# OBJECTIVES AND TERMS OF REFERENCE

The objective of this thesis is to explore the future potential of multimedia applications in business and public sector services. The topic is related to Information Management.

Consequently, two broad areas have to be considered:

1. *Managerial aspects of Information Technology and Information Systems*
   The work by Singh [29] on IT planning models, and Strassmann [30][32] on IT project appraisal has been found particularly useful.

2. *The underlying technology of multimedia*
   In order to evaluate the strategic potential of multimedia applications, a thorough understanding of the needs of multimedia application in terms of network equipment and broadband services is required. Various technical literature has been reviewed. Related work was done by Wright [6], who also made an attempt to evaluate the strategic impact of broadband services and technologies.

The term *multimedia* needs to be defined. References have been made to Minoli [25], Wright [6], and others. Teleseminars are a major multimedia application. Since teleseminars have been conducted in dedicated facilities for many years, market surveys [26] have been helpful in predicting multimedia market trends. Important technical and non-technical issues of teleseminars have been considered as also being valid for multimedia.

The unique part of this work centers around multimedia pilot projects. An invitation to the International Computer Science Institute (ICSI), Berkeley, has made it possible to participate in *BAGNET* project work, meet and discuss the *Health Care Imaging* project with

the project leaders, and visit project sites. Hand-on experience in teleseminar production at ICSI have allowed a critical evaluation of the future potential of desktop teleseminar capabilities. Further major sources of information on the different aspects of both projects have been the CalREN project proposals [43][49], papers on multimedia medical imaging [50][51], and databases on the Internet.

The use of appropriate models from the Information Management literature to evaluate the strategic impact of the multimedia applications under considerations has been limited due to the fact that the projects are still in the initial phase of network installation. Valid evaluation of the applications will be feasible once these applications are running on the testbed, allowing measurements to be taken and comparisons to conventional approaches to be drawn.

# INTRODUCTION

Imagine your computer would allow you to talk to other people located far away, hear their voice and follow their gestures. At the same time, you might want to present a document, or to design collaboratively. It is clear that if these capabilities were widely available on demand, it would have a revolutionary impact on many aspects of life, including education, health care delivery and business. Researchers and professionals could attend meetings, exchange ideas or pursue further education - without even leaving their offices. Students could attend classes from their home, instrumentation could be controlled remotely, marketing presentations could be given to large groups of potential costumes, or patients located in rural areas could be examined by specialists from far away.

The technology does already exist: numerous teleseminars are conducted daily and transmitted even worldwide by using the Internet. The Internet teleseminar tools are easy to use: a mouse click will open a window for the video, adjust the volume of the audio, display a page of a document. However, the limited bandwidth has prevented widespread use of these tools so far. Computer scientists and telecommunications engineers have attacked this bottleneck and developed ATM, a set of network technologies that are expected to be the means by which the information superhighway could become reality. First pilot projects, such as the California Research and Education Network, have already started to operate. The California Research and Education Network, and its use in the applications mentioned above, is the focus of this work.

# CHAPTER 1

# STRATEGIC IMPACT OF INFORMATION TECHNOLOGY AND INFORMATION SYSTEMS

## 1.1. Role of IT/IS

### 1.1.1. Scope of IT/IS

Information is a strategic resource. *Information resources management* deals with the creation, processing and distribution of information. It also determines how an organization conducts its business and supports the management of *business resources*.

*Information systems* (IS) can be defined as 'all formal and structured methods for dealing with management and mission critical systems, plus their interface to embedded information technology (IT) in products or services. Information systems include the fully allocated cost of systems specifications, project management, system startup, operator training and procedural management for all computer and communications applications.'[30]

*Information technology* is 'the principal means for delivering improved information systems. The scope of information technology includes information services (e.g., computer operations, network operations, programming, telecommunications) and systems design (e.g., systems engineering, database design, information architecture).'[30]

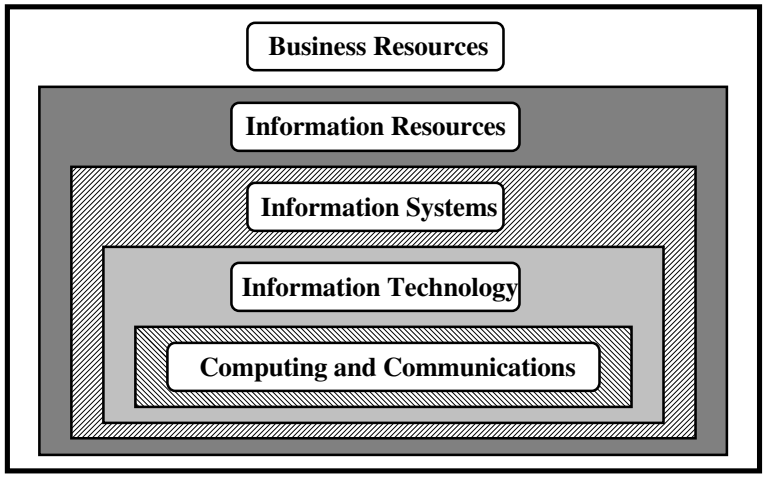


Figure 1.1: Scope of IT/IS [30]

### 1.1.2. IT Project Goals

Earl grouped aims and goals of IT projects in a 'Four-way Framework':

| Aim | Goal | Nature |
|---|---|---|
| Productivity & Performance | Efficiency<br>Effectiveness | Tangible benefits<br>Clear arguments |
| New ways of managing | Change<br>Flexibility | Radical concept<br>Multi-dimensional |
| Competitive advantage | Product-market positioning<br>Competitive equilibrium | Concrete vision<br>Commercial judgment |
| Developing new business | Diversification<br>Growth | Business venture<br>Risk and uncertainty |

Table 1.1: Four-Way Framework [33]

Strassmann [30] distingushed IT projects according to their goals, complexity and time horizon.

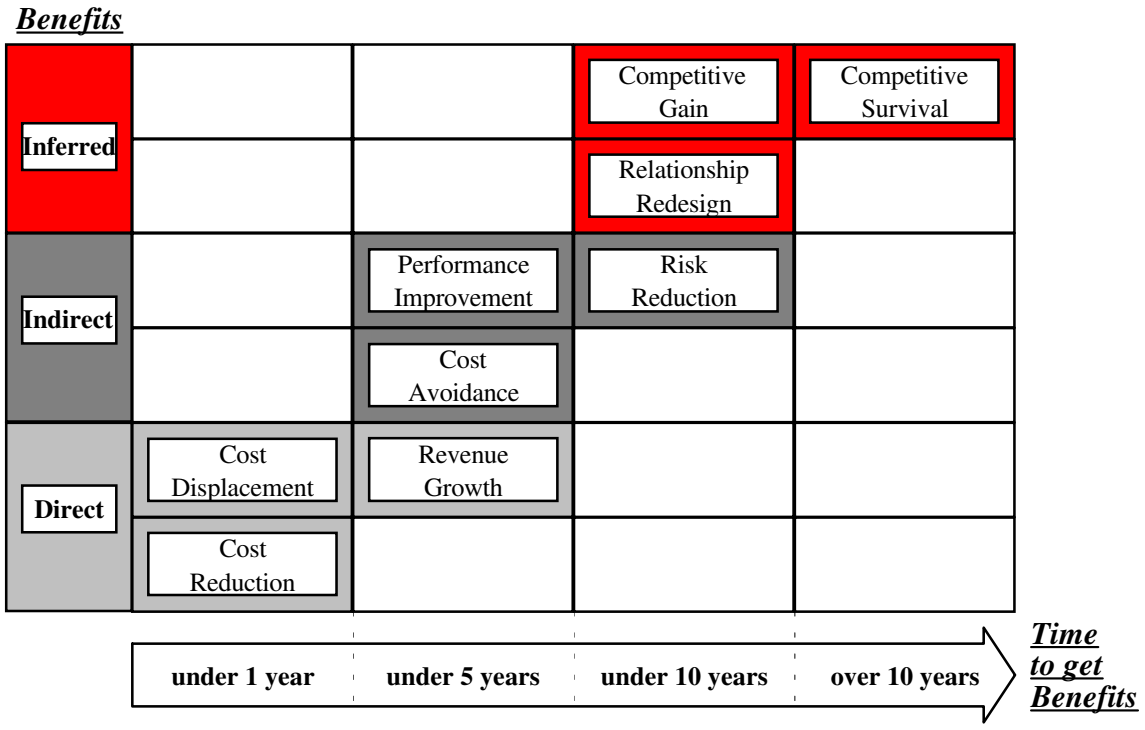


Figure 1.2: IT project goals[1]

Indirect and inferred benefits are more difficult to measure or to predict. Evaluation of inferred benefits has to include risk assessment and aim at risk minimization. Therefore, pilot installations, simulated environments, reported failures or phased installations are useful to assess the risk prior to the implementation of a new IS.

### 1.1.3. Impact of IT on Organizations

The use of IT has evolved from the automation of structured processes to applications that introduce fundamental changes into business procedures. Revolutionary improvements in computing and communications technology have enhanced IT's strategic impact on organizations and its potential to improve organizational effectiveness. In the follow-

[1] Relationship redesign refers to a change of the traditional roles held by suppliers, producers, distribution agents and customers

ing, this view shall be supported by investigating the impact of IT on functional and structural aspects of organizations, and illustrated by examples found in emperical studies.

***Organizational Structure***

IT enables organizations to process decision-relevant information in a more cost-effective way, thus improving the quality and speed of the decision-making processes. The power for decision-making may be passed up or down the organizational hierarchy, depending upon the location of the most competent decision-maker for a particular problem. This either results in a centralization or decentralization of management. The OTISLINE system serves as an example where the customer service system has been centralized as a result of IT deployment, compared to the previously distributed remote field offices.[34] However, an opposite effect has been observed, too. The decentralization of business functions has occurred concurrently with the introduction of distributed computing and corporate networks that improve monitoring and performance measurements. Obviously, IT is an important tool to adapt the structure of an organization to the specific environment in a flexible manner.

***Firm size***

Changes in the underlying cost structure of a firm were reported to have a direct impact on the optimal size of a firm, because cost effective IT reduces both external and internal coordination costs.[34] The impact can be twofold:

1. Firms may remain vertically small and turn to markets rather than integrating with factor suppliers. Coordination along the value chain is achieved by forming value-added partnerships, and facilitated by the use of IT. This certainly applies for airline companies whose ticket reservation has been removed from hierarchical control and is now made through travel agencies.

2. Firms grow vertically (enlargement of the product range) and/or horizontally (integration with factor suppliers). This process is supported by powerful IT that improves control despite of enlarged firm size IBM is an example of a highly vertically integrated 'megafirm', with products ranging from processor chips to integrated computer systems.

IT has also facilitated the creation and exploitation of economies of scale arising from growth and reductions of market transaction costs. This has caused a gradual shift to globalization in a number of classical service businesses, such as auditing, advertising, general trading and securities firms, where informational economies of scale exist.[34] Lower market transaction costs have been an incentive for even small companies to compete globally, as it can be observed in the case of the European Common Market.

***Operations***

Information systems enhances the productivity and flexibility of manufacturing or service operations. Factory automation, CAD/CAM, robotics and other computer based technology have facilitated mass production while contributing to improvements in quality, reductions in lead times and inventory, and cost savings. Benetton, for example, uses a communication network to transfer daily retail sales data between its network of 4,000 shops in 62 countries and the corporate headquarters. Design of cloth is CAD based, and production highly automated. This allows the company to react immediately to new customer trends and achieve a competitive edge.[34]

***Information Processing***

Organizations have become more and more dependent on IS to perform their basic business functions. Most of these functions require high data reliability, integrity and availability. Automation has reduced human intervention and, therefore, improved the accuracy of

information. Displacing paper flow with electronic communications has increased efficiencies in cost, speed and ease of use. The United States Postal Service now charges at least $0.29 for first class mail, while the cost of a single EDI transmission runs at $0.10 or less.[35] Computer protocols have forced the different interconnected partner to use standardized formats for data entry which contributes to information processing efficiency. Storage of huge amounts of data has become feasible by the development of high capacity storage devices. Data is mostly stored in digital form which makes it easily accessible by (digitally) operating computing and communication devices. IT has also helped to displace many of the labor intensive duties associated with collecting and processing information. Employees who were freed from these tasks could be relocated to supervisory or service tasks, thereby gaining a productivity edge or staff net savings.

***Monitoring/Performance Evaluation***

From the perspective of agency theory[1], information systems are relevant because the agency structure affects the distribution of information. Optical scanners monitoring the work scene or wireless computer keeping track of employees' work times are typical examples of how an IS is employed in an effort to decrease agency costs. However, the use of IS to monitor employees' performance in order to mitigate agency problems is controversial and culturally biased. For instance, direct monitoring is more widespread in the US than it is in Japan. Japanese management philosophy is 'not to closely monitor each individual's performance at the expense of team spirit.'[34]

***Decision-Making Support***

Until recently, computers have mainly solved well-defined problems under well-defined constraints and objectives. For example, in order to forecast the most cost-effective way

[1] Agency theory views a firm built upon a set of contracts among self-interested employees rather than as single identity that exists to maximize profits [34]

to satisfy the future needs of an international telephone network, AT&T runs an optimization model involving 42,000 decision variables.[34] Now, IT is about to conquer the human domain of decision-making. Artificial intelligence techniques, such as neural networks, have significantly expanded computers' ability to solve problems that are less structured and whose solutions require reasoning and perceptions. Neural nets can learn by trial and error, thereby minimizing the error probability of solutions to complex problems. This resembles the human learning process. Neural nets have already been employed for business applications, e.g., Avco Financial Services uses a neural net to evaluate loan applications.[34]

## 1.2. Planning and Controlling IT Investment

### 1.2.1. Motivation

Despite impressive advances in technology, IT has often caused more problems than solutions, e.g., rising costs rather than reductions, misuse, or rejection by potential users. Singh [29] identified a gap between the potential for organizational effectiveness enhancement created by IT and its actual use by the organization. IT has often been considered as the solution for business problems rather than a powerful tool to tackle them.

Failure to derive greater benefits from the use of IT has mostly been caused by lack of planning and control rather than lack of technical expertise. Consequently, Information Management literature has suggested a variety of planning models that aim to help organizations to realize and harness the enormous potential inherent in IT. Some of these models will be described in the following.

### 1.2.2. Planning Models Overview

The planning models can be grouped, according to their focus [29]:

| Model | Focus and Scope |
|---|---|
| *Growth Stage Models* | Based on the assumption that the effectiveness of IT use in an organization is subject to a learning process in which the organization proceeds through identifiable stages |
| *Planning Models* | Directed towards enhancing the organization's information management capability<br>Includes activity and resource planning at both strategic and operational level |
| *Project Management Models* | Facilitate effective implementation of IS/IT projects by developing tactical and operational plans and timing;<br>Feedback on project progress enables rescheduling of activities and re deployment of resources |
| *Composite Planning Models* | Integrate strategic, tactical and operational IS planning models |

Table 1.2: IS Planning Models

Appendix 1 gives examples of commonly adopted models.

### 1.2.3. COPE Framework

The models and frameworks as described above are highly fragmented. In order to address all the complex issues involved in the planning process and the linkages between different stages of planning and implementing IT projects, the *Comprehensive Organizational Preparedness Environment* (COPE) was developed by Singh [29]. This model is a more general and pragmatic framework to plan and control IT/IS. It comprises 7 stages, as shown in the figure below.

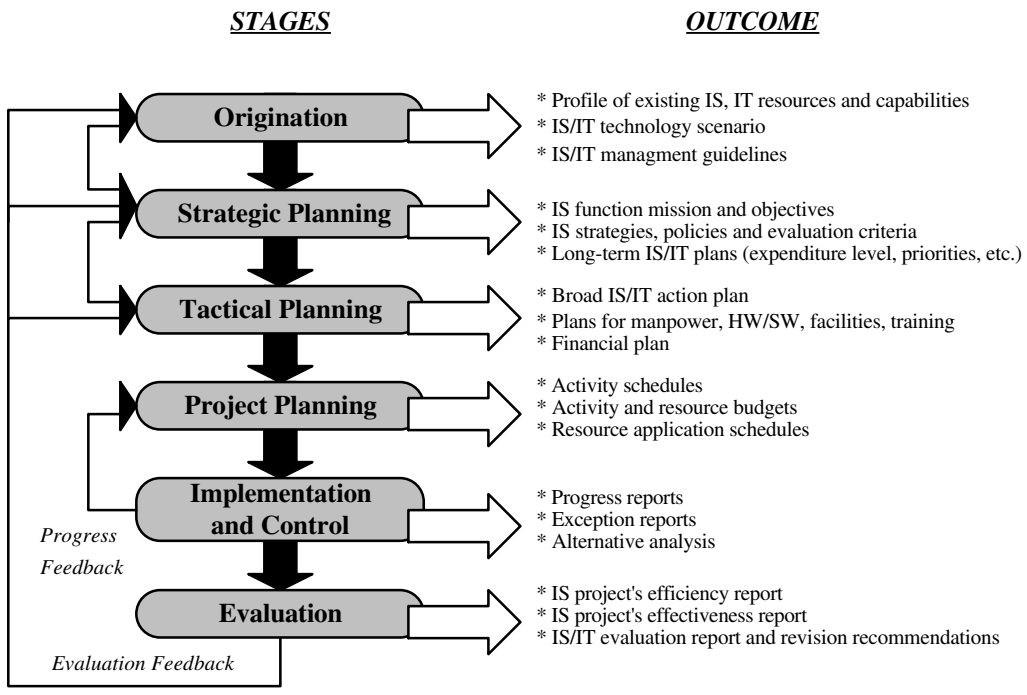


Figure 1.3: COPE Framework for Planning and Controlling IT/IS

### *Origination*

Most organizations already use IT. Therefore, an effort to upgrade the existing IS should start with a characterization of the current IS environment, including 'the nature of applications, cost/benefits, beneficiary constituencies, IT intensity, and top management/user attitudes and involvement.

### *Strategic Planning*

At this stage, IS/IT mission and goals are defined, closely linked to the organization's mission and goals, and strategies for their accomplishment. The planning horizon is 5-10 years, and environmental changes have to be accommodated for.

***Tactical Planning***

A portfolio of medium-term plans is then developed to facilitate resource acquisition, allocation, and control. The planning horizon is 2-4 years. Refinement due to feedback from Implementation and changes in strategic planes is allowed for.

***Project Planning***

An plan of action, containing detailed schedules and budgets, is derived for the short-term (1-3 years). Reformulating of operational plans is necessitated because of changes in tactical plans and feedback from Implementation.

***Implementation and Control***

This phase involves the execution of operational plans on a day-to-day basis. It is essential that progress be monitored and controlled.

***Evaluation***

Finally, the efficiency of IS/IT plan execution is evaluated at different levels. Objectives, plans and performance of the previous phases, as well as the total IS function should be considered in this process. Depending upon the outcome of the review, adjustments are made in one or more of the first three stages, as shown in figure 1.3. The frequency of evaluation is subject to cost/benefit criteria.

## 1.3. Appraising IT Investments

### 1.3.1. Cost and Return of IT

Most IT investment proposals give precise indication of current IT equipment prices but exclude the 'organization costs' for implementation, maintenance, training, etc. These costs also include spending on ergonomics, such as air-conditioning, low noise levels, new office

furniture or improved lighting. Employee dissatisfaction stemming from poor ergonomics can demolish the economic benefits expected from new IT. Training of users is necessary to cope with variety, complexity and speed of a computerized business.

According to Strassmann [30], these organization costs will always exceed the depreciation expense for the IT equipment. This is illustrated in the figure below.

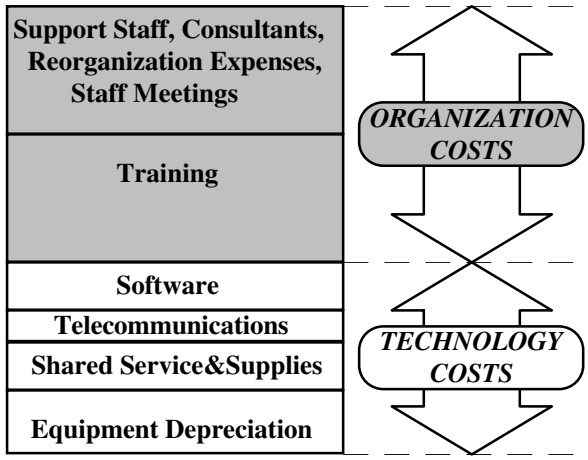


Figure 1.4: First Year Costs of a Personal Computer [30]

There is no simple correlation between money spent on IT and a company's financial performance. Computers are not a direct cause of profitability but they contribute to it. This view is supported by a survey which concluded that computer users and computer non-users did not experience different levels of profitability, as measured by ROCE[1]. It was also found that more profitable organizations did not have a relatively large diversity of computer applications.

Strassmann strongly supports the use of financial management techniques to measure IT projects' profitability. 'You can't control what you can't measure. If you can't measure it

[1] Survey carried out by Chef Sing Yap, Cambridge University; see [30]

you can't manage it.'[30] He recommends avoiding revenue ratios in comparing the expenses and refraining from applying asset-based ratios to measure effectiveness of IT, instead, he promotes the use of 'Value Added'.

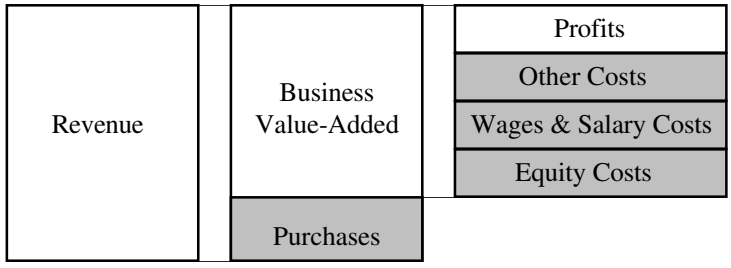


Figure 1.5: Value-Added [30]

### 1.3.2. Financial Planning

The assessment of the financial aspects of an IT investment very much depends on its objective, complexity, and time horizon.

Kaplan[1] argued that 'IS spending decisions fall somewhere between two extremes: a straight machine-replacement decision on the one end, and basic research and development on the other. On the machine-replacement side, costs and benefits are well known. On the research side, however, costs and benefits are typically fixed according to how much a company has available to spend; specific benefits are unpredictable.'

According to Strassmann [31], decisions on IT spending will be made in one of three contexts:

[1] Robert Kaplan, Accounting Professor, Harvard, see [30]

1. Individual expenditure that stands or falls primarily on its unique merits and payback time
2. Investment made in a corporation's overall future
3. Part of the costs required to develop and offer products and services

While investments in the first context can be justified by using conventional financial planning techniques, such as NPV, strategic investments include major subjective elements (e.g., corporate image, employee morale, customer satisfaction) whose impact on overall business effectiveness is more difficult to measure in monetary terms.

Strassmann grouped financial planning techniques according to the IT project's goal and time horizon:

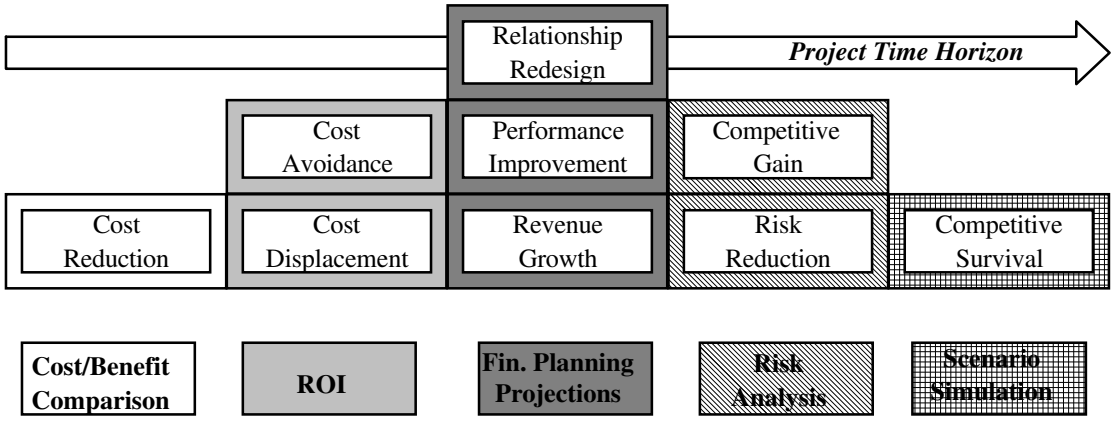


Figure 1.6: Financial Planning Techniques [30]

***Risk Analysis***

Risk analysis helps to examine the uncertainties of IT investment prior to implementation. This is accomplished by 'creating a framework for diagnosing, understanding and containing the inherent difficulties associated with technological and organizational perform-

ance.'[30] Risk assessment is particularly recommended for complex projects with long time horizon.

Strassmann [30] suggested the following algorithm for risk assessment:

1. Classification of costs and benefits
2. Attaching risk profiles to each class
3. Run simulations to obtain NPV profile of project

### 1.3.3. IT Evaluation

The risk of IS failure is also dependent on hardware and software, as well as vendors' and consultants' support. The evaluation of these variables should include the following factors [36]:

***Hardware***

* Software: operating system, software tools
* Performance: speed, capacity, throughput
* Cost: purchase price, operation, maintenance
* Reliability: risk of malfunctions, maintenance requirements
* Availability: delivery lead time
* Compatibility: inter-operability with hardware from competing suppliers
* Modularity: possibility of upgrading with 'add-on' products
* Technology: stage in life cycle, experiences from other users, risk of obsolescence
* Connectivity: interfaces to peripheral equipment and networks
* Ergonomics: air-conditioning, noise level, physical design
* Environmental Requirements: material of components, energy usage, recycling

* User acceptance: convenience, ease of use

***Software***

* Efficiency: modularity, storage requirements
* Flexibility: diverse application without need for major modifications
* Security: tolerance for error, malfunctions, and power failure
* Language: 'popular' or 'odd' programming language used to create object code
* Documentation: user instructions that facilitate modifications
* Hardware: fit between hardware and software
* Others: cost, availability, compatibility, ergonomics

***Vendor***

* Performance: experience from previous deals or from other customers
* System development: availability of consultants, their quality and cost
* Conversion support: service back-up during conversion period
* Training of end-users: quality and cost
* Back-up: contingencies for emergency back-up
* Accessibility: local presence, customer hot-line
* Business position: market dominance, financial position

## 1.4. IT Policy Guidelines

### 1.4.1. Work Design

Before new IS development is started, the work-flow should be simplified and non-essential work eliminated. This requires an analysis of:

* information requirements for and information flow between the various business functions
* who performs these functions and how achievement is measured
* how information should be structured and used in the future system
* overall system architecture and technologies required to support the business

Pilot installations and prototypes should precede the implementation of the new system in order to spot problems and assess the risk. Changes in internal or external environment, which may affect informational, technological and human resource requirements, need to be accommodated by continuous system modifications.

### 1.4.2. Human Resource Management

Motivation and ability are prerequisites for optimal utilization of the IS. Staff motivation can be stimulated by involving them in the whole planning process. Motivated staff are more likely to align themselves with business goals. Management support can be secured by illustrating the value of the IS for furthering organizational goals and objectives. IT should be considered by managers as a tool to improve management methods rather than a challenge to become technical experts.

Design issues, such as user convenience, ergonomic and aesthetic factors, play an important role in gaining user acceptance. Test installation of the system ensures that operating methods are acceptable to every user, prior to system implementation. Thorough training has to be provided, structural mechanisms have to be put in place, and a supportive climate should be created in order to make best use of the system.

Technical personnel plays a key role in the process of IS planning and control. An understanding of the business needs is highly beneficial since it directs the technicians' efforts towards business effectiveness improvement. Provision of career diversification for technical personnel will allow them to acquire company-specific experiences through cross-functional assignments.

The recipients of the information worker's services are most likely to evaluate the usefulness, responsiveness, and timeliness of the services provided through the IS from an objective point of view. Therefore, surveys should frequently gather their opinion.

### 1.4.3. Resource Allocation

The entire IS planning process, as described before, requires commitment of sizable organizational resources over prolonged periods of time. Information technology should not be introduced for the sake of keeping up with innovative technological developments but applied where it has a direct and favorable effect on value added. It was found that 'Management uses information technology more extensively. With only 31% of total costs, they absorb 64 % of the firms' information technology budget.'[30] It is further concluded that shifting IT investment from management to operations, where revenue is generated, should be a top priority.

Whenever IT supports managerial functions, productivity of management should be subject to measurement. Management applications are only justified if they improve overall effectiveness. Although it seems obvious that IT can help management to cope with increasingly complicated problems and improve the quality of decision-making, the outcome is not always measurable in the short-term. Nor is it always possible to isolate the contribution of a new IS to effectiveness from other influential factors, such as environmental

changes. Benefits from new IT can even become worthless if competitors catch up with better technology and a more appropriate organizational structure. Examples for companies that have aggressively adopted new IT and preempted earlier movers in their industries include Japanese auto-makers and clothing retailers like Benetton and The Limited.[34]

Investments into Administration, Sales & Marketing IT can help to reduce overhead costs and increase overall profitability.

### 1.4.4. Executive Responsibilities

Executives who have direct accountability for long-term shareholder returns have to define the information system mission. Information resource policy has to be consistent with key-policy in finance, marketing and operations. This coordination is also executive responsibility.

The multidivisional (M-form) organizational structure, in which operating decision-making is separated from strategic decision-making and delegated to divisional manager, should also be applied to the assignment of IT responsibilities. The Chief Information Resource Officer (CIO) is assigned *corporate responsibility* to manage information resources. *Operating responsibility* and choice of how to execute information resource policies is given to operating managers who are accountable for the results of the projects.

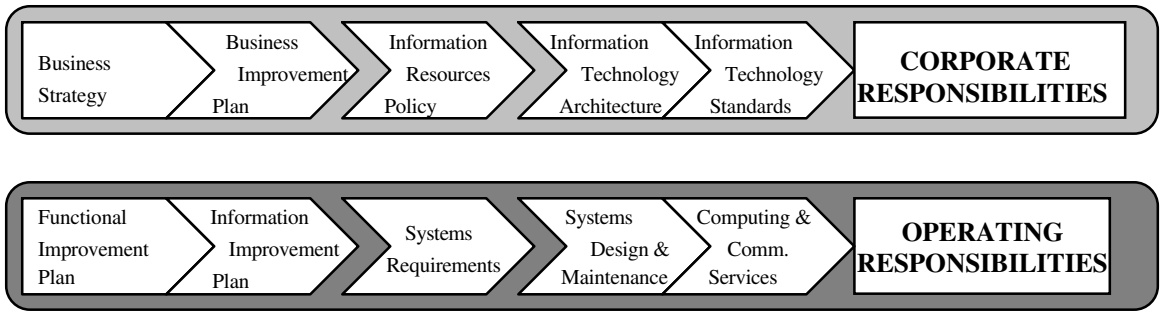


Figure 1.7: Corporate and Operating Responsibilities [30]

In [30], the following IT policy guidelines were given to executives:

* Consider IT as a business influence
* Recognize the role of IT as a business transformer
* Focus on IT investment
* Set the tone for innovation
* Fund and monitor major IT ventures
* Link IT to business planning
* Support an IT awareness program
* Support development of architectural policies
* Review exceptional IT situations

# CHAPTER 2

# COMPUTING AND COMMUNICATIONS EVOLUTION

The first business computers were used in the 1950's to perform simple analysis of information that had been collected manually and transcribed into computer-readable form. This concept was called 'batch processing'. Improvements in computer price/performance made it possible to create 'data centers' that could handle real-time applications as well as remote data entry and output. In 1964, IBM launched the System/360 that was considered as the first true modern computer system with advanced operating system and facilities to support data communications. The 1970's saw major efforts towards networking and standardization that shaped the future of computing and communications. IBM developed a protocol stack, the System Network Architecture (SNA), in 1974. Two years later, the International Standards Organisation (ISO) published the Open System Interconnection (OSI) model which became the standard model on which the following protocol developments have been based on. The ARPANET, a network of computers created by the Defense Advance Research Projects Administration (DARPA) in the 1970's, formed the base for one of the world's mostly used computer network, the Internet. It is estimated that there are now more than 15,000,000 users of the Internet with users in 80% of the world's countries.[43] Initially, the use of the computer for business needs had been limited by the economics of computer power but this changed dramatically when Personal Computers were introduced in the 1980's. As the revolution in very large scale integrated circuitry (VLSI) improved price/performance and reduced the initial costs significantly, computers began to migrate into day-to-day business activities. At the end of the decade, 90% of computing power available to business was residing on the desktop and not in the data center.[1]

What started as a simple way to connect many terminals to a computer in a large data centers in the late 1970's, has become the major drive in computing since then: Local Area Networks (LAN). Media Access Protocols, such as Ethernet or Token Ring, had to be defined to ensure controlled access to the network. LAN's served as the foundation for work group computing which has become the primary focus of new data processing investments. As shown in the figure below, the percentage of PC's connected to LAN's has increased dramatically.

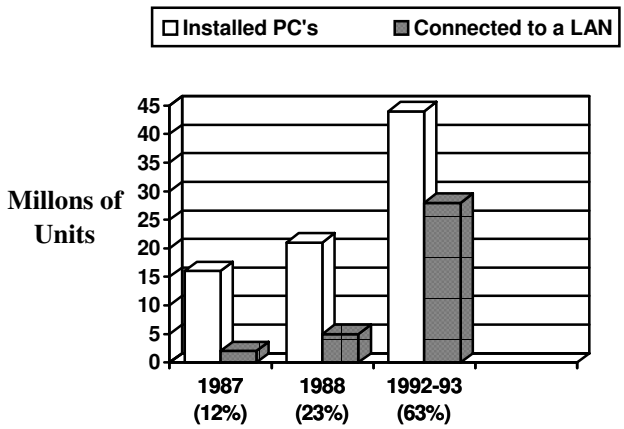


Figure 2.1: PC's - Connected to LANs [1]

Having connected computers within a LAN, it became very soon an incentive to interconnect LANs to form a Wide Area Network (WAN). However, transmission within WANs has had to rely upon the services offered by the telecommunication carriers. Since these services were primarily designed for voice communications, they used analog carrier signals and provided only very limited bandwidth, typically up to 64 Kbps. Carriers have reacted to the need for high-speed transmission of digital data. The Integrated Services Digital Network (ISDN) was introduced in the 1980's, enabling the transmission of non-voice data with significantly higher bandwidth than with the traditional telephone network. Further services, such as Frame Relay, Switched Multimegabit Data Service (SMDS) and

Asynchronous Transfer Mode (ATM) have been introduced, resulting in transmission rates up to several hundreds Mbps. These broadband services have been made feasible by the deployment of fiber optics, which provide a very reliable, high bandwidth medium. An overview of narrowband and broadband services is given in appendix 2.

While traditional telephony networks have been built in a monolithic fashion based on a hierarchy of electronic switches that are connected by trunk lines, there is now a major shift towards distributed switching. This strategy enables new services to be brought to the market more rapidly, providing integrated access for multiple intelligent services via a common user interface and also supports Signaling System 7, an advanced, high-speed signaling system that improves utilization of network facilities. However, new technology has to be capable of accommodating both new and legacy services and a range of different traffic types. As a compromise, services in the near future will be provided by multiple service infrastructures.

A similar trend can be seen in computing, with the move away from the multi-user data center towards the client/server model, or distributed computing. More computing resources are now provided locally, at the 'client', and the remainder is concentrated in a centralized resource, called the 'server'. Distributed computing has become a cheaper and more powerful alternative to the mainframe solutions, offering increased user productivity through graphical user interfaces, the availability of desktop report tools, and image database support. Consequently, traditional companies, such as IBM and DEC, have lost initiative in data processing whereas Microsoft, Intel, Compaq, Apple or Novell could increase their share in the Computer Market by investing heavily in future technologies. But overall, PC business is now characterized by sharply declining prices, slim profit margins and shortening product cycles.[2]

The decade of the 90's is characterized by the convergence of computing and telecommunications. There is also a move towards open, standards based network architecture that allows carriers to work with a variety of vendors for the network management and service solution they require.

Networking has already become the crucial element in most computing environments and is being used to integrate highly sophisticated and diverse technologies as more businesses rely on their computing system to achieve and maintain competitive advantage. This needs ubiquitous, interoperable, multimedia networking on a global scale. In response, the largest information providers have spawned new corporate alliances to achieve the scale necessary to undertake the venture.

Multimedia, a term used for the delivery of video images, data, sound and text in digital form, has emerged as a serious commercial proposition. This brings a third player into the collaboration of computer and telecommunication industry: the entertainment industry as a major content provider. By entering into the multimedia business, telecommunication carriers compete directly with cable companies. Alliances have been formed between companies in the various industries claiming a slice of the fast growing multimedia market: chip producers, telephone companies, telecommunications carriers and service providers, computer manufacturers as well as cable companies.

Multimedia, combined with a steady increase in work group applications and the need for heavy file transfers, has created a bandwidth bottleneck that can only be resolved by the provision of broadband transmission facilities and services. According to [1], the bandwidth consumed by existing applications is growing at a rate of 13% per year. In this respect, Synchronous Optical Network (SONET) and ATM are likely to become the cornerstones of a network that will deliver high-bandwidth services. ATM has been discov-

ered as the vehicle for driving virtually everything with a single technology and a single set of standards.

| CATEGORY | PAST (1960s-1970s) | PRESENT (1980s-1990s) | FUTURE (1990s-2000) |
|---|---|---|---|
| **Topology/Model** | Hierarchical Batch | Mesh/Peer<br>Hierarchical<br>Client/Server | Mesh/Peer<br>Distributed |
| **Drivers** | Terminal-to-host | LAN/WAN<br>Terminal to host<br>Workstation | LAN/WAN<br>Video imaging<br>Multimedia |
| **Traffic** | Character | Mostly character<br>Block mode | Graphical<br>Video |
| **Traffic Patterns** | Intermittent<br>Low volume | Bursty<br>Medium volume | Bursty<br>High volume |
| **User Interface** | Printout<br>Line | Screen<br>Graphical user interface | Multimedia |
| **Benefits** | Automation | Mission critical<br>Strategic information | Competitive advantage |

Table 2.1: Computer and Networking Models [1]

# CHAPTER 3

# BROADBAND SERVICES AND SOLUTIONS

## 3.1. Service Requirements

The implementation of data transmission through a network is often refered to as *service*. Services may have different network requirements with regard to the following parameters:

***Bandwidth***

The maximum transmission rate required is refered to as *peak bandwidth*. The *bandwidth variability* indicates whether the data transfer requires fixed or flexible bandwidth. In the latter case, the *average bandwidth* is another important parameter.

***Burstiness***

Burstiness is defined as the ratio of peak to average bandwidth.

***Connection Type***

The connection type determines the way users are physically interconnected:

* permanently ('leased line')
* for a bounded short-term ('switched connection')
* no connections ('connectionless')

The quality of data transmission through the network, i.e., the performance of the network, can be evaluated by the following criteria:

***Error Rates***

In reality, no ideal transmission link can be provided between two points within the network. Transmission errors can occur for various reasons, such as signal degradation due to noise, network congestion or buffer overflow. The *bit error rate* is a measurement for transmission errors over a physical link. However, bit errors need not result in equivalent information loss if error correction mechanisms are employed.

***Delay***

The delay is the time that elapses between sending and receiving of information. This end-to-end delay, as perceived by the user, can include:

* Propagation time for electrical and/or optical signals
* Coding and decoding delay
* Packetization and depacketization delay at network access nodes
* Queuing time at switches within the network
* Database access time and buffer time at source and destination

***Jitter***

The variability of the end-to-end delay is refered to as *jitter*.

## 3.2. Broadband Services

In order to distinguish between broadband services, a framework has been provided by the International Consultative Committee on Telephone and Telegraph (CCITT) [4]:

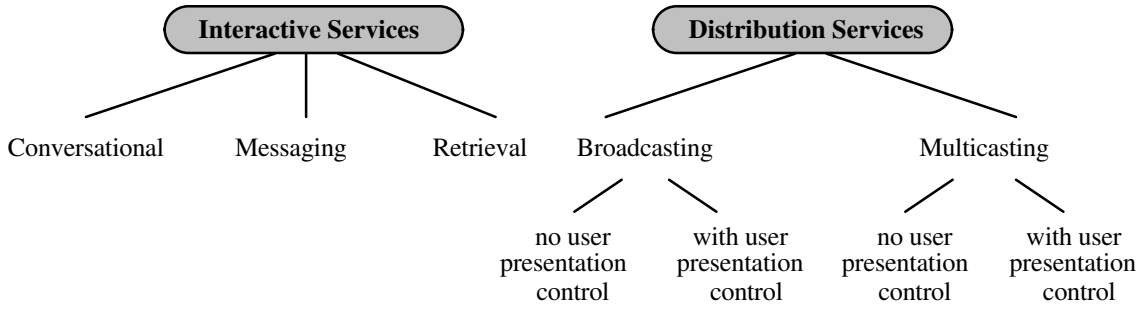


Figure 3.1: CCITT Classification of Broadband Services

***Interactive Services***

Interactive services involve transmission in both directions. *Conversational services* are characterized by bi-directional communication (dialogue) without intermediate buffering of data. *Messaging services* are user-to-user communication with intermediate buffering of data. *Retrieval services* involve retrieval of information stored in the public domain under control of individual users.

***Distribution Services***

Distribution services involve one-way transmission with no possibility to provide a response to the sender. *Broadcasting* is the process of sending information to all interconnected users, as opposed to *Multicasting*, where only a subset of users is addressed. Distribution services can be further distinguished by the user having *presentation control* or not. Control over presentation allows the receiver to select from all the data received just those items that are required.

## 3.3. Transport Options

A service is *isochronous* if it requires a continuous fixed information rate and bounded delay. On the contrary, *asynchronous* services transmit bit streams that are irregular or bursty. Another term for asynchronous service is *variable-bit-rate* service.

Digital voice and video data streams are examples for isochronous services if *fixed-bit-rate (FBR) coding* is used. Asynchronous services use *variable-bit-rate (VBR) coding*. Computer data is regarded as being asynchronous.

The transport capabilities of the network are dictated by the switching equipment employed. *Circuit switching* represents the dedicated availability of a fixed bandwidth to a user across the network, and this is ensured by assigning an end-to-end physical path, called *circuit*, to the user for the entire duration of the data transfer. Another concept is *packet switching*, where data is segmented into packets of limited size. Packets are forwarded from node to node within the network, with the route they take being dependent on bandwidth availability. With circuit switching, unused bandwidth on an allocated circuit is wasted. Packet switching acquires bandwidth only when needed, consequently, is more bandwidth efficient. However, packet loss may occur when buffer at network nodes overflow due to a sudden surge of incoming packets.

The broadband network offers four alternatives for matching service requirements with transport options [6]:

1. Fixed-bit-rate coding (isochronous service) over circuit-switched network

2. Fixed-bit-rate coding (isochronous service) over packet-switched network
   This is also called *circuit emulation*. It requires that packetization and switching be fast enough to ensure delay is bounded according to the user requirements.

3. Variable-bit-rate coding (asynchronous service) over circuit-switched network

4. Variable-bit-rate coding (asynchronous service) over packet-switched network

   This mode offers the opportunity for more efficient transport since it reflect the variability naturally present in the original signal, such as in voice or video. This also applies to computer data that is, in general, asynchronous.

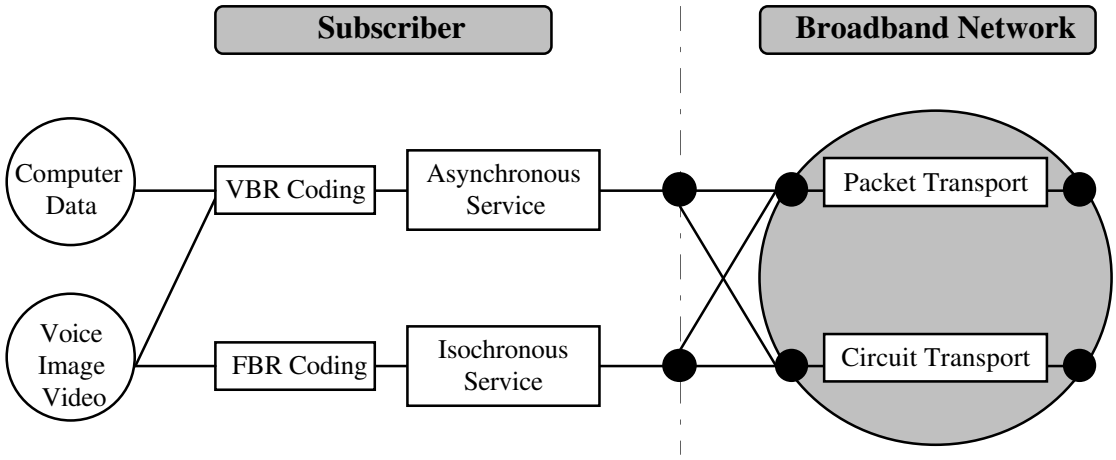


Figure 3.2: Service Requirements and Transport Options

## 3.4. The ISO OSI Reference Model

Communication protocols can be regarded as a set of conventions providing basic network functionality. They contain precise specification of data and control message formats and facilitate the connection of computers or networks from different vendors and of different complexity. A layered architecture is preferable, allowing modularisation of functionality and the incorporation of new protocols whilst maintaining existing service interfaces.

The ISO OSI Reference Model provides a 7-layer architectural framework for networks. The lower three layers (1-3) are concerned with the protocols used for communication between users within a communication subnet. These layers are dependent on the configuration of the network. The upper three layer (5-7) allow interaction of heterogeneous sys-

tems and are network independent. Layer 4 masks the upper protocol layers from the details of the lower network-dependent layer.

| | Layer | Layer Functions |
|---|---|---|
| **7** | **Application** | Provides the service elements to process the exchanged information; Services include resource sharing, file transfer and database management |
| **6** | **Presentation** | Provides services necessary to format exchanged data and manage session dialog |
| **5** | **Session** | Establishes and terminates connections; arbitrates user rights to services; synchronizes data transfers |
| **4** | **Transport** | Provides functions for error-free delivery of messages such as flow control, error-recovery and acknowledgment |
| **3** | **Network** | Provides transparent routing of messages between two entities |
| **2** | **Data Link** | Provides rules for transmission on the physical medium such as packet formats, access rights, error detection and correction |
| **1** | **Physical** | Provides mechanical and electrical interconnections for stations |

Table 3.1: OSI Protocol Layers [18]

## 3.5. Optical Fiber and SONET

### 3.5.1. Physical Properties of Optical Fiber

Optical fiber is made from extremely high quality glass that is many times more transparent than regular glass. With respect to capacity, the *dispersion* of the digital pulse as it traverses the fiber imposes an upper limit on the product P [6]:

$$P=(\text{maximum bit rate})*(\text{distance}) \quad (3.1)$$

At the current stage of technology, the value of P is approximately 1000 Gbps*km.[6]

*Absorption* is another physical phenomena that limits the distance that a signal of a given intensity can be transmitted through a fiber without being re-amplified. Absorption is caused by inherent irregularities, water and other impurities.

Within the fiber core, the light is totally reflected if it hits the boundary of the core. Multimode fibers can carry more than one optical signal at the same time, whereas monomode fiber only transmit a single signal. According to the change of the refractive index of the fiber core, multimode step-index fiber and multimode graded-index fiber are distinguished.

| | **Multimode Step-Index** | **Multimode Graded-Index** | **Monomode** |
|---|---|---|---|
| **Diameter** | > 0.1 mm | approximately 0.05 mm | < 0.01 mm |
| **Refractive Index** | Step change | Gradual change | Step change |
| **Dispersion** | High | Medium | Low |
| **Manufacturing Costs** | Low | High | High |
| **P [Gbps*km]** | 0.5 | 5 | 100 (commercial)<br>1000 (research) |

Table 3.2: Types of Optical Fiber [6]

### 3.5.2. Optical Transmitters and Receivers

***Transmitters***

As transmitters, either *Light Emitting Diodes* (LED) or *lasers* are used, the choice of which is a trade-off between cost and maximum bit rate. Lasers produce coherent light, resulting in low dispersion, and can be pulsed by their controlling electrical inputs at higher rate than LEDs. This enables lasers to transmit higher bit rates than LED's. In contrast, LEDs produce non-coherent light over a certain range of frequencies that is subject

to higher dispersion. However, LEDs and their electrical controlling circuits are less costly than laser technology.

| | **Laser** | **LED** |
|---|---|---|
| **Light** | Coherent | Non-coherent |
| **Pulse Rate** | High | Low |
| **Transmission Rate** | High | Low |
| **Cost** | High | Low |

Table 3.3: Trade-off Between Optical Transmitters

***Receivers***

Two types of receivers are used in conjunction with optical fiber: *PIN photo diodes* and *avalanche photo diodes*. The latter is able to detect much lower intensities of light, resulting in a longer transmission distance, but is more costly.

### 3.5.3. The SONET Standard

SONET is an acronym for *Synchronous Optical Network*. This standard was originally proposed by Bellcore in the mid-1980's and has been agreed to internationally by the CCITT as the standard for fiber optic transmission in North America. In Europe, a largely compatible standard, the Synchronous Digital Hierarchy (SDH), is used. SONET allows the transmission equipment of different vendors to interconnect and is often associated with ATM.

SONET is a set of physical layers. It defines how bytes are transmitted in frames across links, the ways of multiplexing existing transmission line frames, and specifies various operation and maintenance procedures.

The lowest SONET frame rate, known as STS-1, is equivalent to a transmission rate of 51.84 Mbps. This rate has been sufficient so far to transmit digital TV or to interconnect telephone companies' central offices within a telecommunications network. STS-3 and STS-12 were selected by the CCITT for access to B-ISDN. Corresponding to each framing rate, STS-n, are optical fiber medium standards, OC-n. STS-1 can also be divided into lower bandwidth components in order to match the North American electrical standards, e.g. DS1, and the European standard, E1. The highest DS standard, DS3, has approximately the same transmission rate as STS-1.

| Standard | Transmission Rate | European Equivalent | Optical Interface | Application |
|---|---|---|---|---|
| **STS-1** | 51.84 Mbps | | OC-1 | DS3, digital TV, trunking |
| **STS-3** | 155.52 Mbps | STM-1 | OC-3 | HDTV, trunking, B-ISDN (ATM) |
| **STS-12** | 622.08 Mbps | STM-4 | OC-12 | Trunking, B-ISDN (ATM) |
| **STS-48** | 2.488 Gbps | STM-24 | OC-24 | Trunking |
| **STS-n** | n*51.84 Mbps | STM-m | OC-n | |

Table 3.4: SONET Transmission Standards

### 3.5.4. SONET Rings

The huge transmission capacity offered by optical fiber affects the way in which central offices are interconnected in metropolitan areas. Instead of connecting the offices in mesh

topology, such as for electrical cabling, traffic can be carried in a ring structure of connections.

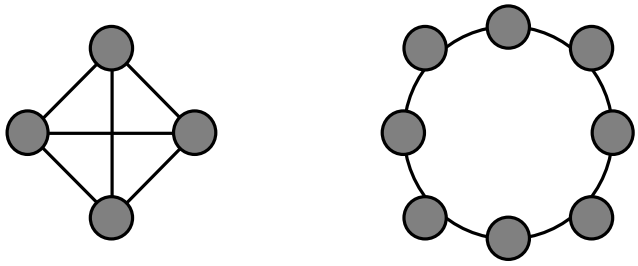


Figure 3.3: Mesh and Ring Topologies

The SONET standard incorporates a mechanism for maintaining operation in case of link failure. Each ring consists of two fibers, one in each direction. During normal operation, one ring is unused. If a link fails, traffic is routed via the second ring. However, reliability is achieved at the expense of redundant transmission facilities, which is only justified for metropolitan areas where bandwidth is relatively low cost.[6] For WANs, where bandwidth is more costly, mesh topologies and rerouting schemes are employed to cope with link failure.

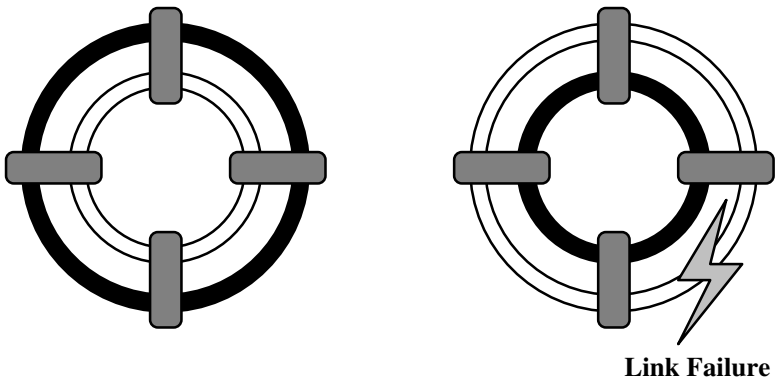


Figure 3.4: Maintenance of operation in case of link failure in SONET rings

### 3.5.5. Strategic Impact of Optical Fiber

#### i) Benefits

***High Bandwidth***

The major benefit of using optical fiber is the very high bandwidth, currently up to 2.4 Gbps for commercial use.

***Security***

It is virtually impossible to tap the fiber in order to get access to the information transmitted without the communicating parties observing the interference. Therefore, fiber offers a high degree of security.

***Low Error Rates***

Light waves are unaffected by electromagnetic interference. Moreover, external light cannot propagate through the opaque sheath surrounding the fiber core. Lack of interference enables transmission with very low bit error rates.

***Simplified Network Management***

Fiber is a very stable material with a long life expectancy. Since optical signals carry low power, no heat is generated during transmission. Optical fibers can be bundled together without the danger of a temperature rise. Also, the small physical size of the fiber cable allows network upgrading in city centers where ducts are already crowded by the existing copper cables. The traffic can be carried on less fiber trunks, compared to an equivalent traffic on copper trunks. This, combined with the automatic fault recovery in the SONET rings, results in simplified network management.

***Costs***

Compared to copper cable, the deployment of optical fiber is cost efficient in the following cases:

* Short distances

  No repeater is needed to filter and re amplify the signal

* Long distances

  The cost for electrical-optical conversion at the repeater is compensated for by the longer inter repeater distance

The raw material for glass, sand, is virtually limitless with no prospect of price rise, as opposed to copper.

**ii) Drawbacks**

Since most of the equipment within a network (multiplexer, repeater, switches) as well as customer equipment is electronic, electrical-optical conversion is a major additional cost of implementing fiber.

Installation of optical fiber cable is more complex than installation of electrical cable. It requires skilled labor for the precise alignment of the termination, adding to overall cost.

Currently, the overall cost of using fiber transmission is slightly higher than the cost of using copper.[6]

### iii) Trends

Fiber was first deployed for inter-office trunking in the early 1980's. The overall percentage of inter-office trunks in North America being fiber rose to 95% in 1990 [6], mainly due to its cost advantage over copper for long distance interconnections. For example, Pacific Bell has connected its central offices by OC-12/48 fiber based SONET circuits.[7] The deployment of fiber in public telecommunications networks contributed to a reduction in telephone tariffs that had come down in real terms by 50% within the last decade.[6]

Business customers were first connected by fiber in 1986, with large scale deployment in the 1990's. Fiber is preferably deployed in city centers because it fits easily in already crowded ducts, thereby making network upgrading feasible. Major corporations already use SONET in their private networks, e.g., General Electric, Citibank, and IBM.[6]

Fiber access to residential customers began in the late 1980's. Currently, the cost of replacing existing copper access lines with fiber is still too high. Therefore, mostly newly built residential areas are provided with fiber lines.

Fiber has great potential because it can transport integrated services. As soon as the demand for future services, such as HDTV, video on demand, video telephony, etc. achieves critical mass, fiber deployment for business and residential customers will increase significantly and overall costs will come down due to economies of scale.

Fiber-optic transmission systems have not matured yet. Research and development focuses on the removal of the bottleneck caused by the electronic switching equipment. Two options are investigated:

* Development of pure optical switching technology
* Development of optical networks without switches

As a result, bandwidth capacity in the Tbps range is envisaged. This capacity would be large enough to design the network as a broadcast network, resulting in a decrease of investment and operating cost. However, security will then increasingly become an issue.

## 3.6. ATM

### 3.6.1. Overview

*Asynchronous Transfer Mode* (ATM) is an important broadband technology which is gaining rapid, widespread acceptance within the telecommunications and data networking industries. It has the potential to 'remove the performance bottlenecks in current LANs and WANs while provisioning network capabilities for the future.'[1] ATM replaces the variable length packets, that are difficult and slow to forward within networks, with fixed length (53 bytes) packets, called *cells*. ATM cells are capable to carry voice, video and computer data across the network in one transmission and switching fabric at very high speed.

A definition for ATM is given by the CCITT:

'ATM is a Transfer Mode in which information is organized in cells. It is *asynchronous* in the sense that the recurrence of cells is not necessarily periodic and that no rigid timing relationship is necessary between switches and hosts.'[8]

ATM was chosen by the CCITT as the technology on which future B-ISDN services should be based on. Transmission rates in B-ISDN networks have been standardized to

45, 155 and 622 Mbps. While CCITT standards are far from complete, sufficient standards (cell formats and protocol definitions) already existed by the early 1990's to enable early commercial availability of ATM products.

The commercial interest in ATM led to the establishment of the *ATM Forum*, a consortium of more than 160 participating members, in 1991. Members include major public and private network vendors, network providers and major workstation vendors. The *International Computer Science Institute* (ICSI) joined the ATM Forum in 1993. The ATM forum is now a major driver of private and public ATM networking standards. The ultimate goal is to transparently interconnect public and private networks in native ATM cell formats.

### 3.6.2. ATM Technology

ATM cells are 53 bytes long and comprise a 48 byte payload and a 5 byte header. The payload contains the user information whereas the header basically consists of the Virtual Channel Identifier (VCI) and the Virtual Path Identifier (VPI) that jointly identify a logical connection across an ATM network. The VCI uniquely identifies a virtual channel from all other virtual channels sharing the same virtual path. The virtual path serves as a higher level aggregation mechanism to bundle together a large number of virtual circuits.

ATM is fundamentally a connection-oriented technology. This implies that prior to data transmission, a connection is set up between the two communicating parties and users' service requirements are specified. This process is called *signaling* and involves every physical link between each two nodes within the network being used for an end-to-end connection being assigned a pair of VCI and VPI. Tables within the ATM switches carry the information of which input port of a given switch has to be connected to which output

port, according to the VCI/VPI of the incoming cells. The switch then swaps the VCI/VPI pair in the header of the incoming cells for the new VCI/VPI that characterizes the link connected to the output port.

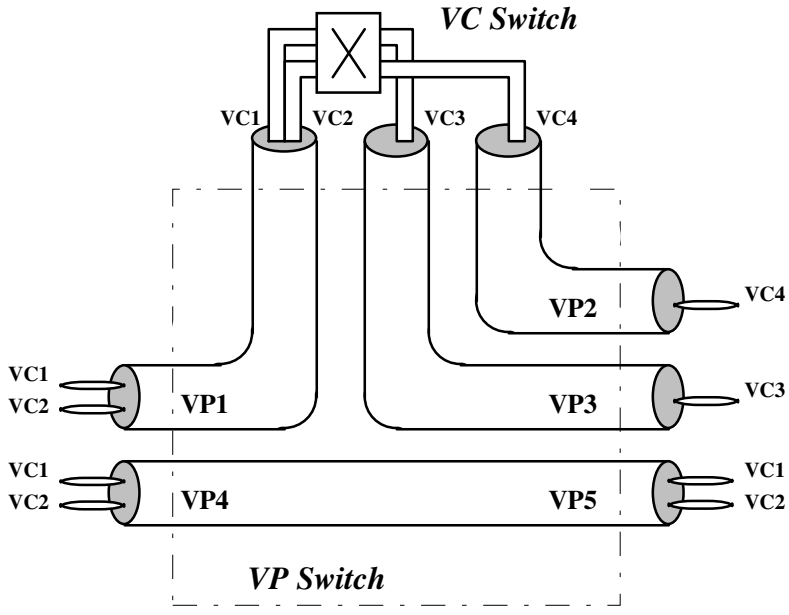


Figure 3.5: Mapping of VCI/VPI across ATM Switches [1]

Connections are virtual in the sense that bandwidth is not permanently allocated to a specific connection, but provided when actually needed, or according to priorities. The mapping between the VCI/VPI of a cell on an input link to the appropriate value on the output link is performed by high-speed hardware. Flexible bandwidth allocation and fast switching are the keys to the large capacity offered by ATM technology.

In order to classify the different user service requirements, four different service classes have been identified (see table below). ATM is able to accommodate different requirements concerning connection mode, bit rate and synchronization.

| Service Class | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Connection Mode** | Connection Oriented | | | Connectionless |
| **Bit Rate** | Constant | Variable | | |
| **Timing Relationship Source/Destination** | Required | | Not required | |
| **Applications** | CBR voice and video | VBR voice and video | ISDN D channel, Signaling, Frame Relay | SMDS, LAN Interconnect |

Table 3.5: ATM Service Classes

The ATM protocol stack can be related to the OSI reference model. Communications from higher layers occurs through three, ATM specific layers: *ATM Adaptation Layer (AAL)*, *ATM Layer* and *Physical Layer*. The ATM protocol differs from the OSI model, however, in the use of 'Planes'. The *User Plane* specifies the operations necessary for user data transfer, the *Control Plane* supports signaling, and the *Management Plane* provides control of an ATM node. A variety of lower layer protocols support ATM, such as SONET, FDDI, SMDS, and DS.

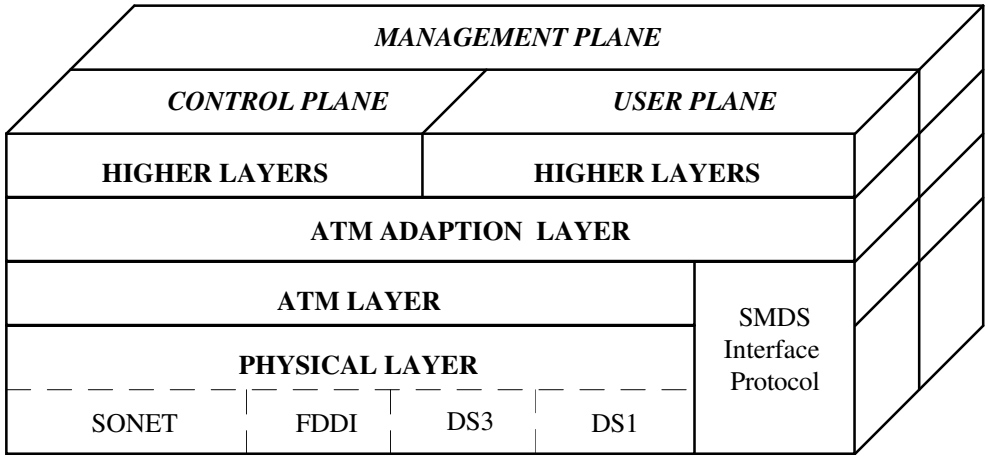


Figure 3.6: ATM Protocol Stack

ATM networks are able to carry integrated services and interconnect a variety of already existing, non-ATM networks. All these functions are performed by only three products: virtual path switch, virtual channel switch and the adapter. The adapter converts between data in ATM and non-ATM format.

### 3.6.3. Strategic Impact

#### i) Advantages

***High Bandwidth***

Increasing power of computing platforms, combined with declining prices, have brought entirely new classes of client-server applications onto the market. These include a wide range of 'visualization', or *multimedia*, applications. Multimedia applications demand very high bandwidth to such extent that even upgraded networks of current LAN technologies are unable to cope. Only ATM can provide the high bandwidth required, currently up to 622 Mbit/s, while operating cost-effectively. This is made possible by fast switching, flexible bandwidth allocation and the use of a connection oriented protocol.

***Provision of a Single Network for all Services***

ATM integrates a variety of different services onto a single network using a single mode of transmission and switching. A variety of requirements in terms of bit rate, response time, connection mode and synchronization can be catered for. Benefit of integration is cost saving in terms of investment, operational and maintenance costs.

***LAN/WAN Integration***

In the past, WANs provided bandwidth far below the capabilities of LANs. Bridges and routers were necessary to convert between the different protocols. With the deployment of ATM in both LAN and WAN, the need for protocol conversion is removed.

***Flexible Bandwidth Allocation***

As for human communication where bandwidth varies dynamically, ATM allows for changing bandwidth requirements during any time of data transmission. This ensures bandwidth efficiency and removes the need for intermediate buffering.

***Future Potential***

Since ATM is very flexible in terms of bandwidth and performance, it can probably cope with the demand of future services that have not yet been anticipated.

**ii) Limitations**

***Lack of Standardization***

The high expectations on ATM have put pressure on private and public ATM equipment vendors. Equipment had been developed before respective standards were agreed on . Future modification of installed equipment in order to reflect standards and ensure compatibility could become very costly.

Currently, there are three technical key issues that have to be solved by the ATM Forum [12]: LAN emulation, the private network-to-network interface (P-NNI) and traffic management. *LAN emulation* is necessary to support multicast and broadcast traffic. It is also critical to the success of ATM because it will allow vendors to provide efficient, low-cost interconnection between ATM and non-ATM LANs. The *P-NNI* addresses the problem of interoperability between ATM switches of different vendors. *Traffic management* deals with network congestion in case of overload. Draft specifications for these three issues are expected to be submitted to the ATM Forum by the end of 1994, with a decision expected to be made in 1995.

***Effectiveness of Service Delivery***

It should also be questioned as to whether ATM can deliver every service more cost efficiently than current technologies, such as N-ISDN. The economic issues of employing ATM have still to be investigated.

***Fixed Cell Size***

While fixed cell size simplifies switching hardware design and cell processing, it has also the disadvantage that optimum cell length varies for different services. The diplomatic choice of 48 byte payload, as a compromise between the North American proposal of 64 bytes and the European proposal of 32 bytes, has been shown to be suboptimal when used to transfer computer data.[9]

**iii) ATM Implementation**

In January 1994, Pacific Bell became the first local exchange company in the US to offer ATM cell relay service at 155 Mbps commercially by providing Numerical Aerodynamic Simulation Program at the *National Aeronautics and Space Administration Ames Research Center* (NASA) at Moffett Field, and *Xerox Palo Alto Research Center* (Xerox PARC) at Palo Alto, access to the ATM network at the 155 Mbps rate.[39]

PacBell plans to roll-out ATM services, as shown in the table below.

| Phase | Time Period | Activities |
|---|---|---|
| 1 | 01/94-06/95 | Market trial, allows to validate certain aspects of the ATM service, such as traffic patterns, pricing, demand for higher and lower speeds, and operation procedures |
| 2 | 07/95-12/96 | Introduction of 1.5 Mbps (DS1) and 622 Mbps (OC-12c) ATM services, and switched virtual circuits (SVC) |
| 3 | 1996-1998 | Provision of integrated SMDS and Frame Relay over ATM, as well as customer network management, based on Simple Network Management Protocol |
| 4 | 1999- | Driven by demand, subject to regulatory approval; addresses the integration of ATM and voice networks |

Table 3.6: Pacific Bell's ATM Implementation Strategy

### iv) ATM Forum Survey

'Communications manufacturers, carriers and computer manufacturer are committed to ATM technology. More and more companies have made ATM deployment a long-term strategy.'[10] Early adopters of ATM stated in a survey, carried out among members of the ATM Forum, that ATM enabled Business Reengineering and change of business strategies through improved infrastructure.[11] It was also pointed out that the deployment of ATM technology was application driven. Since most applications run locally, LANs have been given priority in ATM deployment.

Participants of the survey expected the following benefits from early adoption of ATM technology:

* Improved network performance
* Lower communication cost

* New applications
* Lower operating cost
* Lower equipment cost
* Simpler network management
* Networked collaboration
* Lower network access cost

However, it was found to be difficult to justify investments in ATM technology with conventional techniques, such as ROI. Instead, investments in ATM were seen as strategic investments, with the potential for long-term benefits.

Many companies have still been hesitant with investments in ATM. Key factors that significantly influence the commitment for ATM have been identified, such as [11]:

* Interoperability between devices from different vendors
* Network management
* Carriers 'listening to users'
* Test and certification of ATM equipment
* Coexistence with current technology
* Ability to scale the network in terms of size, scope and speed

**v) Applications**

Assessing applications and opportunities for ATM requires an understanding of the two types of applications that could exist [1]:

***Justifying Applications***

The value of these applications can be readily established and contribute quickly to demand for the ATM service. The application does not require major changes in user business practices or major investment in user equipment. The major justifying application is *LAN internetworking*. Virtually all types of businesses with multiple sites are investing in LANs and desktop systems, and are generating opportunities for internetworking applications, such as CAD/CAM, image transfer, and real time simulation. *Remote transaction support*, another type of justifying application, allows businesses to participate in or record transactions in real time. Remote transactions are characterized by a very large number of access points to the network, and a widely variable set of requirements for low cost, high performance, and security. These applications are also known by the term *Electronic Data Interchange* (EDI). Credit card authorization and electronic funds transfer are typical examples. A final class of justifying applications are *personal connection applications*, that focus on the enhancements of the relationship between individuals in direct communication, e.g., by transferring multimedia information.

***Exploitative Applications***

These applications 'can build a revenue base for a given type of service by offering users an opportunity to leverage an existing network service investment to broaden the benefit scope.'[1] They may require the user make changes in the way business is done and invest in additional equipment. Whenever a sufficient large number of commercial users subscribe to ATM, it becomes a vehicle to broaden the service to other subscribers. A number of new exploitative applications, e.g., distance learning or medical imaging, are expected to stimulate the commercial interest in ATM.

### vi) Future Trends

ATM costs are coming down. Prices for multimode ATM adapters have dropped by 50% within the last two years, and are expected to drop further as economies of scale are achieved.[12] Studies illustrated the importance of business customers for the economic viability of ATM networks.[13][14] The greatest profitability was obtained with large business customer, whereas the provision of ATM to residential customer still remained a challenge. The reason is that local access charges often make up more than half the total cost of a network, and many applications are unable to generate business benefits to offset the current costs.[6] Therefore, techniques to reduce the access network costs, such as High-Speed Digital Subscriber Loop (HDSL), are most important.

The US is by far the biggest market for ATM products. This is mainly because the US telecom market is highly competitive. IBM, in the struggle to reverse its decline, intents to be the leader in the ATM market and plans to spend $100m in developing ATM products, including microchips, intelligent hubs and carrier switches.[2]

Multimedia applications are expected to be the means by which ATM may become attractive to all customer groups, including residential customers, and consequently result in lower investment and operational cost.

# CHAPTER 4

# MULTIMEDIA

## 4.1. Overview

Human beings naturally perceive information through the sense of sight, hearing, smell, and taste, to facilitate human interaction. Computer-user interaction may require the integration of different media types, too. This requirement is called *multimedia requirement of communication*. However, at the current state of technology, smell and taste has not been implemented yet at the *Human-Machine-Interface* (HMI).

Multimedia has emerged as one of the most innovative ways of using computer and telecommunication to achieve effective communication via the HMI. Though being in widespread use, the term *multimedia* has not yet been standardized. Multimedia, as defined in [6], is a combination of four 'key ingredients':

1. Two or more communication media
2. Interactive service
3. Communication with human user involvement in the transmission and/or reception of information
4. Synchronization between the presentation of the different media

In this sense, broadcast TV is not considered as multimedia since it is not interactive. In contrast, videoconferencing is a typical example of a multimedia application, incorporating all four 'key ingredients'.

Corresponding to the CCITT classification, as given in section 3.2., there are three types of multimedia services: conversational, retrieval and messaging.

*Conversational multimedia* involves is a real-time interaction between users. Since voice communication is almost always present, this service can be considered as an enhancement to a telephone conversation.

*Retrieval* comprises the user's request transmitted in one direction, and the provision of a multimedia document in the other.

*Messaging* involves the composition of a multimedia document, its storage and subsequent retrieval by the addressee. Both messaging and retrieval allow for a time lag between the generation of a multimedia document and its display to a user.

## 4.2. Communications Media

### 4.2.1. Audio

***Audio Sources***

The major audio source is human voice. Voice, as perceived by the human ear, takes an audio range from 0.3 to 22 kHz. For *telephone quality* voice transmission, the range from 0.3 to 3.4 kHz is sufficient, whereas *high quality audio* refers to the transmission of the entire voice audio range. Compact disc (CD) players, digital audio tape (DAT) players, or tape recorders are alternative audio sources.

***Standards***

The original audio signal has to be digitized before it can be processed by computers or transmitted through a digital network. The coding technique is *pulse code modulation*

(PCM), in which the signal is sampled and the amplitude of each sample is coded as one or more byte of information. Compression techniques can be used to achieve more efficient digital codes. However, compression may result in loss of quality of the received audio.

Compression techniques have been standardized by the CCITT and ISO; examples are given in the table below.

| Audio Range | Coding Standard | Bandwidth | Applications |
|---|---|---|---|
| 3.4 kHz | CCITT G.711 | 64 kbit/s | Telephony (POTS) |
| 7 kHz | CCITT G.722 | 64 kbit/s[2] | Enhanced quality voice, suited to speaker-phone applications |
| 20 kHz | ISO MPEG | 384 kbit/s[1] | Hi-fi stereo in CD quality, in entertainment, broadcasting and advertising industries |

Table 4.1: Audio Coding Standards

***Performance Criteria***

Human listeners are tolerant to short intermittent errors in the audio stream that appear as 'clicks' on the line or 'clipping' of the spoken words. However, tolerance to information loss is dependent upon the degree of compression used: the more compressed the signal, the more significant the effect of bit errors. Forward error correction coding and interpolation techniques can be used to recover information from bit errors to a certain extent.

Conversational audio services are intolerant to delay. International standards specify end-to-end delay requirements of less than 100 ms.[6] In contrast, messaging, retrieval and distribution services can cope with additional delay. However, since delay incurred within

[2] using compression techniques

the network requires buffer storage and buffer overflow causes information loss, the delay tolerance is limited by the buffer capacity. .

Jitter makes speech difficult to understand and affects badly the quality of hi-fi stereophonic sound. Therefore, buffers at the network periphery should absorb jitter caused by queuing delays within the network.

### 4.2.2. Encoded Text

***Sources***

Encoded text is interpreted as characters represented by an agreed digital code, e.g., ASCII. Files of encoded text can vary in length by a few byte to several MB, though they are either short, representing interactive commands, or very long, representing heavy files.[4] Transfer of encoded text mostly requires an asynchronous service.

***Performance Criteria***

Encoded text is highly sensitive to information loss but, for most applications, tolerant to delay and jitter.

### 4.2.3. Still Images

***Sources***

A still image file is a digital representation of an image. Images can be captured by optical-electrical devices, such as scanner, cameras or fax machines. Images can also be created by graphical drawing programs. The image on the screen is determined by the content of the display memory within the computer. According to the attributes assigned to each single dot of an image, or 'pixel', either monochrome or colored images can be displayed.

The image resolution depends on the graphics adapter. Images are either stored pixel by pixel, or by using image descriptive languages, such as PostScript. Images stored in PostScript require less memory and can be scaled to a different size without distortion.[6]

### *Standards*

In order to reduce the vast storage and bandwidth requirements of images, various image compression techniques are used. The Joint Photographic Expert Group (JPEG) standard offers different compression ratios depending on the degree of allowable image degradation (see table below).

| Image | Pixels | Bits per Pixel | Compression Ratio | Storage Requirement [Mbit] | Transfer Time[1] [s] | Bandwidth Requirement [Mbps] |
|---|---|---|---|---|---|---|
| **Monochrome** | 1024*1024 | 1 | 15:1 | 0.067 | 1 | 0.067 |
| **Gray Scale** | 1024*1024 | 8 | 5:1 | 1.6 | 1 | 1.6 |
| **Color** | 1024*1024 | 24 | 5:1 | 5.04 | 1 | 5.04 |

Table 4.2: Image Storage and Bandwidth Requirements [6]

### *Performance Criteria*

Information loss tolerance depends very much on the application and the service. For example, error free transmission is crucial for medical imaging. In retrieval services, the master copy ought to be error free whereas subsequent retrieval operations are more error tolerant. End-to-end delay up to 2 sec, corresponding to a network transfer delay of 1 sec, seems to be acceptable for most applications.[6] Image transfer services are insensitive to jitter, as long as jitter is not larger than the transfer delay.

[1] chosen as acceptable to users

### 4.2.4. Motion Video

***Sources***

A video signal, such as captured by a video camera, occupies a large bandwidth. Uncompressed high-resolution video is coded at 45-135 Mbps. In order to make video processing economically viable, highly efficient coding techniques are applied. These techniques reduce significantly bandwidth.

***Standards***

FBR coding techniques have been developed to trade-off between two alternative objectives: low cost and high quality. The table below shows the main coding standards designed to operate in conjunction with an analog or FBR digital communication channel.

| Standard | Organization | Bandwidth | Applications |
|---|---|---|---|
| **CIF**<br>**1/4 CIF** | CCITT<br>CCITT | 1.5 Mbps[1]<br>0.256 Mbps[1] | Low-bandwidth videophone and videoconferencing |
| **H.261** | CCITT | 64 Kbps to 2 Mbps[2] | Conversational video |
| **MPEG1**<br>**MPEG2** | ISO<br>ISO | 1.5 Mbps<br>3 to 15 Mbps | Retrieval of motion video from storage devices |
| **NTSC**<br>**SECAM**<br>**PAL** | North America, Japan<br>Europe<br>Europe | 33 to 45 Mbps<br>33 to 45 Mbps<br>33 to 45 Mbps | Residential and corporate TV distribution |
| **HDTV MUSE**<br>**HD-MAC** | North America, Japan<br>Europe | up to 135 Mbps<br>up to 135 Mbps | HDTV for TV and videoconferencing |
| **CCIR 601** | CCIR | 45 to 135 Mbps | Contribution to TV programming |

Table 4.3: Motion Video Standards

[1] with 24:1 Compression Ratio and 30 Frames per Second
[2] bandwidth is divided into 64 Kbps channels

An alternative option arises from VBR coding which, in general, is less complex and therefore less costly. VBR coding can reduce the average bandwidth requirement by more than 40%, as compared to FBR coding.[6] VBR coding works particularly well with VBR network services, such as provided by ATM.

***Performance Criteria***

Loss of pixel information can be easily tolerated by the human eye, whereas loss of synchronization information can disrupt entire video frames until synchronization is regained. High compressed video is more sensitive to bit errors. Conversational video services are intolerant to delay and jitter.

## 4.3. Multimedia Technology

### 4.3.1. Multimedia Systems

Multimedia systems should support the following functions: capture, storage, retrieval, presentation, transfer, group sessioning, and control. *Capture* deals with collecting and transforming the different communication media into computer processable form. *Storage* devices retain multimedia information. A current challenge for multimedia storage devices is to provide real-time access. *Retrieval* involves intelligent search algorithms, particularly if the information is stored in distributed databases. *Presentation* entails the delivery of the information to the end user via the human-machine interface. *Transfer* refers to the ability to deliver information to a remote recipient. *Group sessioning* involves physical connectivity and interaction between two or more parties. Users should have *control* over the creation and/or presentation of multimedia documents.

In order to perform these functions, multimedia systems need to have the following elements:

* Computer with additional hardware for audio and video processing
* Capture devices
* Storage hardware
* Screen and speakers
* Operating system and software tools
* Communication network

Appendix 3 shows a model of a multimedia system that incorporates the aforementioned functions.

Multimedia systems should be able to support several types of interaction, such as:

* Searching and browsing through databases
* Featuring interactive 'buttons' for options, menu selections or portions of the displayed information that can be selected to obtain additional information
* Windowing
* Recording, including fast forwarding, rewinding, pausing and skipping
* Conversational interacting, e.g., discussing or shared editing

### 4.3.2. Multimedia Standards

Multimedia standards can draw upon the existing standards for the communication media that have been described in section 4.2. However, additional standards are required for multimedia, these may relate to a multimedia object as a whole or to individual components of the multimedia object. These standards include such areas as:

* Relation between content and presentation
* Layout of the presentation of the individual components of a multimedia object
* Synchronization and timing between the different components
* Interaction between user and individual components

The CCITT and ISO have combined their multimedia standard activities and formed the *Multimedia and Hypermedia Experts Group* (MHEG).

The *Interactive Multimedia Association* (IMA) was formed in 1987 and now comprises over 200 companies from 15 countries, including hardware manufacturers, software developers, and multimedia service providers. IMA aims at facilitating multimedia cross-platform compatibility. Compatibility can only be achieved if agreements are reached on all details pertaining to the storage, interchange, transmission, and synchronization of information. The IMA adopts suitable proposals for design specifications and gives guidance for future system developments.

### 4.3.3. Multimedia and ATM

***Meeting Multimedia Requirements***

ATM will play a significant role in realizing the flexibility and economy required for multimedia applications. With ATM, connections can be dynamically configured, and bandwidth can be assigned on demand. ATM facilitates group sessioning by supporting setup, modification, and release of multiparty, multiconnection calls. Information types or services can be changed throughout the call. Adaptation to the service requirements of the different communication media is ensured by the service classes, which were described in table 3.5. The required quality of service is specified during signaling by the ATM signaling protocol.

### *Audio and ATM*

Audio transmission through ATM is an example of the manner in which packetization can be used to efficiently transport variable-bit-rate services. The ATM adaptation layer offers the opportunity to exploit silence detection by not generating voice samples during silences. The results are reduced average bandwidth and improved audio quality. By assigning individual bytes in an ATM cell to voice samples from different connections, loss of information from a given conversation is reduced in the event of cell loss due to error bursts. ATM cells carrying error tolerant audio can also be used to act as a 'cushion' for more error-sensitive services. Cells carrying audio are discarded first if buffer overflow occurs.[6]

### *Encoded Text and ATM*

ATM does not provide error correction coding of subscriber data. Therefore, erroneous or discarded cells have to be retransmitted in order to meet Quality of Service (QoS) requirements that were negotiated between the subscriber and the network in the process of signaling.

### *Still Images and ATM*

ATM is particularly suited to image transfer because different Qualities of Service can be provided, according to the requirements of the image to be transmitted. For frequent image transmission, a virtual path can be used in which virtual channels are allocated permanently. In contrast, switched virtual channels can be set up on demand for bursty image file transfer.

*Motion Video and ATM*

Motion video requires high bandwidth. Moreover, end-to-end delay and information loss tolerance may be very stringent. ATM can adapt to these various requirement in a flexible manner. ATM can transport both FBR and VBR video. It effectively provides a statistical multiplexing scheme that takes advantage of the burstiness in the video traffic. Therefore, bandwidth can be assigned more efficiently or, alternatively, the quality of the video improved. By assigning sequence numbers to detect cell loss and high priority to cells containing synchronization information the level of disruption can be reduced.

*Synchronization*

Synchronization between audio and video is facilitated by joint coding and transfer via a single virtual connection. Alternatively, time stamps or an additional synchronization channel can be used if a multimedia application is transferred via multiple connections.[6]

## 4.4. Strategic Impact

### 4.4.1. Multimedia Market

*Growth*

The market for multimedia technology and applications is growing and will continue to grow at a rapid rate. This development is driven by the evolution of computing and communications technology, particularly by the explosion of desktop processing power and the emergence of broadband services.

Videoconferencing, an essential component of multimedia communication, is expected to grow more than 30% annually.[26] The world wide market for videoconferencing was $477 million in 1992, with a 10% share for desktop-videoconferencing.[25] 'The North American market, with its large installed base, transmission networks and superior techno-

logical expertise, will remain the largest market through 1999 but is beginning to lose its share to other regions. Europe, the second largest market, is opening up to competition by dropping its protectionist policies and privatizing government-controlled telecommunications providers. The Pacific Rim will be the fastest growing market for videoconferencing due to the increased business activity of millions of potential users.'[26]

***Business Market***

Early adopters of broadband multimedia application can be expected to come from sectors with high quality requirements of interactive image or video applications, e.g., CAD, telepublishing, and telemedicine.[22] Currently, narrowband multimedia communication, using the services offered by ISDN, predominates the conventional office environment where so far high-resolution video does not seem to play an significant role. This could change, however, with cost effective provision of broadband services, enabling the integration of high-quality video in group sessioning.

Broadband multimedia communication promises support for more efficient handling of tasks and information. Eventually, this will result in more sophisticated products, shorter lead times and a gain of competitive advantage. Currently, the main corporate users are qualified information professionals (e.g., managers, designers, consultants, teachers or doctors) in problem-solving environments, including the insurance industry, publishing industry, health care and education.

Business users of multimedia will estimate with scrutiny the impact of multimedia on productivity and overall effectiveness. If the application is unique, businesses will act carefully because of the higher risk. Unique applications are therefore expected to take years until they penetrate the market. Video-telephony is a typical example. Displacement of current

technology is often assessed against an empirical rule of thumb: the new technology is only adopted if it provides a 10:1 cost advantage over the old technology.[37]

***Consumer Market***

The consumer market is quite different from the business market. The buying decision is a trade between cost and satisfaction of ownership or participation. Costs are currently not yet affordable for the mass market for a wide range of products. With further growth of the market, stimulated by early adopters from the business market, multimedia applications are expected to penetrate the home area, thereby affecting social contacts, entertainment, and leisure activities.

### 4.4.2. Companies and Products

The computer industry, consumer electronics, telecommunications and media have been identified in [24] as the major industries claiming a slice of the promising multimedia market. Furthermore, cable companies have to be considered. Examples of companies for these five segments are given in the table below.

| Industry | Companies |
|---|---|
| Computing | Microsoft, Intel, IBM, Sun, Apple, Motorola, Hewlett Packard, ICL, Oracle, DEC |
| Consumer Electronics | Phillips, Sega, 3DO, General Magic, Goldstar, PictureTel, Siemens, Alcatel, Sony, NEC, Xerox, Eyetel |
| Cable | Videotron, Jones Cable, Encom |
| Telecom | AT&T, BT, Pacific Bell, US West, Cable and Wireless, France Telecom, Sprint, MCI, Northern Telecom |
| Media | Time Warner, Paramount, QVC, Blockbuster, News International, CNN, Reuters |

Table 4.4: Main Industries and Companies with Multimedia Commitment [24][25][26]

In terms of hardware, 'several hundred products are already available. More than sixty software packages were announced in conjunction with the release of Windows with Multimedia.'[25] IBM's 'Multimedia Courseware Catalogue' lists 700 multimedia courses. Meckler's 'International Reference Source and CD ROM Directory 1993' identifies over 3600 CD-ROM titles and 2800 suppliers. Most of these titles are:

* Applications for education, entertainment, or reference
* Software to prepare multimedia presentations
* Software to create new multimedia applications

Some magazines are already available on CD-ROM, e.g., 'Newsweek Interactive', 'Nautilus', 'Time', and 'USA Today'.

### 4.4.3. Applications

Multimedia is relevant to a wide spectrum of applications. Examples for multimedia applications in business, research and education, health care and home are given in appendix 4.

### 4.4.4. Pilot Projects

The complexity of structure and dynamics of multimedia applications have a significant impact on the future development of ATM networks. It is, therefore, important that multimedia applications be tested in cooperation with the ATM service provider. Pilot multimedia applications help to shape realistic usage scenarios and organizational concepts at an early stage, as well as clarify acceptance and requirements of all parties involved.

Examples of current multimedia pilot projects that employ high-speed WAN, mainly based on SONET and ATM, are given in appendix 5.

### 4.4.5. Costs

For commercial use, desktop videoconferencing is generally considered as the major multimedia application. Since most companies have already invested in desktop computers and LAN's, the cost for upgrading their computer system is affordable. The current price of videoconferencing software for workstations is about $500, plus another $500 to $1000 for the camera and the audio system.[27] Implementation on PC's can be more expensive since additional hardware, e.g., for video and audio processing, has to be built in.

Appendix 6 summarizes the capabilities and upgradation costs of current computer-based and workstation-based desktop videoconferencing systems.[27] It can be concluded from appendix 6 ('Transmission Medium'), that the current systems are geared to narrowband transmission, mainly ISDN, resulting in the observed video frame rate not supporting full motion video (full motion video requires 30 frames per second). This is mainly due to the high price tag that WAN bandwidth carries, compared to the low cost of LAN transmission. A comparison of the cost per bit per second per month between LAN and WAN showed a thousand-fold difference. The current costs of a videoconference transmitted through a WAN at OC-3 speed were estimated at $1000 per user per hour.[25]

From a cost perspective, it seems likely that broadcast of video will be the predominating multimedia application in daily back-office operations in the immediate future. Multipoint to multipoint conferences will either be conducted via LAN or via narrowband WAN, until costs for broadband WAN transmission becomes affordable.

For commercial users, who need both lower prices and higher connectivity, it may be better to wait and see what the market produces next. However, it is important to consider the interim cost of postponing investment into multimedia systems while awaiting the perfect solution. Installing a low-end system as a temporary solution and upgrading or replacing the system later is a 'safe' strategy.

For a private user, current costs remain a barrier. Few home-computer users are willing to spend about $1000 to upgrade their system (CD-ROM, sound/video cards) and even more for the application software, many of which cost from $600 to $900.[25]

### 4.4.6. Issues

***Copyright***

Copyright law differ in each country. US copyright law protects 'any original work of authorship fixed in any tangible medium of expression. The requirement of being fixed or a fixation is generally satisfied if the work as fixed can be perceived directly or with the aid of a machine or other device. Ideas, concepts, and techniques are not protected by copyright law, only expressions of such ideas, concepts, and techniques are protected.'[20]

'Multimedia technology involves the convergence of several forms of expressions. These include text, images, graphics, voice, music and full motion video into a single presentation for demonstrative, instructional, educational and other purposes. Such forms of expressions, irrespective of the type of media they are stored, are under usual circumstances protected by copyright.'[28]

There are several types of copyrights involved with multimedia:

* Reproduction right: to copy copyrighted material
* Adaptation right: to modify copyrighted material
* Performance right: to perform copyrighted material in public
* Synchronization right: to use audio material in conjunction with a prerecorded image

***Effectiveness***

Conventional videoconferencing systems are designed to accommodate groups. In contrast, desktop videoconferencing systems are designed for single users. The video window on the screen is too small for comfortable viewing by a group. Meetings, conducted by desktop videoconferencing, do not seem to have the same dynamics as live discussions. In contrast, the effectiveness of computer mediated communications (CMC) was found to be higher than in face-to-face meetings. Particularly, CMC allowed for more opinions to be given by more group members and more willingness to change opinion in order to come to a quality decision. According to Wright [6], these findings allow to draw similar conclusions for the effectiveness of desktop videoconferencing

Ultimately, the goal of business applications is not multimedia but effective communication, presentation, training, and decision making.

***Human Isolation***

Isolation of the virtual office can be a drawback and may reduce employees' productivity. Teleconferencing cannot substitute genuine human interaction. Employers who favor telecommuting have to ensure that staff visit the corporate office regularly to keep in touch and reinforce corporate values and the feeling of belonging to a team.

***Privacy***

Communication including the video display of the communicating parties may not always be preferred by users. Telephone conversation offers more privacy.

***Reliability***

Reliability of the technology is crucial for some applications, e.g., health care imaging. The effectiveness of communication may be reduced by technological malfunctions, bandwidth limitations or network congestion. These interruptions can result in a temporarily frozen image, a cessation of audio or a loss of synchronization between sound and image.

***Standardization***

Standardization remains a major issue for desktop videoconferencing. Lack of appropriate standards prevents users from using equipment from different vendors. As appendix 6 ('Video Coding Algorithm') shows, most desktop videoconferencing systems currently available are confined to proprietary hardware and/or software.

### 4.4.7. Trends: Virtual Reality

Increasing fractions of the computer power have been allocated to make the human-machine interface 'richer'. From a market perspective, the HMI has become a means to differentiate products. Virtual reality has emerged as a future trend of enriching the HMI and as a proliferation of the multimedia concept.

***Definition***

Virtual Reality is defined as 'a human-computer interface where the computer and its device create a sensory environment that is dynamically controlled by the actions of the individual so that the environment appears real to the participant.'[37]

***Market Segments***

In [37], five market segments are identified into which Virtual Reality is likely to differentiate (see table below).

| | **Market Segment** | | | | |
|---|---|---|---|---|---|
| | **Games & Entertainment** | **Distance Communication & Interaction** | **Simulation & Training** | **Telepresence** | **Visualization** |
| **Market** | Consumer | Business | Business, Medicine | Business | Business |
| **Vertical Market** | Home, Parlor & Parks | Conferencing | Training, Design, Surgery | Space, Environmental | Scientific analysis |
| **Critical Path for Creating a Market** | Low cost, Experience level | Ease of use, Effectiveness | Realism of simulation | Control, Realism | Performance, Data interface |
| **Success Criteria** | Unit volume, Attendance | Technology improvement | Greater effectiveness | Uniqueness, Cost | New data understanding |

Table 4.5: Market Segments [37]

*Games & Entertainment* have already conquered amusement parks, parlors and homes. The cost of the products and the quality of experience will determine the pace of growth of this market segment.

*Distance Communication & Interaction* is basically a business application. The vertical niche is similar to teleconferencing.

A critical factor for the success of *Simulators & Training* is the degree of realism. One major potential application is in medicine, e.g., for non-evasive surgery.

*Telepresence* enables a person to feel as if one is actually present in a different place or time. Applications already available include head-mounted stereoscopic displays, 3-D audio environment, and instrument gloves.[25] Telepresence allows exploration of environments that are physically distant, hazardous, or inaccessible.

*Visualization* spans many vertical markets, such as product design or data visualization. It facilitates the understanding of otherwise complex data, usually by means of computer graphics.

### *Market Formation*

Virtual reality is still in an early stage of its product life cycle, but is clearly beginning to grow. An increasing number of firms are implementing systems for sale, and competition is rising. This is particularly true for the Games & Entertainment market segment. The table below illustrates the strategies adopted for virtual reality products in the Introduction and Growth phases of the product life cycle.

| | **Introduction** | **Growth** |
|---|---|---|
| **Customers** | Innovators | Early adopters |
| **Competition** | Few | Growing number of imitators |
| **Product Strategy** | Basic | Extensions, features, service |
| **Price Strategy** | Cost Plus | Market broadening |
| **Distribution Strategy** | Selective | Build broad network |
| **Communications** | Create awareness | Stimulate wide trials |

Table 4.6: Strategic Market Decisions [37]

# CHAPTER 5

# MULTIMEDIA APPLICATIONS ON THE CALIFORNIA RESEARCH AND EDUCATION NETWORK

## 5.1. The CalREN Trust

Multimedia application development faces a classic chicken and egg dilemma: which will come first, the communications infrastructure, or the applications? Application developers will wait for the infrastructure to be put in place, while the infrastructure developers wait for the market demand. Pacific Bell, the major telecommunications carrier in California, has attacked this deadlock by:

1) Accelerating the deployment of communications technology in the San Francisco and Los Angeles area, targeting the provision of three specific Pacific Bell services:

   * Tier 1: ATM at 44.736 Mbps and 155.52 Mbps
   * Tier 2: SMDS at rates between 1.544 Mbps and 45 Mbps
     Frame Relay at rates between 56 Kbps and 1.5 Mbps
   * Tier 3: ISDN BRI (144 Kbps)
     ISDN PRI (1.544 Mbps)
     SDS-56 (56 Kbps)

2.) Promoting applications development by funding data communications services for approved projects.

Pacific Bell established a trust, known as the California Research and Education Network (CalREN), in December 1993. The trust is financed with $25 million and runs through 1995.[39] CalREN's purpose is to stimulate the development and utilization of applications for high-speed switched data communication services by funding projects that aim at [40][41]:

* Improvements in education and health care delivery
* Improvements in business and governmental processes
* Facilitation of new business development and creation of jobs
* Environmental monitoring
* Control and distribution of intelligence
* Advanced manufacturing processes
* Stimulation of commercial product development
* Improvement of California's competitiveness

Says Phil Quigley, President and CEO of Pacific Bell: 'By funding these projects today, we are speeding the benefits of the communications superhighway to all Californians, in the workplace and at home. We are turning the evolution of our public telecommunications network into a revolution for California.'[39]

Approved projects will receive funding for PacBell's communication services, which covers installation and recurring charges for the project's duration, for a maximum of 2 years. Currently, rates for 45 Mbps access are $5,000 for installation and $4,850 monthly for unlimited usage with no mileage charges. Rates for 155 Mbps access are $8,500 and $7,899, respectively.[42] The costs of the other components of the project, such as application software, computer and communications equipment, end user training, and project management are expected to be contributed by project participants.

CalREN's budget can accommodate 48 ATM connections at 155 Mbps, divided equally between the San Francisco and Los Angeles metropolitan areas. PacBell plans to connect 5 - 10 users per month, starting in January, 1994.

In return for Pacific Bell's support, the project participants have to agree to publicly share the results of their development projects. At a minimum, this refers to a project's final report or findings. However, some parts of the project may be proprietary, with rights solely owned by one or more participant.

It is intended that projects explore the *potential* of new products and processes for commercial applications. CalREN funding is limited to demonstrations, trials or pilots that do not further application development to a competitive level.

CalREN encourages intra-industry and inter-industry collaboration and cooperation. Team projects are promoted, because they [40]:

* permit small companies to gain access to advanced technology and resources
* provide an environment for standard-setting activities
* allow participants to leverage their resources with others
* provide an environment for users and suppliers to forge closer relationships than those in the typical customer-vendor relationship

## 5.2. CalREN Projects

On January 17, 1994, Pacific Bell presented the first award to the *Bay Area Gigabit Network* (BAGNET), a consortium of 14 organizations in the San Francisco Bay Area.

The award provides two years' free usage of PacBell's 155 Mbps ATM Cell Relay service to each member organization. The award is worth $2.8 million[1] .

In March 1994, Pacific Bell awarded another $2.6 million in high-speed network services to seven teams composed of businesses, schools and public agencies in the San Francisco Bay Area.[39] These 7 projects will test a variety of multimedia applications. One of these projects is the Health Care Imaging Project. Appendix 7 gives an overview.

## 5.3. The Bay Area Gigabit Network Project

### 5.3.1. Overview

The largest CalREN project in the Bay Area is the Bay Area Gigabit Network Testbed. Its overall goal is to 'develop and deploy the computer multimedia network infrastructure needed to support a diverse set of distributed applications in a large scale, metropolitan ATM network environment. Applications are seen as capability demonstrations, and infrastructure building and testing that will pave the way for large scale commercial and public applications.'[43] Another goal of the project is to integrate ATM networks into the Internet environment.

The featured application for the testbed is a real-time multicast teleseminar capability. This will allow participants to conduct teleseminars from their normal work environment, using personal multimedia workstations. The proposal calls for 200 to 300 hours of public teleseminars per month.[41] Furthermore, the development of large scale, distributed mass storage systems shall enable storage of multimedia streams for later viewing. Property rights, privacy, confidentiality and social issues will also be addressed as a part of the project.

[1] according to A. Albanese, Staff Scientist at ICSI and Executive Committee Member of BAGNET

PacBell has awarded each organization the provision of one sequence preserving, connection oriented ATM transport service with customer access at OC-3c (155.52 Mbps) rate. The service is available at no charge 24 hours every day throughout the project's two year period. Some organizations will upgrade to OC-12c (622 Mbps) when it becomes available, in order to support the high data rates required for specific applications.

Major milestones of the BAGNET project are specified in appendix 8.

### 5.3.2. Participants

The BAGNET has currently 14 participants, including almost all the major government laboratories, research universities, research institutes, and technology companies in the San Francisco Bay Area:

* Apple Computer
* Digital Equipment Corporation (DEC)
* Hewlett-Packard Laboratories
* International Computer Science Institute (ICSI)
* Lawrence Berkeley Laboratory (LBL)
* Lawrence Livermore National Laboratory (LLNL)
* NASA Ames Research Center
* Sandia National Laboratories
* Silicon Graphics Inc. (SGI)
* Stanford Research Institute (SRI) International
* Stanford University
* Sun Microsystems Inc.

* University of California, Berkeley (UCB)
* Xerox Palo Alto Research Center (Xerox PARC)

### 5.3.3. Participants' Contributions

***Software Development***

Project participants contribute by developing software that is needed to support distributed computing applications, including addressing, routing, data transport, signaling and application management.

***Equipment***

Each of the participating organization is expected to supply [43]:

1) All required customer premise equipment to connect to a SONET OC-3c medium reach fiber interface
2) ATM LANs, usually in the form of an ATM switch that conforms with the ATM-Forum recommendations
3) Computer workstations equipped with ATM interfaces
4) Video and audio equipment as well as conference room facilities

In addition, a number of sites will make their high-performance computing facilities available to BAGNET, including:

* Supercomputers at NASA Ames and LLNL
* RAID-II storage system at UCB
* Connection Machine and MasPar (massively parallel computer) at SRI and LBL
* National Storage Laboratory (NSL) at LLNL

* Prototype remote instrumentation systems and high-speed ATM routers and gateways at LBL

***Personnel***

Computer science, engineering, telecommunications and administrative personnel at each participating site will need to be allocated to BAGNET related work on a full or part time basis.

### 5.3.4. Costs

For most of the sites, the equipment fully dedicated to BAGNET is valued at $400,000 to $600,000.[43] Appendix 9 gives an example of equipment and network investment costs of providing teleseminar facilities to support BAGNET teleseminar applications. The aggregate value of the partly dedicated high-performance computing facilities 'easily runs to the hundreds of millions of dollars, and even the fractional use by the testbed will be substantial.'[43] The staff costs are difficult to estimate because of the varying commitments of staff and different institutional costs. Taking staff and equipment together, a conservative estimate of in-kind contributions resulted in $0.75 million per site in the first year. The second year is expected to incur comparable higher staff costs and somewhat lower equipment costs.[43]

The network costs, covered by the CalREN award, are $8,500 for installation and $7,899 operational costs per months.[42] This is equal to $103,288 per site per year.

Providing desktop teleseminar capability achieves an immediate cost advantage since some of the equipment is already there and only partly dedicated to the teleseminar application, and will consequently be more utilized than equipment in dedicated teleconferencing

rooms. In the example in appendix 9, more than 40% of the investment costs are sunk costs and therefore need not to be considered for financial project justification.

As already discussed in chapter 1, the organizational costs are expected to be higher than the equipment costs. For instance, professional production of teleseminars requires dedicated staff, at least until the system operates smoothly.

### 5.3.5. Applications

#### i) Teleseminars

There is a wealth of technical information available in the San Francisco Bay Area. This is due to the high concentration of universities, government laboratories and high-technology companies. However, distance, schedule, time and congestion constraints prevent many researchers and professionals from attending meetings, collaborating or pursuing further education. These constraints could be overcome if teleseminars were offered at users' normal place of work.

The concept of teleseminars is not new, teleseminars have already been conducted for many years. However, users had to leave their offices and use dedicated teleconferencing rooms. The range of users has typically been limited to executives of large companies, primarily due to the high equipment and operational costs.

The new revolutionary development is to provide teleseminar capability in the participants normal work environment by using multimedia workstations. Multimedia tools and protocols have been developed for the Internet that can readily be implemented on BAGNET.

A teleconference on the *Internet Multicast Backbone* (mbone) typically uses the session directory (SD) to announce and coordinate sessions, the video audio tool (VAT) to manipulate the audio streams, the network video tool (NV) to display images or video, and the whiteboard (WB). The whiteboard supports the display of documents in Postscript format, or the collaborative design of documents. The representation of documents can also be controlled externally, e.g., by the Phone Assisted Teleconferencing (PAT) tool[1] .

The mbone teleseminar tools are easy to use. This allows a vision of everybody being able to organize and control a teleseminar, once the system is set up and people are taught of how to use both the mbone tools and external equipment, such as lighting. This vision is less of an illusion if one recaps the revolutionary breakthrough of other Internet services, such as electronic Mail. By being committed to running teleseminars, computer scientists among the BAGNET community will feel challenged to improve the tools, an effect that has already been observed. BAGNET is in the unique position of having the three main designers and implementors of the mbone teleconferencing tools[1] within the testbed community.

A live local audience that participates in a presentation can also be accommodated. Existing meeting rooms can easily be upgraded to allow for interaction between speaker, local audience and remote audience. The speaker can be lecturing, or interacting with a remote or local audience, and simultaneously present multimedia material.

Appendix 10 shows a configuration of an upgraded conference room in which teleseminars can be conducted. It also illustrates how the multimedia information is displayed on the workstation of a remote participant, using the mbone tools *SD*, *WB*, *VAT* and *NV*.

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[1] developed by A. Albanese, A. Gil and A.S. Gonzales at ICSI, Berkeley
[1] Ron Frederick, Xerox PARC; Van Jacobsen, LBL; Steve McCanne, LBL

Due to the high bandwidth available through ATM, the number of remote participants in a BAGNET teleseminar can be as high as several hundred-effectively unlimited for practical applications.

In addition to the real-time distribution, seminars will be captured and stored for later viewing, electronic submission of queries (written, drawn, spoken, graphical) and their subsequent response by the speaker or a designated panel of experts. This will be done in conjunction with the deployment of a large scale, distributed mass storage system.

The availability of a generalized teleseminar capability on demand could have a revolutionary impact on the effectiveness of almost any kind of organization. In the following paragraphs, this view will be supported by discussing other applications to be implemented on BAGNET.

**ii) Large Scale Distributed Storage and On-line Multimedia Libraries**

Limitations in storage and networking technology have so far made it impossible to access mass data in real-time. However, real-time access is fundamental for real-time applications. This is also an issue for the teleseminar applications envisaged as running on BAGNET. Multimedia streams must be preserved, indexed, and made available in a digital multimedia library. It is likely that these massive amounts of data will be stored in a distributed fashion at participants' site. Rapid data transfer will then be required to retrieve sessions from these storage systems, as will various types of data management.

Specifically, the BAGNET project can benefit from the experiences of one of its members, the Lawrence Livermore National Laboratory. Its National Storage Laboratory (NSL) was organized to [43]:

* Test, evaluate and demonstrate high-performance, distributed, hierarchical storage system architectures
* Provide the capability to handle gigabyte files and multiple terabyte databases at Gbps data rates
* Set priorities, test and demonstrate productivity increases made possible by the NSL system architecture

A later BAGNET activity will be to integrate with NSL to develop an IEEE compliant mass storage system that is cost-effective and scalable. Research will focus on the functionality, performance, reliability, security and data integrity of the hardware and software solutions.

**iii) Collaborative Engineering Environments**

Software tools that emulate a collaborative work environment allow design teams to cooperate on large projects despite being located in different places. Extension of this concept to large geographic areas, and expanding its scope to scientists, engineers, staff and managers to support any kind of corporate communication, should have a profound impact on the manner and efficiency with which large scale projects are undertaken.

Much of the acceptance of *computer supported collaborative work* (CSCW) will depend on its functionality, effectiveness and cost, compared to face-to-face meetings. CSCW requires workstations be capable of capturing, storing and displaying multimedia streams at

reasonable quality and speed. This implies the provision of bandwidth ranging up to several hundreds Mbps[1] .

Almost all participants have extensive expertise with proprietary CSCW tools. Consequently, the testbed offers the opportunity to test interoperability of systems from different vendors by developing and evaluating a heterogeneous CSCW system distributed across several sites. A prototype CSCW system will be used by a design team of up to six persons, working collaboratively but at different locations. Multiple windows on the workstation console enable the concurrent display of the design object, live video of team members, a scratch pad for writing notes and a control window for floor management or bringing up database information. Applications that are envisaged as running on BAGNET in order to test the feasibility of the prototype CSCW system may include the collaborative development of [43]:

* semiconductor chips, printed circuit boards, or entire computer systems
* software
* marketing presentations, publication materials, sales presentations

Examples for future applications of the CSCW system are numerous. For example, private consultants could improve their productivity by participating in several projects at the same time without ever leaving their office. Removing the need for car travel also addresses its direct and indirect drawbacks that have become major issues in the Bay Area: traffic congestion and car related environmental pollution.

[1] Real-time transmission of a rotating CAD drawing requires 100 to 300 Mbps (1024*1024 pixels, 24 bits coding length per pixel, 10 to 30 Hz window refresh rate) [43]

### iv) Remote Instrumentation

Remote instrumentation can be described as the ability to control activities and processes remotely, independent of location or availability of specialized resources. Applications of this functionality include remote control of electric generating plants, remote monitoring and control of energy use, telemedicine, and advanced manufacturing. All applications have in common that they require real-time control and real-time data delivery.

The BAGNET project will focus on the remote control of microscopic processes. This capability will 'revolutionize laboratory procedures, because it is impossible to control microscopic instruments using current conventional sensing techniques.'[44]

Real-time micro-control of a microscopic environment involves the following steps: sensing (by imaging through the microscope), extraction of the important information from the images, and a mechanism for controlling the environment. Since the environment is dynamic, imaging will produce motion video, the real-time processing of which depends on high-speed data collection, transfer and computation. The process in which information is extracted from high-speed data streams and high-speed analysis to control some aspects of the environment being imaged is called 'visual serving'.

This high-speed data flow aspects will be investigated in BAGNET. Remote control of the instrumentation is not confined to one site but can be available between geographically dispersed sites (figure 5.1). This could stimulate collaboration and consulting, remote use of scarce facilities, on-line laboratory teaching, etc.

The figure below illustrates, how the movement of the video camera could be controlled remotely.

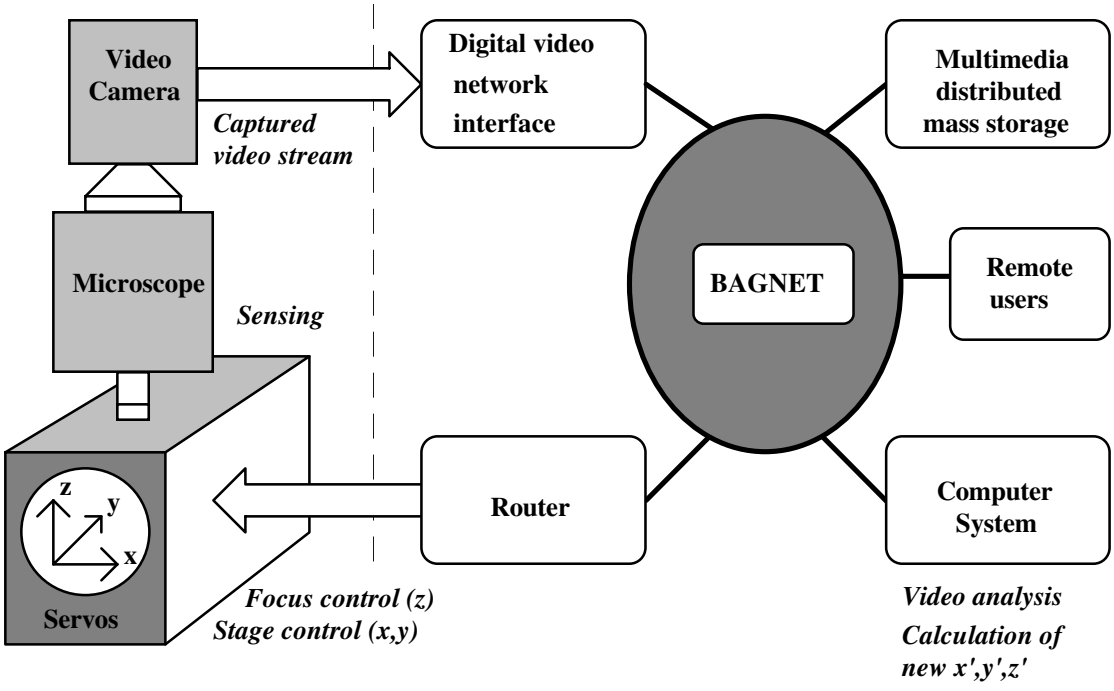


Figure 5.1: Network Based Remote Microscope Control [44]

Planned implementations include micro-manipulations, imaging of live micro-organism by automatic tracking and focusing and control of in-situ micro experiments.

### v) On-Demand Manufacturing

Advanced manufacturing systems in the future will enable distributed manufacturing operations aimed at customized or on-demand production. Both the process of designing and debugging the manufacturing process in a laboratory environment, and the actual implementation in a production plant, will then make use of communication networks and distributed computing facilities. On-demand manufacturing could become an important and significant activity of large scale ATM networks.

Once sufficient infrastructure is in place in the BAGNET testbed, experiments in advanced flexible manufacturing will be carried out.

### vi) Architectures for Regional Health Care Information Systems

There is a tremendous utility and synergy in connecting regional groups of physicians, nurses, medical researchers and students, to widely accessible public networks.[7] Architecture for Regional Health Care Information Systems are being developed to provide new capabilities for regional health care environments. Such environment is characterized by [43]:

* Large-scale, distributed, multimedia, federated databases for patient records
* Representation of knowledge and medical/laboratory protocols
* Security and privacy concerns
* Accounting and billing requirements
* Interface to laboratory systems (auto acquisition of lab results)
* Distributed instrumentation (telemedicine)
* High-bandwidth, high availability image servers (teleradiology)
* High reliability, large scale archival storage
* Widespread tele-education for mandatory life long learning
* Heterogeneous telecommunications access
* Digital libraries
* High payoff/quality of life

BAGNET will use the Hub concept[1] to model a future health care information system. The Hub is 'an information center that serves as an on-line library and consulting service

[1] developed by Dr. Ace Allen, University of Kansas Medical Center

for the medical community, as well as providing a variety of information and communications services'.[43]

Major architectural elements of the Hub are:

1) Shared mass storage system
2) Shared computing resources
3) Computerized patient record systems
4) Shared accounting and billing
5) Multimedia gateway

Hub information services are inherently communications intensive.[43] BAGNET provides the means to investigate and implement Hub services. Appendix 11 illustrates the relationship and connectivity of the elements of an implementation.

It is envisaged to connect some of the many large Bay Area health care provider facilities to BAGNET. Synergy between BAGNET's work on architectures for regional health care information systems and the Health Care Information System project is anticipated due to LBL's participation in both projects.

### 5.3.6. Expected Project Benefits

Project beneficiaries are as diverse as scientists, researchers, engineers, students, educators, managers, and doctors. In the long-term, a broader range of people will benefit directly or indirectly from the enhanced information-dissemination tools and techniques to be developed in the course of the BAGNET project.

Benefits from the BAGNET project are expected to be threefold [43]:

1) Implementation and testing of ATM networking technology that is able to cope with the future increase in bandwidth demand
2) Development of high-speed networking applications that have the potential to revolutionize information exchange and technical collaboration in California and the United States
3) Testing of the market potential of applications developed in the context of the BAGNET project, and stimulation of demand by illustrating the benefits to a diverse user community

***Technological Benefits***

In the process of implementing applications, new multimedia tools will be developed that enhance people-to-people collaboration. The performance of mass storage systems that have acted as a bottleneck to the effective use of high-bandwidth networks will be improved. Pioneering experiences are expected from applications that perform remote control.

Other high-speed network developments will benefit from experiences gained from BAGNET, including:

* Interconnection of heterogeneous equipment
* Scaling ATM to large metropolitan areas
* Implementation of Internet protocols on ATM networks
* Multicasting with ATM
* Multimedia transmission and storage requirements

### *Information-Exchange Benefits*

The benefits that will be derived from the generalized teleseminar capability have already been discussed. Furthermore, BAGNET will 'support technology transfer, continuing education/professional development programs, science-education outreach, and training.'[43]

The project addresses a long-term issue, namely how to cope with an increasing amount of information. Visualization facilitates an understanding of complex problems; high-speed networks and mass storage system make information available when actually needed, and network connectivity promotes active collaboration between experts from industry, academia and government.

### *Commercial Benefits*

Information technology and product development has become increasingly vital to the economy of California.[43] Exploitative applications run on BAGNET will stimulate the market potential and proliferation of ATM networks. This in turn will make a variety of multimedia applications cost efficient, thereby broadening the range of users in education, health care, and entertainment, and other areas. Hence, BAGNET 'will make a significant contribution towards achieving CalREN's goals of improving education, health care, business and governmental processes, control and distribution of intelligence, and stimulation of commercial product development.'[43]

BAGNET participants will gain long-term benefits from their technology leadership. Keeping up with state-of-art technology will enable the development of innovative products and services, provide effectiveness improvements and will eventually result in a competitive advantage.

### 5.3.7. BAGNET: A Realistic View

#### i) Current State of the Project

***ATM Connectivity***

Compared with the milestones in the project proposal, the actual implementation of the project is lagging behind. On July 11, 1994, five sites[1] were not connected yet.[48] ICSI was finally connected at the end of August, 1994. Delays were mainly due to the late release of the latest ATM switch version by SynOptics. Among the connected sites, some cannot handle multicasting.[47] The maximum number of hosts per site that can currently have access to BAGNET is limited to 4, the limiting factor being the trunk interconnect between the two PacBell switches.

***Applications***

Due to the lack of full connectivity, the start of teleseminars and mass storage experiments has been postponed. With the delivery of the ATM switches in progress, they are expected to start in September, 1994. The storage and playback of meetings has been deferred until more is known about the required infrastructure. However, experiments with ATM and multimedia have already proved that ATM is capable of transporting lightly compressed video with a quality comparable to broadcast TV, along with CD quality audio.[46]

Project management has been facilitated by making use of the great potential offered by the World Wide Web (WWW) , a distributed hypertext system on the Internet. Participants regularly update information on the BAGNET home page[1] . WWW is also expected to be used as scheduling and announcement tool for BAGNET applications.

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[1] ICSI, LLNL,SGI, Stanford University and UCB

[1] The BAGNET home page on WWW is <http://george.lbl.gov.BAGNet.html>

***Issues***

The ultimate goal is to reach not only enhanced high-performance workstations but also the ordinary workstations connected to the conventional LANs. However, software decoding of video streams requires high computing power. Therefore, the less powerful the workstation, the lower the quality of the displayed video. This is illustrated in the table below.

| Image Size | Platform | Decode/Display Rate |
|---|---|---|
| 512*512 pixel | Sparc10 | 1 fps |
| 512*512 pixel | Sparc2 | 0.5 fps |
| 256*256 pixel | Sparc10 | 5 fps |
| 256*256 pixel | Sparc2 | 2.5 fps |

Table 5.1: Display Rate of a Software Decoded JPEG Video Signal [47]

While experimenting with teleseminar productions on mbone, non-technical issues arose that are also significant for the BAGNET teleseminar applications:

* Lighting, camera movement, audio volume, video brightness and contrast, etc.
* Session control systems to enforce policies on who can do what
* Technical and intellectual property issues of teleseminars re-use
* Agreement on recording policies
* Privacy issues

It was agreed that BAGNET will not be used as an alternative path for Internet traffic to avoid paying Internet access/use fees, nor will it be as a transit network for non-BAGNET traffic.[46]

***Looking into the Future***

The first major public demonstration of a BAGNET application is planned for the Second ACM International Conference on Multimedia in San Francisco, October 17-19, 1994. A two-hour panel discussion about BAGNET will be conducted, involving both BAGNET participants located at various BAGNET sites as well as participants located at the main conference site.

Connections between BAGNET and other CalREN project members in the SF Bay Area and Southern California have been under discussion. Connections will be established as soon as the SVC service becomes available.

The Swedish Royal Academy, which has a BAGNET-like setup in Stockholm, is interested in extending it internationally and has expressed its interest in a collaboration with BAGNET.[47] Though major technical problems will need to be tackled, an expansion of the scope of BAGNET applications could have huge future potential. For example, SIEMENS is currently investigating the pros and cons of collaborative work among its multinational subsidiaries[1] . Working on one project at multiple locations around the globe may replace the need for working shifts at a single location, and result in significant time and productivity gains.

Financial justification of applications run on BAGNET will be crucial for the continued operation of BAGNET once the CalREN award terminates. This is particularly true for the participating companies whose research projects are subject to strict financial control. However, in the face of limited government grants, even universities and government research laboratories will have to justify the benefits of ATM connectivity in monetary

[1] according to Rainer Storn, research scientist at SIEMENS AG, ZFE, Munich

terms. Even now, BAGNET participants 'must think about evaluation of results rather than mere anecdotal evidence.'[46]

## 5.4. The Health Care Imaging Project

### 5.4.1. The US Health Care Industry

In the US, health care costs rose from $240 billion in 1980 to $666 in 1990 at which point it accounted for 11% of GNP.[6] Federal Government expects this percentage to rise to as much as 15% of GNP by the year 2000.[53] In 1990, there were 6,500 hospitals in the US, serving 40 million patients with 1 million beds.[6] These figures indicate, that health care is one of the major sectors in the US economy.

Despite this large expenditure[1], the US health care industry is facing a 'growing crisis of runaway costs, poor health outcomes, and an uneven distribution of health care.'[53] This view is supported by the following facts:

* The hospital occupancy rate was only 65% in 1990 [6]
* The infant mortality rate of the US is higher than that of many other western industrialized countries [53]
* Health care costs have increased by 50% above of inflation [6]

Medical costs are divided between insurance companies, patients, and the government. In 1990, the individual shares were 35%, 25% and 40%, respectively.[6]
The large costs and the inefficient use of funds have prompted government and insurance companies to take measures to control costs. This has been achieved by making patients

[1] Health care expenditure accounts for 9% of GNP in Canada and 5.5% of GNP in Japan [6]

pay more for expansive and optional treatments, and specifying fixed fees for diagnosis related groups. These measures have resulted in [6]:

* Decline in hospital utilization
* Switch to outpatient visits as opposed to inpatient stays, particularly for medical imaging, 70% of which was performed on an outpatient basis in 1990
* Increased utilization of physicians offices, as opposed to hospital visits
* Increased use of medical imaging
* Increased use of EDI between health care facilities and insurance companies

The present US government has made health care reform the flagship of its domestic policy. Clinton's original proposal calls for 'universal coverage (not just access), uniform benefits, cost control and structural system reform.'[57] However, since employers' contribution will rise if the proposal gets approved, in particular small businesses are lobbying heavily against this proposal, and have won the backing of the American Medical Association. Broadband technology is poised to help to attack this deadlock. Says Roy Neel, USTA president and former White House deputy of staff: 'The Federal Government is looking at technology to make health care more efficient and bring down costs.'[57]

### 5.4.2. The Work Flow in a Health Care Imaging Environment

In a medical institution, the activities are based on the so-called 'medical examination', a series of tests performed on a patient on request of the patient's referring physician. In a health care imaging environment, the test consists of medical images taken of the patient and interpreted by a specialist. The work flow can be divided into three phases: *preliminary phase*, *procedural phase*, and *result phase*.[50] The tasks to be performed in each

phase, and the personnel involved, are shown in appendix 12, and will be described in the following.

***Preliminary Phase***

Information on the patient is gathered by the patient's referring physician, such as:

* Demographic data (names, date and place of birth)
* Social insurance number, address, employer, insurance company
* Medical data (blood group, medical history, allergies, etc.)

The referring physician fills out a form in which he requests an examination to be performed on the patient by an imaging specialist. This request, along with all relevant patient data, is sent to the specialist. The request is then reviewed, and, if appropriate, accepted by the imaging specialist. The data is stored in the Hospital Information System (HIS), and an appointment scheduled.

***Procedural Phase***

Upon arrival at the imaging department, the patient is registered. If necessary, the patient is injected with contrast media by medical personnel prior to the image acquisition. Images are taken in a process which involves a technician placing the patient in front of a camera. All information (dose, images, comments, etc.) is recorded and stored.

***Results Phase***

During this phase, images are viewed, processed and analyzed, and a report dictated by the imaging specialist. The report is typed by the transcriptionist, reviewed (and edited if necessary) and approved by the specialist. The report is then sent both to the referring

physician and to the hospitals' archiving system. Pertinent information is also passed to the hospital's Financial Department and to the Insurance Company.

### 5.4.3. Motivation for the Health Care Imaging Project

Coronary artery disease (CAD) is the leading cause of death in older men and women in the US.[49] Angiography is a technique where x-rays are taken from the patient before and after injection of a contrast material that is opaque to x-rays. Numerical subtraction of the resulting images highlight the contrast agent without interference from the shadows of other body parts and can be used to detect blockages in blood vessels.[6]

Procedures used to restore coronary blood flow[1] are expensive. In an effort to minimize costs, medical care providers have concentrated these services in a few high volume tertiary care centers.

Kaiser Permanente (KP), a health maintenance organization serving about 2.5 million Kaiser Health Plan members in its facilities located in Northern California, currently maintains four tertiary care centers. 5000 patients per year undergo cardiac catherization at one of these centers, of which 2500 patients are treated in the San Francisco Cardiac Catherization Laboratory.[49] Patients are referred to these centers by physicians at their home facilities, and the results of the procedural phase are then returned to the referring physician.

Though centralization of services is more cost effective, benefits are largely offset by the failure to rapidly and accurately deliver the medical information obtained in the procedural phase back to the treating physician in the patient's home facilities.

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[1] percutaneous transluminal coronary angioplasty, directional atherectomy and coronary artery bypass graft surgery [49]

***Delivery System***

The delivery system currently used to transfer patient information between the patient's home facility and tertiary care center include interoffice mail, US mail, fax, telephone, and courier. In many cases, these systems are 'inadequate and could potentially introduce delays in patient care.'[49]

Images are stored on films. Access to films, stored in a library, can result in significant time wastage for the imaging specialist or physician. Furthermore, there is the risk of the films be misplaced or lost. In this case, exams have to be repeated at additional cost. Film based imaging may lead to wasted physician's time, additional nursing, administrative effort, and inconvenience to patients.[51]

***Consultation***

Consultation between the local physician and the tertiary medical center is an important activity that improves the effectiveness of the diagnosis. Information about the patient, as well as medical opinions, are exchanged, e.g., in the case of:

* Requests for referral are made to plan the treatment to follow
* Referring physicians, having received an examination report, may need further clarification
* Consultations occur with colleagues located in-house or in other medical institutions

Currently, this consultative process can occur through face-to-face meetings, telephone conversations, or the delivery of patient information as described above. However, face-to-face meetings require both participants to be in the same place at the same time, which is difficult to arrange due to the traveling involved. In the case of non face-to-face infor-

mation transfer, patient data might becomes distributed and is not always where it is needed. The current process of consultation is, in general, time-consuming, inefficient, and can cause delays in patient treatment.

### 5.4.4. Project Overview

The Health Care Imaging project, supported by a CalREN award, will explore the use of ATM technology to facilitate the collection, storage, analysis, distribution and delivery of coronary angiograms and accompanying information. The multimedia imaging system will work in parallel to the conventional film-based system for the projects duration to ensure data integrity and allow for performance comparisons. The project will start in September 1994 and run for a two years period.[49]

Project participants include:

* Kaiser Permanente Medical Care Program
* Lawrence Berkeley Laboratory
* Phillips Research Laboratory, Palo Alto

Other companies have expressed their interest in participating in this project, including Novell, Sony Medical Systems, and Sun Microsystems.[49]

The project goals are [49]:

* Collection and delivery of large images and digital video data sets to local medical facilities in order to provide transparent access to coronary angiograms

* Real-time displays of images at the local medical facilities, allowing on-line collaboration between a patient's local physician and the cardiologist in the tertiary medical center
* Use of low cost, distributed, digital server technology for caching 'active' data
* Evaluation of the form of the delivered image information for diagnostic purposes, relative to current practice
* Determination of maximum allowable image degradation due to compression and minimum bandwidth to support these applications
* Identification of potential limitations of using ATM technology for health care imaging, including loss of image resolution and the effect of data compression
* Determination of suitable ATM network configurations
* Quantitative analysis of arteriogram images to improve the accuracy of standard measurements and to develop new techniques and measurements that may be useful in the diagnosis, treatment and prognosis of CAD

Further issues that will addressed in this project include [49]:

* Quality of Service guarantees for live transmission of medical video image streams
* Security and authentication procedures for handling this type of medical data in the environment of a public network
* Amount, type, and location of storage facilities

### 5.4.5. Project Plan and Network Configuration

The project plan calls for network installation and development of software tools (LBL), installation of scanners and remote playback (Phillips), and evaluation of the clinical benefits (Kaiser Permanente). The major project milestones are shown in appendix 13.

***Kaiser Permanente-Cardiac Catherization Lab***

The images are acquired at the Cardiac Catherization Lab. Images are fed as NTSC video into the multimedia system. Images can be compressed and stored locally, or retrieved from remote sites. In addition, catherization multimedia reports are generated on workstations, including images and dictated comments, and printed. These reports, along with a pointer to the storage location, will be made available to all remote sites connected to the ATM network. Collaboration is facilitated by the workstations' teleseminar capability.

***Kaiser Permanente-Cardiology and Nuclear Medicine Departments***

Computer workstations and printers provide the capabilities of retrieving, displaying and printing multimedia reports as well as participating in teleseminars. In addition, the Nuclear Medicine Department will compare the results of angiography with results from non-nuclear scanning. The ability to perform these comparisons 'will enable nuclear medicine to improve the sensitivity and specificity of its scan and will be used for medical quality assurance.'[49]

***Kaiser Permanente-Division of Research***

This department will use the system to conduct performance evaluations, and to improve analysis software for measuring the degree of stenosis. System utilization will be monitored, and the system's impact on physicians treatment decisions and patient management measured. DOR already has T1 interface which provides Internet connectivity.

***Lawrence Berkeley Laboratory***

LBL has strong expertise in working with high-speed distributed imaging systems, parallel-distributed file servers for video and large images, massively parallel computers for real-time control and processing of video, as well as ATM technology. This expertise

will be used to design and install the communications and data management systems, perform data analysis and design experiments for distributed image storage and real-time access. The Health Care Imaging project will benefit from synergy derived from LBL's participation in BAGNET. LBL is also an active member of the Internet community, contributing to the development of Internet standards and software platforms.

***Phillips Research and Others***

Phillips will provide the expertise and equipment of their medical instrumentation group. Other industrial partners are expected to contribute communications and computing equipment. *Novell* has developed a video networking product to manage video images in a LAN environment. *Sony Medical Systems* has developed a video archiving, storage and retrieval system for cardiac catherization labs. *Sun Microsystems* manufactures computer workstations and video boards for handling video streams.

ATM OC-3c network connections are requested for:

* Cardiac Catherization Laboratory at the Kaiser Permanente Medical Center (KPMC), San Francisco
* Cardiology and Nuclear Medicine Departments at the KPMC, Oakland
* Cardiology Department at the KPMC, Hayward
* Kaiser Permanente Division of Research (DOR), Oakland
* Lawrence Berkeley Laboratory[1]
* Phillips Research, Palo Alto

The network configuration and components at the single sites connected through the ATM network are shown in appendix 14.

[1] LBL is provided ATM connectivity through a connection to BAGNET

### 5.4.6. System Requirements

***Viewing Stations***

A major requirement of health care imaging systems is to provide viewing stations that give at least as good diagnostic accuracy as film, at as low a cost as possible. Users have three main diagnostic requirements:

* Adequate resolution of individual images
* Ability to compare several images of the same modality[2]
* Ability to display both images and other media concurrently, e.g., written reports

The size of a typical coronary angiogram is 512 by 512 pixels.[6] To match aforementioned requirements, viewing stations have to have either higher resolution monitors, e.g., 1024*1024 pixel, or only portions of the image can be displayed at its original resolution. Physical size of the screens is also important, computer images of about 75% of life size give diagnostic accuracy comparable to film.[6]

***Bandwidth and Storage Requirements***

Coronary angiograms are recorded via NTSC video at 30 frames per second with 512 by 512 pixels resolution. Each pixel is coded using 16 bits.[6] A typical angiogram video sequence is about 2000 frames.[49] This results in data volumes of 1000 MB per exam and a peak bandwidth of 120 Mbps. The ATM network at OC-3c speed is capable of transmitting these uncompressed, high resolution, monochrome digital video streams in real-time between sites. Relatively low cost LAN technology makes it feasible to provide real-time access locally, as well.

[2] Radiologists typically view eight films at once on a single eight-panel light box [53]

Storage of uncompressed image files at the Cardiac Catherization Lab in San Francisco would require a juke box arrangement of at least 19 optical platters for short-term storage (5 days), and a library of 4,900 optical disks would be required to hold five years of images for archival purposes[1]. However, image compression and decompression algorithms could be used to significantly reduce the storage requirements.

### 5.4.7. Strategic Impact

***Key Objectives***

The effectiveness of health care cannot be evaluated by mere financial measures. In a Hospital Project at the Central Middlesex Hospital [55], the following key objectives were identified against which the effectiveness of the Health Care Imaging project could be measured also:

* Increase the quality of care delivered and improve patient outcomes
* Increase patient satisfaction
* Increase staff (nursing, therapist, clerk) satisfaction
* Increase physician's satisfaction
* Reduce documentation
* Reduce length of stay
* Reduce or maintain costs

***Diagnostic Effectiveness and Satisfaction Improvements***

There will be a substantial reduction in the delay between the cardiac catherization procedure and the delivery of reports and images to the treating physician. Patients will 'benefit

[1] 2500 patients a year, i.e., 48 patients a week; one optical disk (2.5 GB) can store 2.56*1000 MB

from shorter delays between catherization and treatment decision, and from the educational value of viewing their own angiograms.'[49] Cardiologists will benefit through faster access to reports and images, and the ability to conduct teleseminars to discuss a diagnosis or to trigger new considerations leading to a different diagnosis. Clinical experiments have proven a causal relationship between rapid delivery of radiological information and improved diagnostic and therapeutic effectiveness.[54] It is also clear that improved effectiveness makes it possible to decrease the average in-patient stay, which involves the financial management of the hospital administration and health-care insurers. Furthermore, digital x-ray detectors require lower x-ray doses than film, resulting in less exposure of patients to x-rays.[6]

Approximately 600 patients per year who are treated at the KPMCs in Oakland and Hayward would benefit directly from the improved access to catherization reports and images. If the ATM network is eventually extended to all catherization laboratories and cardiology departments, over 5000 patients per year could potentially benefit.[49]

Project beneficiaries include the 7 cardiologists and 3 nuclear medicine physicians from Oakland and 5 cardiologists from Hayward who start to use the system as soon as it is deployed. If extended to all facilities, 50 cardiologists and 30 nuclear physicians, and many more primary care physicians, would benefit.[49]

***Reduced Documentation***

Advantages of a multimedia systems in terms of documentation are twofold: the time for transcribing, processing and editing reports is likely to be reduced, since reports are created and transferred as digital file rather than printouts on paper. Secondly, the archive will be transformed from a conventional film library to a digital library. The advantages are well-known [54]:

* no lost images
* no problem with retrieval of old images
* images are easily available
* shared access of the same image is possible

With a multimedia health care imaging system, film library staff could be replaced by computer systems personnel, resulting in a net staff saving.[6]

***Cost Benefits***

At the current (initial) stage of the project, no data concerning cost benefits derived from the use of a multimedia imaging system, as opposed to a film-based system, has been gathered. However, studies have been conducted on this issue at the University of Washington Medical Center. A comparison of capital cost and operating costs is shown in appendix 15. It can be concluded that a new imaging system involves a heavy initial capital investment, but results in savings in operating costs. According to this study, physicians' time savings are the most significant factor. It has been shown, that, in this particular case, an additional time saving of a further 1% would drop the systems break even time period from 8 to 6 years.[6] Time savings of other personnel, e.g. library staff, is a second important determinant of health care imaging systems' profitability, and operating cost savings is a third.[6] Another study indicated that 'a PACS storage using high-speed communications is not only the most effective from a human factor standpoint, but also the most cost-effective.'[53] This result certainly supports ATM connectivity.

***Long-Term Benefits***

The project will evaluate the clinical potential of providing direct facility-to-facility communication of catherization lab reports and angiograms, thereby investigating the feasibil-

ity and usefulness of transmitting medical data and images via ATM networks. Experiences should contribute to the planning of future medical data communication networks which 'could change the scale of economy for health care by sharing the consultative expertise of health care professionals over wider geographical areas.'[53] Telemedicine has the potential to significantly improve the quality and range of health care services offered in small urban and rural hospitals and clinics as they will gain access to the scarce resources (specialists, equipment, etc.) commonly located at the urban hospitals.

The results of the project may also be useful for other medical image-oriented applications, such as in nuclear medicine or pathology.

### 5.4.8. A Realistic View

***Issues***

'The radiological experiences until now show that radiologists do not yet accept PACS.'[54] This statement relates back to 1991. It can be expected, that the major barriers for user acceptance, namely image resolution and user interface, have been lowered due to technical progress and experience in advanced system developments. But other questions arise:

* What is the new system's impact on the work flow?
* Who is responsible for the archive of images?
* To what extent will data compression be juridically allowed?
* How will the relationship between radiologists and physicians change?
* How can data security be guaranteed?
* How does the payment structure (patient, insurance, government) for the improved service change?

* Will the technical expertise to maintain the system be acquired in-house or outsourced?

***Current Stage of the Project***[1]

The first computer fully dedicated to the project, a Sun Sparc10, has been delivered to DOR, with Solaris 2.3 installed. It still needs to be configured with an ATM board and a SDV digital interface board. A Sparc10 may turn out to be too slow for some of the real-time image processing and data transfer (e.g., biplane image capture), however, allows some software to be tested. A Sparc20 is expected to replace the Sparc10 soon.

Fiber has now been run to both DOR and Oakland Cardiology, with some additional wiring remaining to be done. The installation is complete at the Cardiac Catherization Lab, San Francisco. According to the project milestones (appendix 13), full network installation and integration of all workstations is to be completed by December, 1994.

Baseline measurements in Nuclear Medicine, Cardiology and the Cardiac Catherization Lab are being conducted for the evaluation of the project.

A first major test of project components is envisaged as running at a convention at the Moscone Center[2] on October 22, 1994. Angiograms will be captured by digitizing catherization lab videos, stored at LBL and replayed on a Sparc10 station at the Moscone Center.

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[1] according to the project leaders: Joseph Terdiman, DOR, and William Johnston, LBL

[2] requires the temporary installation of either ATM or a T1 service in the Moscone Center

# CONCLUSIONS

Information Technology has a profound impact on the structural and functional aspects of organizations. To utilize IT optimally, thorough planning and financial control of IT projects is necessary.

Current IT development is characterized by the increasing importance of networking applications, creating a need for broadband services and solutions. Using fiber as transmission medium has great potential because it supports high bandwidth applications. ATM is considered to be the broadband technology of the future, providing high bandwidth for a large variety of applications while operating cost-effectively. Though not yet fully standardized, ATM technology has already been deployed by a number of commercial users as part of their long-term strategies. ATM demand is expected to increase rapidly once lower cost multimedia systems and applications attract a larger number of both commercial and private users. However, multimedia has already emerged as a serious commercial proposition. Currently, users are predominately professionals in problem-solving environments, such as education, health care, insurance, and publishing.

The BAGNET project and the Health Care Imaging project have the potential to serve CalREN's goals of improving education, health care delivery and business effectiveness. Teleseminars, as explored in the *BAGNET* project, will provide enhanced information-dissemination tools to scientists, students, professionals and doctors. These tools can cope with the increasing quantity and complexity of information surrounding us, eventually resulting in cost and time savings as well as effectiveness improvements. However, the project implementation lags behind due to network installation delay. The *Health Care Imaging* project is expected to improve the quality of health care delivery, patient satisfaction, and achieve operational cost savings, in the face of a growing crisis of the US health care

industry and the current plans for major reform. However, health care imaging requires a major initial capital investment, and user acceptance is very much dependent on diagnostic accuracy and the user interface.

The CalREN projects are still in the initial phase. Project benefits, as envisaged, need to be measured and compared against conventional approaches. Financial justification of the multimedia applications will be crucial once the CalREN award terminates.

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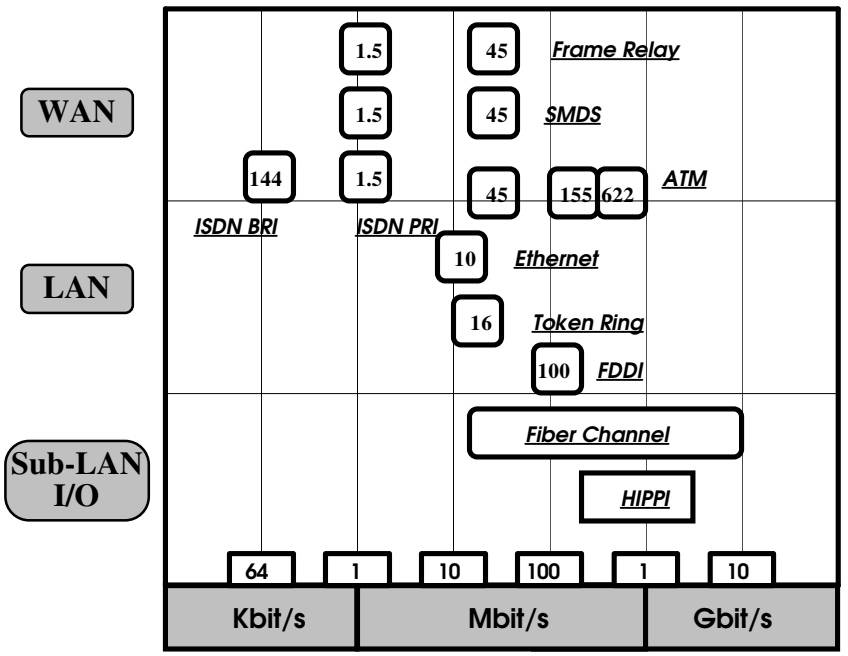
# Appendix 1 IS Planning Models [29]

| Model | Focus and Scope |
|---|---|
| ***Growth Stage Models*** | |
| Nolan's Stage Model (Nolan, 1979) | Organization must progress through a series of definite intermediate stages before it makes optimal use of IT. These stages include: Initiation, Expansion, Formalization, Integration, Data Administration, and Maturity. |
| Information Processing Eras Model (Rockart et al, 1984) | IT penetrates business functions in 3 areas:<br>1. Administration and Accounting<br>2. Main operations, e.g., Manufacturing and Marketing<br>3. Strategic decision-making and planning |
| Earl Stage Model (Earl, 1988) | Suggests 5 stages for IS/IT planning:<br>1. IS/IT Mapping: defining organization's current position<br>2. Business Direction: aligning IS function with business needs<br>3. Detailed Planning: developing a balanced application portfolio<br>4. Competitive advantage: achieved through use of IS/IT<br>5. IT strategy connection: IS strategic planning is part of business strategy formulation |
| ***Planning Models*** | |
| Portfolio Approach to IS (McFarlan, 1974) | Assessment of the risk associated with IS projects. |
| IS Strategic Grid (McFarlan and McKenny, 1983) | Relationship between strategic impact of existing and proposed IS applications portfolio. Definition of organization's IS positions: "Strategic", "Factory", "Support", or "Turnaround". |
| Value Chain (Porter and Miller, 1985) | System of inter-dependent activities and internal linkages. Linkages often create trade-offs that could be optimized. IS/IT can then be used to create substantial and sustainable competitive advantage. |
| Strategic Value Analysis (Curtice, 1987) | Methodology to develop long-term plan that considers business strategy, data flow, existing systems and capabilities. Stages include database design, system synthesis, architecture design, project creation, plan development, and maintenance of plans. |
| ***Project Man. Models*** | |
| Davis, Olson, 1984 | Contingency approach, dependent on risk associated with the project. Factors of risk are project size, structure of task, level of technology relative to the organization. |
| Accomplishment Value Procedure (Aharonian, 1979) | Each completed task is credited with a certain value. Progress of individual projects and group projects is monitored by summing up the values achieved. |
| ***Composite Planning Models*** | |
| Business System Planning (IBM, 1975) | Development of an overall IS strategy and architecture, at both strategic and operational level. Top-down analysis of organizations IS needs. Bottom-up implementation: general design, detailed design, development, test, installation, and operation. Information system plan linked to business plan. |
| Three-Stage Model (Bownan et al, 1983) | Identification of three generic planning activities: strategic planning, organizational information requirement planning, and resource allocation. |
| Enterprise-Wide Information Management (Parker, 1985) | Orientation of IS towards top management needs. Includes identification of critical success factors as well as key decisions and information needs related to them. |

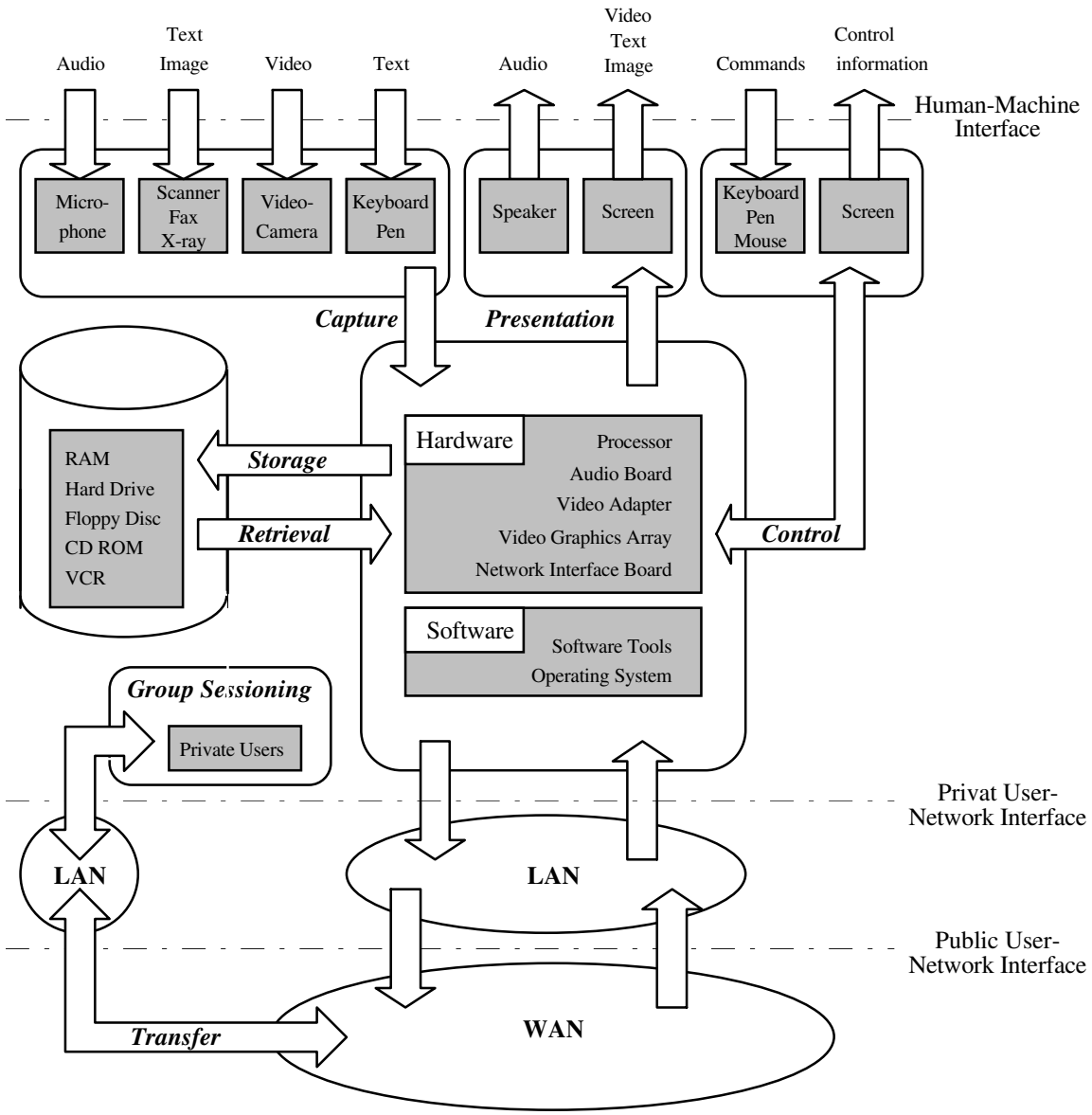
# Appendix 2

## Network Services



# Appendix 3

## Multimedia System Model



# Appendix 4 Multimedia Applications

| User group | Applications |
|---|---|
| **Business** | Computer-supported cooperative work (CSCW)<br>- Videoconferencing<br>- Telecommuting<br>- Virtual Office<br>- Shared Editing<br>- Messaging<br>- Consulting |
| | Distance learning and remote training |
| | Presentations of products & services |
| | Multimedia documentation and publishing |
| | EDI |
| | Remote manufacturing and control, CAD/CAM |
| | Distributed planning, design and decision making |
| **Research and Education** | Distance learning |
| | Multimedia library |
| | Virtual museum |
| | Multimedia education and training |
| | Multimedia email |
| **Health Care** | Imaging |
| | Lecturing |
| | Expert systems |
| **Home** | Teleshopping |
| | Video on demand |
| | Video games |
| | Video telephony |
| | Virtual reality |

# Appendix 5

## Multimedia Pilot Projects [7][19]

| Project Name | Participants | Multimedia Applications |
|---|---|---|
| **Bay Area Gigabit Network (BAGNET)** | 14 participants (governmental laboratories, universities, and technology companies in California), Pacific Bell | Provision of teleseminar capability for a wide range of applications in education, health care, and engineering |
| **AURORA** | University of Pennsylvania; Bellcore; IBM Watson Research Center, New York; MIT | Teleconferencing |
| **BLANCA** | AT&T Bell Laboratories, New Jersey: University of Wisconsin, Madison; University of Illinois, Urbana-Champaign; LBL and UCB, Berkeley | Remote visualization and control of simulations;<br>Medical Imaging;<br>Teleconferencing |
| **CASA** | San Diego Supercomputing Center; Los Alamos National Laboratory; Jet Propulsion Laboratory, Pasadena; Caltech, Pasadena | Modeling of chemical reactions and long-term global climate changes;<br>Interactive visualization of data describing the Earth's crust |
| **North Carolina Information Highway (NCIH)** | State of North Carolina (NC); medical centers and schools; Area Health Education Centers; Medical College of NC; Southern Bell; GTE; Sprint and 25 other telephone companies | Distance learning;<br>Teleconferencing;<br>Telemedicine and imaging;<br>Multimedia collaboration |
| **VISTANet** | NC Supercomputer Center; NC State University | Medical imaging |
| **Superjanet** | Universities of Manchester, Edinburgh, Cambridge, London; Rutherford-Appleton Laboratory, Oxfordshire; British Telecom | Surgery teaching;<br>Videoconferencing in molecular chemistry |
| **Berlin Communication System (BERKOM)** | Deutsche Bundespost Telecom; state of Berlin; over forty companies, such as Apple, Alcatel, Siemens, DEC, and IBM | Telemedicine;<br>Telepublishing;<br>Multimedia information systems |

# Appendix 6

## Desktop Videoconferencing Systems [27]

| | Workstation-based systems | Computer-based systems | | | |
|---|---|---|---|---|---|
| | | High-end PC-based | Mid-range PC-based | Low-end PC-based | Macintosh-based |
| **Cost to add videoconferencing** | $1,000-$1,500 | $8,000-$12,000 | $1,000-$3,000 | $150 | $5,500 |
| **Operating System** | UNIX MS Windows | MS Windows DesqView | MS Windows | OS/2 | System 7 |
| **Video Coding Algorithm** | Proprietary | CCITT H.320 | Proprietary | Proprietary | Proprietary |
| **Video Frame Rate** | 2-15 fps | 5-30 fps | 5-10 fps | 0.5-10 fps | 2-5 fps |
| **Video Window Size** | Stamp-sized to full screen | 3/4 screen | up to 1/4 screen | up to 1/16 screen | about 1/4 screen |
| **Transmission Rate** | up to 256 kbps | 56-364 kbps | 112-128 kbps | 112-128 kbps | 112-128 kbps |
| **Transmission Medium** | LAN/WAN modem | Sw56/ISDN-BRI | Sw56/ISDN-BRI | Sw56/ISDN-BRI | ISDN-BRI |
| **Multipoint Capability** | Some multi-window | Some multi-window | Some multi-window | Some multi-window | No |
| **Video Resolution** | Low-medium | Low-medium | Low-medium | Low-medium | Low |

# Appendix 7 CalREN Award Summary [39]

| **Project** | **Distributed Interactive Simulation** |
|---|---|
| Field | Virtual Reality |
| Focus | Military simulations using virtual reality, involving 100-1,000 participants |
| Participants | Lockheed Missiles & Space Co., ARPA, Sandia National Laboratories |
| **Project** | **Concurrent Collaborative Simulation-Based Hardware Design** |
| Field | CAD/CAM |
| Focus | Real-time collaborative multimedia design of wire cable harnesses on a shared electronic blackboard; Storage in a common database |
| Participants | Lockheed Missiles & Space Co., Sandia National Laboratories |
| **Project** | **Statewide Distance Education using Multimedia** |
| Field | Education |
| Focus | Delivery of an entire degree education program (Master of Library and Information Science), by connecting multimedia data bases and campus-wide video infrastructure |
| Participants | San Jose SU, Newbridge Networks Inc., SF SU, Stratacom Inc., California SU Fullerton, General Telephone, California SU System, AT&T, National Science Foundation, UCB, Pacific Internet Consortium, UCLA, Pasadena Public Library, California State Library |
| **Project** | **Regional Biomedical Information System** |
| Field | Health Services and Education |
| Focus | Remote access to the extensive on-line medical literature of the UCSF; Throughput comparison between ATM and Ethernet technology; Collaboration between partners from Education, Health Care and Commercial Business fields |
| Participants | UCSF, Genentech Inc., Sun Microsystems Inc., AT&T Bell Laboratories, Springer-Verlag |
| **Project** | **Neuro-Imaging Testbed Network** |
| Field | Health Service |
| Focus | Transmission and management of neuro-images and associated medical data; Interpretation, transmission and storage of CT and MR images |
| Participants | UCSF, Sun Microsystems Inc., Mt. Zion Hospital, SF General Hospital, SynOptics, SF Veterans Administration, SF Medical Center, MR Imaging Center |
| **Project** | **Tele-education, Tele-science and Electronic Libraries linking Silicon Valley, Santa Cruz and the Monterey Peninsula** |
| Field | Education |
| Focus | Tele-science experiments and tele-education based on digital interactive multimedia |
| Participants | UC Santa Cruz, UC Extension Santa Cruz, Tech Museum of Innovation, Monterey Bay Aquarium Research Institute, California SU Monterey Bay, Naval Postgraduate School UCB, Newbridge, Sprint, Sun Microsystems Inc., Ask/Ingres |
| **Project** | **Health Care Imaging Information** |
| Field | Health Services |
| Focus | Collection and transmission of medical images of the human heart between tertiary care hospitals and the office of a patient's local physician |
| Participants | LBL, Kaiser Permanente, Phillips Research, Sun Microsystems Inc. |

# Appendix 8

# BAGNET Project : Milestones [43]

| Time Period | Activities |
|---|---|
| 01/1994 | Connection established between PacBell and the first two testbed sites: NASA Ames Research Center and Xerox PARC |
| 01-03/1994 | Initial testing of the ATM network technology; connection of the remaining sites; Establishment of a functioning IP network |
| 04-06/1994 | Deployment of initial applications;<br>Technical meeting, conducted using the prototype teleseminar implementations;<br>Network management experiments |
| 06-09/1994 | Teleseminar applications widely deployed throughout the site campuses;<br>Mass storage experiments started |
| 09/1994 | Start of routine broadcasting of lectures and seminars |
| 12/1994 | Intermediate report on characteristics of the network and interaction with applications |
| 01/1995 | Further teleseminar experiments using mbone conference tools;<br>Network Video Microscope remote instrumentation prototype brought on-line |
| 03/1995 | Demonstration and documentation of multimedia mass storage in a distributed environment |
| 06/1995 | Coupling teleseminar applications and Network Video Microscope to distributed mass storage system;<br>Collaborative Engineering demonstrations |
| 09/1995 | Demonstration of distributed mass storage system as a large scale digital library |
| 12/1995 | Health Care Information System: teleradiology demonstrations |
| 01/1996 | CalREN final report;<br>Proposal for on-going testbed network |

# Appendix 9

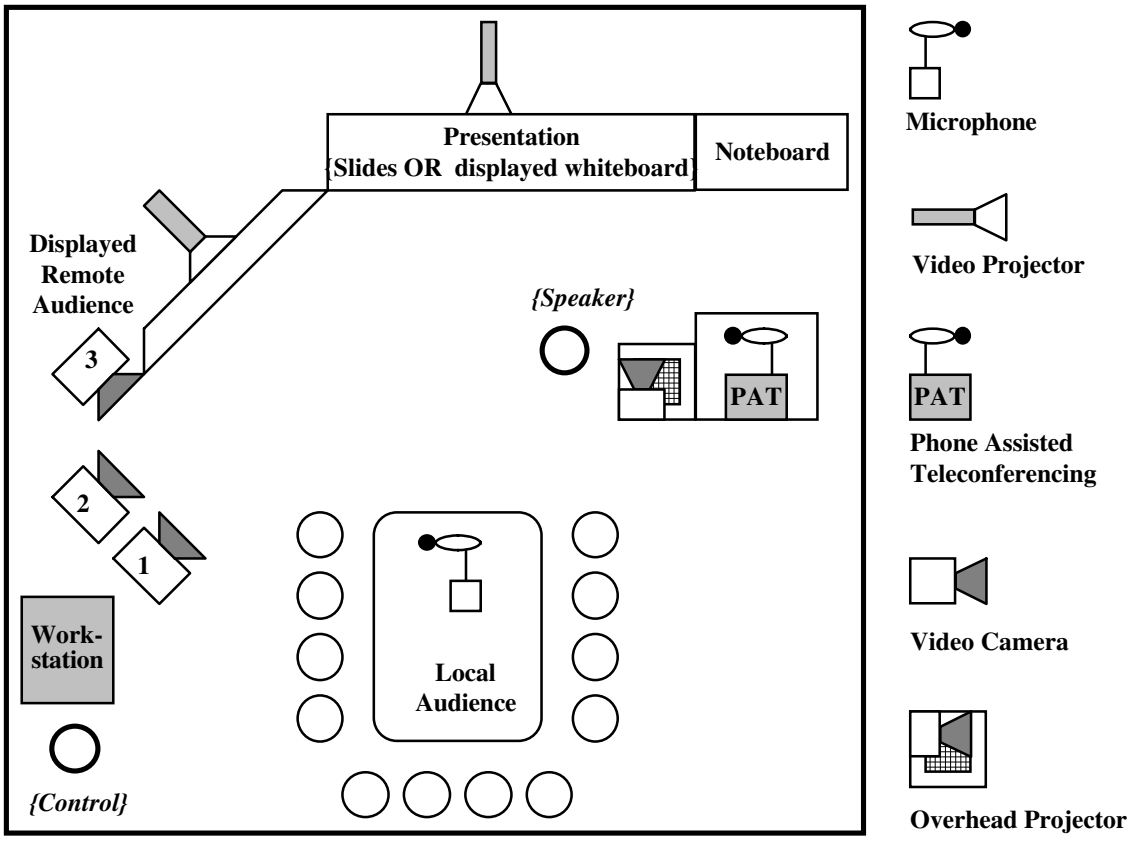
## Current Equipment and Network Costs of Providing Teleseminar Facilities to 14 Workstations[1]

| Item | Type | Details | Cost per Item | Multi-plier | Total costs |
|---|---|---|---|---|---|
| **Hardware/Software** | | | | | |
| Workstations[2] | Sun Sparc2 | includes Solaris OS and X Windows | $5,000 | 15 | $75,000 |
| Multimedia Tool | Sun Multi-Media Kit | includes camera, board, software | $ 1,137 | 15 | **$17,055** |
| **ATM Access** | | | | | |
| LAN[3] | Wiring | Unshielded twisted pair MM fiber, | $8,600 | 1 | **$8,600** |
| ATM Switch[4] | Model 10114-SM | 16 Port ATM Switch (2 SM + 14 MM Sonet/ SDH 155 Mbps ports) | $36,360 | 1 | **$36,360** |
| ATM Management[4] | Model 698 | Release 1.1, for Lattis-cell ATM Switches | $2,796 | 1 | **$2,796** |
| SVC Connection Management[4] | Model 761 | Release 1.1, for Lattis-cell ATM Switches | $3,996 | 1 | **$3,996** |
| ATM SBus Adapter[4] | Model 975-192 | Sonet/SDH MM fiber 155 Mbps | $1,436 | 14 | **$20,104** |
| Installation[5] | ATM WAN access | PacBell, 155 Mbps | $8,500 | 1 | $8,500 |
| **Conference Room** | | | | | |
| Video Equipment[6] | | video board, cam-corders, video player, video heads, video editor, tripods, cable | $16,700 | 1 | **$16,700** |
| Audio Equipment [6] | | Audio mix, mikes, ca-ble | $3,100 | 1 | **$3,100** |
| Video Display[6] | | Sbus board, NTSC video monitors, cable | $4,000 | 1 | **$4,000** |
| **Upgrading Costs** | | | | | **$112,681** |
| Total Costs | | | | | $196,181 |

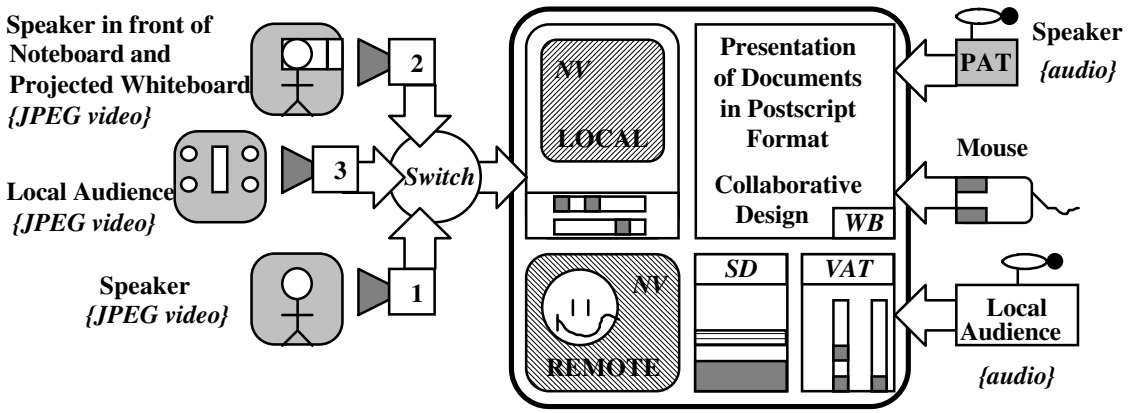
[1] Survey carried out at ICSI in August, 1994
[2] already installed, but need to be upgraded to Solaris; one worksation dedicated to conference room to control sessions
[3] cost estimation, based on costs for wiring offices in 1993
[4] includes 20% discount given to CalREN project members by SynOptics
[5] costs covered by CalREN award
[6] cost estimation by Brian Costales, System Administrator at ICSI

# Appendix 10

## Teleseminar Room Configuration

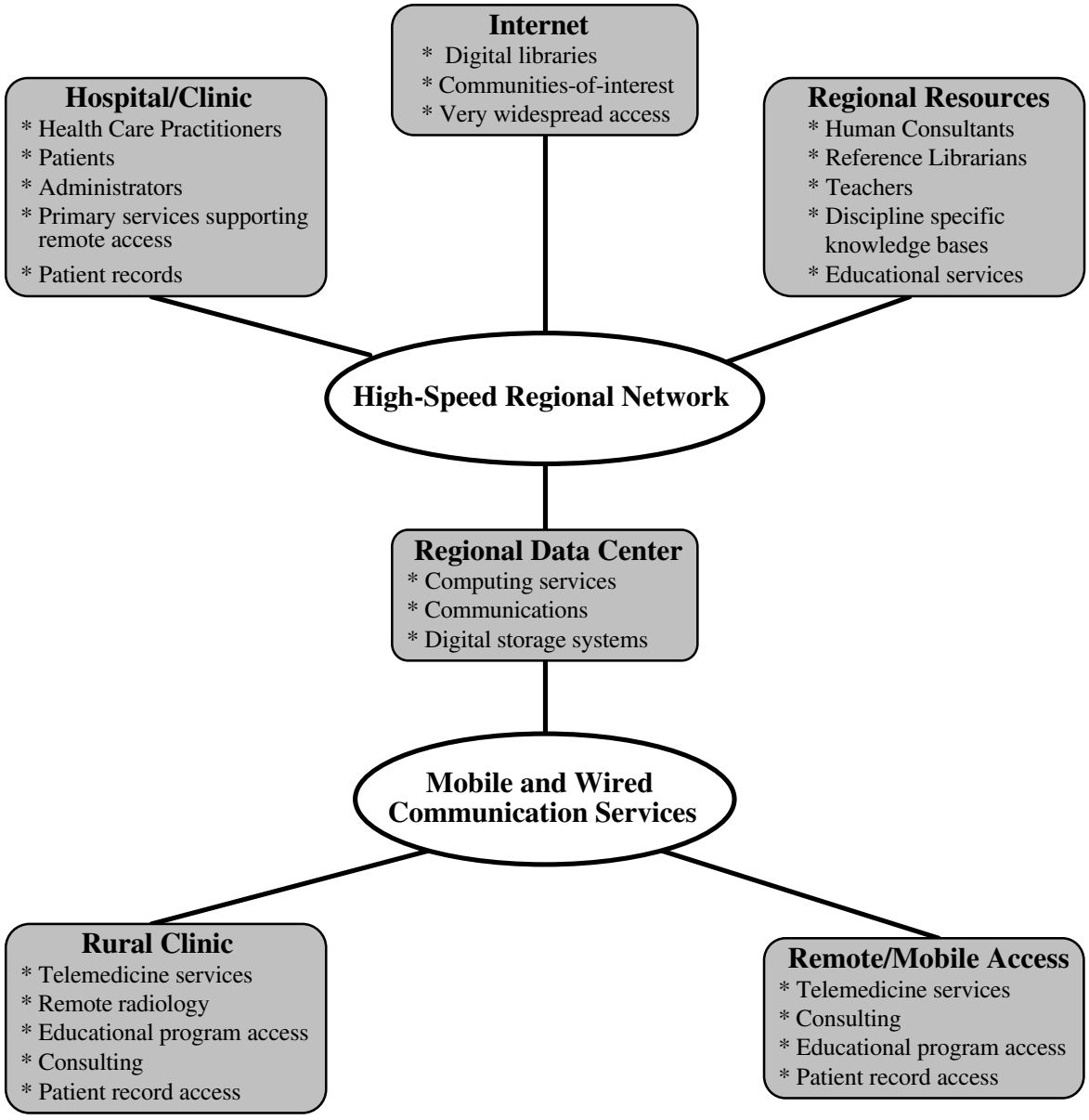



## Screen Layout



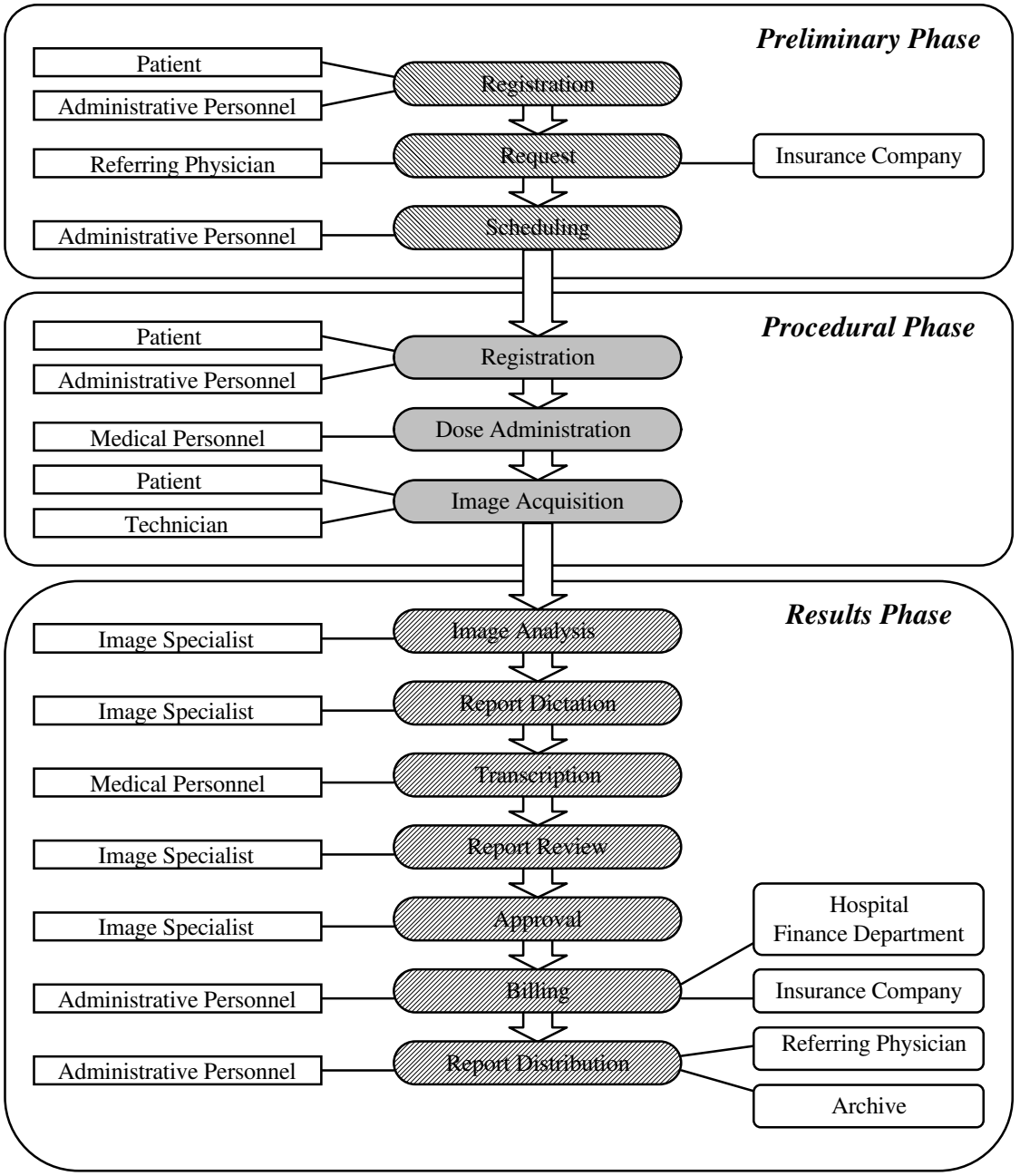
# Appendix 11

## Regional Health Care Information System [44]



# Appendix 12

## Work Flow Chart Medical Imaging



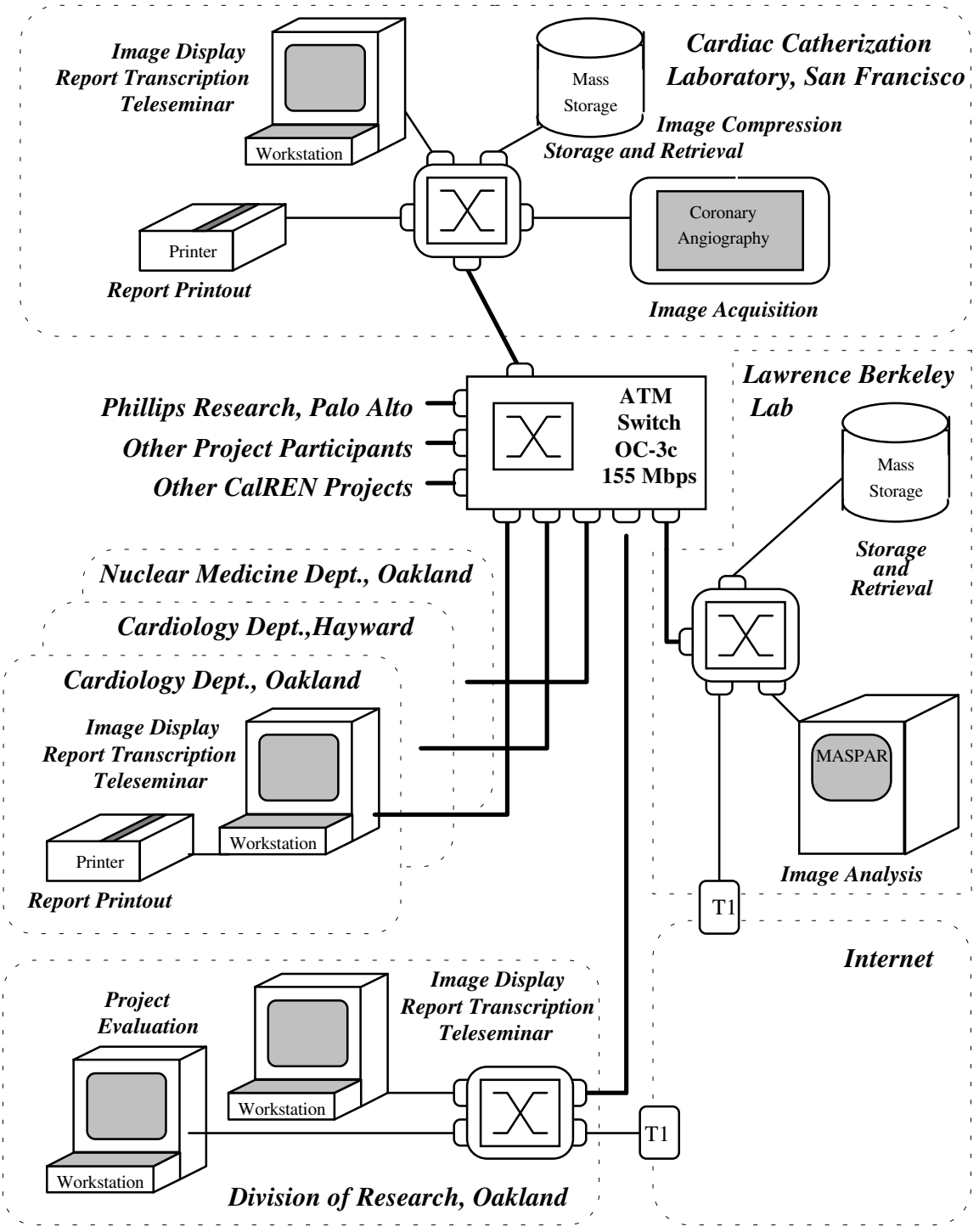
# Appendix 13

## Health Care Imaging Project : Milestones [49]

| Completion by month | Tasks |
|---|---|
| 4 | Network installation and integration of workstations at Kaiser |
| 8 | Software tools for video transmission and reception over the network |
| 9 | Software tools for archiving and accessing the video data base and batching the video over the network |
| 12 | Integration of LBL multi media file server |
| | On-line installation of a Phillips scanner with remote playback capability of video streams |
| 22 | On-line quantitative analysis and visualization of cardiac images by looping the video into a MasPar (parrallel computer) and then transmitting the result with additional data over the ATM network |
| 23 | Evaluation of ATM network in the clinical setting |
| 24 | Submission of technical report |

# Appendix 14

## Health Care Imaging Project : Network Configuration and Components



# Appendix 15

## Capital Costs per Radiographic Procedure [6]

| | Film-Based ($ per Procedure) | PACS ($ per Procedure) |
|---|---|---|
| **Film-handling equipment** | 2.9 | |
| **Film Library** | 1.0 | |
| **Workstations** | | 12.7 |
| **Computer radiography** | | 8.1 |
| **Equipment (Network, Storage, etc.)** | | 18.5 |
| **Installation and training** | | 2.5 |
| **Total** | **3.9** | **41.8** |

## Operating Costs per Radiographic Procedure [6]

| | Film-Based ($ per Procedure) | PACS ($ per Procedure) |
|---|---|---|
| **Supplies and storage** | 0.59 | 2.60 |
| **Maintenance** | 0.14 | 0.92 |
| **Storage materials** | 4.16 | 0.34 |
| **Physicians**[1] | 1.41 | |
| **Other Personnel**[1] | 1.02 | |
| **Total** | **7.32** | **3.86** |

[1] personnel costs for the film-based system represent the time savings that can be achieved from the introduction of a PACS