning systems [4].

In our evaluation and field test, the VIEW-U prototype will be connected to an ATM network to create a heterogeneous network environment. Multimedia tools that allow the efficient use of the network resources by telelearning applications will also be evaluated. Further details of the field tests are described in Project 5.

Project 2: Tools to support advanced learning and instructional models
Principal Investigator: Linda Harasim (Simon Fraser University)
Co-Investigators: Wo-Shun Luk (Simon Fraser University)
Jiawei Han (Simon Fraser University)

The research focus of this project is on the conceptualization, development and evaluation of three classes of discipline independent tools to support telelearning in a hypermedia environment:

- tools to enable learning activities such as collaborative learning and knowledge building [9,13,14].
- tools to structure, manage and evaluate courses.
- tools for knowledge discovery from textual and multimedia databases and automated construction of knowledge-bases to support collaborative learning [7].

Collaborative learning requires a flexible system to support discussions in large and small groups (groupware). Text based systems, such as Lotus Notes or First Class, provide good models, but must be extended to video conferencing and to support the use of hyperlinks between conference material and other text, image or video items. Evaluation is facilitated if there are tools for some level of automatic discourse analysis.

Knowledge building requires that the learner make linkages between different knowledge items. These can be text fragments in course documents, in group discussions, or in any documents accessible through the internet. This is extended to images and video clips, although the latter presents indexing problems. In building these hyperlinks, the learner forms new ideas - it is important for evaluation and research to be able to visualize these links.

These aspects are being investigated in depth in the TeleLearning NCE and the goal here is to link the results of that research based in cognitive science and education to technical systems on broadband networks.

This project involves parallel development with Project 1; hence, there is overlapping membership in the research teams.

Project 3: Virtual Laboratories for education and training
Principal Investigator: K.S. Booth (University of British Columbia)
Co-Investigators: C Mackenzie (Simon Fraser University)
Tom Calvert (Simon Fraser University)
Stefan Joseph (BCIT)
George May (University of Victoria)
Peter Driessen (University of Victoria)
Andrew Schloss (University of Victoria)

There are many questions related to how laboratory learning experiences and the physical skills involved in many complex tasks can be handled in network learning environments. We propose to investigate several virtual laboratory situations and several tasks that involve physical skills and real-time performance.

A virtual laboratory for studies of how human hand movements are controlled, perceived and used in control and communication tasks is being established between SFU and UBC. This work is supported in part by an NSERC Strategic Grant and the proposed work builds on the work done under the strategic grant. Experience gained with the virtual laboratory will be used to design and evaluate virtual training environments. Comparisons of physical objects and actions with virtual objects and actions will be used in development and design. Training/learning exercises will be developed to evaluate learning, performance, transfer and usability on hybrid systems with virtual and physical components. Tasks will include grasping, moving, manipulating and transforming objects [11]. In addition to the visual images of virtual hands and virtual objects, force feedback will be provided.

The Technology Centre at BCIT will be the site of a series of experiments into how skilled tasks can be taught with telelearning. Under the direction of Stefan Joseph and with the advice of Dr. C. MacKenzie, a series of network based experiments will test how the various skills needed by

those operating a clinical laboratory can be taught. These experiments will be designed in collaboration with BCIT's School of Health and Metro-McNair Clinical Laboratories. Experiments will run on BCIT's Burnaby campus which has an installed fiber loop for high speed data communications between various buildings and laboratories. Data communications may also be extended to the new Metro-McNair facilities currently under construction adjacent to BCIT; some experiments may then run at these new facilities.

When R-Net is extended to BCIT, all experiments will be linked directly to the SFU Human Motor Systems Lab. The knowledge gained in this study will be used to guide the development of skills training in other situations such as remote manipulation in endoscopic surgery, training in simulators (eg, ship loading and unloading, flight, air traffic control, etc), undersea tele-operation and telesurgery.

In another study, the co-investigators at the University of Victoria are collaborating with Media Magic Enterprises Inc. and ACD Systems Ltd. to explore the use of broadband networks to enable performing artists and music students in different locations to rehearse, perform and record together. We propose to design and test a "super-audio/video-conference" facility between multiple venues (eg, recording studios, rehearsal halls). The networking requirements of this application are rather demanding, specifically when one considers the temporal constraints in the synchronization of multiple streams of audio and video. We will investigate local configurations of microphones, speakers, cameras, and displays, and coordinate with the Broadband Services major project on the required ATM networking technologies, to maximize the sense of actually performing together in the same space, and to minimize any subtle degradation of the quality and artistic merit of such a "distributed musical event." Our system will allow musicians to rehearse together without traveling to a common location, to offer master classes at a distance, or to perform remote auditions, among other applications. We will also test the "super-video conferencing" in the more traditional video conference markets to determine whether putting all parties in the same "virtual acoustic space" would result in a more natural and comfortable conference.

Project 4: Reactive Shared Classroom
Principal Investigator: D.C. Coll (Carleton University)
Co-Investigators: D. Dillon (Carleton University)
G. Karam (Carleton University)
Tom Calvert (Simon Fraser University)

The Reactive Shared Classroom project is based on the hypothesis that classrooms designed to be responsive to the requirements of lecturers and students, connected by broadband video and data communications, and controlled by software on a distributed computer network can

provide an effective enhanced learning environment for teaching at a distance. This project is about designing and evaluating the infrastructure for innovative user interfaces in a reactive classroom. We will address the following issues: i) easy-to-use conventional and reactive user interfaces that will overcome feelings of isolation and alienation that remote students have ii) improved conventional and reactive user interfaces that will reduce the penalty on concentration, cognitive processing, teaching and learning when instructor, local students, and remote students have to manage the distance learning equipment and environment iii) a reactive approach leading to improved audio quality than is available in most video conferencing rooms and iv) improved user interfaces that will improve multimedia document presentation and student support.

The reactive shared classroom is an outgrowth of the research systems that were developed as part of the Ontario Telepresence Project [12]. Hardware and software systems developed under that project, ie, the reactive room [3], Telepresence conference software [10], and the Telepresence media space [2], will be used in our initial investigation. These systems provide easy-to-use control by instructors and students over room selection and switching, camera actions (panning, zooming), audio loudness, switching of cameras, microphones and speakers, and playing of multimedia programs, courseware and displays.

The prototype room at Carleton University will be completed. The user interface to the existing software will be further developed to improve user control over the room and the remote camera. The research challenge is to design an interface that is as completely transparent to the lecturer as possible. This includes the use of teaching position (document camera, file access, console computer use, remote camera control, and resource retrieval) in a variety of ways. The real-time distributed models and methods introduced by Karam will be finalized and implemented. Our research plan also includes an investigation of the synchronous delivery of pre-loaded multimedia slides and student support software systems, and an evaluation of user performance and satisfaction with the systems, together with analysis of results.

The Carleton University room will be used to deliver graduate courses to the University of Ottawa over OCRINet. We will bridge across the country to other universities (University of Toronto and SFU) with ATM service over CANARIE . A series of formal evaluations of student and instructor acceptance and performance will be carried out. These evaluations will provide valuable input towards the requirements for deployment over ATM, eg, multicast, minimum acceptable bandwidth, and maximum acceptable compression. We will coordinate with the Broadband Services major project in the development of ATM-based technology to support reactive shared classrooms, especially in the area of multicast routing. In addition, formative

usability testing methods will be used at all stages of the user interface development process.

Project 5: SkillNet Implementation and Evaluation
Principal Investigator: Lucio Teles (SFU Distance Education)
Co-Investigators: All investigators from projects 1-4

This project is the receptor for research results in projects 1-4 and represents a series of field trials to investigate the best way to offer and deliver a range of courses to different industrial environments. SkillNet is an organization set up by Simon Fraser University, BCIT, Science Council of BC and the Technology Industries Association (TIA) to sponsor the development and delivery of education and training to BC's technology based companies. Initial offerings use interactive video; the goal of this project is to move to the Virtual-U platform (projects 1-3) and to enhance existing passive video facilities to the reactive classrooms (project 4) connected by ATM network technologies over R-Net. It is proposed to establish a Learning Centre in the space made available by MDA in Richmond. This is directly adjacent to other high technology companies (Hughes, Prism, etc). Other sites will be established at the SFU downtown Harbour Centre Campus and at the University of Victoria to serve lower Vancouver Island.

It is proposed that the first course to be specifically developed for Virtual-U platform be "Design and Evaluation of User Interfaces". This topic is of interest to all of the industrial partners and represents an area of strength among the researchers at UBC (Booth) and SFU (MacKenzie, Calvert). The team from Project 1 will be involved in evaluation of the outcomes and will use the results to modify course design and system design.

2.2.4 References

[1] Ackerman, D. & Tauber, M.J. (1990). (eds) Mental Models and Human-Computer Interaction 1, Amsterdam: North-Holland.

[2] Buxton, "Telepresence: Integrating Shared Task and Person Spaces," Proceedings of Graphics Interface '92, Vancouver, B.C., May 1992.

[3] Cooperstock, J.R., K. Tanikoshi, G. Beirne, T. Narine, and W. Buxton, "Evolution of a Reactive Room", CHI '95.

[4] Gemmell, D.J., J. Han, R. Beaton, and S. Christodoulakis, (1994) "Delay Sensitive Multimedia on Disks", IEEE Multimedia, 1(3):56-67, 1994.

[5] Green, T.R.G., (1990). Limited Theories as a framework for human-computer interaction. In Mental Models and Human-Computer Interaction I, D. Ackermann and M.J. Tauber (editors), pp. 3-39, Elsevier.

[6] Grosky, W.I., (1994) Multimedia Information Systems, IEEE Multimedia, Spring, 1994, pp. 12-24.

[7] Han, J., Y. Cai and N. Cercone, (1993) "Data-Driven Discovery of Quantitative Rules in Relational Databases", IEEE Transactions on Knowledge and Data Engineering, 5(1):29-40, 1993.

[8] Harasim, L. (1993). Collaborating in cyberspace: Using computer conferences as a group

learning environment. *Interactive Learning Environments*, 3(2), pp. 119-130.

[9] Hiltz, S. R. (1994). *The virtual classroom: A new option for learning via computer networking*. Norwood, NJ: Ablex.

[10] Karam, G.M., B. McLeod, and G. Boersma, (1995) "A Network Services Interface for Telepresence Applications," to appear in IEEE Intl. Symp. on Autonomous Decentralized Systems (8 pages).

[11] MacKenzie, C.L. and Iberall, T. (1994). The Grasping Hand. Amsterdam: North-Holland (Elsevier Science).

[12] Riesenbach, R. (1994) "The Ontario Telepresence Project," CHI'94 Conf. Companion, ACM Conf. on Human Factors in Computing Systems, pp. 173-174, Boston, MA.

[13] Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the Learning Sciences, 1*(1), 37-68.

[14] Scardamalia, M., & Bereiter, C. (1993). Technologies for knowledge-building discourse. *Communications of the ACM, 36*(5), 37-41.

2.2.5 Milestones

6 months

Project 1
- Initial field test results from VIEW-U prototype.
- Initial conceptualization and design of version 1 of VIRTUAL-U taking account of Reference Architecture and API definition.

Project 2
- Initial field test results from VIEW-U prototype.
- Initial conceptualization and design of learning and structuring tools taking account of Reference Architecture and API definition.

Project 3
- Initial experiments with Virtual Hand Lab and shared musical performance at ATM speeds.

Project 4
- Preliminary version of reactive shared classroom using TCC/NSI completed.
- Design of experiments and site selection for initial controlled trial phase completed.

Project 5
- Establishment of SkillNet sites and first courses offered using video and VIEW-U.

12 months

Project 1
- VIRTUAL-U prototype 1 complete and lab tested.
- Deployed for field tests on SkillNet.
- Re-implement VIRTUAL-U using API from Broadband Services.

Project 2
- Initial implementation and lab testing of learning (knowledge building and collaborative learning) and structuring tools complete.
- Deployed for field tests on SkillNet.

Project 3
- Integration of Virtual Hand Lab results into training environment at BCIT over R-Net.
- Integration of music rehearsal capability into course delivery on an experimental basis.

Project 4
- Completion of trials using initial site.
- Version 2 of reactive shared classroom using feedback from trials completed.

Project 5
- VIRTUAL-U and new tools deployed for field tests in SkillNet.

18 months

All Projects
- Completion of second controlled trial phase and creation of final Version for use in full university/industry trials at different SkillNet and other industry sites.

24 months

Project 1
- Delivery of VIRTUAL-U.
- Demonstration of a Tele-Learning application over the ATM network utilizing the coherent common architecture and the API developed in the CBAR program.

Project 2
- Delivery of learning and structuring tools for VIRTUAL-U.

Project 3
- Delivery of Virtual Hand Lab demo and guidelines for use of telelearning in training for skilled tasks.
- Delivery of modules to support music rehearsal.

Project 4
- Delivery of a demo Reactive Shared Classroom. Guidelines for effective use of the Reactive Shared Classroom.

Project 5
- Delivery of Field Test results for course delivery using VIRTUAL-U and video and guidelines for effective course delivery.

All Projects
- Final report that includes assessment of initial implementations and field tests in all projects.

2.2.6 Equipment

The projects require ATM switches to be installed in a number of locations. In some cases these can be immediately connected to local networks (such as R-Net in B.C, OCRINet in Ottawa, and CANARIE as a country-wide backbone) and campus based ATM networks. (Note: In December 1994 the Government of BC announced the allocation of $1.3 million to extend R-Net; OCRINet is funded until the end of 1996). In other cases the local ATM installation will be initially "stand-alone" until a suitable network connection is available.

1 SFU Faculty of Applied Sciences - existing R-Net connection. 16 port 36150 switch with 3 OC3/LATM, 2 T3, 2 Ethernet and 2 video (JPEG) interfaces. Will support Projects 1, 2, 3 & 5.

2 SFU School of Communication - not yet accessible to R-Net. 8 port 36150 switch with 1 OC3/LATM, 1 T3, 2 Ethernet and 1 video (JPEG) interfaces. Will support Projects 1, 2 and 5.

3 UBC MAGIC Lab - existing R-Net connection. No ATM switch necessary. Will support Projects 3, 5.

4 BCIT Technology Centre - not yet accessible to R-Net. 8 port 36150 switch with 2 OC3/LATM, 1 T3, 2 Ethernet and 1 video (JPEG) interfaces. Will support Projects 3 and 5.

5 Richmond SkillNet Centre - (MDA complex). Not yet accessible to R-Net. 8 port 36150 switch with 1 OC3/LATM, 1 T3, 2 Ethernet and 1 video (JPEG) interfaces. Will support Project 5.

6 SFU Harbour Centre Campus (downtown Vancouver). Not yet accessible to R-Net. 8 port 36150 switch with 1 OC3/LATM, 1 T3, 2 Ethernet and 1 video (JPEG) interfaces. Will support Projects 1, 2 and 5.

7 University of Victoria. Not yet accessible to R-Net. 16 port 36150 switch with 3 OC3/LATM, 2 T3, 2 Ethernet and 1 video (JPEG) interfaces. Will support Projects 3 and 5.

8 University of Toronto (Dept. of Computer Science). Standalone until University of Toronto connection to CANARIE becomes available. 8 port 36150 switch with 1 OC3/LATM, 1 Ethernet and 1 video (JPEG) interfaces. Will support Project 4.

9 Carleton University (Dept. of Systems and Computer Eng.). Will connect to OCRINet (which networks it with BNR Ottawa, and Univ. of Ottawa, and CANARIE). 8 port 36150 switch with 1 OC3/LATM, 2 Ethernet and 1 video (JPEG) interfaces. Also can leverage Carleton's existing Newbridge ATM switch. Will support Projects 4 and 5.

A network diagram for the major project is shown in figure 3.

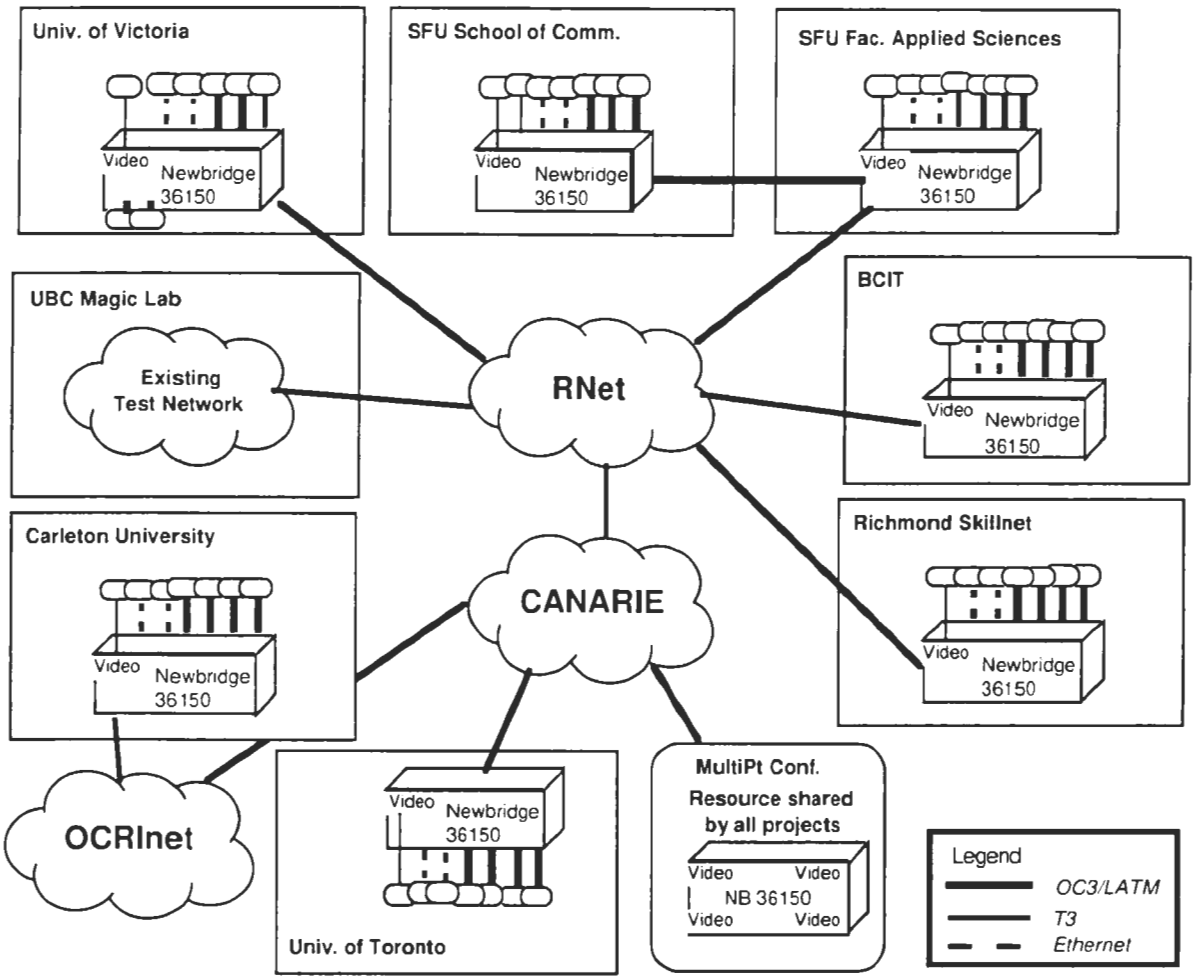
Univ. of Victoria
Video
Newbridge
36150
SFU School of Comm.
Video
Newbridge
36150
SFU Fac. Applied Sciences
Video
Newbridge
36150
UBC Magic Lab
Existing
Test Network
RNet
BCIT
Video
Newbridge
36150
Carleton University
Video
Newbridge
36150
CANARIE
Richmond SkillNet
Video
Newbridge
36150
OCRInet
Video
Newbridge
36150
Univ. of Toronto
MultiPt Conf.
Resource shared
by all projects
Video
Video
NB 36150
Video
Video
Legend
OC3/LATM
T3
Ethernet

Figure 3

2.3 Multimedia Tele-medicine over ATM Networking
Major Project Leader: Nicholas Georganas (Univ. of Ottawa)
Co-Leader: Trevor Cradduck (LARG*net)

2.3.1 Objectives

This major project is focused on distributed multimedia tele-medicine applications over high-speed, terrestrial and satellite ATM (Asynchronous Transfer Mode) networks. It is a multi-disciplinary initiative motivated by the opportunity to develop and evaluate applications for cost effective delivery of health care.

A major objective is to develop and demonstrate a multi-modal prototype multimedia tele-medicine application incorporating a "Virtual Patient Health Record". The application will be used for different consultation modalities, eg, digital angiography,3-D high frequency ECG and endoscopy support for rural areas.

A reference architecture and APIs for multimedia presentational and conversational applications will be developed jointly with the other CBAR Major Projects and in particular the CITR Broadband Services Major Project.

The Virtual Patient Health Record (containing various medical data modalities, such as digital angiograms, High-Frequency ECGs, medical interview video-clips, etc.), its ATM-based access over a distributed database environment and collaborative work based on it are the unifying elements of this Major Project. The results will not only impact the design and commercial development of medical informatics applications but also demonstrate the effectiveness of such applications over ATM networks, such as OCRInet, LARG*net and the CANARIE National Test Network. Newbridge ATM switching equipment and/or Satellite Communications equipment will be used in the nodes of the project in London, Ottawa, Kingston, Calgary and remote communities in the North of Ontario and Alberta.

2.3.2 Background and rationale

The practice of medicine and the effective provision of health care are heavily dependent on various forms and types of information. Such information is frequently carried by "media" such as images, video, audio, text, etc. The record of a patient, for example, contains today items such as X-rays, written reports, lab test results, EEC and ECG prints, angiogram films, CAT scans, MRI and PET images and many other pieces of medical information. Most of these items are produced from image acquisition machines that have digital output, but for various reasons

are recorded in analog film, tape or just plain paper. These forms of information presentation inhibit remote consultations among specialists and attending physicians and quite often result in prolonged hospital stays and increased health care costs. By shifting to completely digital patient records and health care systems interconnected by high-speed networks, "virtual" meetings of medical experts can be achieved and multimedia medical information can be effectively communicated across thousands of kilometers.

In the last ten years, communication of images from hospital Picture Archiving and Communications Systems (PACS) has moved from local storage retrieval to interactive high-resolution display over long distances [3,4,5]. Now, with the emergence of broadband communications ATM networks, these communications can include truly multimedia sessions. A good review of relevant work may be found in the Sept. 1992 issue on "Medical Communications" of the IEEE Journal on Selected Areas in Communications[1] and the recent issue of IEEE Network on the "North Carolina Information Highway" initiatives [2].

The goal of this major project is to perform research on key technical issues, develop a common software/hardware platform for multimedia tele-medicine applications , develop a multimodal, multimedia tele-medicine prototype application and evaluate the performance of such an application over ATM networks such as OCRInet in Ottawa, LARG*net in London, Wnet in Calgary, an ATM satellite network and the CANARIE National Test Network.

An extremely important consideration is the design of "virtual health records" for patients. Such records may "logically" consist of a variety of data at various sites throughout a health information network. This data may range from textual/numeric information (eg, typical patient record data), to laboratory reports (including graphs), digital images (such as x-rays), and even audio/video information. These records would be virtual in the sense that from the user's perspective, the interface would provide a single view of patient information. In actuality, the data may be kept at multiple sites, in different forms, etc. Connection of the sites in a metropolitan area could be provided by an ATM network infrastructure. The architecture of the virtual health record and data integrity and security are key issues for investigation [6,7,8].

Another key issue to be addressed is the effective communication and tele-consultation of image-sequence data of high bandwidth and lossless compression demands. Cardiac angiograms are such image sequences. They are currently recorded as analog information at 30 frames per second onto stock 35mm cine film [9]. These analog films are currently used for diagnostic purposes in each Cardiac Hospital unit without the possibility of remote consultation. Digital angiograms consist of sequences of 30 frames per second, where each frame is of size 512 x 512 x 8 bits. This corresponds to a raw data rate of 63 Mbits/sec without

compression. The data record sizes are typically 3.5-5 Gb and 5.3-7.6 Gb for an 8-view and 12-view study, respectively. We note that the cardiac image sequences have significant amount of redundancies which can be exploited to achieve compression. Lossless compression schemes based on MPEG-2 extensions [10] and video indexing [11] and browsing are key issues for research.

In March 1993, the Faculty of Medicine at The University of Calgary, in partnership with the Drumheller Regional Health Complex (DRHC), Hughes Aircraft Corporation and Hughes Aircraft Corporation of Canada and AGT (formerly Alberta Government Telephones), initiated a twelve-month (March 1, 1993 to February 28, 1994) pilot project that offered an innovative, alternative method of health care provision and professional education. The service, known as the Remote Consultative Network (RCN), was an interactive video and computerized telecommunications system that provided consultation between health care providers practicing at a rural site in Drumheller, Alberta with specialists and experts at the Faculty of Medicine. The RCN was motivated by the desire to provide timely, cost-effective specialist service to under-serviced areas by providing second opinions for remote site physicians, reducing the time required for a diagnosis and treatment of patients, improving physician's willingness to practice in the rural environment and creating an effective tool for enhancing education networks. This project was successful in that it demonstrated that technology provided more timely (equitable) access to health care services for persons living in geographically remote locations. The pilot used fractional T1 circuits for telecommunications. Certain issues were raised during the pilot project, including the determination of the minimum acceptable bit-rate and the improvement of technological interfaces. This proposed research will address these issues. Broadband communications to remote locations could be provided by either terrestrial or satellite ATM links. The latter case presents many challenges. ATM technology is basically designed for physical media with good error characteristics, such as optical fibre. Transmission of ATM over satellite links presents some unique problems [12, 13, 14], such as how to map ATM cells on satellite multiple access procedures, how to improve the performance of the noisy satellite channel carrying ATM cells and how to design more efficient satellite multiple access techniques.

The electrocardiogram (ECG), is another important data modality in the "virtual health record". In its traditional form as a 12 lead configuration, sampled at 250 Hz with a bandpass filter at 100 Hz, it remains the traditional yardstick in diagnosing Coronary Artery Disease (CAD). Such diagnosis is based on the morphology of the waveforms. However, this method has a poor sensitivity and specificity in diagnosing CAD. Using a three lead orthogonal system of ECG leads (X, Y, Z Frank lead system) and High Frequency ECG (HFECG) data acquisition (1000

Hz) per channel, both the morphology and frequency content (up to 300 Hz) of the Frank leads in normals, and also in patients with angiographically proven CAD and awaiting coronary artery surgery, has been analyzed. Using four bandwidths for content analysis, a scoring system (SEECAD) has been developed to diagnose CAD [15,16]. Such a scoring system, based on a graphic representation of deviation from normality, has shown a marked increase in sensitivity (90%) and specificity (90%) in diagnosing CAD compared to the 12 lead ECG taken concurrently. The real-time capture, creation and communication of these 3-D HFECG maps, with simultaneous multimedia conferencing among specialists and non-specialists, requires the development of new techniques and real-time communication protocols over ATM.

2.3.3 Research plan

The proposed research in tele-medicine has four constituent parts that are outlined below. Their common objective is the development of a software/hardware platform for the access of, and collaborative work with, a "virtual health record" consisting of multiple-mode imaging and other data modalities over ATM networks. A multimedia tele-medicine application will be developed by four co-operating university teams, allowing tele-consultation of health records, or parts of, in both presentational mode (multimedia database browsing and retrieval) and conversational mode (real-time multimedia medical conferencing).

Collaboration among the Major Projects on a CBAR program-wide basis will allow us to develop common reference architecture and APIs for application development. The following milestones reflect these common goals:

Confirmation of reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API (after 3 months).

Refinement of application requirements and confirmation of the API (after 6 months).

The four teams in this Major Project will use the CANARIE ATM National Test Network both for their collaborative work, application development and application testing.

Project 1: Virtual Health Records: Service Architecture and Design
Principal Investigator: M. Bauer (University of Western Ontario)
Co-Investigators: S. Osborn (University of Western Ontario)
H.L. Lutfiyya (University of Western Ontario)

The objectives of this research are to identify an initial information model for a Virtual Health Record and to assess the computer and communication services to provide access and retrieval of such records over fast metropolitan or regional networks, such as those provided by

metropolitan ATM networks. These records may involve data that can include textual/numeric information (eg, typical patient record data), laboratory reports (including graphs), digital images (such as x-rays), monitoring data (eg, from devices such as heart monitors) and even audio/video information. The types of services that are required include: security and authorization, access and retrieval from heterogeneous databases, and distributed services for location transparency, remote access, data transfer and replication. The work will also explore the utility of HL-7 (a health informatics data protocol) as a basis for the inter-operability between systems. The project will focus on information within a metropolitan area domain and initially involve two geographically separate sites connected to LARG*net.

An architecture to support "virtual health records" and the applications which make use of such records will be defined. Such an architecture might consist of a set of logical layers, their dependencies, and the categories of services offered by each logical layer. The logical layers could be: an applications layer, a primary service interface layer, a layer of basic services (data services, communications services, distributed services, presentation services, security services, and management services), and a layer of underlying system support and proprietary services.

The proposed work will focus on the development, refinement and validation of an initial architecture and those services required for access and use of health care information distributed across multiple sites. Particular focus will be on those services which are needed to take advantage of ATM communications. The initial architecture will be based on the concepts presented above. Validation will be done by building a tele-medicine application prototype over ATM networks. The LARG*net ATM test-bed in London will be used to connect to CANARIE NTN, Wnet and OCRInet.

Project 2: Digital Angiogram Compression, Indexing, Browsing and Performance over ATM
Principal Investigator: S. Panchanathan (University of Ottawa)
Co-Investigator: N.D. Georganas (University of Ottawa)

Cardiac angiograms are currently recorded as analog information at 30 frames per second onto stock 35mm cine film. These analog films are used for diagnostic purposes in each Cardiac Hospital unit without the possibility of remote consultation. Digital angiograms consist of sequences of 30 frames per second, where each frame is of size 512 x 512 x 8 bits. This corresponds to a raw data rate of 63 Mbits/sec without compression. The data record sizes are typically 3.5-5 Gb and 5.3-7.6 Gb for an 8-view and 12-view study, respectively. We note that the cardiac image sequences have significant amount of redundancies which can be exploited to achieve compression.

The MPEG-2 standard video/audio coding algorithm[10] employs the DCT (Discrete Cosine Transform) for compression, which is essentially a lossy coding technique. The residual data between the MPEG-2 decoded frames and the original frames can be computed, during the document database storage phase, which can then be compressed using the variable length coding module to result in a lossless compressed stream. The MPEG-2 algorithm will be thus extended for lossless compression of cardiac angiograms. Since the adjacent frames of such angiograms are highly correlated with only minor differences between the frames in terms of the motion of the dye as well as the timing of the cardiac cycle, alternate compression schemes such as vector quantization may result in a better coding performance. Investigation of other high-performance techniques for cardiac image sequence compression will also be done. Since angiograms have specific properties, the subjective quality of the images and/or compression ratios can be further improved by employing application specific pre- and post filtering operators. For example, morphological operators can segment the image sequence in terms of their anatomical significance. The compression algorithms can then be employed on these segmented images resulting in better quality reconstructed images at high compression.

In clinical studies, large volumes of cardiac image sequences necessitate the use of video browsing tools to navigate, locate and retrieve a sequence of interest. This research aims at developing various representations which will enable flexible browsing of the cardiac angiogram sequences.

There are two major challenges in location and retrieval of a specific cardiac image sequence from a library of sequences. First of all, the image sequences have to be indexed for efficient retrieval. Secondly, we need to design powerful search algorithms which can retrieve images based on user specification. The index of the image sequences essentially reflect the content. Novel algorithms for content abstraction of cardiac image sequences will be designed and combined text-visual indices will be developed.

A video browser prototype for cardiac angiograms will be developed at the MCRLab at the University of Ottawa and integrated within the common tele-medicine application . The prototype design will involve continuous input through extensive interactions with the cardiac specialists at the U. Of Ottawa Heart Institute at the Civic Hospital to develop an appropriate user interface and interactive tools for browsing. The prototype will incorporate the lossless compression and video indexing, search and retrieval algorithms investigated in phase 1 of the research. The cardiac specialists will access the angiographic image sequences from both intra-hospital and inter-hospital units. The imaging workstations at the MCRLab and the U. of Ottawa Heart Institute at the Civic Hospital will be interconnected over OCRInet using a

Newbridge ATM switch in each location. The MCRLab switch will also serve the project on Tele-medicine to Remote Locations, as also the Multimedia Synchronization project of the CITR Broadband Services Major Project. Subjective evaluations will be conducted on the compressed sequences for acceptability. The performance of the prototype and network behavior will be analyzed through field trials using the OCRInet infrastructure. The prototype and results will be first demonstrated to a client Hospital in Ottawa, as also some smaller clinics in the city periphery, and will then be integrated within the target tele-medicine application.

Project 3: Tele-medicine Consultations Network for Remote Areas
Principal Investigator: A. Yongacoglu (University of Ottawa)
Co-Investigators: M. Watanabe (University of Calgary)
P.A. Jennet(University of Calgary)
W.G. Hall (University of Calgary)
A. Lakhani (Telesat Canada)

Building on a recently completed study of providing clinical consultations to rural sites from the University of Calgary, which used terrestrial fractional T1 bandwidths, this project will test the target multimedia medical tele-consultation application for wide area use on a heterogeneous network. Certain sites will be connected by terrestrial broadband ATM networks and others by satellite ATM networks operating at T1/E1 rates. It will evaluate the clinical impact and usefulness of the lower-speed channels ((T1/E1) on the tele-consultation, as compared to the DS3 and OC3 ATM channels used on the terrestrial ATM networks of this project.

The target multimedia medical tele-consultation application will be tested over a six-site tele-medicine pilot project in two provinces (Alberta and Ontario) . Four of the six sites will be remote sites while the other two will be metropolitan sites. The three remote sites in Ontario will be Nursing stations not equipped with "normal" communication facilities. The remote site in Alberta will be the Drumheller Regional Health Complex outside Calgary. The two remaining sites would be the University of Ottawa Multimedia Communications Research Laboratory (MCRLab) connected to OCRInet and through it to the University of Ottawa Heart Institute at the Civic Hospital, and the Faculty of Medicine at the University of Calgary. All six sites will be equipped with medical informatics tools (eg, WinRad Teleradiology application) and connected to ATM cell makers (DSU/CSU) or ATM switches. The cell makers will be linked to either the Telesat Headquarters' ATM hub using T-1/E1 ATM satellite link/s, or ATM Wnet using DS3 links.

For communications to and from remote/rural communities, satellites often provide the most feasible (and frequently the only reliable) links. Transmission of ATM over satellite links presents some unique problems [12,14]. ATM was basically designed for physical media with good error characteristics, such as optical fibre. Satellite communication links must afford high

performance to support ATM traffic.

Research issues to be investigated are: efficient multiple access techniques for transmission of ATM cells over satellite; coding and interleaving suitable for improving the performance of ATM over satellite channels; study of the requirements of real- and non-real time traffic over ATM satellite channels; development of standard ATM cell mapping on efficient satellite multiple access techniques and performance evaluation of the tele-medicine application. The project will also contribute the software for T1/E1 ATM transport selectivity to the target tele-medicine application.

The project will assess the value of including short (1 to 2 minutes) video clips of a remote patient interview, as part of the target multimedia "virtual health record" . The clips will be digitized to allow ease of access, manipulation, and retrieval. The appropriate clinical scenarios for this form of medical record keeping will be evaluated. Software development will include the programming and interface development to keep the immediate past 0.5 to 1 minute of video and, upon input from the operator, the next 0.5 to 1 minute of video a permanent and accessible part of the digital record maintained at the host site. It will also assess the clinical impact of providing large frame, high quality video for a real time application (eg, endoscopy support to rural physicians with basic endoscopy skills in Alberta. Gastroenterologists at the host site will effectively be present and guide the clinical procedures). The clinical effectiveness, therapeutic impact, and cost effectiveness will be key features of this evaluation. In addition, testing to provide the best trade-off between spatial resolution and motion detail on a procedure or diagnosis basis will be assessed. Software development will include integrating video I/O drivers to the target multimedia tele-medicine application.

Project 4: 3-D HFECG and Real-Time ATM Protocols for Efficient Coronary Artery Disease Diagnosis

Principal Investigator: **H. Mouftah (Queen's University)**
Co-Investigators: **P. Martin (Queen's University)**
R. Seegobin (Kingston General Hospital)
L. Higginson (Univ. Of Ottawa Heart Institute)

The main objective of this project is to develop, and integrate within the target tele-medicine application, a simple non-invasive method for the accurate diagnosis of the presence and severity of coronary artery disease with complete tele-conferencing consultation. A new clinical data modality, namely 3-D HFECG, will be considered in the "virtual health record", and will be integrated in the target application. The system will have the patient stay geographically remote, have a simple non-invasive test, and have the data travel to and from the centres of cardiac care excellence and centralization for immediate analysis and subsequent teleconferencing consultation. Multimedia communications and the development of a real-time

transport protocol and an application over ATM networks will be an important part of this project.

Currently HFECG acquisition involves signal averaging over 100 beats to achieve a summed average. This yields three averaged beats (X, Y, Z) which are collected once before and twice after the cold pressor stress, ie, three measurement points in a ten minute period of data collection. This technique reduces random noise but may detract from content analysis, as averaging is based on low frequency morphology and such averaging may obtund sought after changes in the higher frequency ranges. To overcome such limitations, data will be collected continuously over the whole test period with 16 bit resolution which will yield a database of up to 60 Mb per patient test (6 Mb per minute).

The efficacy of signal averaging will be compared to beat-to-beat frequency analysis of the ECG waveforms. Methods of lossless compression of the raw ECG data will be adopted, in collaboration with project 2.2 above, in order to attain the most efficient transmission over the communication channel to and from the centres of excellence. Three dimensional maps will be generated of time and frequency domain analysis of the four bandwidths of the HFECG. The rate of data acquisition needed for HFECG analysis exceeds the capabilities of traditional communication networks. Near real time analysis can however be achieved with the use of high bandwidth communication links to allow the immediate transfer of data to the central laboratory for immediate parallel processing analysis and the subsequent retransmission of the three dimensional maps as they are generated.

In order to achieve this connectivity for remote data collection and teleconferencing consultation a real time transport protocol will be developed for multimedia communications over ATM networks. The real time protocol and the 3-D HFECG maps will be integrated within the target multimedia tele-medicine application.

A functional model for such a system will be developed and its corresponding OSI architecture will be derived. This real time protocol should provide means by which a participant user can join a session, receive and send multimedia medical information to other participant users. The protocol should control all the interactions between participants, provide participants' general information and manage the identification. Also the protocol will multiplex media into the appropriate channels and upon receiving multimedia information will gather them in a structured multimedia document with the objective of synchronizing all media with each other and in time. Multimedia synchronization techniques will be adopted from research carried out in the CITR Broadband Services Major Project.

The Newbridge ATM switch will be located in the Computer Networks Research Laboratory (Department of Electrical and Computer Engineering) at Queen's University where the multimedia real-time protocol and application will be developed. This lab will be acting as the ATM communications centre for this project. It will be connected to both Kingston General Hospital where SEECAD is being developed and data is analyzed and processed, the Department of Computing and Information Sciences at Queen's University and the University of Ottawa Heart Institute. In both locations data are collected and tele-medicine consultation takes place. Other peripheral locations are expected to be added as the project development progresses. Terrestrial and/or satellite ATM links may be used in this project.

2.3.4 References

[1] Special issue on "Medical Communications", IEEE JSAC, Vol.10, No.7, Sept. 1992

[2] Special issue on "North Carolina Information Highway", IEEE Network, Vol8, No.6, Nov/Dec.1994

[3] A. Karmouch, G. Sudhakar and N.D. Georganas, "Design and Performance Considerations for a Multimedia Medical Database", IEEE Trans. on Knowl. & Data Eng., Vol.5, No.5, Oct. 1993, pp. 888-894

[4] L. Orozco-Barbosa, A. Karmouch, N.D. Georganas and M. Goldberg ," A Multimedia Inter-Hospital Communications System for Medical Consultations", IEEE Journal on Selected Areas in Communication, Vol.10, No.7, Sep.1992, pp. 1145-1157

[5] L. Orozco-Barbosa, A. Karmouch, M. Goldberg and N.D. Georganas, "A Multimedia Medical Communications System", IEEE Journal on Selected Areas in Communication,Vol.8, No.3,April 1990,pp.325-339.

[6] M. Bauer, N. Coburn, D. Erickson, P. Finnigan, J. Hong, P. Larson, J. Pachl, J. Slonim, D. Taylor, T. Teorey, ``A distributed system architecture for a distributed application environment'', IBM Systems Journal, Volume 33, No. 3, 1994, pp. 399-425.

[7] M. Bauer, P. Finnigan, J. Hong, J. Rolia, T. Teorey, G. Winters, ``Reference architecture for distributed systems management'', IBM Systems Journal, Volume 33, No. 3, 1994, pp. 426-444.

[8] M. Nyanchama and S. Osborn, ``Access Rights Administration in Role-Based Security Systems,'' Proc. IFIP WG 11.3 Eighth Annual Conf. on Database Security, Aug. 1994.

[9] W. Grossman, "Cardiac Catherization and Angiography", LEA & Febiger, Philadelphia, 3rd edition, 1986.

[10] D.J. LeGall, "The MPEG video compression algorithm", Signal Processing: Image Communication, vol. 4, pp. 129-140, 1992

[11] F. Rabitti, P. Savino, "Automatic Image Indexation to Support Content-based Retrieval", Inf. Process. & Manage., Vol. 26, No. 1, 1990, pp. 135-170.

[12] D.M. Chitre et al., "Asynchronous Transfer Mode (ATM) Operation via Satellite: Issues, Challenges and Resolutions", Int'l J. Sat. Comm., Vol. 12, pp. 211-222, June 1994.

[13] W. A. Brewer et al., " VISTAnet and MICA: Medical Applications Leading to the NCIH", IEEE Network, Vol. 8, No. 6, pp. 24-31, Nov./Dec. 1994.

[14] C.C. Haw and A. Lakhani, "ATM for Multimedia and Broadband", Spectrum 20/20 1994, session 2 paper 5, December 7/8, 1994.

[15] A.G. Qureshi, R.D. Seegobin and H.T. Mouftah, "Signal Processing for High Resolution

ECG Signal Analysis," Proc. Biennial Symposium on Communications, Kingston, Ontario, pp. 402-405, June 1992.

[16] S. Abboud et. al., "High Frequency Electrocardiography Using an Advanced Method Signal Averaging for Non-Invasive Detection of Coronary Artery Disease in Patients with Normal Conventional ECG, J. of Electrocardiology, Vol. 19, No. 4, pp. 371-380, 1986

2.3.5 Milestones

6 months

all projects
- Preliminary architecture for the multi-modal, multimedia tele-medicine system (application, virtual health record and hardware/software platform) defined. Refinement of application requirements and confirmation of the API.

Project 1
- Evaluation of the basic communication services completed. Interfaces for different modalities defined.
- Exploration of the utility of HL-7 (health informatics data protocol) as a basis for the inter-operability between systems completed.
- Completion of an initial information model of a virtual health record.

Project 2
- Evaluation of the basic communication services completed. Interfaces to the virtual health record and multi-modal, multi-media application defined.
- Lossless compression extension to the MPEG-2 standard algorithm completed.
- Preliminary design of the video browser completed.

Project 3
- Evaluation of the basic communication services completed. Interfaces to the virtual health record and multi-modal, multi-media application defined.
- Identification of performance requirements over satellite and remote DS3 link (Wnet) completed.
- Burst and random error channel modelling for satellite ATM channels completed.

Project 4
- Evaluation of the basic communication services completed. Interfaces to the virtual health record and multi-modal, multi-media application defined.
- Functional modelling of tele-medicine application completed.

12 months

Project 1
- Development of an initial set of application-oriented primitive communication services completed; initial draft of the VHR architecture completed.
- Prototype application utilizing the VHR that validates the draft architecture and services completed.

Project 2
- Demonstration of a preliminary indexing, search and retrieval system for cardiac angiograms.

- Preliminary design of the angiogram browsing prototype completed.

Project 3
- Development of coding and interleaving techniques for satellite ATM completed.
- Efficient algorithms for multiple access for satellite ATM completed.
- Study of integration of real-time video clips in remote tele-medicine application completed.

Project 4
- Improved data collection implementation for 3-D HFECG completed.
- Preliminary Design of Real Time Application Protocol Completed.

18 months

all projects
- Multi-modal, multi-media telemedicine system demonstrated.

Project 1
- Extension of tools and services for VHR completed.
- Refinement of the prototype VHR application completed.

Project 2
- Integration of the lossless compression algorithm and angiogram browsing tools into the prototype completed
- First trials over OCRInet completed.
- Demonstration of high-performance lossless compression algorithms for medical image sequences.

Project 3
- Prototype of Tele-medicine application for Remote Location consultations demonstrated.
- Evaluation of cell loss, delay-throughput over satellite completed.
- Performance evaluation of first tele-medicine prototype over satellite links using simulation completed.
- Assessment of first real-time remote tele-medicine application prototype.

Project 4
- Integration of three dimensional maps generation in the application completed.
- Completion and demo of real time application protocol .
- Demonstration of HFECG modality in the overall application.

24 months

all projects
- Demonstration of multimedia tele-medicine application using the API developed in the CBAR program.

Project 1
- Completion of prototype VHR application and documentation.

Project 2
- Demonstration of prototype and access to cardiac angiograms between hospitals through OCRInet.
- Testing, performance analysis and user studies of the angiogram browsing prototype.

Project 3
- ATM cell mapping & access strategy for satellite channels completed.
- Testbed and clinical impact assessment for remote tele-medicine application

development over satellite and Wnet links completed.

Project 4
- Validation of 3-D HFECG tele-medicine application completed.
- Performance Evaluation of Real Time Application Protocol Completed.

2.3.6 Equipment

The common objective of all projects in the Tele-Medicine Major Project is the development of a target multimedia tele-medicine application over ATM Networking (terrestrial and satellite). OCRInet, Wnet and CANARIE NTN provide 45 Mbps lines (DS3), while LARG*net provides 155 MBPS lines (OC3). The rationale and proposed deployment of the Newbridge ATM switching equipment is given below. ATM networking will be used both for application development and for collaborative work over video-conferencing among the four university teams and participating industry and medical institutions. A multi-vendor conferencing standard, such as Communique! (used by OCRInet as a standard), could be used for this collaborative work as also in the application itself. ATM links between Ottawa, London and Calgary are currently functional. Kingston will be connected shortly.

The proposed switch locations, the port size, the interface cards and terminal equipment are given in Appendix 1.3.

A network diagram for the major project is shown in figure 4.

Note 1

To connect the Multimedia Communications Research Laboratory (MCRLab), in Electrical Engineering, to OCRInet, and through it to the University of Ottawa Heart Institute at the Civic Hospital. MCRLab has currently OCRInet connectivity through a small VIVID ATM switch (1.6 Gbps), suitable for Local ATM connectivity. That switch cannot accommodate interface cards other than OC3 ones built-in. The larger 36150 one will be used for connecting video cameras for tele-consultation and video-conferencing, and workstations used not only in two projects in the Tele-Medicine Major Project but also two projects in the Broadband Services Major project where both Profs. Panchanathan and Georganas are involved. UOHI is a centre of excellence in cardiac care and will have an OCRInet FMT connection very shortly, as it is involved in several OCRInet projects. It is also involved in three projects in this Tele-Medicine Major Project and requires an ATM switch to connect to OCRInet.

Note 2

Two ATM 8-port Newbridge 36150 switches are required to connect to Wnet both the Drumheller Regional Health Complex and the University of Calgary Medical School. Connecting

the Drumheller Regional Health Complex to the adjacent Wnet/AGT fibre optic line between Edmonton and Calgary is expected to be done soon. Planned completion of a fibre optic link between the Health Sciences Centre and the fibre optic backbone on the main campus of the University of Calgary. Completion of the fibre optic link between the Wnet node and the fibre optic backbone on the main campus of the University of Calgary. ATM link to OCRInet in Ottawa will be provided by the CANARIE NTN. The project also will link Telesat, MCRlab and three Nursing stations in Northern Ontario, by ATM satellite connections. The ATM switch required by Telesat will link to their current ATM switch, CISCO router , OCRInet and satellite ATM at T1/E1 rates. Cards (beta) from Newbridge for T1/E1 ATM connectivity have been loaned to Telesat and will soon be a product. At the remote site Nursing stations, PCs on Ethernet will be connected to a CISCO Router and ADC Kentrox cell maker, then to a satellite modem and antenna (to be provided by Telesat). Network connectivity will be thus achieved by Wnet DS3 links, ATM satellite links running T1/E1 rates, OCRInet at DS3 rates and the CANARIE NTN at DS3 rates.

Note 3

To connect the High Speed Computer Networks Research Lab at the Department of Electrical and Computer Engineering, Queen's University to Kingston General Hospital FDDI network and to the University of Ottawa Heart Institute at the Civic Hospital, initially by satellite. Mobile Satellite equipment will be used for the initial connection from Kingston to CRC in Ottawa and through OCRInet to the University of Ottawa Heart Institute at the Civic Hospital. Very soon (Spring'95) the backbone campus network at Queen's University will be operating at 100 Mb/s (TAXI) and it is expected soon afterward to have an ATM connection to the CANARIE NTN. A network diagram for the major project is shown in figure 4.

Tele-Medicine

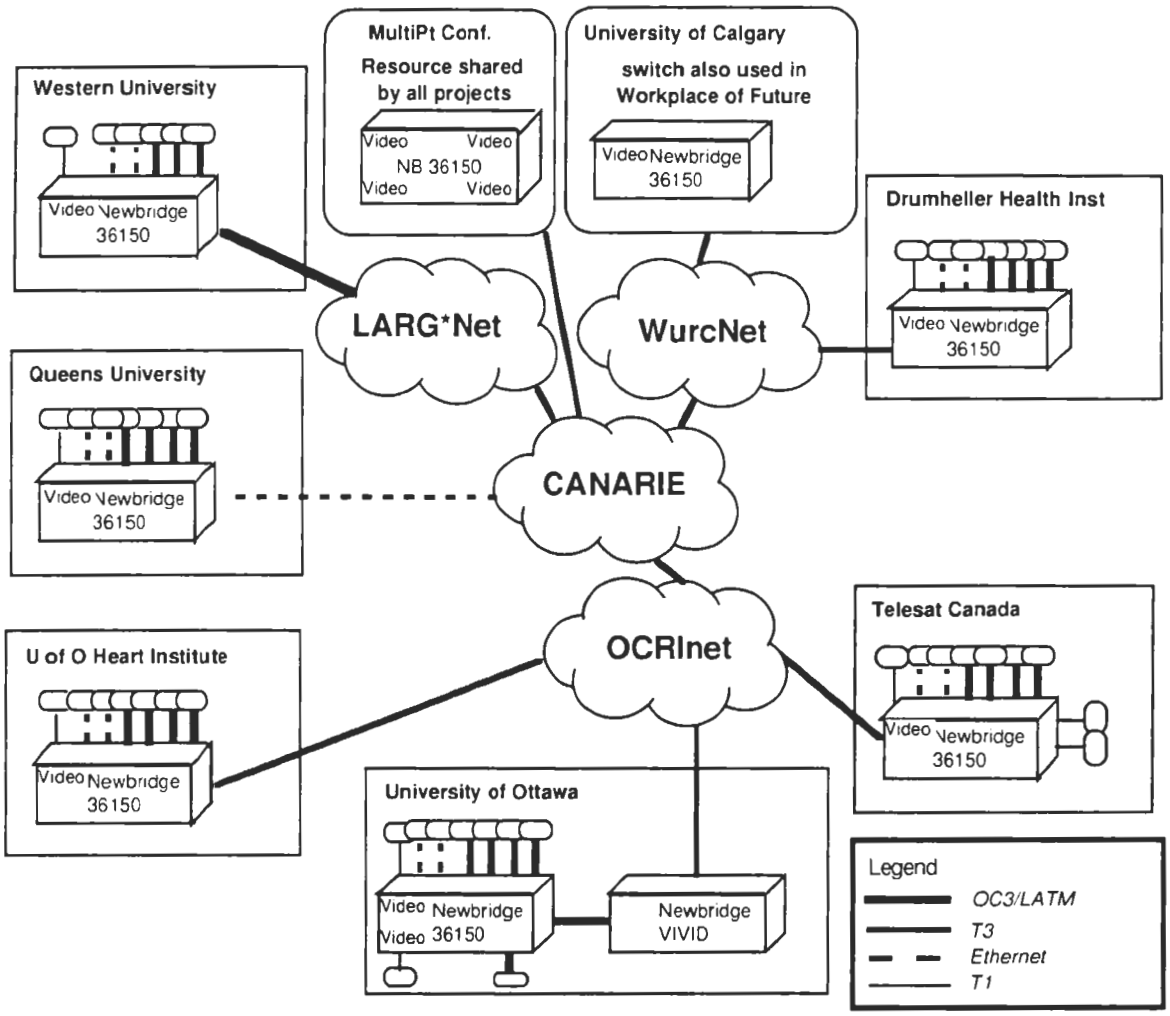

Figure 4

2.4 Workplace of the Future
Major Project Leader: Brian Gaines (University of Calgary)
Co-Leader: Larry Wilson (WURCNet)

2.4.1 Objectives

The overall aim is use high-speed network capabilities to develop new modes of working that will increase the competitive position of Canada in the world economy (Porter, 1990; Conklin, 1994).

The specific objectives are:-

- to establish a set of experimental situations in which advanced network capabilities are integrated with the routine work practices of groups typifying activities significant to the Canadian economy.
- to evaluate the impact of various uses of the network on the work practices and productivity of these groups in order to develop a requirements specification for new technologies to support the work processes.
- to develop system architectures, including enterprise models, work management procedures and collaborative work software, that meet the requirements.
- to test the system architectures in a range of real-world situations, and to evaluate their effectiveness in order to improve the architectures and implementations.
- to collaborate with the other Major Projects of CBAR program in order to develop a common reference architecture and API for broadband application development.
- to transfer the technologies and experience underlying the systems developed to Canadian commercial partners for purposes of product development.
- to use the situations developed as show-case applications for Canadian organizations who stand to benefit from new technologies in the workplace.

2.4.2 Background and rationale

Enterprises world-wide have to operate in an environment of increasingly rapid change and increasingly strong competition. This is leading to major and continuing restructuring as the enterprises which survive adapt to change. Principled restructuring is based on defining the basic goals of the enterprise, identifying the processes currently supporting those goals, re-engineering the processes to serve the goals more effectively, and maintaining the quality of those processes by a program of continuous process improvement. In the literature this

approach may be seen as a combination of business process re-engineering (BPR) (Hammer and Champy, 1993) and total quality management (TQM) Deming, 1993; Gitlow and Gitlow, 1994).

Process restructuring generally involves major changes in work practice. Existing processes have been largely determined by the technologies available to support them. Processes have evolved that are predicated on physical communication between employees, customers and suppliers, and involve common locations for major groups of employees and physical travel for customer liaison. These processes predate the availability of low-cost, high-bandwidth telecommunications, and are not targeted on the effective use of new communication technologies. Much of the business process re-engineering literature is concerned with more effective processes that are predicated on new computer and communications facilities, and involve major changes in work practice to make effective use of them (Morton, 1991; Currid, 1994).

Conversely, from a technological perspective, it is ineffective to introduce new technologies in the workplace unless work practice is re-engineered at the same time. The workplace of the future is not that of today with the addition of advanced computer and communication technologies. It requires a fundamental reassessment of all aspects of the enterprises involved.

However, principled restructuring of enterprises to used advanced telecommunications facilities effectively requires empirical data derived from applications experience. It requires modeling and simulation tools to support the planning process. It requires workflow tools that package and the functionality of the new technologies into humanly usable systems, and integrate that functionality with existing information systems. The models and the systems must be based on deep models of organizational cultures, discourse and coordination practice, and must be themselves supported through documentation and training that facilities their deployment (Furnham and Gunter, 1993; Nordhaug, 1993).

This is the background and rationale to the workplace of the future project, to provide the enabling experience, knowledge and technologies through which advanced communication technologies may be used to support the competitive, adaptive transformation of Canadian enterprises.

2.4.3 Research plan

The research plan involves: the development of computer-based tools to model and simulate enterprise processes; the development of computer-based tools to support enterprise processes in a distributed, networked environment; and the testing of models, simulations and support tools in a range of test-beds representing both routine office activities and creative research

activities.

The research methodology is to:

1 select a number of target areas that have the potential for high impact on Canadian competitiveness and span the range of workplace situations from low-end office technologies to high-end high-tech industries and advanced research.
2 model each area in terms of work practices, current technologies used, and the scope for high-speed networking to be used in re-engineering and improving the work processes.
3 introduce existing technologies in order to re-engineer and improve the work processes, and to evaluate their impact in order to develop requirements specifications for improved technologies that are more effective.
4 design new system architectures, prototype them rapidly, and field test them with user groups in the target area; subsequently, port applications to the agreed common CBAR application development environment provided by the Broadband Services Major Project.

The initial test-bed areas selected are:

i office of the future: the administrative functions of a complex organization involving over 100 professional and administrative staff.
ii manufacturing workplace of the future: supporting concurrent engineering and design processes at distributed sites.
iii research workplace of the future: creating critical mass in cutting edge research through telecollaboration in virtual laboratories common to collaborating researchers or a network of centres of excellence.

Project 1: Enterprise Modeling and Simulation for Communication Planning
Principal Investigator: B. Unger (University of Calgary)
Co-Investigators: P. Gburziinski (University of Alberta)
C. Williamson (University of Saskatchewan)

The identification of the goals and processes of an enterprise on an in-depth, quantitative basis provides an operational model of that enterprise that may be integrated into its routine operations, providing a basis for planning, performance tracking, and decision making. Enterprise modeling has become a major topic of research (Petrie, 1992) but current applications largely focus on manufacturing where high levels of computer-controlled automation allow work processes to be tracked in detail routinely (ESPRIT Consortium AMICE, 1989; Scheer, 1989).

The objective of this project is to develop tools for modeling and simulating an enterprise at a sufficient level of detail to encompass the human interactions requiring communication (Gaines, 1990). The model will focus on the work flows and their coordination across people. It will interface to deeper models of the complete enterprise on one hand, and to detailed communication models on the other. However, it will address a middle ground which is not emphasized in existing models, the flows of information and knowledge necessary to coordinate human activities, and the use of communication technologies to support that coordination.

The deliverable will be EnterSim, a modeling and simulation package that enables an organization to establish a base-line model of its existing workflow and communication processes and compare this with alternative processes involving different organization and communication models. For example, comparing a division operating with all employees in one location with one operating on a networked basis involving distribution of workers across many sites, including customer premises, mobile locations, and the home.

The simulation component will enable the model to be run with different assumptions and the workflows and costs displayed graphically. This type of graphic simulation has proved to be very effective in factory design and operation (Fishwick and Modjeski, 1991), and is increasingly being used as a basis for business process re-engineering (Bhaskar, Lee, Levas, Pétrakian, Tsai and Tulskie, 1994; Bridgeland and Becker, 1994).

The implementation will be based on past experience in the development of simulation packages for the lower levels of the OSI model (Unger and Lomow, 1993; Unger, Goetz and Maryka, 1994; Unger and Zhong-e, 1994). It will be programmed in C++ using a similar application development framework to that for the TeleSim ATM-TN system design package (WurcNet, 1995), and the workflow simulation package will be designed to interface to the TeleSim package so that detailed traffic analysis may also be investigated.

EnterSim will contain explicit models of the knowledge level workflow tools developed in Project 2. It will be evaluated through use in the test-beds of Project 3.

Project 2: Knowledge Level Workflow Tools
Principal Investigator: D. Norrie (University of Calgary)
Co-Investigators: B. Gaines (University of Calgary)
S. Greenberg (University of Calgary)

Enterprise models make overt the goals and processes underlying enterprise activities—they describe work practices at the knowledge level making explicit what is normally tacit knowledge. To be effective the models need to be applied in the workplace itself so that human activities are coordinated through an overt model of the goals and processes involved.

Workflow tools provide computer-based coordination of work practices but existing tools largely implement static processes that encodes *what* to do but not *why*. The tools also focus on information flows, and the associated human knowledge flows and coordination interactions are not modeled.

The objective of this project is to develop knowledge level workflow tools where the goals and rationales of all processes are explicit and comprehensible to the people involved. Provision will be made for tracking human interactions for purposes of decision-tracing, learning and various forms of audit. The major aims will be to increase flexibility and support continuous process improvement through easy access to overt models and records of enterprise activities.

The deliverable will be KFlow, a knowledge coordination package, using real-time and stored multimedia communications capabilities to coordinate distributed group work processes. KFlow will be designed as a multi-client, multi-server, networked architecture in which distributed client and server agents communicate over high-bandwidth links and provide user services through a uniform and simple interface.

The KFlow architecture is a generic re-design of our *Mediator* prototype system for managing data and knowledge flows in manufacturing throughout the product life cycle (Gaines and Norrie, 1994). KFlow will be open-architecture and support the heterogeneous integration of a wide range of relevant tools available from other research groups and commercial organizations.

The design draws upon experience in using knowledge acquisition and representation tools to model and manage complex projects internationally (Gaines and Shaw, 1994c; Gaines and Shaw, 1994b), visual languages for indexing multimedia databases (Gaines and Shaw, 1994a; Kremer and Gaines, 1994), and tools supporting collaborative writing with distributed authors (Gaines and Malcolm, 1993), multimedia active documents (Gaines and Shaw, 1993; Shaw and Gaines, 1994); and intelligent agent technologies and applications (Kwok and Norrie, 1993b; Kwok and Norrie, 1993a).

Project 3: Distributed Concurrent Engineering and Design
Principal Investigator: P. Gu (University of Saskatchewan)
Co-Investigators: D. Norrie (University of Calgary)
B. Gaines (University of Calgary)

Manufacturing is a major industry sector where high-bandwidth communications can have a major economic impact. The need to base manufacturing operations on computer-supported enterprise models and knowledge-level workflow tools is already accepted (Scheer, 1989; Petrie, 1992). However, current research focuses on materials and information flow, and neglects knowledge-flows between people. Such personal interaction is critical in requirements

engineering and design decision making, and the integration of high-bandwidth multimedia communication is essential to support the management of distributed manufacturing operations.

This project will focus on the support of concurrent engineering and design throughout the product life cycle. Product life cycle design simultaneously considers all life cycle issues at product design stage including functionality, manufacturability, assemblability, testability, serviceability and recyclability. Therefore, decisions must be made collaboratively by experts from all the concerned departments such as engineering design, manufacturing, testing, service and environment (Ishii, 1993; Yan and Gu, 1995). A design proposal is put forward by designers, other team members evaluate it based on each individual life cycle concern. Many decisions have to be made on real time basis. Concurrent engineering design team approach has been recognized as an effective approach to this problem (Chan, Pardasani, Atabakhsh and Graefe, 1993; Hashemian and Gu, 1994). To support such concurrent engineering design, facilities are required to allow team members in different geographical locations to express their opinion or carry out evaluations for the possible design alternatives. Design information, knowledge and decision making process must be completely recorded and processed for the future reuse.

The objective of this proposed research is to demonstrate that product life cycle design can be carried out using concurrent engineering design approach with support of high speed network facilities. The main aims will be to apply the available tools such as groupware and standard toolkits for design activity coordination and management of design knowledge and information. We will work closely with the EnterSim and KFlow projects, and develop extension specifically targeted on concurrent engineering and design.

A design case will be selected; several designers will work on the design project, their communications and decision making will be captured. Design evaluations and review will be modelled with the tools identified. It is expected that results will show that such a design approach will be very useful for large and complex products design that involves many personnel in different locations.

The deliverable will be the methodology of real time concurrent engineering design to product life cycle design, and the demonstration models of coordinated team design activities and design information capture and documentation.

Project 4: Evaluation Test-Beds
Principal Investigator: M. Shaw (University of Calgary)

Evaluation test-beds will be established to support empirical experiments evaluating enterprise

models, simulation results, and work-flow tools. The test-beds will also provide capabilities for rapid deployment and evaluation in workplace applications of diverse technologies from the other major projects and other sources.

The test-beds will be instrumented at both a traffic-flow and a content level (with safeguards regarding privacy and confidentiality). Automated content analysis (Gaines and Shaw, 1994c) and Bales and Cohen's (1979) SYMLOG methodology will be used to model the discourse and coordination processes. Shaw's (1979; 1980) repertory grid and social network elicitation and modeling tools will be used to collect ethnographic data from participants.

The primary deliverables of the evaluation test-beds will be: empirical data validating the enterprise modeling and simulation techniques; empirical data evaluating the knowledge level workflow tools; enhanced requirements specifications for both sets of tools; and the methodology itself as a basis for other test-bed studies by potential users of high-bandwidth communication facilities in the workplace.

A shared goal of the CBAR program is to come up with an application development environment, comprised of an API and a set of tools. This project will work with its counterparts in other Major Projects towards achieving this goal. Specific areas of participation will be in confirmation of reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API followed by the refinement of application requirements and confirmation of the API.

Sub-project A Office-of-the-Future
Principal Investigator: M. Shaw (University of Calgary)
Co-Investigator: L. Katz (University of Calgary)

The office-of-the-future test-bed is targeted on clerical, administrative and middle management functions in organizations re-engineering the processes on a networked basis to achieve flexible and efficient functioning in a rapidly changing environment.

This test-bed is based extending an existing collaboration with the Faculty of Kinesiology where Dr Katz, Dr Shaw and their students and technical staff are developing a faculty-wide administration system using existing TCP/IP applications. In particular, an integrated system for faculty coordination has been developed through an interactive client-server system based on the World-Wide Web HTTP and HTML protocols, and studies are being made of the changing work practices of the faculty based on the new facilities.

The important features of this test-bed are that the Faculty of Kinesiology has major commercial

responsibilities in operating sports and recreational facilities open to the general public. The diversity of its activities provide a microcosm for the requirements of other enterprises. The existing relationships and safeguards relating to privacy and confidentiality allow the test-bed to be instrumented and communication flows and work practices to be studied at a level of detail that would be very difficult with an arms-length, external enterprise.

The Province of Alberta is providing funds for the Faculty to be fibred and for personal computer workstations to be provided for all administrative personnel, including teaching faculty. The Faculty already has major multimedia development capabilities and experience, and is interested in extending the network to incorporate video conferencing to replace face-to-face meetings. This provides an opportunity to experiment with high-volume video traffic using JPEG encoding in a routine workplace environment without the expense of long-distance communications.

The Faculty is able to supply technical staff experienced in high-speed multimedia communications to support installation, maintenance and training. The project will focus on using the Faculty activities as a test-bed to validate the enterprise model and simulation tools, and to evaluate the workflow tools in routine administrative activities.

The size and manageability of this facility may also make it a useful test-bed for some of the other major projects.

Sub-project B Telecollaboration in the Research Workplace
Principal Investigator: M. Shaw (University of Calgary)
Co-Investigators: P. Prusinciewicz (University of Calgary)
W. Remphrey (University of Manitoba)

A major problem for Canada is building critical mass research teams given the low population density and long distances between research locations. This is particularly true in cross-disciplinary research where the probability of relevant collaborators being in the same organization is very low. The research telecollaboration test-bed is targeted on small research teams that are geographically distributed but use telecollaboration to achieve a workplace environment equivalent to that of an integrated laboratory.

It is often assumed that creative research is essentially anarchistic, and that the concept of workflow tools for expediting research is inappropriate. However, there is increasing evidence that research work practices can be modeled (Kim, 1991), and the use of advanced information technology for the systematic acceleration of scientific research was one of the major objectives of Japan's sixth generation computer research program (Gaines, 1986).

It is important in an initial test case of research telecollaboration to work with a research group that has well-defined, cutting-edge research objectives, already uses computers effectively as a major component of the research, and is enthusiastic and informed about the potential of high-speed network to support close collaboration. Such a distributed research team is available in a collaboration on plant biology between Dr Przemyslaw Prusinciewicz, University of Calgary, and Dr. William Remphrey, University of Manitoba. They are working together on a long term study involving computational biological modeling, plant growth simulation, graphical rendering, and comparison with experimentally grown plants, in order to trace the chemical structure of the hormones hypothesized to signal various stages of plant growth. The researchers at both sites have Silicon Graphics workstations with ATM connectivity, and are interested in creating a true telecollaboration in one another's working environments.

Dr Prusinciewicz and his students have already undertaken the development of hypermedia scientific notebooks using active document technology supporting animation and simulation. These techniques will be incorporated in the knowledge-level workflow tools and combined with video-conferencing and telecollaboration tools to provide a detailed instantiation of a scientific workplace of the future.

Research interactions and discourse will be logged and analyzed, and members of the research team will act in the role of participant observers, recording their reactions to the technology, its impact on their research, and defining detailed requirements for research telecollaboration systems.

The researchers in this project are themselves deeply interested in the scientific processes underlying their research program, and wish to see an overt model developed of these processes.

Sub-project C Co-ordination across a Network of Centres of Excellence
Principal Investigator: M. Shaw (University of Calgary)
Co-Investigators: B. Unger (University of Calgary)
P. Gburziinski (University of Alberta)
C. Williamson (University of Saskatchewan)

The problems of critical mass research in Canada have been addressed through government programs such that for Networks of Centres of Excellence. However, these projects establish geographically distributed collaborative research activities without putting in place a technological infrastructure to support it. The project management requirements for large-scale research networks go beyond the telecollaboration model for small teams, and involve overt representation of research objectives and activities (Gaines and Shaw, 1994c; Gaines and Shaw, 1994b) in such a way that the functioning of a large distributed group can be managed as

effectively as if they were at one site. The research coordination test-bed is targeted on large research teams consisting of geographically distributed research groups using a variety of forms of communication to coordinate joint research activities.

Again, it is important that an initial test case is offered the maximum opportunity to succeed by involving a research network where the researchers have a high degree of personal knowledge of, and commitment to, the technologies involved. It is proposed to use the ongoing TeleSim project as a test-bed. This involves researchers at the Universities of Alberta, Calgary and Saskatchewan, has an international link to the University of Waikato, an industry link to Jade Simulations Inc, and has other industry partners. Workstations with ATM links are available at all the project sites, and the project objectives and timescales are well-defined and can be rapidly represented in knowledge-level workflow tools.

This test-bed will be distinguished from the research telecollaboration test-bed by its emphasis on coordination tools for a large-scale distributed project with tight time-scales and major deliverables. It provides a microcosm of typical industrial research activities and of many existing networks of centres of excellence.

Sub-project D Co-ordinating Manufacturing Design, Engineering and Research
Principal Investigator: M. Shaw (University of Calgary)
Co-Investigators: P. Gu (University of Saskatchewan)
D. Norrie (University of Calgary)
B. Gaines (University of Calgary)

Manufacturing is a research area of critical importance to Canada where the problems of distance and critical mass impede research in government, university and industry. In particular it impedes collaboration between researchers in these three sectors. The National Research Council Institute for Advanced Manufacturing Technologies (NRC IAMT) has become very concerned about the need to achieve effective use of manufacturing research resources through telecollaboration, and is consulting with the University of Calgary about establishing high-bandwidth links to IAMT's future location in Western Ontario. Atomic Energy Canada faces problems of coordination between its various sites across Canada, and with its potential customers worldwide. The move towards concurrent engineering and virtual factories in the manufacturing sector is potentially highly advantageous to Canada, but requires a level of proficiency and experience in the use of high-bandwidth communications that is currently lacking.

Dr Gu, Dr Norrie, Dr Gaines and Dr Dagnino from the Alberta Research Council were the Canadian participants in the international Intelligent Manufacturing Systems (IMS) research test case, GNOSIS, knowledge systematization for manufacturing and design, in 1993-94. They

worked with colleagues in 31 other institutions world-wide to develop techniques and tools for managing manufacturing processes throughout the project life cycle. They were responsible for setting up the Internet tools and digital document systems that were used in coordinating the GNOSIS project, and have been asked by Industry Canada to set up similar facilities for all the IMS projects during the full 10-year program commencing in April 1995.

The appointment of Dr Gu to the NSERC/AECL Chair in Advanced Engineering Design at the University of Saskatchewan breaks up the Calgary-based team, but introduces a significant opportunity for a group who have worked closely together, and understand the problems of distance collaboration, to continue joint research using high-bandwidth communications.

This test-bed will link the AED group at Saskatchewan with the DME, KSI and ARC groups in different locations in Calgary, and evaluate the effectiveness of research based on telecollaboration with the past baseline of local collaboration.

Other Test-Beds

Industrial partners have already expressed interest in additional test-bed situations. It is intended to make the test-bed methodologies available to partners together with the enterprise modeling and workflow tools so that empirical data collection can be extended and a wider range of situations investigated. The funding for such additional test-beds will be provided by the partners involved, and the staff of the major project will provide as much support as possible within the scope of the project in exchange for access to the results of the studies.

This mode of operation will leverage the empirical studies while managing the confidentiality and privacy issues effectively.

2.4.4 References

[1] Bales, R.F. and Cohen, S.P. (1979). SYMLOG: A system for the multiple level observation of groups. New York, Free Press.

[2] Bhaskar, R., Lee, H.S., Levas, A., Pétrakian, R., Tsai, F. and Tulskie, B. (1994). Analyzing and re-engineering business processes using simulation. Tew, J.D., Manivannan, M.S., Sadowski, D.A. and Seila, A.F., Ed. Proceedings 1994 Winter Simulation Conference. pp.1206-1213. San Diego, Society for Computer Simulation.

[3] Bridgeland, D. and Becker, S. (1994). A successful strategy for business process reengineering . Tew, J.D., Manivannan, M.S., Sadowski, D.A. and Seila, A.F., Ed. Proceedings 1994 Winter Simulation Conference. pp.1214-1220. San Diego, Society for Computer Simulation.

[4] Chan, A., Pardasani, A., Atabakhsh, H. and Graefe, U. (1993). Concurrent engineering using an enterprise modelling system. Gu, P. and Kusiak, A., Ed. Concurrent Engineering: Methodology and Applications. pp.117-134. Amsterdam, Elsevier.

[5] Conklin, D.W. (1994). Reengineering to Compete: Canadian Business in the Global

Economy. Scarborough, Ontario, Prentice Hall.

[6] Currid, C. (1994). Reeingineering Toolkit. Rocklin, CA, Prima Publishing.

[7] Deming, W.E. (1993). The New Economics: For Industry, Government, Education. Cambridge, Massachusetts, MIT Centre for Advanced Engineering Studies.

[8] ESPRIT Consortium AMICE, Ed. (1989). Open System Architecture for CIM. Berlin, Springer.

[9] Fishwick, P.A. and Modjeski, R.B., Ed. (1991). Knowledge-Based Simulation. New York, Springer.

[10] Furnham, A. and Gunter, B. (1993). Corporate Assessment: Auditing a Company's Personality. London, Routledge.

[11] Gaines, B.R. (1986). Sixth generation computing: a conspectus of the Japanese proposals. ACM SIGART Newsletter 95 39-44.

[12] Gaines, B.R. (1990). Organizational integration: modeling technology and management. Zunde, P. and Hocking, D., Ed. Empirical Foundations of Information and Software Sciences II. pp.51-64. New York, Plenum Press.

[13] Gaines, B.R. and Malcolm, N. (1993). Supporting collaboration in digital journal production. Journal of Organizational Computing 3(2) 195-213.

[14] Gaines, B.R. and Norrie, D.H. (1994). Mediator: information and knowledge management for the virtual factory. SIGMAN AAAI-94 Workshop: Reasoning about the Shop Floor. Menlo Park, California, AAAI.

[15] Gaines, B.R. and Shaw, M.L.G. (1993). Open architecture multimedia documents. Proceedings of ACM Multimedia 93. pp.137-146.

[16] Gaines, B.R. and Shaw, M.L.G. (1994a). Concept maps indexing multimedia knowledge bases. AAAI-94 Workshop: Indexing and Reuse in Multimedia Systems. pp.36-45. Menlo Park, California, AAAI.

[17] Gaines, B.R. and Shaw, M.L.G. (1994b). Knowledge acquisition and representation techniques in scholarly communication. Proceedings SIGDOC'94: ACM 12th Annual International Conference on Systems Documentation. pp.251-260. New York, ACM.

[18] Gaines, B.R. and Shaw, M.L.G. (1994c). Using knowledge acquisition and representation tools to support scientific communities. AAAI'94: Proceedings of the Twelfth National Conference on Artificial Intelligence. pp.707-714. Menlo Park, California, AAAI Press/MIT Press.

[19] Gitlow, H.S. and Gitlow, S.J. (1994). Total Quality Management in Action. Englewood Cliffs, New Jersey, Prentice Hall.

[20] Hammer, M. and Champy, J. (1993). Reeingineering the Corporation. New York, HarperCollins.

[21] Hashemian, M. and Gu, P. (1994). A constraint-based system for product design. Journal of Concurrent Engineering: Research and

[22] Applications in review.

[23] Ishii, K. (1993). Modelling of concurrent engineering design. Kusiak, A., Ed. Concurrent Engineering: Automation, Tools, and Techniques. pp.19-40. New York, Wiley.

[24] Kim, S.H. (1991). A formal model of creative decision making. Robotics and Computer-Integrated Manufacturing 8(1) 53-65.

[25] Kremer, R. and Gaines, B.R. (1994). Groupware concept mapping techniques. Proceedings SIGDOC'94: ACM 12th Annual International Conference on Systems Documentation. pp.156-165. New York, ACM.

[26] Kwok, A.D. and Norrie, D.H. (1993a). Integrating multiple reasoning in intelligent agent

systems. Integrated Computer-Aided Engineering 1(2) 83-90.

[27] Kwok, A.D. and Norrie, D.H. (1993b). Intelligent agent systems for manufacturing applications. Journal of Intelligent Manufacturing 285-293.

[28] Morton, M.S.S., Ed. (1991). The Corporation of the 1990s: Information Technology and Organizational Transformation. New York, Oxford University Press.

[29] Nordhaug, O. (1993). Human Capital in Organizations: Competence, Training and Learning. Oslo, Scadinavian University Press.

[30] Petrie, C., Ed. (1992). Enterprise Integration Modeling. Cambridge, Massachusetts, MIT Press.

[31] Porter, M.E. (1990). The Competetive Advantage of Nations. New York, Free Press.

[32] Scheer, A.-W. (1989). Enterprise-Wide Data Modeling. Berlin, Springer.

[33] Shaw, M.L.G. (1979). Conversational heuristics for eliciting shared understanding. International Journal of Man-Machine Studies 11 621-634.

[34] Shaw, M.L.G. (1980). On Becoming A Personal Scientist: Interactive Computer Elicitation of Personal Models Of The World. London, Academic Press.

[35] Shaw, M.L.G. and Gaines, B.R. (1994). Active documents combining multimedia and expert systems. Proceedings SIGDOC'94: ACM 12th Annual International Conference on Systems Documentation. pp.166-175. New York, ACM.

[36] Unger, B.W., Goetz, D.J. and Maryka, S.W. (1994). The fast parallel simulation of telecommunication networks. IEEE Communications Magazine 52-62.

[37] Unger, B.W. and Lomow, G.A. (1993). The telecom framework: a simulation environment for telecommunications. Proceedings WSC'93, Winter Simulation Conference. San Diego, Society for Computer Simulation.

[38] Unger, B.W. and Zhong-e, X. (1994). The fast parallel simulation of telecommunication networks. Morito, S., Sakasegawa, H., Yoneda, K., Fushimi, M. and Nakano, N., Ed. New Directions in Simulation for Manuafcturing and Communications.

[39] WurcNet (1995). TeleSim Project Plan: ATM-TN System Design. University of Calgary.

[40] Yan, X. and Gu, P. (1995). Assembly/disassembly sequence planning for life cycle cost estimation. Symposium on Life Cycle Engineering, 1995 ASME Winter Annual Meeting. pp.in review.

2.4.5 Milestones

6 months

Project 1
- Well-defined and documented requirements specifications for the enterprise modeling tools; development of preliminary models for each test-bed; prototyping of graphic interfaces to tools.

Project 2
- Well-defined and documented requirements specifications for the knowledge level workflow tools; mock-ups of applications for each test-bed; prototyping of open-architecture framework.

Project 3
- Well-defined and documented requirements specifications for enterprise modeling and workflow tools used to support the effective application of high-bandwidth communications to concurrent engineering and design.

Project 4
- Pre-trial data collection on existing work practice; goal and process identification; user expectation modeling; basic software and hardware for each test-bed installed and tested with existing communication packages.
- Refinement of the application requirements and confirmation of the API for the CBAR application development environment.

12 months

Project 1
- Version 1 of enterprise tools issued internally; models for each test-bed encoded and simulated; user trials commenced.

Project 2
- Version 1 of workflow tools issued internally; objectives, activities and existing materials for each test-bed loaded; user trials commenced.

Project 3
- Version 1 of manufacturing coordination tools issued internally; objectives, activities and existing materials for manufacturing test-bed loaded; user trials commenced.

Project 4
- Re-engineered process models developed for each test-bed activity; user trials commenced in each test-bed situation.

18 months

Project 1
- Feedback from test-bed applications analyzed and requirements specification refined; Version 2 of enterprise tools issued internally and delivered to external partners for productization.

Project 2
- Feedback from test-bed applications analyzed and requirements specification refined; Version 2 of workflow tools issued internally and delivered to external partners for productization.

Project 3
- Feedback from test-bed application analyzed and requirements specification refined; Version 2 of manufacturing tools issued internally and delivered to external partners for productization.

Project 4
- Post-trial data collection on changes in work practice in each test-bed situation; re-elicitation of requirements specification; detailed analysis and evaluation of outcomes.

24 months

Project 1
- Version 3 of enterprise tools delivered including interface to TeleSim; product plan documented for ongoing process of product improvement against expected future requirements.

Project 2
- Version 3 of workflow tools delivered including interfaces to other tools; product plan documented for ongoing process of product improvement against

expected future requirements.

Project 3
- Version 3 of manufacturing tools delivered including interfaces to other tools; product plan documented for ongoing process of product improvement against expected future requirements.

Project 4
- Data collection completed; data analyzed and documented; evaluation methodology fully documented; evaluation methodology assessment and further development documented.
- Demonstration of a workplace of the future application over the ATM network utilizing the coherent common architecture and the API developed in the CBAR program.

2.4.6 Equipment

The objective of this major project is the development and real world testing of system architecture for distributed workplace of the future. The research will be done by setting up evaluation testbeds for the following workplace scenarios:

- Office of the future
- Research collaboration
- Research co-ordination
- Manufacturing

A broadband ATM Network will be an intrinsic part of the testbeds. The projects require ATM switches to be installed in a number of locations. The proposed switch locations, the port size, the interface cards and terminal equipment are given in Appendix I.4.

A network diagram for the major project is shown in figure 5.

Workplace of the Future

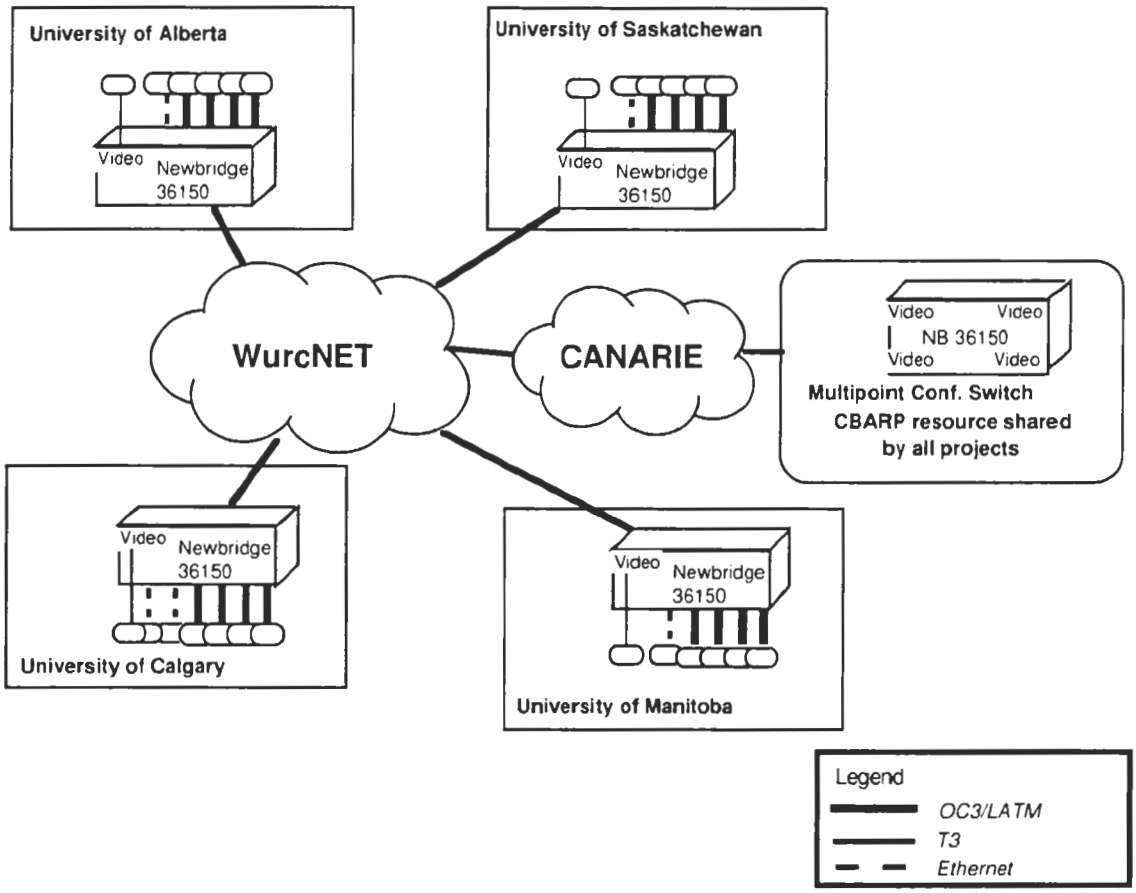

Figure 5

2.5 Distributed Multimedia Digital Libraries
Major Project Leader: Renato De Mori (McGill University)

2.5.1 Objectives

This major project is focused on distributed multimedia digital libraries that will provide easy access to geographically dispersed users through communications networks such as INTERNET and Broadband ATM Networks. The objectives are to investigate key issues related to the representation and access methods for multimedia information. The primary approach would be through rapid prototyping and demonstrators. This Major Project will work with other Major Projects to arrive at a coherent architecture for applications.

A major objectives of this research is to explore novel techniques for multimedia document representation that will be useful both for retrieval and hierarchical abstraction for presentation purposes. The research will encompass representation of different media including integrated multiple media documents.

A second objective is to discover new methods of generating and modelling metadata related to multimedia documents. Information stores (or digital libraries) will contain a very large number of heterogeneous documents. Organization and structuring of such a large collection requires the knowledge of data about data, which is referred to as metadata. The classification methods of conventional libraries are inadequate to deal with image data, video clips, or their structured interactions in multimedia documents. The metadata will be useful to organize the network of digital libraries into hierarchies of directories for the purpose of directing the search to respond to user queries.

A third objective is to develop efficient access methods to the desired information. This will involve several aspects: assisting the user with the help of software agents, in an intelligent manner, in query formulation; design of adaptable user interfaces; translating the queries to be suitable for distributed search over the network of libraries; transportation over the network and presentation at the 'user premise equipment' of the multimedia document or its abstracted document surrogates.

Finally, a prototype system will be built to demonstrate the concepts researched for the distributed multimedia library.

2.5.2 Background and rationale

ARPAnet, the first scientific computer network was launched in 1969. Thanks to the scientific and technological development since then, digital libraries are now feasible [10]. Today, about a million US scientists and engineers are engaged in some $100 billion USD in R&D publishing in over 2000 science journals. Easy, on-demand availability of information is now a feasible and challenging concept.

Hardware advances in communications and networking have led to increasingly fast transmissions over copper wire, coaxial cable and optical fibers.

The ARPAnet led to the INTERNET which serves perhaps 20 million users and to the emerging Education Network which will run at gigabit per second speed.

This growth in usage reflects a steady progression to end-user computing and support of increasingly effective user-interfaces. On-line access has gone from time sharing systems to client interfaces on personal workstations. For the latest clinical information, medical practitioners can use "The on-line journal of current clinical trials" prepared by the American Association for the Advancement of Science and the On-Line Computer Library Center.

Efforts have focused on enhancing the quality and quantity of information available over networks.

Recently, six research projects have been funded in the US by the National Science Foundation (NSF), the Advanced Research Project Agency (ARPA) and the National Aeronautics and Space Administration (NASA). Their focus is advancing the means to collect, store and organize information in digital form and make it available for searching, retrieval and processing via communication networks in user-friendly ways.

Some of the interesting problems on which researchers are working now are:

- representation of documents which may contain text, image and audio components. Database organization and access.
- automatic extraction of document metadata for retrieval purposes, with particular emphasis on robust recognition and retrieval of certain classes of information characterizing collection topics.
- document management, automatic annotation to generate metadata, especially based on combination of visual and acoustic features.
- document presentation.
- communication and negotiation models.

- search of compressed representations in distributed archives. Search for new representations that facilitate efficient semantic or perceptual searching.

In the Canadian context, interesting results on various aspects of distributed databases have been obtained by other projects of the Canadian Institute for Telecommunications Research.

Bunyip, a company started by McGill students and internationally known now for its product ARCHIE, will provide assistance to the organization and retrieval of multimedia documents.

The applicants have experience on various aspects of information representation and search and are actively involved in research on the above mentioned problems. Several applications will be developed in such areas as news and music libraries. A prototype will also be developed showing the possibility of integrating video, graphics, text and acoustic documents. The possibility of integrating existing information sources and databases will be seriously pursued in collaboration with organizations in the information sector.

2.5.3 Research plan

The research will involve five projects.

The first project builds on existing strength at the University of Waterloo in document representation and search. It considers textual metadata for multimedia documents and its use for classification and retrieval from autonomously-controlled, diverse and heterogeneous collections.

The second project explores the area of acoustic documents in which little has been done so far (noticeable exceptions are the MIT media lab and Cambridge University in the UK). The project is based on previous work on music representation in computer form and on speech analysis and recognition. It will involve the faculties of Music and of Engineering at McGill University. The project will also benefit from the experience of Bunyip.

The third project will mostly focus on metadata for graphical and video information. It is built on past experience on object-oriented databases and will involve competence in information systems as well as library systems.

The fourth project is based on previous experience on distributed artificial intelligence and will address the problems of user interfaces and knowledge-based search in distributed information repositories.

The fifth project will focus on the development of a common prototype demonstration system.

In collaboration with the other projects, it will define the system architecture and interfaces between the different components developed by the other projects. It will also coordinate the development of a common template for metadata suitable for all the different types of information (text, visual and acoustic). The project will also investigate the automatic construction of an abstracted view of a database and all the documents contained in it. Finally, multi-lingual document retrieval will be investigated.

Figure 6 shows the logical architecture of a hierarchical, distributed multimedia library system and indicates the areas covered by the different projects. The projects are further described below.

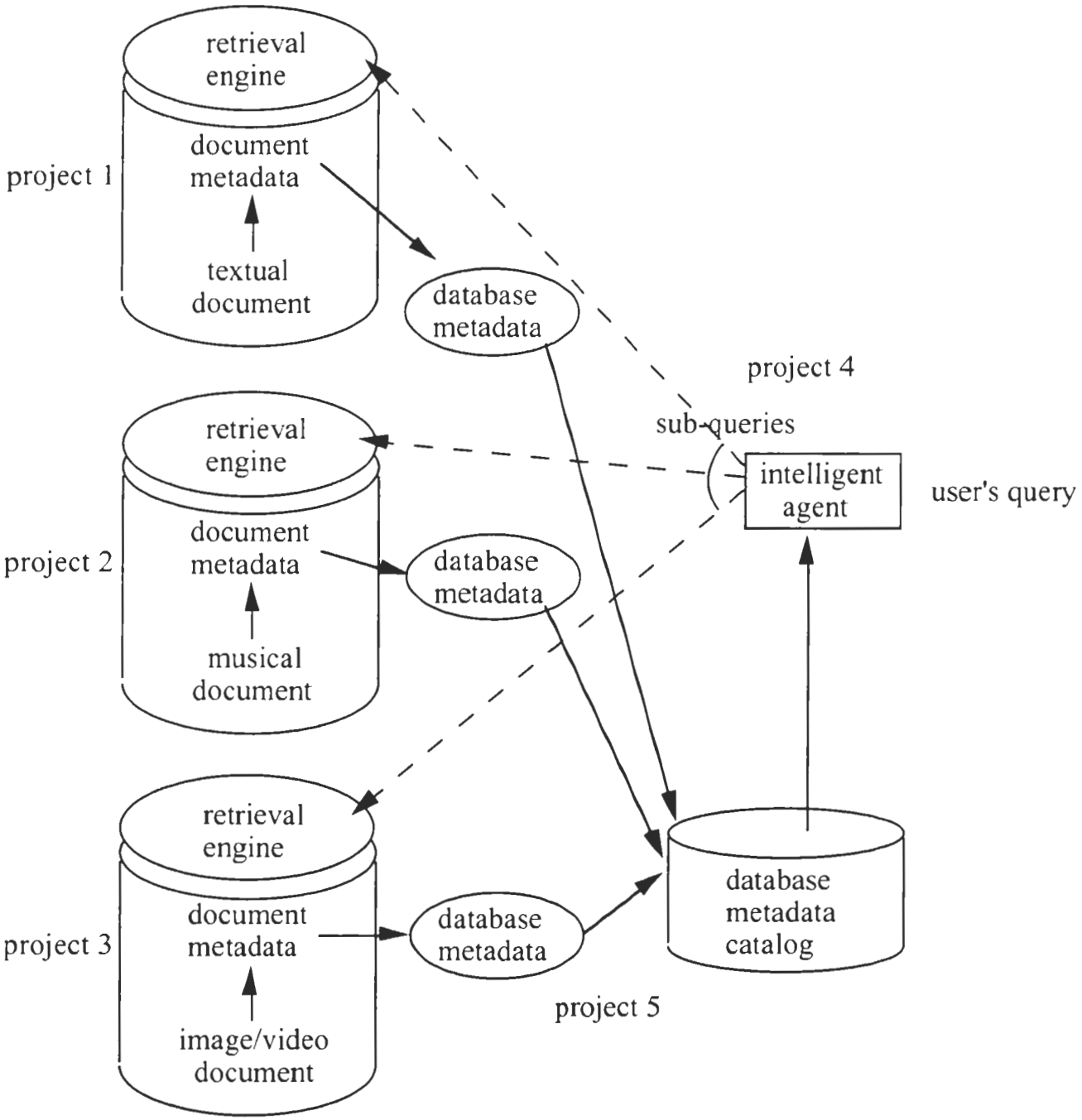

Figure 6

Project 1: Exploitation of structured text metadata for document retrieval
Principal Investigator: F.W. Tompa (University of Waterloo)
Co-Investigator: M. Consens (University of Waterloo)

The focus of this project is to explore the benefits to be gained by representing metadata as structured text, searchable by hybrid text-and-relational retrieval engines [1]. The project builds on previous work in structured text retrieval, with particular attention placed on retrieval from

multimedia digital libraries connected by high-bandwidth communications channels.

The architecture envisioned includes structured text retrieval engines deployed at several sites as part of the indexing component of advanced resource discovery architectures (such as those proposed by WHOIS++ [9] and Harvest [2]). An extremely heterogeneous environment is assumed: autonomous agencies define idiosyncratic templates, both in form and in choice of field names, for storing metadata describing complex documents covering multiple media. For example, there are today 70 Harvest brokers, each offering pointers to information gathered from the INTERNET and ranging from collections of WWW home pages to a database of Security and Exchange Commission filings to a collection of pages describing AT&T 800 information services. Each broker characterizes data according to different attributes: from title, headings and keywords in one to company-name in the second to phone-numbers in the third.

An ideal system will support a flexible metadata format, which does not involve a globally agreed-upon schema. Metadata is structured: templates for storing metadata have attributes and may themselves be nested. Many attribute values are textual (although other types may be present as well). The extraction or creation of metadata, whether by automatic or manual means, is not a focus of research within this project (but see projects 2 and 3 below); however we will work with others to define useful templates that include highly structured information fields and to define an application program interface to access metadata stored as structured text. The resulting infrastructure will provide scalability in terms of sites, data volume, and heterogeneity of the document collections.

Beyond defining prototypical templates that include highly structured metadata, an important goal of this project is to support searching in a heterogeneous environment without increasing the complexity of the retrieval process from the user's point of view. Users will continue to issue simple queries. Agents incorporating user models, such as developed in project 4 below, will then refine the queries to reflect the users' information needs in context. Next, these queries will be distributed to selected indexing sites, using, for example, site selection techniques developed in projects 4 and 5 below. Especially when resource discovery is a goal of querying, many heterogeneous collections will be included in the selected set of sites. Each of the chosen indexing sites will then be responsible for refining basic user queries into more complex expressions that make use of the additional structure and specific vocabulary known at a given site. Algorithms for data-driven query conversion will be developed as part of this project. To preserve generality, it is expected that query refinement will involve negotiation protocols between sites. This approach supports large-scale diversity by translating general requests into structured queries that make use of specific knowledge of topical collections at each one of the

sites.

The main objective of our research is to increase the richness of the answers returned by the resource discovery system. Currently deployed and proposed systems (such as WAIS, WHOIS++ [9], Harvest [2], MIT's Content Routing Servers [19]) typically return a set of pointers to document fragments that are considered relevant to a user's request for information. Thus, for example, a naive request to find information about AT&T sent to the 70 existing Harvest brokers will return pointers to every page in the AT&T 800 information services collection (since AT&T appears in every value of the gatherer-name attribute for summaries in this site), burying in the noise those pages that really deal with AT&T information. Instead of returning a flat set of references, we propose that each site performs two additional steps. First, sites should appropriately package the information to be returned into meaningful units (using the additional structural information available to a given topical collection). For example, matches can be clustered into those that are likely meaningful (eg, "company-name = AT&T" in one database, "title contains AT&T" in another, etc.) and those that are less informative. Second, individual indexing sites should provide not only references to data, but they should also return more detailed metadata that characterize the features of the information units found to match. For example, additional summary information (eg, the number of hits and the names of attributes containing the most significant data) can be provided for each cluster. With this approach, data characterizations known to parts of the system can be conveyed to the user so that richly varied information sources can be fully exploited.

The research results will include the design and implementation of prototypes for two software components: (1) tools to build customized agents that serve as front ends to indexing sites and perform query rewriting and result summarization specifically tailored to the data collection at that site; and (2) back ends for clients or metadata servers that can process summary relations that include structured text (see project 5).

Project 2: Acoustic and Music Libraries in Internet Directory Services
Principal Investigator: R. De Mori (McGill University)
Co-Investigator: B. Pennycook (McGill University)

The goal of this research is to explore indexing and retrieval of audio documents in the distributed environment provided by a high-speed communications network. This research will yield a prototype server of audio documents for specialized audio queries, as well as metadata descriptions of audio documents.

Current focus in Internet information indexing is largely on textual (ascii) information -- text documents (marked up in SGML, HTML, or otherwise), textual templates describing non-

textual information (eg, ascii-tagged documents).

There is already much demand for access to audio material on the Internet (several popular music distributors have established an Internet presence by describing their products on World Wide Web homepages). Research in the area of audio documents should extend to determining features that characterize audio documents and appropriate indexing structures to allow sample-based retrieval of audio documents. This work will first focus on musical data, and extend to speech documents.

Although there has been work done in some areas of audio document manipulation (eg, [17] - segmenting musical MIDI signals, [16] - similarity measurement mechanisms for music, and [8] - timbral classification), most work has focused on musical accompaniment or composition. Previous work that has specifically addressed issues in multimedia document indexing has dealt primarily with non-musical media (eg, [22] - indexing and retrieval of facial photographs). The synthesis of these approaches into a system that would allow similarity-based retrieval of music is in itself pioneering work.

In general terms, the planned research will proceed through determining a useful and usable music indexing and retrieval structure, finding a suitable resource directory services architecture for the server, and exploring applications in indexing and retrieving speech documents.

Music retrieval

In the realm of music retrieval, retrieval by form has been achieved in some sense. The system described in [15] matches signals (fragments of music from radio broadcasts) against a database of known songs. It can therefore identify individual renditions of particular musical pieces. However, this does not solve another common music retrieval task, namely, rendition-independent retrieval of music. There is need for a mechanism that supports the matching of a small segment of music specified (eg, by performing it) by a user against a large body of music performed in different arrangements, stored in different formats, etc. Since this is independent of signal mode (ie, score, audio, MIDI), it is not retrieval by form. Instead, it can be described as retrieval by similarity.

The retrieval is neither purely based on the search fragment signal, nor does it attempt to fathom semantic implications from the performance of the presented string.

The music server will maintain several different indexes -- each feature is considered separately in the indexing process. This allows maximum flexibility in matching a retrieval fragment against the database since it means that each feature can have its own comparison mechanism or

similarity metric.

Research efforts will focus on identifying features that will yield maximum effectiveness and efficiency in retrieval, as well as determining an efficient indexing structure.

Speech documents

Another important step will be the extension to include speech documents in the audio document index structure developed for music. The same approach of analysis and indexing developed for music documents can be used. The analysis work can draw on experiences of general speech recognition tasks, and the indexing techniques will likely be a hybrid of traditional text indexing (eg, as in [4]) and the music audio indexes.

Audio Document Server

WHOIS++ ([9]) is designed to be a distributed directory service, with a novel and efficient indexing architecture for rapid search, and the ability to serve many needs through the use of attribute-value 'templates' which can hold many types of information. WHOIS++ will first be explored as the most likely candidate directory service architecture, with the expectation that the prototype audio document server will be integrated into a WHOIS++ resource directory. This server will be accessible to the integrated demonstration system for specialized queries. Designing the audio metadata template as an extension of the common metadata template developed under coordination of project 5, these audio documents should be accessible from the common demonstration prototype.

Project 3: Classification and Indexing for Visual Documents

Principal Investigators: **R. Godin (Université du Québec à Montréal)**
B. Kerhervé (Université du Québec à Montréal)
Co-Investigator: **J. Turner (Université de Montréal)**

The objective of this project is to explore classification and indexing for visual documents in the context of digital libraries. The general goals are: (1) to specify metadata for visual documents, (2) to propose methods for digital media classification and indexing combining textual and visual descriptions, and (3) to integrate classification and indexing strategies as well as search strategies in an environment allowing sharing and re-using of existing metadata.

Libraries of the future will integrate different types of data, such as texts, graphics, images, video and audio, in multimedia information systems [10]. Typically such systems must manage a very large amount of data, coming from different sources and generally stored in distributed databases. Potential users of such systems require efficient access to pertinent information using appropriate retrieval strategies. Images and videos in digital form are unstructured and

voluminous, and they also lack the alphabet which makes text searching possible. Due to these particularities, there is an evident need to investigate various issues in order to offer methods for digital media classification and indexing. The first issue to be resolved is to define abstractions of raw data through the description of metadata, ie, data about data [26]. Such abstractions can be textual descriptions of the content as well as the association of visual elements to digital media. The second issue deals with the organization of these descriptions and their combination to offer various search strategies. The third issue concentrates on the efficient storage and access of this metadata in a persistent environment provided by database systems, in order to permit sharing and re-using of existing descriptions.

This project proposes to address these three different issues for still images and videos. This work will be done in the context of a real application where image indexing and classification is required. We aim at proposing indexing and classification techniques combining textual and visual descriptions by the use of a visual dictionary as a front end to the image collection. We will investigate management, access and sharing of these descriptions through the specification of a coherent template for metadata. This template will be designed in order to be integrated within project 5, where metadata for other media will be considered. An application program interface will be designed to provide access to metadata for images and videos. Search strategies will be integrated in the multi-agent architecture provided by project 4.

Multimedia data presents a new set of problems in indexing because of the simple, but revolutionary fact that still image, sound, and video data do not contain text which can be filtered by algorithms in order to derive keywords and meaning, which allows the application of automatic indexing and classification techniques [27]. Yet for the purpose of storage and retrieval, words are always associated with still and moving pictures and with sound material. One of the important reasons for this is that users looking for such material in information systems almost invariably arrive with a verbal request.

Some experimental research into using visual elements to retrieve pictures has been undertaken [25] and has met with some success. However, the general conclusion that can be reached from this work is that, while other types of access than strictly verbal access to multimedia information objects may be desirable in some circumstances, it is neither possible nor desirable to eliminate textual indexing of non-text information objects. We propose to investigate the specification of metadata by linking textual representations of indexing concepts with pictorial representations of the concepts in a classification scheme showing whole-part relationships. This approach allows users to use words and pictures together in order to retrieve visual information objects.

Metadata for classification and indexing will be studied to support querying and browsing of images represented by concepts and taxonomical relations between the concepts. The metadata are the result of automatic conceptual clustering of the texts and images using the basic content representation.

Management of the persistent object environment will be conceived by storing, in an object-oriented database system, metadata for classification and indexing. This part of the research deals with the representation, storage and access of metadata and with the efficient interaction with the database system.

Project 4: Intelligent Agents for User Interfaces
Principal Investigator: T. Radakhrishnan (Concordia University)
Co-Investigator: R. Shingal (Concordia University)

There are two goals to this project. One is to investigate the potential use of agent-based support for user accesses to digital libraries, and the second is to design and implement a user interface to a prototype multimedia digital library. By the term "agent", we refer to a software system realized in the form of an object following the principles of object oriented paradigm. An agent contains some domain specific knowledge encapsulated and stored explicitly. This knowledge can be validated, verified, incrementally updated or maintained. We envision two types of agents in this context: (1) a user agent, supporting the user who performs information retrieval tasks, and (2) an agent playing the role of a reference librarian and assisting in the translation of user queries into a set of sub-queries to be searched in a distributed database of the library network. Much of the work reported in the literature on user modelling has been concerned with modelling at the individual task or keystroke levels [3]. For our research, we wish to model the user interactions as a set of coordinated tasks; in performing of these tasks, the user will be possibly supported by several agents. During the query formulation, for example, the user agent and the query transformation agent may communicate with each other in assisting the user. In another context, one user agent may communicate with another user agent in the network (to which permission is given) in order to enrich the information contained in the query. Thus, several agents will interact and cooperate with each other.

In the context of a user accessing a distributed digital library, we envision a typical scenario as follows: The user will interactively formulate a query. In query formulation, the user may use multiple media [23]. The query may be inexact and incomplete when formulated initially. The cycle of tasks - specify a query, look at the response, and reformulate the query - may be repeated several times. A software agent will assist the user in these tasks. The query so formulated will be transformed into a set of sub-queries, each of which may be processed at

different sites in the network, possibly concerning different media types. The query transformation will be assisted by another type of agent that contains relevant knowledge about the data distribution in the network, metadata about media objects, indexing and cataloging. The partial responses obtained for sub-queries at different sites will be transported to the user's site, and presented in an easily understandable manner. While considering multimedia documents, synchronized presentation of the retrieved (continuous media) information for interactive perusal is a non-trivial task. Some work on these presentation issues is also planned under this project.

User modelling and multiple agents interacting with each other in the context of distributed AI are two topics of current research [24]. In the area of user modelling, this project will advance the field of research by considering the problem of modelling a user who performs multiple and coordinated tasks. This is one of the areas in user interface design not well addressed in the literature. In the context of multi-agent communication, this project will investigate specific issues pertaining to digital libraries, such as the effective use of metadata and the user profiles of fellow workers to improve the retrieval performance measures (recall and precision).

In the first year of research, we propose to test our user interface and the agent support using the prototype system developed by the Broadband Services group for News on Demand application. Once the different media servers (text, audio, video & image) are available, the network details are known, and the ATM network is in place, we will work with other groups to link the user interface subsystem with the other subsystems of the overall project.

Project 5: System Integration
Principal Investigator: J-Y. Nie (Université de Montréal)
Co-Investigators: G. v Bochmann (Université de Montréal & CRIM)
M. Desmarais (CRIM)

The main objective of this project is to ensure the integration of the different components which relate to the different projects, into a coherent demonstration system. A shared goal of the CBAR program is to come up with an application development environment, comprised of an API and a set of tools. This project will work with its counterparts in other Major Projects towards achieving this goal. Specific areas of participation will be in confirmation of reference architecture, selection of document architecture, tools, and hardware/operating systems platforms, identification of application requirements, and initial definition of the API followed by the refinement of application requirements and confirmation of the API.

An overall system architecture and an application will be developed based on precise definitions of the interfaces between the different components provided by the other projects. A

distributed implementation environment and related communication protocols will be selected in considering the requirements of the other projects. As a starting point for the environment into which the results of the research projects should be integrated, we plan to use the news-on-demand prototype system developed under the CITR Broadband Services' Major Project. This prototype system demonstrates remote access, over ATM, to multimedia news stored in an object-oriented database and real-time file servers, which are used for the time-critical audio and video information. Research results generated on metadata, query processing and user interfaces in our library project will be incorporated into the prototype for the final demonstration.

In order to ensure an easy integration of the entire project in a demonstration system, we will start with the assumption that, although the document structure is different for each media type, there is a basic document metadata template common to all media types. This common template will allow the representation of common metadata and corresponding searching operations on all documents, irrespective of the media type and of the searching requestor. During the first year, a simple version of such a common metadata template will be elaborated in collaboration with the other projects. We will also review, in collaboration, the existing systems (for example WHOIS++) in order to determine whether they could be used to store the metadata which are required by all the projects involved. We keep in mind, however, that documents in different media may indeed have different features which cannot be represented within a completely uniform template. Thus, a proposal for, and possibly an implementation of, a richer and more flexible version of a metadata structures will also be elaborated in collaboration with the other projects.

Due to the distributed characteristics of the library project, it would be useful to have a global catalog which contains information about the features (eg, main topics) of different databases; we call such information database metadata. A catalog of database metadata will allow users, or retrieval agents, to determine the best candidates of databases to be searched [6], as required in project 4. Research in this project will address the questions of how to automatically extract representative database metadata from the document metadata included in a database, and how to allow the retrieval agents to use such database metadata. For simple versions of document metadata templates, the extraction may use a method similar to term clustering. The database metadata extracted in this way are highly structured and possibly in a textual form; therefore the structured text retrieval engine developed in project 1 may possibly be used for the querying of catalogues of database metadata. For a richer document metadata structures, more characteristics of different media types will be considered in the extraction and accordingly, a more complex querying method may be needed. The database metadata may also be useful for

the specialization of queries, as investigated under project 1.

Finally, we will also study how multilingual querying support can be provided to libraries. The objective here is to make it possible to use English queries to retrieve information from a French database, and vice-versa. For this purpose, we will integrate a bilingual thesaurus (eg, TERMIUM, BTQ) into the system in order to translate either document metadata or queries from one language to another.

2.5.4 References

[1] Text/Relational Database Management Systems: Harmonizing SQL and SGML, Blake, G. and Consens, M. and Kilpelainen, P. and Larson, P. and Snider, T. and Tompa, F., Proceedings of the ADB'94 Conference, June 1994.

[2] Bowman, C. and Danzig, P. and Hardy, D. and Manber, U. and Schwartz, M. Harvest: A Scalable, Customizable Discovery and Access System, University of Colorado Technical Report CU-CS-732-94, 1994.

[3] D. Browne, P.Totterdell and M.Normam, Adaptive User Interfaces, Academic Press, 1990.

[4] Bruza, P. D. and T.P. van der Weide, The Modelling and Retrieval of Documents using Index Expressions, SIGIR FORUM, Fall 1991.

[5] Special Issues on Hypermedia, Communications of the ACM, vol. 35, no. 1, January 1992 and Communications of the ACM, vol. 37, no. 2, Feb. 1994.

[6] [Cailliau, R., ed., Selected papers of the First World-Wide Web Conference. Vol. 27, Computer Networks and ISDN Systems, 1994.

[7] P.G.Chander, R.Shinghal, and T.Radhakrishnan, Static determination of dynamic functional attributes in rule based systems. in Proc. of 7-th International Conference in Systems Research, Information and Cybernetics, Baden, Germany, pp 79-84 August 1994.

[8] Cosi, P., G. De Poli, and G. Lauzzana, Timbre Classification by NN and Auditory Modeling Proceedings of ICANN'94 (International Conference on Artificial Networks) Ed. Maria Marinaro and Pietro G. Morasso, May, 1994.

[9] Deutsch, Peter, Rickard Schoultz, Patrik Faltstrom and Chris Weider, Architecture of the WHOIS++ Service, IETF Draft, July 1994.

[10] E. A. Fox, Digital Libraries, IEEE Computer, Nov. 1993, pp. 79-80.

[11] Froehlich, Thomas J., ed. Special Issue on Relevance. 3 vols. Vol. 45: Journal of the American Society for Information Science, 1994.

[12] H. M. Gladney, Data Replicas in Distributed Information Services. ACM Transactions on Database Systems. vol. 14, no. 1, 1989, pp. 75-97.

[13] Gray and A. Reuter, Transaction Processing: Concepts and Techniques. Morgan Kaufman, 1993.

[14] Special issue on Document Image analysis Systems. IEEE Computer, July 1992.

[15] Lubman, Sarah, "Adapting Skills From Cold War To 'Hear' Music", Wall Street Journal, Friday, July 8, 1994.

[16] Opren, Keith S., and David Huron, Measurement of Similarity in Music: A Quantitative Approach for Non-parametric Representations Computers in Music Research, Volume IV, Fall 1992.

[17] Pennycook, Bruce, Dale R. Stammen, and Debbie Reynolds Toward a Computer Model of

a Jazz Improviser Proceedings of the International Computer Music Conference, ICMC'93.

[18] Pozzi S. and Celentano A., Knowledge-Based document filing, IEEE Expert, vol. 8, no. 5, Oct. 1993.

[19] Sheldon, M. and Duda, A. and Weiss, R. and O'Toole, J. and Gifford, D., Content Routing for Distributed Information Servers Proc. of the 4th Intl. Conf. on Extending Database Technology, March 1994.

[20] G.A. Story, L. O'Gorman, D. Fox, L.L. Levy Schaper, H.V. Jagadish The RightPages Image-Based Electronic Library for Alerting and Browsing. IEEE Computer, Sept. 1992, pp.17-27.

[21] Weider, Chris, Jim Fullton and Simon Spero, "Architecture of the Whois++ Index Service", IETF Draft, July 1994.

[22] Wu, J. K., Y. H. Ang, P. Lam, H. H. Loh, and A. Desai Narasimhalu Inference and retrieval of facial images Multimedia Systems, June, 1994, Vol. 2 No. 1.

[23] Yoshitka.A, S.Kishida, M.Hirakawa and T.Ichikawa, Knowledge Assisted Content Based Retrieval for Multimedia Databases, IEEE Multimedia, Winter 1994, pp 12-20

[24] Sullivan.J.W and S.W.Tyler. Intelligent User Interfaces, ACM Press Frontier Series, 1993.

[25] Besser, H. (1990). Visual Access to Visual Images: the UC Berkeley Image Database Project. Library Trends, 38, 4 (spring) , 787-798.

[26] Klas, W., & A., S. (1994). Metadata for Digital Media: Introduction to the Special Issue. ACM Sigmod Record, 23, no 4 (december 1994) , 19-20.

[27] Turner, J. (1994) Determining the Subject Content of Still and Moving Image Documents for Storage and Retrieval: an Experimental Investigation. Toronto.

2.5.5 Milestones

6 months

Project 4
- Development of a user model for accessing a multi media library.

Project 5
- Preliminary design of prototype demonstration system including architecture, common software infrastructure and interfacing between modules from different projects.
- Refinement of the application requirements and confirmation of the API.
- Identification of common metadata template (in collaboration with other projects).

12 months

Project 1
- Development of a prototype indexing subsystem (within the framework of an already deployed resource discovery tool) that makes use of a structured text database completed.
- Simple query translation into structural queries demonstrated.

Project 2
- Prototype music index archive for sample-based retrieval of music completed.
- WHOIS++ architecture modified to accommodate multimedia data and sample-based retrieval in the networked environment.

- Metadata for music documents defined and extracted.

Project 3
- Development of an image classification tool prototype interconnected with an object-oriented database management system completed.
- Specification of the API for access to metadata for still images.

Project 4
- Prototyping of the user model and interface on a multimedia platform.
- Validation of the new model by accessing a simulated library or multimedia database using prototype interfaces.

Project 5
- Initial prototype demonstration (including preliminary database catalogue, multilingual retrieval).
- Identification of enlarged system architecture for final prototype.

18 months

Project 2
- Metadata for spoken documents defined and extracted.

Project 3
- Prototype extended with the integration of a visual dictionary.

Project 4
- Agent-to-agent communication and negotiation demonstrated.

24 months

Project 1
- UI for queries against the extended indexing engines, returning semantically richer answers demonstrated.

Project 2
- Prototype spoken document index archive completed.
- Integration of the audio document index findings into an INTERNET resource directory service to provide a prototype document server.

Project 3
- Extension of the initial prototype with image indexing structures.

Project 4
- Evaluation experiments of the user interface and the user models completed.

Project 5
- Final prototype demonstration over the ATM network utilizing the coherent common architecture and API.

2.5.6 Equipment

The availability of ATM test equipment at all locations will greatly enhance research progress. For each constituent project, it is crucial that an ATM test bed is available locally to test the system component being developed. Since we have adopted a client server model for our distributed applications, our test bed must consist of servers and client machines. We thus request OC3 and LATM interface cards for client and server connections as indicated in Appendix I.5.

The major project is concerned with distributed multimedia applications. The requested JPEG cards will provide a facility for presenting a video document, with synchronized audio, to the

end user. A related usage of these JPEG cards is video conferencing. The major project plans to use video conferencing for conducting meetings and research discussions. The network diagram for the major project is shown in figure 7.

Multimedia Digital Libraries

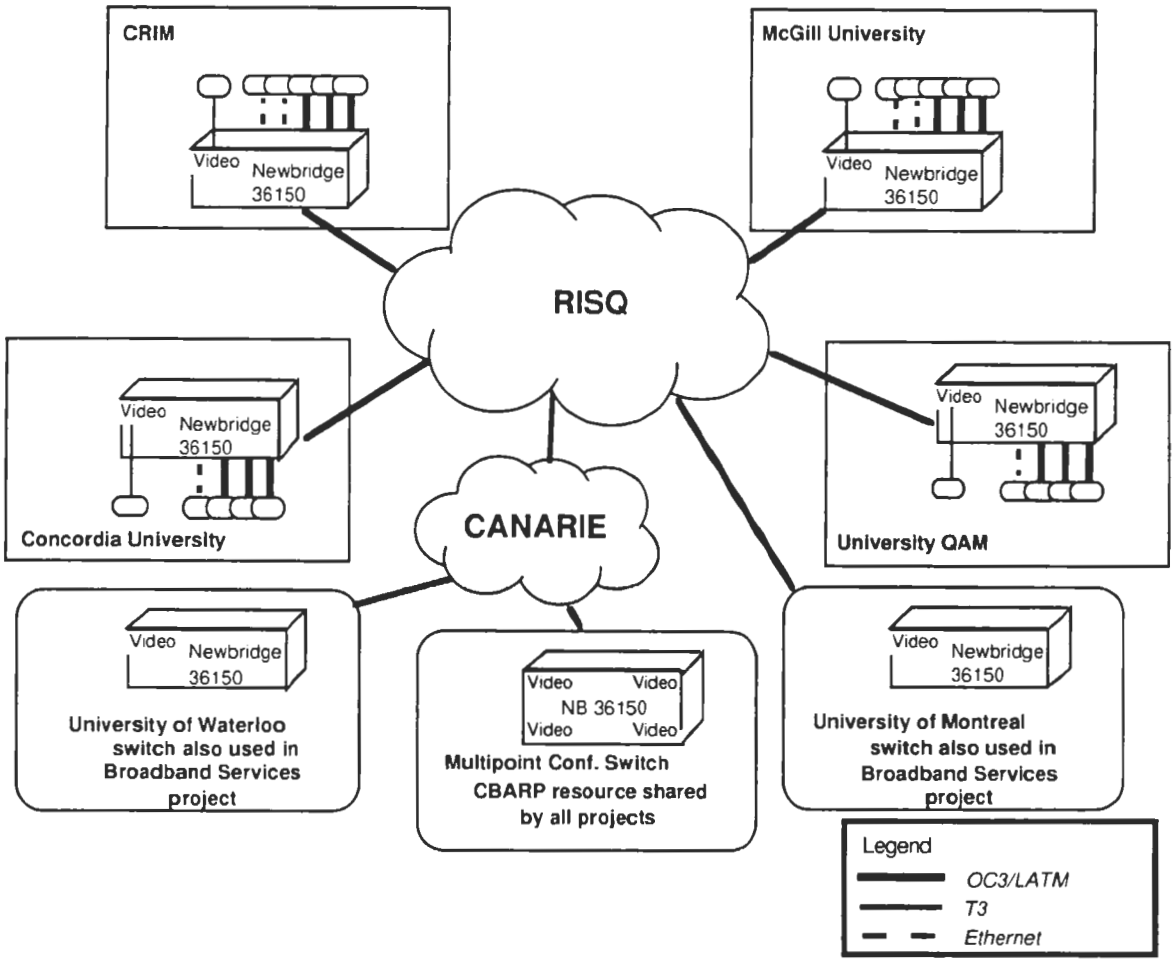

Figure 7

3 Network Management

3.1 Introduction

The idea of creating a national program devoted to research on broadband applications over ATM networks was first advanced by Newbridge Networks Corporation in the summer of 94. The company offered nearly $4 million of ATM switching equipment to get the program off the ground, and recruited six major Canadian organizations, each with a mandates to promote university-industry collaborative research, to participate on an Advisory Committee for the program. Members of the Committee represent the following organizations:

- Canadian Institute for Telecommunications Research (CITR)
- Telecommunications Research Institute of Ontario (TRIO)
- Information Technology Research Institute of Ontario (ITRC)
- Centre de recherche informatique de Montreal (CRIM)
- TR Labs
- Advanced Systems Institute of British Columbia (ASIBC)

CITR was selected to organize and manage the program since, as a federal Network of Centres of Excellence in telecommunications, it had the mandate to operate in all parts of the country. The Advisory Committee selected the Major Project Leaders, ensured appropriate research participation from different parts of the country, and assisted in attracting funding from regional sources.

3.2 Program Planning and Organization

The challenge in managing this program is to channel the efforts of a large number of excellent researchers, distributed across the country, into selected areas of activity that, in time, can enhance the competitiveness and productivity of both the private and the public sector. Since CITR faces the identical challenge, we adopted many features of its planning and management processes in building CBAR (Canadian Broadband Research Applications) program.

We have divided the research program into a number of large projects that demand a team effort. We refer to them as 'Major Projects' and reserve the term 'project' for the components of a Major Project. The research objectives of a Major Project have sufficient scope and challenge to require a solid collaborative effort of perhaps four to six principal investigators. Each principal investigator leads an individual project with clearly defined deliverables toward the

shared goals of the Major Project. In this way, we expect a Major Project to attain larger, more significant goals than can be achieved through more traditional programs.

Each Major Project is led by a strong academic researcher who provides the leadership necessary to ensure successful completion of the research. The leader holds the planning and operations responsibility for the research, and has the authority to select, recruit and organize the research team as well as the responsibility to ensure appropriate coupling to industry and/or a user community.

The management strength of a Major Project is enhanced by the appointment of a co-leader either from industry or the user community. The co-leader normally has complementary management and technical skills, and works for an organization that has a strong interest in the Major Project. In addition, we plan to appoint an Advisory Committee (we refer to it as an Area Committee) to each Major Project, made up largely of experts from industry and the user community, to oversee research progress and aid the planning of future program changes.

Newbridge Networks Corp. provided industrial input to the planning of all of the Major Projects. As well, considerable care was devoted to establishing working relationships with other organizations and/or programs that could strengthen the CBAR program (see Section 4). From the outset, it was our intention to fold into this program other relevant research activities that were in the planning stage around the time Newbridge proposed the CBAR program so that we may create a stronger, more focused Canadian research effort. The largest of such programs was the CITR research activity in Broadband Services which was organized in close collaboration with IBM Canada and a number of other companies. The severe cutback in NCE funding placed its funding in jeopardy beyond 1996; thus, by integrating it into the CBAR program, the research can flourish and provide important component of base technology to the other parts of the CBAR program. The planning process also integrated pertinent activities of the new Centre of Excellence in Tele-Learning which was recently established by the NCE program under Professor Tom Calvert of Simon Fraser University. This linkage is mutually advantageous and offers an important opportunity to integrate tele-learning and broadband technology research.

Appropriate working relationships have also been created with five regional broadband ATM networks (Rnet, WurcNet, LargeNet, OCRInet and RISQ) and CANARIE. These will permit the CBAR program researchers to communicate with one another at speeds up to video rates. The regional networks have agreed to provide free access to CANARIE gateways and CANARIE has waived communications charges between gateways as long as we respect test network regulations.

3.3 Program Management

Dr. Birendra Prasada, Vice President of CITR, will be responsible for managing the program and providing the leadership necessary for it to succeed. He is ideally suited to this task since he has held important R&D management responsibilities at BNR Ltd. in the area of multimedia technology/services for many years prior to his recent retirement. He also has considerable experience in academia including expertise in university-industry collaboration. A brief summary of Dr. Prasada's background is presented in Appendix 2.

The CBAR program involves 65 professors at 20 different universities and is designed to collaborate with a number of industrial companies and a diverse user community. Our objectives can only be met if we motivate the researchers to work together effectively. Dr. Prasada will work closely with the Major Project Leaders in building the teamwork needed to carry out the research and exploit the synergy between Major Projects. We plan on using a number of mechanisms to achieve this goal including:

- holding two meetings of all the investigators in the 'research network', one at the outset of the program to exchange information and identify specific linkages for building synergy between Major Projects, and a second, about one year later, to review progress with representatives of industry and the user communities.
- holding regular meetings of Major Project leaders to share research experiences and results on key issues such as robustness, scalability and technology transfer strategies.
- establishing electronic linkages, including multi-point video communications, between researchers for both research management and technology interaction purposes.
- providing a specific budget item in each project to cover the cost of networking between researchers.

3.4 Program Administration

CITR will be responsible for the administration of the CBAR program which includes the financial administration of the NSERC funding and establishing policies for intellectual property and the reporting of scientific information. Because of the infrastructure CITR has in place, the incremental cost of the carrying these tasks will be relatively low. Dr. Maier Blostein, President of CITR, will be responsible to the Board of Directors of CITR for all aspects CITR's involvement with the CBAR program.

Financial administration will be carried out in accordance with NSERC regulations and will be under the supervision of Ms. Lynn-Marie Holland, Manager of Network Administration for

CITR. Ms. Holland has a good working relationship with virtually all of the universities participating in the CBAR program since all but three already participate in CITR.

The CITR Internal Network Agreement will define the rights and responsibilities of the various universities and research institutions participating in the CBAR program. The Agreement outlines the manner in which participating universities (and researchers) manage and report funding, purchase and use equipment, license intellectual property, handle confidential information, publish and settle disputes. Further details on the arrangements with industry are described in Section 4.

4 Networking and Partnerships

4.1 Introduction

Networking between researchers and collaborative activities or partnerships with groups outside the university community represent a strategic aspect of this proposal. As explained in Sections 2 and 3, the research objectives of the technical program have been designed to require a high degree of interaction between researchers, both within and between Major Projects. Equally important , however, is the interaction of researchers with industry and appropriate elements of the user community. We expect to create economic value for these groups in a reasonable time frame and this can be achieved only by working closely with them. In this Section, we describe our strategy for industrial interaction and outline the research collaborations we have established thus far with outside the university community.

4.2 Interaction with Industry

Our industrial interaction policies follows reasonably closely those outlined in the strategic plan of CITR. We refer to companies that contribute to and benefit from the CBAR program as Industrial Affiliates. Each Major Project has a unique set of Industrial Affiliates and networking with industry occurs at several different levels: assisting in the planning and the monitoring of progress (through participation in the Area Committee), participating in the research program, and participating in the management of a Major Project through Industrial Co-Leadership. We expect Industrial Affiliates to make either in-kind or cash contributions to the Major Project they belong to and in return they gain privileges with respect to the licensing of Intellectual Property.

As mentioned in Section 3.4, provisions to license Intellectual Property (IP) developed in this proposal will be governed by the CITR Internal Network Agreement. CITR does not own IP; it is owned either by the researcher or his /her employer as dictated by the regulations of each particular university. However, the IP policy of the Agreement does oblige the universities and/or researchers to grant the rights mentioned below to Industrial Affiliates (on a Major Project basis):

- early access (pre-publication) to IP.
- free access to IP for non-commercial purposes.
- guaranteed rights to a non-exclusive license to IP on terms more favourable than available to third parties, ie, to companies not classed as Industrial Affiliates.

- the right to fund additional research that builds on the non-exclusive IP with exclusive licenses for the new or incremental IP.

Since CITR does not own IP, it does not negotiate licenses with companies or pay patent costs. It does, however, sit at the negotiating table to assure that Affiliates are treated fairly; and, it has the right to act on behalf of multiple owners of IP in the situation where there is disagreement between owners. The key policies with respect to licensing are that (i) Industrial Affiliates can only obtain a non-exclusive license from research supported by this funding, and (ii) third parties may not receive licenses until at least one year after PI is announced, and then only under terms that are less favourable than those received by Affiliates.

Newbridge and its affiliates (a company is an affiliate of Newbridge if Newbridge has 30% equity participation in it), IBM Canada, BNR Ltd, MPR Teltech, Stentor and Mitel Ltd. are Affiliates of the original CITR Major Project on Broadband Services. Newbridge and its affiliated companies have agreed to become Industrial Affiliates of the four other Major Projects while Bunyip Information Systems and Jade Simulations Ltd. are Affiliates of the programs in Digital Libraries and Workplace of the Future, respectively. We anticipate expanding the number of Industrial Affiliates once the program is approved. In view of its large in-kind contribution, Newbridge and its affiliates will be granted a non-exclusive, royalty-free license to PI generated by the new, non-CITE Major Projects.

4.3 Collaborative Research Activities

We have made a serious effort in building this program to work closely with companies and the user community in order to accelerate the development, demonstration and adaptation of the research. We anticipate developing applications with user feedback and participation in the manner so successfully promoted by INTERNET. We describe below, very briefly, a number of collaborative activities we are arranging with partners from industry and different user groups. As the program evolves, added emphasis will be placed on gaining involvement from content providers, publishers and service providers.

Newbridge Networks Corp. has been the key industrial company behind this proposal and, in conjunction with some of its affiliated companies, it expects to collaborate on all Major Projects. It has participated actively in all phases of the program planning process and, most particularly, in the identification and deployment plans for the switches. In addition to donating three and one half million dollars worth of switching equipment, the company will devote two and a half man years for equipment installation, maintenance and support, and research interaction. We also anticipate that several of companies that are Newbridge affiliates

will collaborate in several of the Major Projects.

The Major Project on Broadband Services was initiated in CITR in the summer of 1993 and has attracted significant support from IBM Canada since its inception. IBM will continue to provide the services of Dr. K. Lyons as Industrial Co-Leader and pay half of the salary of Dr. R. Velthuys, who currently leads the project integration team. MPR Teltech, BNR Ltd., Stentor and Mitel have indicated their intention of collaborating in this Major Project as Industrial Affiliates. We are also in the process of concluding an arrangement with Canadian Broadcasting Corporation which will allow us to use CBC news documents in the news application under investigation. The CBC is interested in finding innovative ways to generate new revenue streams by exploiting news and other programs they own.

The research on Networked Learning Environments is based on results from the VIEW-U concept which was developed as part of a prior collaboration between Simon Fraser University, MPR Teltech Ltd., Stentor Resources Inc., the Open Learning Agency and Science World of British Columbia. We anticipate that MPR Teltech and Stentor will continue to collaborate in this Major Project as an extension of the original VIEW-U development. This Major Project will also be actively involved with SkillNet, a collaborative activity supported by the Technology Industries Association of BC (TIA) which has been established to provide training-at-a-distance in high technology companies. Specific collaboration will take place with MDA and Hughes Electronics Canada, two major Vancouver-based high technology companies. Studies will also be conducted with Metro-McNair Clinical Laboratories on using tele-training for the skill development of those carrying out laboratory testing processes. The Industrial Co-Leader for this major project is Mr. John Dunn from the BC Telephone Education Centre, Burnaby. BC Tel is interested in exploring different ways to use our technology for training. This Major Project will work in close collaboration with the newly established NCE on Tele-Learning Research on the one hand and Broadband Services major project on the other to provide a scalable, robust, switched ATM architecture, service layer and API for the downstream development of educational applications in the NCE program.

In the area of Tele-Medicine, Telesat Canada will provide satellite access to nursing stations in Northern Ontario as well as associated terminal and medical equipment at the remote sites. It will also assign Mr. A. Lakhani to participate in the project on Telemedicine Consultations Network for Remote Areas. Communications Research Center (CRC) will collaborate by providing the facilities of BADLAB for ATM/satellite interconnection. In addition to these collaborations, the Major Project on Tele-Medicine will be involved with a number of hospitals and health providing institutions.

The initial version of the Virtual Health Record(VHR) will be developed with the collaboration of the diabetes research group at Victoria Hospital in London, Ont. Different medical data modalities (eg, Digital Angiograms, High Frequency ECG, medical interview video clips etc.) used in other projects with different hospitals will all use the VHR format and protocols.

Three other major collaborations have been negotiated with hospitals across the country. We will work with the University of Ottawa Heart Institute (UOHI) at the Civic Hospital in developing applications and service trials to client hospitals and clinics in the Ottawa region over OCRInet. Similarly, we will collaborate with the Kingston General Hospital in developing a simple non-invasive method for accurate diagnosis of cardiac artery disease using the 3-D High Frequency ECG. In Alberta, we will develop remote real-time consultation applications in collaboration with the Drumheller Regional Health Complex.

Bunyip Information Systems, a small company that is internationally known in the INTERNET community for its product ARCHIE, will assist in developing access strategies for multimedia documents over such vehicles as the as INTERNET or other broadband ATM networks. Bunyip is particularly interested in commercializing research activities in the project on Acoustic And Music Libraries through INTERNET Directory Services.

The Major Project on Workplace of the Future will have a number of collaborations. Jade Simulations Inc. of Calgary will provide access to high-speed simulation software and will produce and market enterprise modeling and simulation tools that will be developed. Secondly, in collaboration with AECL and the newly created AECL/NSERC Industrial chair in the Department of Mechanical Engineering at the University of Saskatchewan, we will develop a manufacturing application in support of concurrent engineering and design of a product through its lifecycle. We will also be working actively with the Alberta Research Council (ARC) in order to maximize opportunities for technology transfer to a variety of firms. ARC has a wide range of activities nationally and has a special interest in stimulating the commercialization of new technology. WurcNet Inc., which supports high-bandwidth network facilities across five prairie university sites, will be closely involved in all aspects of this part of the research program.

5 Highly Qualified Personnel

The development of broadband applications and services over the Information Super-Highway represents the best opportunity for growth in the information technology sector over the next decade. The widespread availability, at low cost, of large amounts of communications bandwidth will transform how and where people work, play, learn and receive services. The transformation will have an impact on society at least as great as that of the microprocessor; it will enhance national productivity quite significantly and create many opportunities to develop new industries. Canada's ability to seize these opportunities will be dependent on the availability of innovative manpower with the skills to design, implement and deliver broadband applications over the Super-Highway.

A major objective of the CBAR program is to develop the skilled manpower needed to fuel this revolution. Our strategy is to create new opportunities for postgraduate studies in applications-oriented research which involve collaboration with industry and user groups. The program stresses teamwork in the solution of large, complex, multi-disciplinary problems and emphasizes the rapid development and evaluation of applications over experimental ATM test beds. Further, it will create a broadband test network interconnecting many Canadian universities, providing opportunities for nationwide seminars and research interaction at a distance. Such training is currently limited in Canada and is highly relevant to the rapidly emerging broadband applications industry. We expect that most of the postgraduate students participating in the program will be in great demand upon graduation.

Our plan will influence the education of more than one hundred postgraduate students and a dozen postdoctoral fellows over a two period from Departments of Computer Science, Electrical Engineering, Mechanical Engineering, Medicine, Plant Biology, Kinesiology, Distance Learning and Music. The plan is very ambitious and will have a strong impact on postgraduate education nationally because of the size and diversity of the student body, and because the research activities will be distributed widely across the country.

The CBAR program will provide a stimulating exposure of ATM technology and applications to professors, students and other professionals, and give entrepreneurial researchers the breadth and depth of knowledge to create wealth by developing new businesses.

Appendix I

Note: Newbridge will endeavour to meet the researchers' original requests as stated in the proposal, however Newbridge reserves the right to substitute interfaces depending on availability. Newbridge anticipates finalizing the details by the end of August 1995.

This appendix contains information on the proposed switch locations, the port sizes, the interface cards and the terminal equipments. The network diagrams for the broadband networks for the Major Projects are included in section 2 at appropriate places.

The availability of ATM test equipment at all locations will greatly enhance research progress. The CBAR program is organized such that the components of the software infrastructure required are developed by different universities. For each constituent project, it is crucial that an ATM test bed is available locally to test the system component being developed. It is also important that the sites are connected as a wide area network. Since we have adopted a client server model for our distributed applications, our test beds must consist of servers and client machines.

A brief overview of the Newbridge equipment is given below:

Equipment Overview

The Newbridge 36150 MainStreet Access switch is a high capacity broadband switch that uses advanced cell-switching technology based on B-ISDN Asynchronous Transfer Mode (ATM) standards. The switch provides support for a variety of transmission and service interfaces including OC3, LATM, T3, T1, Ethernet and Video/NTSC. Fully configured, the 36150 provides support for 16 transmission/service interfaces.

The ATM switches being made available as part of this program contain release 1 components, are completely refurbished and fully upgradable. The Newbridge 36150 ATMnet switch is a proven winner in terms of reliability, ease of use, functionality and flexibility. Newbridge has sold more ATM WAN switches than all their competitors combined as reported in a March 1995 market research report published by International Data Corporation. Switches identical to those being donated are presently in use throughout the world by telephone companies, research institutions and private corporations.

Transmission Interfaces

Transmission interfaces receive and deliver ATM cells to the 36150 switching fabric. LATM (140 Mb/s and 100 Mb/s), and OC3 (155 Mb/s) interfaces are often used to connect high performance workstations and personal computers to ATM switches over fiber optic cables. They can also be utilized to interconnect two ATM switches together. T3 interfaces, operating at 45 Mb/s are used throughout the CANARIE backbone to tie regional broadband networks together.

OC3 / LATM

These interfaces provide a very high speed interconnect between a workstation and an ATM switch or between two ATM switches. Using single mode fiber, OC3 and LATM interfaces may be used to connect two switches located as far as 40 kilometers apart. Multimode LATM 100 transmission interfaces allow users to connect workstations to switches up to a distance of 2 km.

T3

Utilizing coaxial cable, the T3/PLCP interface card allows researchers to connect to regional and national broadband networks. It may also be used to connect to a digital service unit (DSU) which may in turn be connected to commonly available ethernet routers.

Service Adaptation Interfaces

Service adaptation interfaces allow non-ATM services such as Video/NTSC and Ethernet traffic to be carried over an ATM infrastructure.

Ethernet Interface

Provides support for Ethernet LAN bridging over an ATM network. Two ethernet networks may be connected so that all computers at either location appear to be on the same ethernet. Alternatively, a dedicated 10 Mb/s ethernet segment may be utilized to provide low contention ethernet services over ATM.

Video/NTSC Interface

Provides a bi-directional baseband video and audio connection between two end-stations over an ATM network. Utilizing JPEG variable bit rate compression this card provides an excellent facility for high quality video conferencing and video database access.

T1/TDM Interface

Provides a point to point interface between two T1 networks over an ATM backbone using AAL1. This interface has particular utility in the satellite-based telemedicine project.

Major Project: Broadband Services

Switch Location: University of Alberta

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	3
OC3 (155 Mb/s)	2
JPEG (Full motion video)	2

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network WurcNet
LATM	Workstation
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
JPEG	TV / video camera for video conferencing
JPEG	Analog video for hybrid multimedia

Major Project: Broadband Services

Switch Location: University of British Columbia

Interface Cards	Number required for research
DS3 (45 Mb/s)	2
LATM (100 & 140 Mb/s)	5
OC3 (155 Mb/s)	2
JPEG (Full motion video)	2

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Rnet
DS3	regional network Rnet
LATM	switch interconnect (new 36150)
LATM	switch interconnect (existing 36150)
LATM	Workstation
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
JPEG	TV/ video camera for video conferencing
JPEG	Analog video for hybrid multimedia

Major Project: Broadband Services

Switch Location: University of Waterloo

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (100 & 140 Mb/s)	4
OC3 (155 Mb/s)	2
JPEG (Full motion video)	2

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network (future)
LATM	switch interconnect (new 36150)
LATM	switch interconnect (existing 36150)
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
JPEG	TV/ video camera for video conferencing
JPEG	Analog video for hybrid multimedia

Major Project: Broadband Services

Switch Location: University of Montreal

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (100 & 140 Mb/s)	8
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	2

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
DS3	regional network (RISQ)
LATM	switch interconnect (new 36150)
LATM	switch interconnect (existing 36150)
LATM	Workstation
LATM	Workstation
LATM	Workstation
LATM	Workstation
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing
JPEG	Analog video for hybrid multimedia

Major Project: Broadband Services

Switch Location: University of Dalhousie

Interface Cards	Number required for research
DS3 (45 Mb/s)	**1**
OC3 (155 Mb/s)	**2**
JPEG (Full motion video)	**2**

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network ACORN
OC3	Workstation
OC3	Workstation
JPEG	TV/ video camera for video conferencing
JPEG	Analog video for hybrid multimedia

Major Project: Networked Learning Environments

Switch Location: SFU - Faculty of Applied Sciences

Interface Cards	Number required for research
DS3 (45 Mb/s)	2
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
DS3	regional network Rnet
DS3	regional network Rnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV / video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: SFU - School of Communications

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Rnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: BCIT Technology Centre

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Rnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: Richmond SkillNet

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Rnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: University of Victoria

Interface Cards	Number required for research
DS3 (45 Mb/s)	2
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Rnet
DS3	regional network Rnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: University of Toronto

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network SmartNet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Networked Learning Environments

Switch Location: Carleton University

Interface Cards	Number required for research
LATM (140 & 100 Mb/s)	3
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	**16**

Interface Card	Terminal equipment
LATM	Switch Interconnect (old 36150)
LATM	Switch Interconnect (new 36150)
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: University of Western Ontario

Interface Cards	Number required for research
LATM (100 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	regional network LARG*Net
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for video conferencing

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: University of Ottawa

Interface Cards	Number required for research
LATM (140 & 100 Mb/s)	4
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	2

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
LATM	Workstation
LATM	Workstation
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	OCRInet via University 36150
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for teleconferencing
JPEG	Analog video for hybrid multimedia

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: Queens University

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
DS3	Future CANARIE connection
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for teleconferencing

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: University of Ottawa Heart Institute

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network OCRInet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for teleconferencing

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: Telesat Canada

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
T1 /TDM (1.544 Mb/s)	2
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
DS3	regional network OCRInet
T1	satellite connection
T1	satellite connection
LATM	switch interconnect (new 36150)
LATM	switch interconnect (existing 36150)
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for teleconferencing

Major Project: Multimedia Tele-medicine over ATM Networking

Switch Location: Drumheller Regional Health Complex, Alberta

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network Wnet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/ video camera for teleconferencing

Major Project: Workplace of the Future

Switch Location: University of Manitoba

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	1
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network WurcNet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
JPEG	TV/video camera for video conferencing

Major Project: Workplace of the Future

Switch Location: University of Saskatchewan

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	1
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Interface Card	Terminal equipment
DS3	regional network WurcNet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
JPEG	TV/video camera for video conferencing

Major Project: Workplace of the Future

Switch Location: University of Alberta

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	1
JPEG (Full motion video)	1

Ports Required (8 or 16):	**16**

Interface Card	Terminal equipment
DS3	regional network WurcNet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
JPEG	TV/video camera for video conferencing

Major Project: Workplace of the Future

Switch Location: University of Calgary

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	2
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	16

Interface Card	Terminal equipment
DS3	regional network WurcNet
LATM	Workstation
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/video camera for video conferencing

Major Project: Distributed Multimedia Digital Libraries

Switch Location: CRIM

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	1
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Technical equipment connected to each card

Interface Card	Terminal equipment
DS3	regional network RISQ
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/video camera for teleconferencing

Major Project: Distributed Multimedia Digital Libraries

Switch Location: McGill University

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	1
OC3 (155 Mb/s)	2
Ethernet	2
JPEG (Full motion video)	1

Ports Required (8 or 16):	16

Technical equipment connected to each card

Interface Card	Terminal equipment
DS3	regional network RISQ
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
Ethernet	Local Ethernet
JPEG	TV/video camera for teleconferencing

Major Project: Distributed Multimedia Digital Libraries

Switch Location: Concordia University

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	1
OC3 (155 Mb/s)	2
Ethernet	1
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Technical equipment connected to each card

Interface Card	Terminal equipment
DS3	regional network RISQ
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
JPEG	TV/video camera for teleconferencing

Major Project: Distributed Multimedia Digital Libraries

Switch Location: UQAM

Interface Cards	Number required for research
DS3 (45 Mb/s)	1
LATM (140 Mb/s)	1
OC3 (155 Mb/s)	2
Ethernet	1
JPEG (Full motion video)	1

Ports Required (8 or 16):	8

Technical equipment connected to each card

Interface Card	Terminal equipment
DS3	regional network RISQ
LATM	Workstation
OC3	Workstation
OC3	Workstation
Ethernet	Local Ethernet
JPEG	TV/video camera for teleconferencing

Appendix 2 - Background Information on B. Prasada

Birendra Prasada (Fellow IEEE '89) received the B.Sc. and M.Sc degrees in physics from Banaras Hindu University, the D.I.C. diploma in electrical engineering from Imperial College, London, and the Ph.D. degree in electrical communications from the University of London. He is currently the Vice-President of the Canadian Institute for Telecommunications Research (CITR) and a Visiting Professor in the Department of Electrical Engineering at McGill University in Montreal.

Prior to joining CITR he was employed by BNR Ltd. for nearly 18 years, most recently as Director of the Multimedia Applications, Services and Technology Laboratory, where he provided leadership in the development of world class technology in the fields of video, multimedia and speech technology. In this capacity he organized an application-driven research program and developed effective mechanisms to transfer technology into products and services.

The laboratory had a number of notable successes, particularly in the area of speech recognition where products using the technology have been widely deployed throughout the North American telecommunication network. The laboratory also participated in the development of DV45 and DV45B - a family of DS-3 rate video codecs; GTCS, a PC based multi-media conferencing system, and a TDMA Cellular system. In each case, the enabling technologies developed by the research team were introduced into product rapidly.

Between 1973-76, Dr. Prasada was a Member of Technical Staff at Bell Laboratories in Murray Hill N.J. Between 1966-73, he was Professor of Electrical Engineering at the Indian Institute of Technology of Kanpur, India. He served as Head of the Electrical Engineering Department from 1968-1972 and as Head of the Advanced Center for Electronic Systems from 1972-1973. In 1965-66 he was Assistant Professor in the Department of Electrical Engineering at the Massachusetts Institute of Technology, Cambridge, Mass.

Dr. Prasada has been active in many facets of the Communications Society (COMSOC) of the IEEE for many years. Most recently he was the Chairman of the COMSOC Awards Board (1989-94) and currently serves as a member of the Board of Governors and Chair of the COMSOC External Awards Committee.