The Specifications of an Expert System for Configuring Teleconferencing Systems

by

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(ABSTRACT)

Use of teleconferencing systems can have a major impact on mobility-impaired office workers. This technology helps in bringing jobs to the workers' geographic location, thereby integrating mobility-impaired workers into the work force. However, configuration of teleconferencing systems is difficult, time-consuming, and expensive. The aim of the work reported here was to find an affordable and efficient way of configuring teleconferencing systems. In the past, expert systems have been successful in solving similar configuration problems. In this report, an expert system is proposed to aid in the configuration of teleconferencing systems. The report also includes detailed problem specifications, justification for choosing an expert system as a solution, and high-level functional specifications for the development of an expert system.

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INTRODUCTION

With the increase in information activity throughout the world, most jobs require exchange of information on a more frequent basis than ever before. This has created many jobs dealing with storage, manipulation and exchange of information. A vast majority of workplaces have incorporated computers into their everyday routine. Information systems, which were used mainly for accounting-oriented and clerical applications in the past, now permeate managerial functions. Global economy has forced many companies to expand into foreign markets, thereby creating jobs in different cities around the world. The industry has responded to this scenario by promoting the use of teleconferencing systems. Almost a decade ago, [Johansen, Bullen, 1984] and several others outlined the potential benefits of teleconferencing.

Teleconferencing systems enable two or more people at geographically distant locations to communicate electronically. Depending on the system used, they can exchange messages, drawings, plans, or sketches and even make presentations and update colleagues without interrupting their work schedules or paying for expensive travel, hotel accommodations and car rentals. Teleconferencing, when mixed with computing, provides the building blocks for new forms of organization, and physical location of employees becomes irrelevant in selecting a given job.

1.1 Impact of Teleconferencing Systems on Disabled Workers

Of the 12 million working-age Americans with disabilities, more than 8.5 million are unemployed [Williges, Williges, 1993], representing a large untapped resource for American business [U.S. Bureau of Census, 1982, 1985] [Bowe, 1987]. Teleconferencing can play a major role in integrating disabled workers into the main stream work force. For a mobility-impaired office worker, hereafter referred to as the *home-worker*, teleconferencing opens the door to numerous previously denied job opportunities. Some of the new opportunities are jobs which require:

- frequent communication with coworkers and/or management;
- traveling to other cities or countries for negotiations or promoting products;
- traveling to participate in the everyday decision making process;
- working at a remote site or home and reporting to a central office frequently;
- information processing that can be done from home, and many more.

Since communication with anyone anywhere is possible without the inconvenience of traveling, all these jobs can now be done right from the office whether it be a remote site or right at home ("*Home Office*"). A well equipped Home Office can act as the home-worker's window to the whole world. Today's state of the art telecommunications equipment can provide facilities to exchange audio, graphics, video and computer-data with anyone, anywhere in the world. Video teleconferencing provides the capability to hold face-to-face interactions with individuals or groups, creating a social presence, which is critical for the success of many interactions. In other words today's teleconferencing technology enables a user to travel, meet and interact with other people without leaving his/her office. Some specific applications of this concept are "Telecommuting", "Surrogate traveling" [Williges, Williges, 1993], and "Home Work". In the U.S., both federal and state governments are playing an active role in the implementation and public access of telecommunications services. In October 1986, the U.S. Congress reauthorized the rehabilitation Act of 1973, amended by section 508 of Public Law 99-506, mandating computers to be equally accessible to able-bodied and disabled workers in the electronic office environment. Government participation has led to "Satellite" and "Neighborhood Telework Centers". Federal regulations like the Americans with Disabilities Act [ADA] of 1990 along with the Clean Air Act Amendments [CAAA] of 1990 and the Intermodal Surface Transportation Efficiency Act [ISTEA] of 1991 have contributed to the promotion of teleconferencing systems.

1.2 Problem Description: Configuration of Teleconferencing System

In spite of great advantages and wide spread interest, assembly or configuration of teleconferencing systems is still a difficult task. This is mainly due to the basic characteristics of any configuration task in general and configuration of teleconferencing systems in particular. Some characteristics which contribute to the problems in configuration are a large solution space, dependencies between components that comprise a solution, etc. The specific characteristics associated with configuration of teleconferencing systems are:

- large volume of technical and vendor information;
- knowledge from related but different domains like communications, networking, audio, video and computers;
- many possible solutions satisfying the specifications;
- system objects made up of discrete components. For example, the computer component of the configuration may be made up of personal computer, modem, etc.
- dependencies between system objects. For example, specifications of the graphics card depends on the operating system, end-user computer, monitor, desired quality of graphics, etc.
- heuristic decisions are involved. For example, choosing objects among the various alternatives, choosing suitable standards and protocols, etc.
- uncertainity, due to ever changing market, technology, standards, etc.

- tasks require scarce, expert reasoning

These characteristics clearly indicate the effort and expertise involved in building suitable configurations. Diversity and sophistication in the telecommunications field have also contributed to the difficulty in configuration of teleconferencing systems.

Large corporations build and equip public teleconferencing rooms for the use of all their employees. More often than not, such large corporations can afford to hire experts to evaluate their employees' specific needs, design, and install an appropriate teleconferencing facility. On the other hand, smaller companies and individual users planning to equip their home offices find hiring telecommunication firm/experts prohibitively expensive. Users with limited knowledge about teleconferencing systems find it extremely difficult to attempt building these systems on their own. Any such efforts are error-prone and time-consuming. The overhead cost of configuration also increases with time.

1.3 Scope of the Problem

Any solution to problems in configuration of teleconferencing systems will benefit a wide spectrum of the population such as workers who head single-parent families, have family responsibilities or live in remote locations. However, this study focuses on its impact on mobility-impaired workers, in particular those with mobility problems. The type of teleconferencing equipment and technology considered is limited to those currently available in today's market. Solutions are also influenced by cost and affordability, thereby excluding expensive solutions like satellite links.

1.4 Solution: An Expert System

This report proposes and makes the case for an expert system as the solution to the problem of configuration of teleconferencing systems. An expert system can be used as a tool to aid end-users in configuring teleconferencing systems. It can store, retrieve, and infer from extensive knowledge related to:

- telecommunications technology;
- telecommunications equipment;
- telecommunications (domain) experts' knowledge on the appropriate usage, relative merits and demerits of the above.

An expert system, built with an easy to learn, easy to use and interactive interface, can guide end-users with step-by-step instructions to configure a teleconferencing system. It can store voluminous data, use procedural rules to make technical decisions, and apply heuristics to make intelligent choices all along the way. Development of an expert system is an involved and expensive task. But, development of the expert system constitutes a one-time investment cost which can be easily recovered by its usefulness, and minimal maintenance cost. By maintaining a low set-up cost, this solution ensures that teleconferencing technology is within the reach of all those who find it useful. The impact of such a solution on the mobility-impaired worker is great.

1.5 Summary

Teleconferencing systems can bring more jobs to mobility-impaired office workers. Wide spread use and application to diverse fields will reduce the cost of teleconferencing systems in the near future. However, configuration of these systems require scarce expertise in the field of telecommunications. An expert system can help overcome difficulty in configuration and make teleconferencing systems accessible and affordable to one and all.

Chapter 2 of the report sets the context for importance of the development of an expert system to configure teleconferencing systems. Chapter 3 includes problem description and characteristics of the problem. Chapter 3 also presents an expert system as the solution to the problem. Chapter 4 contains the functional specifications of the expert system.

Chapter 2

CONTEXT

In this chapter information about teleconferencing technology, different forms of teleconferencing, and various applications of this technology is presented. This chapter also includes a brief introduction to expert system technology, its application to configuration tasks, and some successful projects.

2.1 Teleconferencing Systems

Most work processes require groups to meet and discuss concepts, ideas, plans and strategies. The nature and structure of these meetings are varied. Meetings can be categorized by size, frequency of occurrence, composition, motivation, and the decision process used. For example, a daily meeting of peers is a fairly unstructured process, an annual meeting with peers and upper management is fairly structured, presentations are almost always highly structured, etc. But the purpose of all these meetings is exchange of information. Sometimes a simple audio channel is sufficient to convey messages.

Addition of graphics can enhance the quality of this audio exchange. But, conversations naturally include speech, grunts, nods, eye-contact, eye-brow movement, smiles, touches, pointing to objects, and bodily posture [Waterworth, 1992]. In situations, where subtle factors like gestures and facial expressions decide the success or failure, there can be no substitute for face-to-face meetings. But, face-to-face meetings may not always be feasible due to numerous reasons like cost, distance, mobility, etc.

Teleconferencing systems allow geographically separated individuals to meet as a group without the inconvenience of traveling. The term "teleconferencing" refers to one or two way electronic communication between two or more individuals, or groups in geographically separate locations [Olgen and Parker]. There are many forms of teleconferencing in use today. Some of the common forms are:

- audio teleconferencing;
- audio-graphics teleconferencing;
- video teleconferencing;
- computer teleconferencing.

One important difference among the different forms of teleconferencing is the time element. In synchronous conferences, all participants are present simultaneously regardless of location or time zone. In asynchronous conferences, participants communicate by joining and leaving the conference at their convenience. Even though various forms of teleconferencing differ in complexity and cost, they have several factors in common (Olgen and Parker, 1983):

- they use some form of communication channel and technology;
- they link individuals or groups of people at multiple locations;
- they are interactive, providing two-way communication;
- they are dynamic and live, involving the active participation of people.

Each of the above four forms of teleconferencing is briefly discussed below.

2.1.1 Audio teleconferencing

The term "audio conferencing" refers to voice communication between three or more people. An ordinary telephone is the only tool required for audio conferencing. Most major telephone companies offer audio conferencing service for a very reasonable price. Some common ways of establishing an audio-teleconference are:

- dedicated network, in which designated locations are permanently wired together via leased telephone lines;
- dial-up, allows ad-hoc point-to-point or multipoint conferences via telephone lines, sometimes assisted by a local telephone operator.

Audio conferencing has found its own niche in the market due its low cost, integration into familiar telephones, and ease of use.

2.1.2 Audio-graphics teleconferencing

The term "audio-graphics conferencing" refers to exchange of information in the form of audio, text, and graphics. Graphical representation of data is found to be very effective supplement to audio information. Systems like facsimile transmission, telewriting (transmits hand-drawn sketches in compressed form) and electronic blackboards are becoming an integral part of business meetings and presentations. Audio-graphics systems include devices like electronic pens, blackboards, tablets, computer systems, random access microfiche, slide projectors, facsimile machines, etc. Freeze-frame video units which are used to send pictures of persons and objects are sometimes grouped under this category.

Graphics have proved very useful in presenting and summarizing data. Most audio-graphic devices are fairly economical and easy to use. A major drawback of this form of teleconferencing is that it does not allow information from the originating source to be modified at the receiving end.

2.1.3 Video teleconferencing

In addition to audio, text, and graphics, video conferencing systems provide images of people and their surroundings in the form of freeze-frame, compressed video, and full motion video. For some kinds of work-place interactions, there can be no substitute for face-to-face conversations. Video conferencing and desktop computer teleconferencing can provide the means for such interactions. These systems relay non-verbal communications in the form of gestures and facial expressions (social presence), which are important aspects of communication between people. For a review of the theory concerning the value of the visual channel in telecommunications, refer to [Elton, 1985], [Gale, 1991].

Applications like catalog shopping can be effective with freeze frame images, whereas applications like "news-on-demand" require compressed video [Angiolillo, Blanchard, Israelski, 1993]. Person-to-person calls can be accomplished with small screens, cameras and handsets, whereas group-to-group calls require large screens, cameras that pan and zoom, and high quality speakerphones. But both person-to-person and group-to-group calls provide spontaneous and clear face-to-face interactions. Today, this technology has found applications in:

- Medical record retrieval associated with a patient
- Bank-by-phone services
- Brokerage business
- Reports and presentations
- Public hearings
- Public school instruction
- Press conferences
- Catalog ordering service

and the list is growing everyday. Wide-spread use of two-way video conferencing has been hindered by high cost. For a comprehensive discussion on video teleconferencing, refer to [Bodson, Schaphorst, 1989].

2.1.4 Computer teleconferencing

Computer conferencing is a means by which an unlimited number of people can communicate with each other through computer terminals or workstations. [Sarin, Greif, 1988] is one of the earliest and most comprehensive articles identifying the general principles underlying the design and implementation of computer-based real-time conferencing systems. Some advantages of computer teleconferencing include low cost, and the flexibility of synchronous and asynchronous forms. Computers can provide a permanent record of conference proceedings that can be stored, referred to, and exchanged.

Electronic mail, the widely used form of information exchange through computers has been more of a person-to-person activity rather than a group activity [Olgen, Parker, 1983]. Whether it can be grouped under computer conferencing is highly debated. Conversion of the person-to-person electronic mail applications to group applications is underway. Addition of audio to computer systems has encouraged fields like music to use computers for storage, editing, selective retrieval, and exchange of musical notes. [Degen, Mander, Salomon, 1992], [Resnick, Virzi, 1992] report on their experiences with integrating audio to computer applications. Computers with high resolution monitors are widely used in visualization of information in geographic information systems, electronic publishing, public classrooms, etc. Computer animation has proved useful in training and presentation.

Multimedia has added a new dimension to computers. Multimedia is the integration of information in the form of text, sound, music, graphics, animation, narrative, video, and images. Multimedia in combination with inherent feature of computers i.e. interactivity (between individuals and the computer, or between individuals/groups with computers as the medium) has proved to be a powerful tool. The workstation technology of today incorporates integrated multimedia conferencing capabilities. [Lantz, 1988] reports an experiment in integrated multimedia conferencing.

Teleconferencing is a valuable asset to any organization which wants to take advantage of rapid advancement in telecommunications technology. But, teleconferencing systems have had both positive and negative impacts. While providing managers with the ability to control and keep closer contact with workers, these systems may make workers feel scrutinized, restricted or violated. Social acceptance of these systems can come only with wide-spread use. Some organizations have used work-at-home as a demonstration of the corporation's service to society [Olson, 1988]. In the US, both federal and state governments are playing an active role in implementing and providing public access to telecommunications services. Government participation has led to Satellite and Neighbourhood Telework Centers. Federal regulations that have provided great impetus to the growth of teleconferencing are:

- The Americans with Disabilities Act [ADA] of 1990
- The Clean Air Act Amendments [CAAA] of 1990
- The Intermodal Surface Transportation Efficiency Act [ISTEA] of 1991

For more details on the federal bill to promote the use of telecommuting, refer to [H.R. 5082, 1992].

2.2 Teleconference Systems: Related Technology

Some related technologies that have had a tremendous impact on the field of teleconferencing are:

- Digital switching permits high speed transmissions. It improves transmission quality and makes possible wide range of services like voice mail to video on demand.
- Fiber Optics provides high transmission capacity at high speeds. It improves transmission quality, provides greater security, reduces maintenance costs and offers virtually unlimited bandwidth.
- Signalling System 7 (SS7) is a dedicated signalling network which frees the regular telephone message network for full flexibility for advanced services like call forwarding and call screening services.
- Integrated Services Digital Network (ISDN) is a telecommunications architecture that allows the transmission of voice, data and image services over a single line. Without ISDNs' integration capability, customers would require separate lines for each service used.

- Synchronous Optical Network (SONET) allows for the connection of multiple transmission systems, and brings international standards to the field of fiber optics. SONET ensures network diversity, and minimizes the impact of any network outage.

- Workstations are computers designed for a single user, built for network integration, and equipped with high-resolution graphics [Smith, 1992]. They have revolutionalized computer (desktop) conferencing.

- Computer Supported Cooperative Work (CSCW) is an inter-disciplinary subject area, bridging the gap between the human sciences, which provides knowledge of cooperative work practices and associated communication processes, and the application of information technology, which provides knowledge of mechanisms to implement computer communication systems to support cooperative working [Bowers, Benford, 1991].

Telecommunication networks should be designed to support a large number of telecommunication services. These telecommunication services require "extensive, standardized and complex software" characterized by "huge volume, high efficiency, high reliability, continuous service, customer and country dependencies, multiple suppliers, heterogeneous and distributed environment" [Trigila, Bregant, Larsson, 1992]. ROSA is one of a number of RACE projects involved with Integrated Broadband Communication Network (IBCN) software infrastructure. It deals with the proposal of an architecture that is open to changes in service requirements, in equipment technology and network infrastructure. The ROSA architecture supports designers of both telecommunication services and networks. For more details refer to [Trigila, Bregant, Larsson, 1992]. For details on teleconferencing room equipment and design refer to [Olgen, Parker, 1983]. For a list of terminology, related technology and references in the area, refer to Appendix-A.

2.3 Expert Systems (ES)

[Rolston, 1988] defines an ES as a computer application that solves complicated problems, that would otherwise require extensive human expertise, by simulating the human reasoning process. An ES consists of three main components:

- KnowledgeBase
- Inference Engine, and
- User Interface.

The knowledge base consists of rules, heuristics (rules of thumb), and problem solving capability which simulate human expertise in the domain. Methods used for knowledge encoding include rules, predicate calculus, frames, semantic networks, object-attribute-value (OAV) triplets, neural networks, scripts, etc. The inference engine contains controls to manipulate and apply the stored knowledge to the problem at hand. Inferences and new knowledge can be derived from the existing knowledge base. The user interface is the front-end which controls interaction with the end-user of the ES. Hereafter, an end-user of the ES is referred to as the "user". Functions of the user interface include accepting home-worker specifications as input, questioning strategy, and the explanation facility which explains the reasoning of the ES. Choosing the right ES shell for developing an application is not easy. The cost of ES shells ranges anywhere between nil for public domain ES shells to over $100,000 for ES shells running on powerful workstations. There are over 150 different ES shells on the market [Gevarter, 1987], [Stylianou, Madey, Smith, 1992].

2.4 Expert Systems: Related Technology

The major task in the development of ESs is knowledge acquisition. Tools are available to automate the knowledge acquisition process. An ideal knowledge acquisition tool deals with an expert only at the knowledge level and automates the processing of the knowledge acquired [Bachant, 1988]. Knowledge acquisition tools can [Marcus, 1988]

- elicit relevant domain knowledge from experts;
- maintain that knowledge in a form that makes it accessible for analysis, review, or modification;
- use the knowledge to perform a specific task

Tools and shells are also available to develop ESs for specific tasks. KNACK, SIZZLE, MORE, MOLE, SALT, are some tools for building expert systems. For more details refer to [Marcus, 1988], [Harmon, Maus, Morrissey, 1988]. Evaluation and selection of ES shell for a particular task consists of four major steps: [Stylianou, Madey, Smith, 1992]

- Identification of required capabilities and features
- Identification of potential shells
- Evaluation of shells based on required capabilities and features
- Selection of the appropriate shell

The evaluation criteria of an ES shell is grouped into 8 categories: [Stylianou, Madey, Smith, 1992]:

- End-User Interface Criteria
- Developer Interface Criteria
- System Interface Criteria
- Inference Engine Criteria
- Knowledge Base Criteria
- Data Interface Criteria
- Cost-Related Criteria

- Vendor-Related Criteria

Evaluation of selection of a specific ES shell to build the proposed ES is beyond the scope of this report and is included in the list of future work. The common ES shells available in the market incorporate reasoning and explanation (report) facility. But user-feedback analysis is difficult and not a common feature.

Chapter 3

PROBLEM SPECIFICATIONS

There is no cookbook for building a successful teleconferencing system [Johansen, Bullen, 1984]. To understand the problems associated with the process of configuring a teleconferencing system it is essential to understand the process itself. The process consists of assembling hardware and communication components to configure an effective and efficient teleconferencing system. For ease of understanding, the process can be broken down into the following basic steps. Gather user needs about type, frequency, and expected quality of interaction, user skill,and any other relevant information. If necessary, gather information about availability and cost of network service in the home-worker's locality. It would be useful to have an on-line database, that can provide current information about available networking at any given location. The next step is to analyze the gathered information and suggest type of teleconferencing, required networking, communication equipment, hardware such as telephone, computer, cameras, connectors, and cables, groupware tools, conference management tools, etc. Any solution should take into consideration the expectations, needs, and skills of the home-worker. Clearly the problem is one of "configuration of objects" to build an effective and affordable teleconferencing system.

3.1 Characteristics Of The Problem

In general, configuration problems are characterized by the fact that solutions are composed of objects which are in turn composed of smaller subobjects [Najmann, Stein, 1992]. Configuration tasks have the following fundamental characteristics [Gunter, 1990]:

- large solution space;

- objects are composed of components;
- dependencies between the objects;
- heuristic decisions;
- consequences of the decisions are not totally predictable.

The above characteristics make configuration tasks time-consuming, expensive and require usually scarce domain expertise. Specific characteristics associated with configuration of teleconferencing systems are:

- large volume of technical and vendor information;
- knowledge from related but different domains like communications, networking, audio, video and computer;
- many possible solutions satisfying the specifications;
- objects are composed of components. For example, the computer component of the configuration may be made up of personal computer, modem, etc.
- dependencies between objects. For example, specifications of the graphic card depends on the operating system, user-end computer, monitor, desired quality of graphics, etc.
- heuristic decisions are involved. For example, choosing objects among the various alternatives, choosing suitable standards and protocols, etc.
- uncertainity, due to ever changing market, technology, standards, etc.
- tasks require scarce expert reasoning

Information related to teleconferencing technology is available in extensive quantity. Numerous books and journals are dedicated to the field of teleconferencing systems. But, no single source or even a manageable number of sources provide a home-worker with this large volume of technical and vendor information. Even experts in the field do not agree on protocols, standards, or appropriate application of the technology. So the burden of acquiring all this knowledge and making intelligent decisions falls on individual home-workers. In addition to the quantity, quality of information is also varied and involves related but different domains like communications, networking, audio, video and computers.

Home-workers have to make choices about the communication medium depending on the characteristics of expected interactions. Some interactions require audio, video or computers, or some combination of these media. There is no single configuration of teleconferencing systems that can satisfy all the requirements of home-workers. One configuration may be cost beneficial, whereas another may have higher quality of graphics or video. Home-workers interested in teleconferencing systems may be computer-literate and have a high-level understanding of teleconferencing systems. But it is not fair to expect all these home-workers to have technical knowledge about all the configuration objects which are composed of sub-components. For example, the computer component of the configuration may be made up of personal computer, modem, cables, graphics card, etc. Dependencies between objects like specifications of the graphic card depending on the operating system, user-end computer, monitor, desired quality of graphics, etc. can also contribute to the confusion. The task of configuration requires heuristic decisions along the way like choosing objects among the various alternatives, choosing suitable standards and protocols, etc. These decisions require practical and long term experience in configuring teleconferencing systems. A fairly high degree of uncertainity is also involved in the process due to ever changing market, technology, standards, etc. All the above characteristics contribute to the complexity involved in configuration of teleconferencing systems.

3.2 Existing Solutions

There are different approaches we can take to configure a teleconferencing system. One method would be to collect specifications from the home-worker, decide on the appropriate configuration, accumulate relevant information like vendor claims from magazines and catalogues, identify the necessary components, contact individual suppliers, compare and negotiate price, purchase components, read the manuals, and assemble the system. This is not only an overwhelming and time-consuming task, but also requires considerable knowledge of hardware and software components, familiarity with jargon of communications and computer fields. The user has to be familiar with telecommunication protocols and standards to make intelligent decisions on the relative merits and demerits of alternative choices. The first synthesis of teleconference evaluations found over 200 studies of audio, video, and computer-based teleconferencing in 1979 [Johansen, Bullen, 1984]. Today the number is mind boggling.

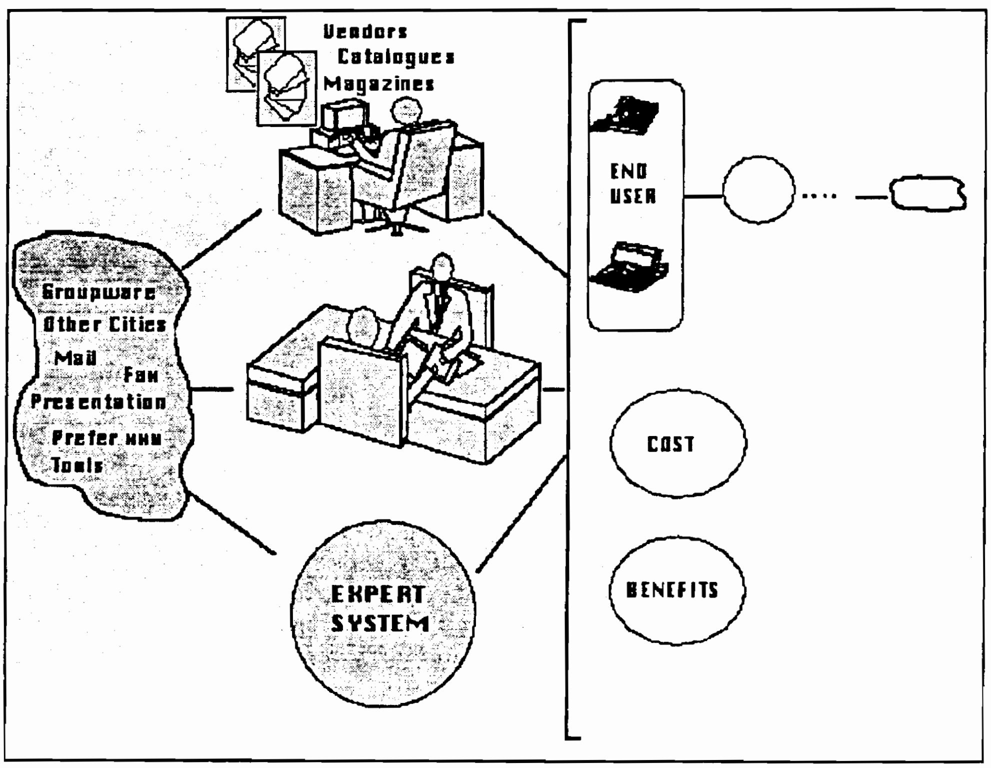

Figure 3.1: Solutions

The second alternative way of configuring the system is to hire telecommunications firm/experts to do the job. Major disadvantage of this option is the high cost involved. This option may be suitable for customers, who can afford the price, such as large corporations designing a public teleconferencing room. The prohibitive price of this option may discourage small businesses and home-workers. Other disadvantages of manual procedures are susceptibility to errors and delay. Today's competitive world requires automated supported to avoid delay (in implementation) and associated loss of revenues.

3.3 Proposed Solution: An Expert System

The third alternative is to use an "Expert System". An ES to solve problems in configuration of teleconferencing systems was first proposed in [Williges, Williges, Koushik, 1993].

The characteristics of the problem listed in Chapter 3.1 determine that the problem domain is suitable for ES application. Some unique characteristics of an ES that sets it apart from traditional software applications are it's capability to:

- store large volume of information in the form of facts;
- apply procedural rules to simulate human expertise in evaluating a product's quality, usability, suitability to a specific task, relative merits and demerits etc.;
- follow hueristic rules, which are hunches or rules of thumb, gathered by experts through years of experience.

Traditional software applications cannot deal with uncertainity and dynamic knowledge. An ES reduces hours of manual work, by application of known facts, procedural rules and hueristics. Hueristics contribute greatly to the flexibility of ESs. An interface that is both easy to learn and use can greatly enhance the usability of the ES, making it appealing to users of diverse skill range. Other benefits of using ES are ability to capture scarce expertise, ability to work with incomplete and uncertain information, increased power to solve complex problems, cost reduction, consistency of output, faster response, etc.

ES technology provides suitable formalisms and mechanisms to handle typical configuration problems. In the past, ESs have been successfully employed in configuration of systems. The best known example being XCON (also known as R1), an expert system that configures DEC computer systems [McDermott, 1982], [Bachant, McDermott, 1984]. ESs have been employed in ISDN service negotiation context [Ferguson, et. al 1987], [Acosta 1989]. INES, an expert system built to help salesmen in service negotiation of ISDN services reports increased efficiency and sales [Astegiano et al 1989]. KNACK, a tool for building expert systems, has been used to build systems assisting in the definition of requirements for software systems.

The ES kernel PLAKON, developed at the University of Hamburg, is a tool for planning and configuration tasks in technical domains. It provides a knowledge engineer with representation and inference methods which are well suited for planning and configuring tasks. For a full description of PLAKON refer to [Cunis, 1991]. This ES kernel has been successfully employed in numerous configuration tasks [Kopisch, Gunter, 1992]. At McDonnel-Douglas Helicopter Co.'s plant in Missouri, workers use Nexpert Object expert systems software from Neuron Data Inc. (Palo Alto, California) on a HP 9000 computer to make sure all the pieces of the aircraft are sized and weighed properly for the aircraft to work. Caterpillar Inc. uses Aion's ADS in the same way to design bulldozers [Baldwin, 1992]. XKL is an ES designed to configure a passenger aircraft cabin [Najmann, Stein, 1992]. Numerous other successful applications are listed in [Baldwin, 1992], [Belli, Radermacher, 1992], [Harmon, Maus, Morrissey, 1988]. The next chapter outlines high-level specifications for the ES. This stage includes user, functional, and task specifications.

Chapter 4

EXPERT SYSTEM SPECIFICATIONS

Development of an ES is very much a software development process. But the traditional software development life-cycle model is not suitable for development of ESs. One major difference is that the traditional life-cycle model is linear, whereas development of complex software systems like expert systems involve numerous iterations. Major characteristics of the ES model as defined by [Rolston, 1988] are as follows:

- The user and the domain expert are involved throughout the entire development process. This is in contrast to traditional systems in which the user specifies the requirements and just waits for the final product.

- Frequent demonstrations of work to date are encouraged. Such interactive sessions allow the user and the expert to visualize the functionality of the system and plan necessary changes.

- Change is viewed as healthy-in fact, it is the central concept. Changes are encouraged during the prototype phase. Earlier the stage in which changes and modifications are made, easier they are to incorporate into the system. ES development tools can assist in managing the effect of changes.

This chapter outlines the user and functional specifications of the proposed ES. The last section provides a prototype of user scenarios to illustrate the functionality of the proposed ES.

Note: A home-worker may or may not also be the user (of the ES).

4.1 User Specifications

The unit of measuring the success of any software is its usability. [Hix, Hartson, 1993], [Hartson, 1989] To ensure that the ES is easy to learn and use it is essential to consider the characteristics and skills of the intended user population. The next section describes the characteristics and skills of the intended users of the ES. Expected user population includes computer system administrators, network managers, telecommunication managers, teleconference coordinators, home-workers, occupational therapists, etc. The ES should cater to users of varying skills. The interface to the ES should provide maximum amount of usability for the novice user while incorporating maximum functionality and services for the sophisticated user. The system should allow an informed user to decide protocols, standards, and be able to make the appropriate choices for a novice user. Only a minimum amount of training should be necessary for any level of expertise in using the ES. Specific skills necessary for using the ES include the following:

- moderate computer experience
- familiarity with graphical interfaces
- moderate knowledge of network technology
- familiarity with adaptive devices

Extensive tests should be performed on a prototype of the ES to ensure that the system is tailored for the intended user population. The next section describes the functional specifications of the ES.

4.2 Functional Specifications

The main goal of the ES is to provide a tool to aid users in configuring teleconferencing systems. To achieve this goal the ES should provide the user with the necessary functionality. A prototype of the ES, developed using Supercard (a rapid prototyping tool), is used to illustrate the features of the system. The functionality listed below is only a start, and the list of supported functions is expected to change and grow throughout the development process.

The major functionality of the ES include provision to :

- Accept home-worker's requirements
- Display configuration(s)
- Tune configuration(s)
- Provide configuration and installation instructions

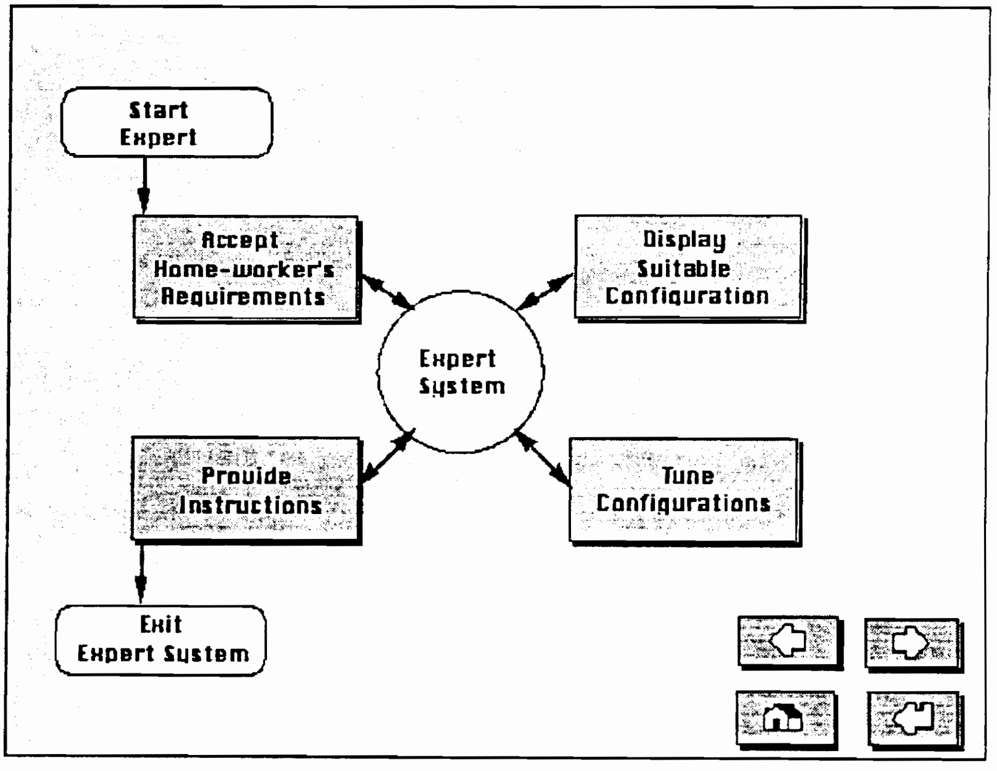

Figure 4.1: Flowchart

4.2.1 Accept home-worker's requirements

The desired functionalities of the ES include provision for accepting the home-workers' requirements. It is essential to extract the home-worker's requirements without burdening him/her with low-level technical details. Details like required network bandwidth, network protocol, etc. must be hidden.

The interaction between the user and the ES takes place through the user interface of the ES. User interface is a front-end of the ES through which the user holds a dialog with the ES. For maximum effectiveness, the overall usability goals of the user interface should:

- be easy to learn
- be easy to use
- adapt to accommodate a wide range of handicaps
- hide the underlying mechanism of the ES
- allow for uncertainity

An ideal interface should adapt to individual users and their specific handicaps. This entails provision of easy, flexible, and alternative ways of interacting with the ES. Adaptive systems or intelligent interfaces, include handwriting recognition, speech recognition, touch screens, etc.

To acquire a home-worker's requirements it is necessary to obtain details of his/her skills, needs, expectations, component choices, etc. Throughout this phase it is essential to allow for uncertainity on the user's part. Some of the parameters which contribute towards understanding a home-worker's requirements are discussed below.

To determine the bandwidth, speed and other capabilities of the teleconferencing system it is necessary to know the expected type, and rate of traffic. The distance over which teleconferencing takes place can be classified as either short (within the same building), or medium (within the same city), or long (inter-state, inter-continental). Network facilities varies from region to region of a country. So it is necessary to determine its availability in the home-worker's locality. If the home-worker has some components and devices on hand, it is necessary to consider configurations This reduces the overall cost of the system. It is important to consider software tools the home-worker has previously used. This reduces the home-worker's time spent in learning to use the teleconferencing system.

Some parameters which can help determine the traffic conditions, network availability, experience with software are outlined below:

1. Level : One-way / Two-way
2. Format : Structured / Unstructured
3. Time Domain : Synchronous / Asynchronous
4. Distance : Short / Medium / Long Distances
5. Medium : Audio / Audio-graphics / Video / Computer / Combination

Availability of / Experience with

1. Network: Analog Telephone Line / Digital Telephone Line / Ethernet / ISDN / Other
2. Hardware Components: Personal Computer / Workstation / Dumb Terminal / Host Computer / File and other kinds of Servers / Other
3. Software Components : Word Processor / Drawing tool / Presentation Tool / Conference Tool / Conference Management Tool / Groupware Tool / Communication Management Tool

Services which a home-worker can choose should include electronic mail, voice mail, facsimile, group meeting, telephone- conversations, audio/video/computer conferences, bulletin board, electronic- board, special interest group, presentation, etc. The selected set of services also determines the traffic conditions, type of network, necessary devices, etc. Highly skilled users should have the option to choose the above parameters.

The next step is to configure and display the ES's solutions in the form of configurations. The internal processing of the ES like application of procedural rules and heuristics should be hidden from the user.

4.2.2 Display configuration(s)

Configuration of the teleconferencing system consists of selecting the appropriate components like network, computing, software, and conferencing tools that match the home-workers' requirements. In choosing a network, different variables like functionality, performance, reliability, and cost have to be carefully weighed and balanced.

The initial step in building a teleconferencing system is to determine the raw materials of the network, which consist of the following:

- Media: which serves as the physical connection between sites. Eg. coaxial cable, twisted-pair, fiber optic, etc.

- Network hardware: which is the connection between medium and the computing device's internal environment. Eg. network card for personal computer, network interface units connected to I/O channel of mainframe computer, etc.

- Connecting devices: can stretch networks beyond the normal manufacturer recommended lengths, isolate faulty segments, isolate network segments for security reasons, perform conversion between networks that have dissimilar datalinks or dissimilar network protocols. Eg. bridges, routers, repeaters, gateways, etc.

In designing the teleconferencing network, it is important to provide for future expansions and enhancements. Only standards and protocols which have been widely tried and accepted should be considered.

The next step in the configuration process is to choose the computing device, audio and video equipment. The choice of these components depends on the teleconferencing room, desired quality, budget, number of participants, etc. The right kind of lighting and acoustics in the teleconferencing room go a long way in enhancing the quality of the teleconference. It is important to consider using equipment the home-workers may already own. For example, the home-worker's preference for a operating system or a particular standard of video technology should be taken into account.

In case of computer-conferencing, the last step in the configuration process is to decide on necessary software tools. Software tools include spreadsheets, word-processing, mail, conference management, groupware, graphics, drawing, painting, presentation, etc. As mentioned earlier, software tools that the home-worker has prior experience with should be given preference.

The next phase in the configuration process is to display the ES's solutions in the form of configurations. The internal processing of the ES like application of procedural rules and heuristics should be hidden from the user. The display of configurations should have the following characteristics:

- graphical: The configurations should be displayed in a graphical mode for easy understanding.
- hierarchical: Initially, a top level view of the configuration should be displayed. On request, the user must be allowed to navigate through the lower levels to get details of individual components, and their subcomponents.
- interactive: Information about individual components should be displayed at the user's request, preferably by pointing at a component.

The user-scenarios presented at the end of the chapter illustrate the above features.

4.2.3 Tune configuration(s)

The third phase of the configuration process is to select and fine-tune the chosen configuration. This is mostly for the benefit of the highly skilled user. Some specific features included at this stage are to :

- Allow the user to incorporate adaptive devices and interfaces.
- Allow the user to make component level changes
- Display the revised configuration, benefits, and cost estimate.

Since the teleconferencing system is intended for home-workers with mobility problems and other handicaps, their special needs have to be taken into consideration. Choice of adaptive devices, interfaces, etc. have to be incorporated into the tuning of the teleconferencing system. An associated database of available adaptive devices and interfaces will prove useful.

1. Devices: Mouse / Keyboard / Monitor / Speaker Phone / Other
2. Interface: Mouse / Keyboard / Voice Activated / Touch Screen / Other

The user can make component level changes, and view the effect it has on the total configuration. This allows the user to try "What If Scenarios", and arrive at an optimum configuration. This feature comes is handy in ensuring that the total system is within an affordable price range. This feature also ensures that home-worker's preferences for hardware and software tools are incorporated.

4.2.4 Provide configuration and installation instructions

The last phase in the configuration process is to give the step-by-step instructions to purchase and assemble components.

In addition to the vendor contact details, their claims about the component should also be included. If users of the ES are willing to contribute their experience with individual components, it can be incorporated into later configurations. On request, a complete report on the ES's reasoning in selection of components should be available. Most ESs come with their own automated explanation facility which can be used for this purpose.

It is necessary to ensure that the information is displayed in an easy to read and understand format. The usefulness of the ES will be greatly enhanced by providing easy to follow multimedia instructions.

4.3 Sample Scenario

This section presents a scenario representing a typical interactive session with the ES. The user can choose a single type or a combination of services. Figure 4.2 and Figure 4.3 illustrate the user choosing computer and audio-graphics services. If the user fails to select a specific parameter, a default value is used, and the user notified of it.

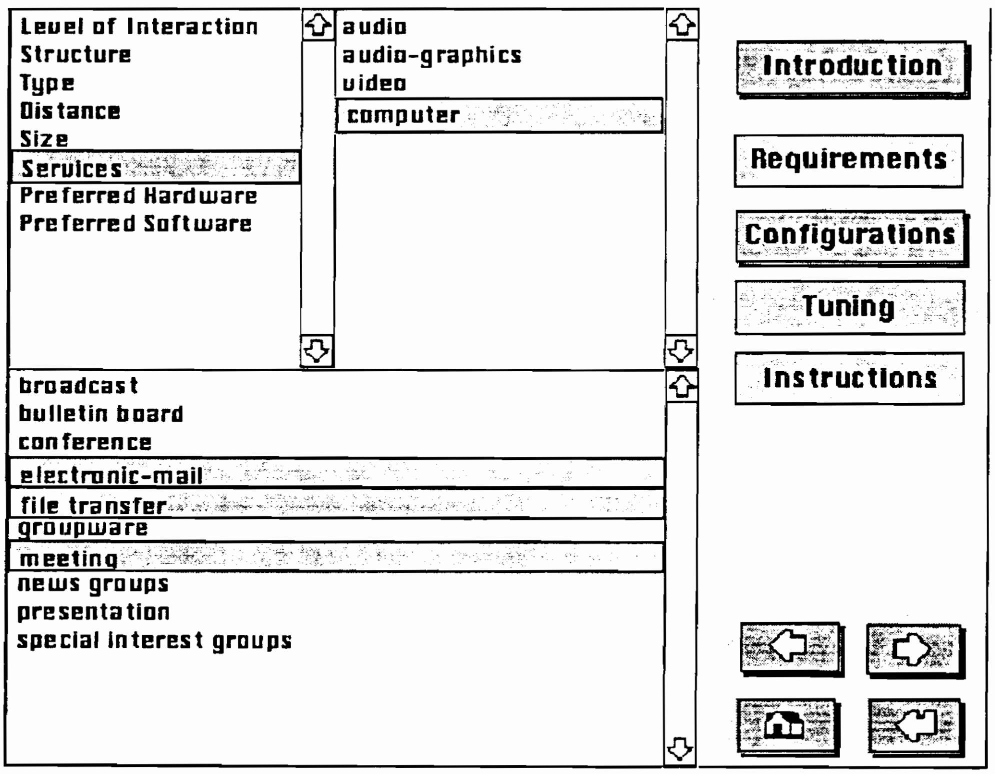

Figure 4.2: Service Requirements 1

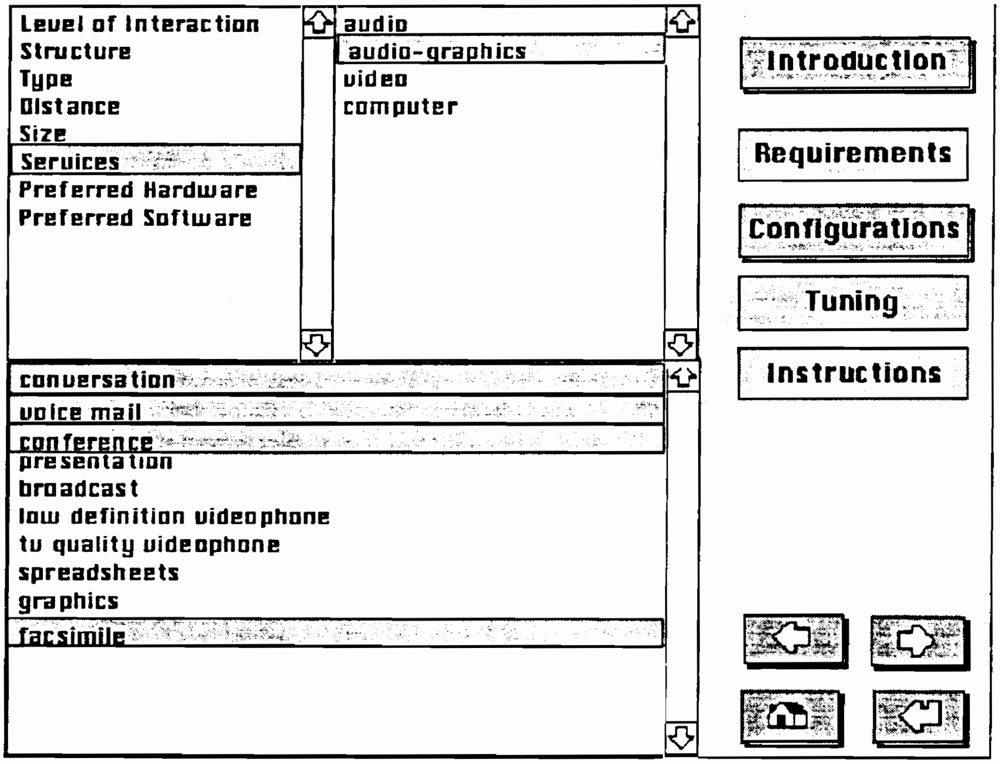

Figure 4.3: Service Requirements 2

In the next stage the ES's solution i.e. configurations matching the user's requirements are displayed. At this stage, only a high level view of the configuration is displayed as illustrated in Figure 4.4 and Figure 4.5. Each configuration has a cost/benefit analysis report which helps the user to select a configuration best suited to his/her needs.

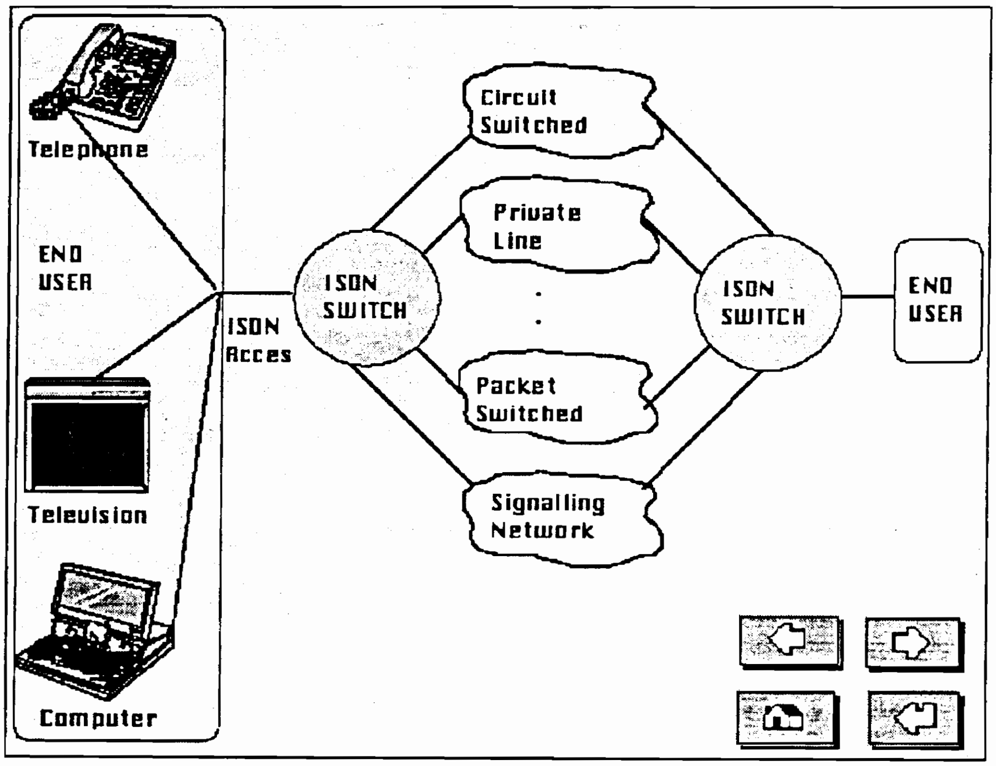

Figure 4.4: Configuration 1

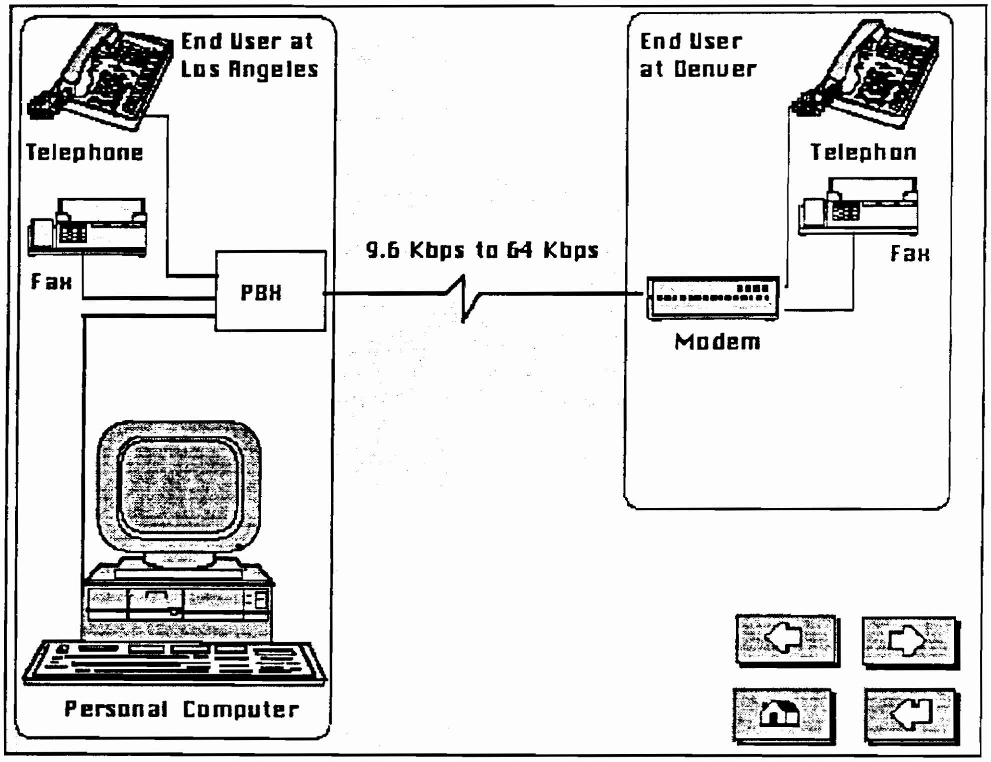

Figure 4.5: Configuration 2

On request, the individual configuration parameters are displayed in a hierarchical form as shown below. This hierarchical format of configuration can help user to analyse individual components without the distraction of the complicated total configuration.

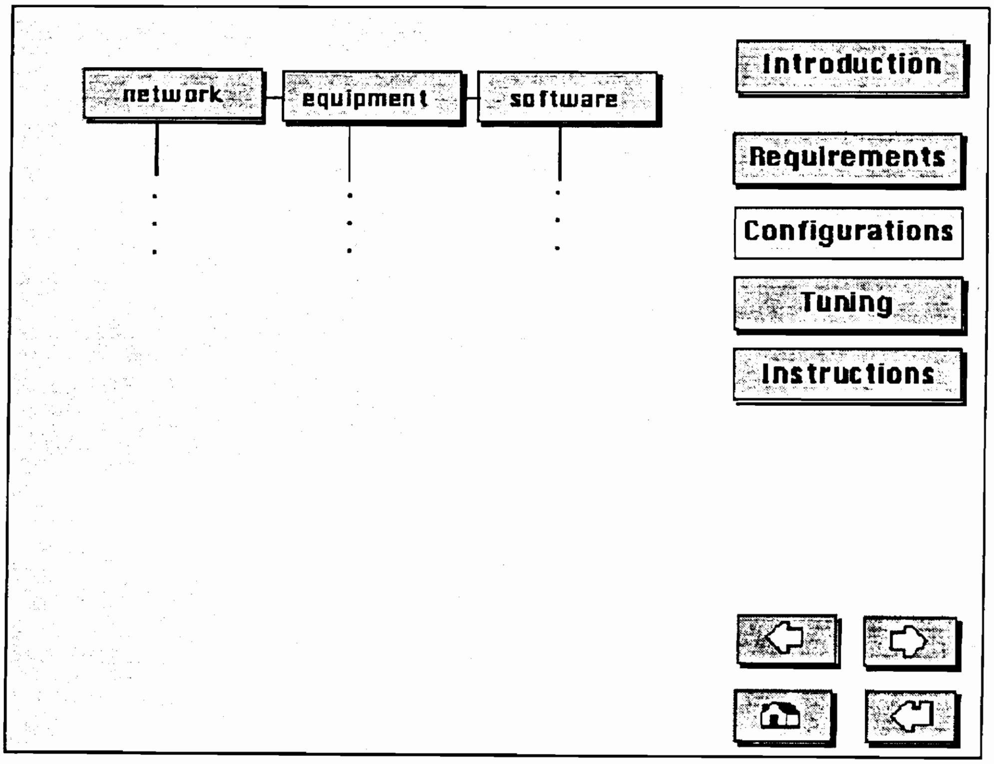

Figure 4.6: Configuration Step 1

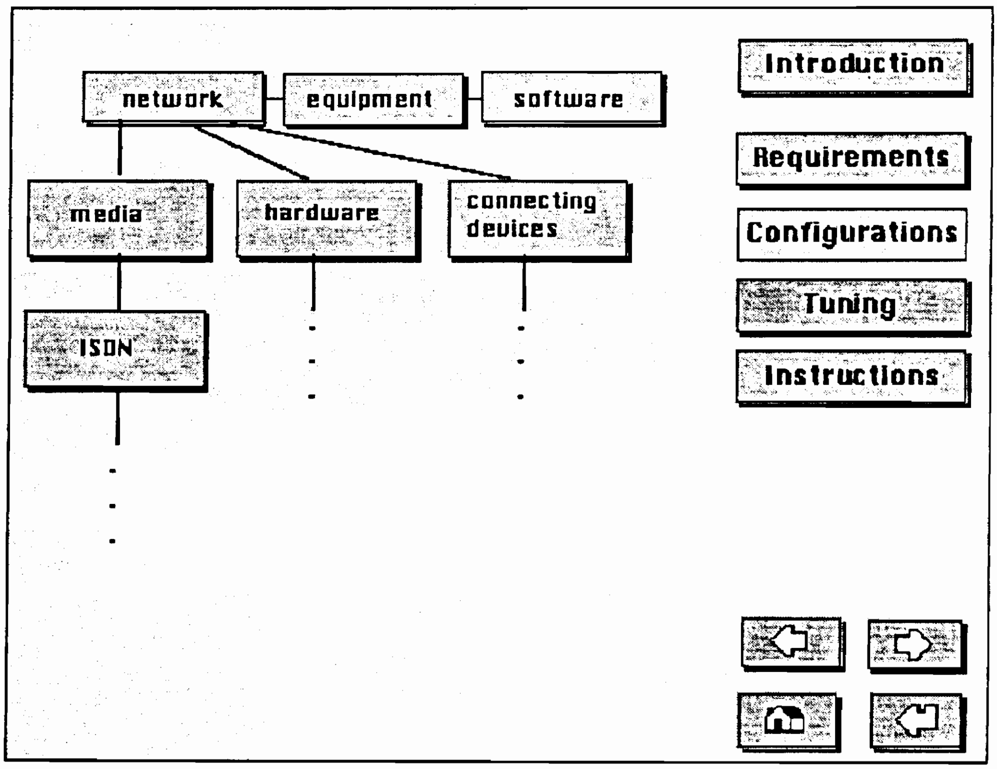

Figure 4.7: Configuration Step 2

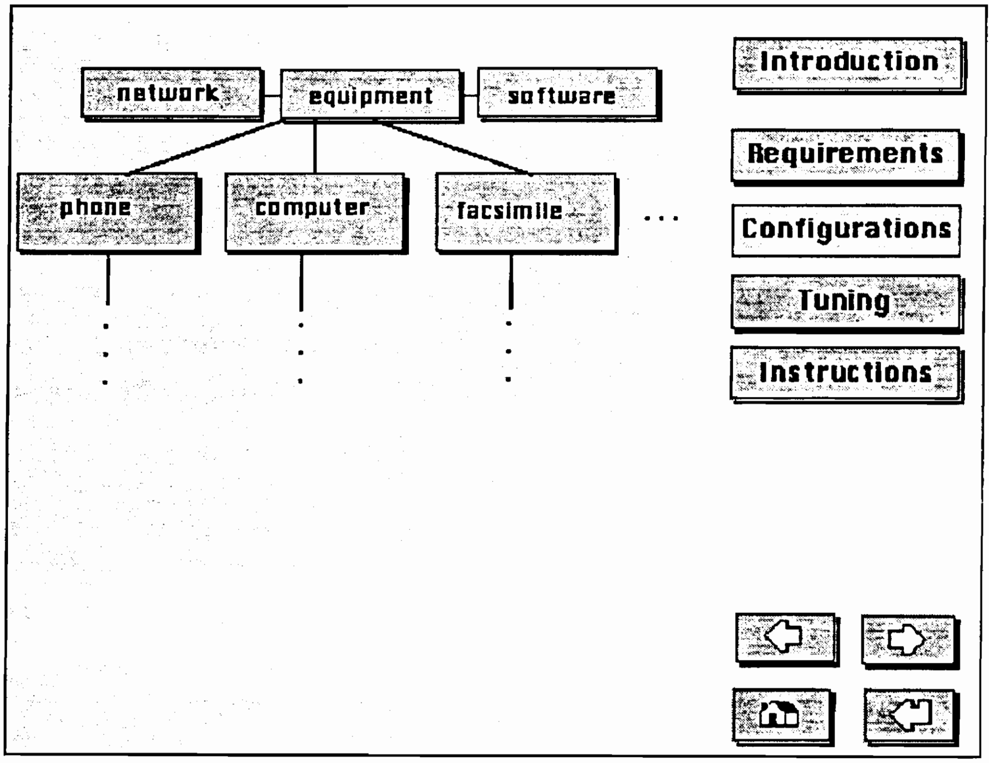

Figure 4.8: Configuration Step 3

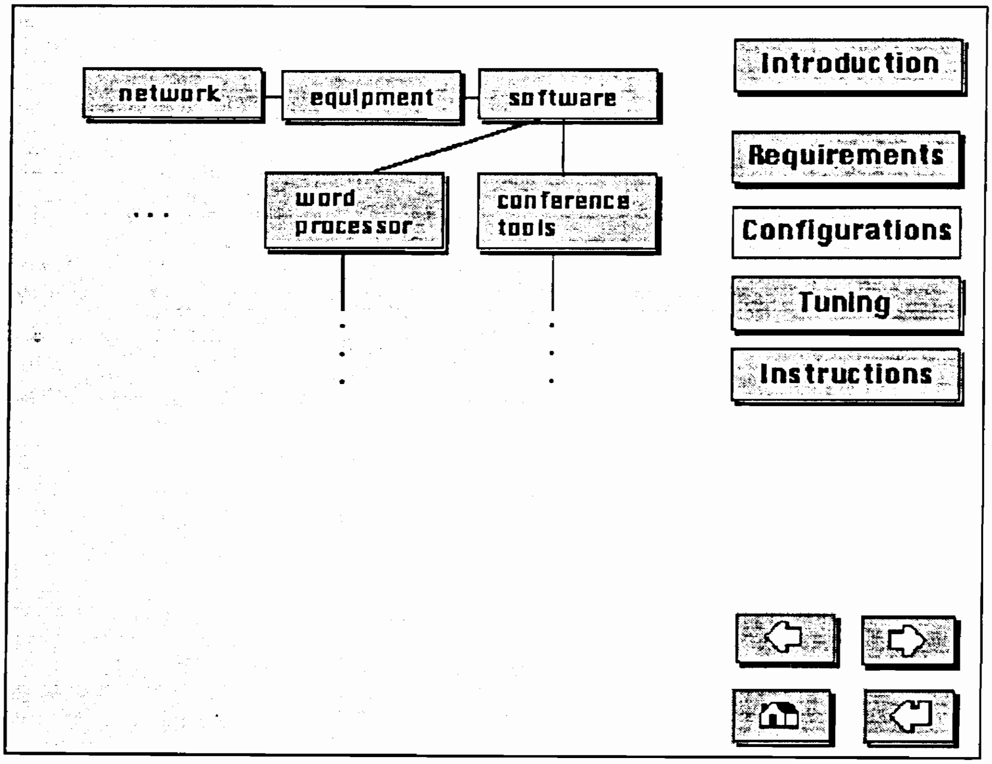

Figure 4.9: Configuration Step 4

sectionFuture Work Development of the ES is an iterative process. The functionality of the system is expected to change and grow throughout it's life-time. Further steps necessary to develop the ES are:

- Selection of knowledge representation scheme
- Selection of appropriate ES shell
- Task Specification for the ES
- Knowledge (domain) acquisition
- Development of the ES Prototype
- Usability Testing of the ES prototype
- Development of the ES
- Testing of the ES, Expert Evaluation

Chapter 5

CONCLUSIONS

Teleconferencing can help in ensuring that mobility-impaired workers are not left behind in the race for success in a global market economy. Teleconferencing systems can provide mobility-impaired workers the chance to participate in the information revolution going on. In the US, teleconferencing has been adopted only by a fraction of all government and private organizations. But the trend is changing fast and the cost is bound to reduce with widespread interest and usage. New projects like Blacksburg Electronic Village, which hope to bring computers and information to each and every home is a promising start of this trend.

Chapter 6

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Appendix A
GLOSSARY

CCITT: International Telegraph and Telephone Consultive Committee; an international group that establishes transmission standards for telecommunications.

Computer Supported Cooperative Work (CSCW): The term was coined jointly by Irene Greif and Paul Cashman. There is a lot of debate going on as to the precise definition of CSCW [Bannon, Schmidt, 1991]. CSCW is an inter-disciplinary subject, bridging the gap between the human sciences, which provides knowledge of cooperative work practices and associated communication processes, and the application of information technology, which provides knowledge of mechanisms to implement computer communication systems to support cooperative working [Bowers, Benford, 1991].

[Sarin, Greif, 1988] is a collection of papers describing to the first steps toward CSCW, new technologies, and design theories of CSCW. In an effort to draw design principles for future CSCW systems [Harper, Hughes, Shapiro, 1991] examine how computer-based systems can support and sometimes hinder cooperative working. [Dollimore, Wilbur, 1991] share experiences in building a configurable CSCW system. [Bonfiglio, Malatesta, Tisato, 1991] discusses the Conference Toolkit (a system layer supporting multimedia, real-time cooperation among users via shared applications) approach for the development of conferencing systems. For design of computer supported meeting environment, refer to [Ferwagner, Wang, Lewe, Krcmar, 1991]. For empirical studies in computer teleconferencing refer to [Kiesler, Siegel, McGuire, 1984], [Crowston, Malone, Lin, 1988].

Electronic Blackboard: A device that is based on the ordinary backboard, but has a conductive surface for producing hand written information that can be sent over a telecommunications channel.

ETHERNET: Ethernet is a physical layer network protocol that supports a branching bus topology and uses a CSMA-CD protocol at the hardware level. It was jointly developed by DEC, Intel, and Xerox in 1980 and since then has been a very pervasive means of networking personal computers and workstations.

Fiber Optics: Fiber optics is a communications medium based on a laser transmission that uses a fiber, or a thread-like material, which carries light. Fiber optics provides high capacity at high speeds, improves transmission quality, provides greater security, reduces maintenance costs and offers virtually unlimited bandwidth.

GROUPWARE: Groupware is software and hardware for shared interactive environments. For more details refer to the article groupware-intro on Usenet newsgroup comp.groupware.

HYPERTEXT: Ted Nelson, one of the pioneers of "Hypertext", defines it as "a combination of natural language text with the computer's capacity for interactive branching, or dynamic display... of a nonlinear text... which cannot be printed conveniently on a conventional page" [Nelson, 1967]. [Conklin, 1987] surveys some hypertext systems, their applications and their design.

ISDN-BISDN: Digital transmission and switching architecture being used to build a new all_digital telecommunications infrastructure [Stallings, 1989]. Rapid advances in computer and communication technologies have resulted in the increasing merger of these two fields. The byproduct of this merger is ISDN technology. ISDN is a public switched service that allows the digital transport of voice, data and image over one one network. It allows users to replace private branch exchanges (PBXs), modems and expensive leased telephone lines. It can provide on-demand bandwidth, handle video conferencing and graphics applications. Best known application is automatic number identification (ANI) used in customer service operations and telemarketing. Its true potential lies in the benefits to smaller and mid-sized companies that cannot afford more expensive alternatives [Kerr, 1992].

To control ISDN evolution and impact, massive effort at standardization is underway. There are 2 key aspects to ISDN: Universal access and User services. By standardizing the interfaces to ISDN, all ISDN-compatible equipment like, telephone, personal computers, computer terminals will be able to attach to the network anywhere in the world and connect to any other attached system [Stallings, 1989].

Broadband ISDN (BISDN) CCITT defines BISDN as "a service requiring transmission channels capable of supporting rates greater than the primary rate". BISDN paves the way for services, especially video services which require data rates orders of magnitudes beyond those that can be delivered by ISDN. Integration of a wide range of communications facilities and the support of, in effect, universal communications with the following key characteristics [Stallings, 1989]:

- Worldwide exchange between any two subscribers in any medium or combination of media.
- Retrieval and sharing of massive amounts of information from multiple sources, in multiple media, among people in a shared electronic environment.
- Distribution, including switched distribution, of a wide variety of cultural, entertainment, and educational materials to home or office, virtually on demand.

For details on ISDN Customer Premises Equipment and Applications refer to [Griffiths, 1992]

MODEM: The modem (acronym for modulator-demodulator) is used to interface data terminal equipment like terminals, printers, etc. with analog telephone lines. Modems can be divided into four basic categories in regard to speed of operation:

- Narrow-band modems up to 300 bps, used for low speed terminals like teletypewriter machines.
- Voice-grade modems 1200, 2400, 4800, 9600 bps and above. High speed modems are capable of operation up to 14,400 bps.
- Wideband modems 19,200 to 64,000 bps.
- Limited distance or short-haul modems can handle data rates up to 1,500.000 bps (1.5 Mbps).

Other features are synchronous or asynchronous operation, "smart modems" with built-in microprocessors, etc. For more details refer to [Pairitz, 1985].

MULTIMEDIA: Multimedia has added a new dimension to computers. Multimedia is the integration of information in the form of text, sound, music, graphics, animation, narrative, video, and images. Multimedia in combination with inherent feature of computers i.e. interactivity (between individuals and the computer, or between individuals/groups with computers as the medium) has proved to be a powerful tool. The workstation technology of today incorporates integrated multimedia conferencing capabilities. [Lantz, 1988] reports an experiment in integrated multimedia conferencing. The April 1991 issue of the CACM was devoted to emerging compression standards with relevance to digital multimedia.

NETWORKS:

- File transfer and Real-Time messaging: File transfer usually means that the time lapse between transmission and reception of the data is not critical. Real-time messaging means that data must arrive at its destination in a predictable amount of time.
- Email: Email is a embellished file transfer feature.
- Virtual terminal: Allows your workstation or dumb terminal to access a host

computer that normally requires a specific terminal type. Virtual terminals translates terminal functions into the format that the host computer understands.

- Network Management: Network management to monitor performance, problem detection, security safeguards etc.
- Directory Services: In the network, the number is the network address of another node with which a computer wants to communicate. A network address is analogous to a phone number.
- Wide and Local Area Networks: The difference between WAN and LAN is the distance between nodes and the form of technology used to deliver messages. LANs spans within a building or between nearby buildings. WANs span between buildings or cities or countries. Easiest networks to build are those that connect a small number of nodes of the same make and model.

Private branch Exchange (PBX): A very simple form of PBX is the key telephone. It is a small station switching device. There are 2 basic types of PBX: analog and digital. The basic difference between the two is the form in which the signal passes through the switching network. With a analog PBX voice signal is passed through in its original analog form. Digital data to and from a terminal or other digital device must be converted to an analog form before it can be switched. This is handled by a modem. With a digital PBX digital data is switched in digital form. Voice signals are converted from analog to digital form by a codec in the telephone set and then switched. SL-1 is Northern Telecom's first digital PBX.

SDL - the Specification and Description Language: SDL is one of the three specification languages, or Formal Description Techniques (FDTs), supported by the CCITT for specifying networks.

SIgnalling System 7 (SS7): SIgnalling System 7 is dedicated signalling network which frees the regular telephone message network for full flexibility for advanced services like call forwarding and call screening services.

Surrogate Electronic Traveller (SET): SET is a tool or package consisting of hardware and software. SET was proposed as an alternative to traveling for mobility-impaired workers [Williges, Williges, 1993]. The idea is similar to remote participation through teleconferencing.

Synchronous Optical Network: SONET : SONET allows for the connection of multiple transmission systems, and will bring international standards to the field of fiber optics. SONET will ensure network diversity, and minimize the impact of any network outage.

VIDEO TRANSMISSION: AT&T introduced its picturephone at the NewYork World's Fair in 1964. The major problem has been the need for very broad bandwidth to carry the tremendous load of information in a video signal. When a standard monochrome television picture is digitized, each image is sampled over a grid of 512x480 pixels. Each pixel is coded with 8 bits for a total of 256 possible shades of gray.To display motion, the picture is sampled at 30 frames per second. The rate is 59Mb/s(512x480x8x30). Adding color information brings the data rate to 90 Mb/s.

One solution suggested was the use of advanced video bandwidth compression techniques. Bandwidth compression or 'bitrate reduction' reduces the data rate required to reconstruct the video signal at the receiving end. Elementary forms of compression like sampling the picture at 15 frames per second still requires about 45 Mb/s Video compression devices, Codecs, digitizes and compresses the analog video signal. Today powerful codecs can operate over 56 or 64 Kb/s networks. One scheme in particular removes any information that is not absolutely necessary to recreate the picture at the other end. The codec predicts what the image will look like from one instant to next. Then it compares the actual image with the prediction and transmits only the difference between the two. Since there is not much much movement during a video conference, there is not much "difference" to transmit.

The codecs are available in either the North American 525 lines NTSC standard or the European 625 lines PAL standard. The higher the data rate, the sharper the picture quality. The most popular rate is 112 Kb/s using two switched 56 Kb/s lines. A videophone, as a stand-alone terminal, will be equipped with a 3 inch by 3 inch color liquid crystal screen, a video camera, and a codec. In addition, it incorporates the features of a handsfree digital telephone set. When connected to ISDN, it will support the simultaneous transmission of image, speech and data. Interactive dynamic display system (IDDS, now commonly known as Multimedia), marketed by a Canadian company, Eyetel Communication Inc., integrated television sources and computer generated still images into the world of the personal computer. The screen displays in a "windows" environment, full motion color video conferencing with display capabilities of independent data. The package includes a color camera, a codec, a mousepen (for drawing), the software and one printed circuit board, to be plugged into the expansion slot of a personal computer. Using 56, 64 or 384 codecs, the system operates over any of the switched data services offered by most telephone companies. For the majority of videophone applications, dial-up switched service, typically at 112 Kb/s (using 2 switched 56 lines), is both the most convenient and economical. A coast-to-coast videoconference using two switched 56 lines can cost around $25 per hour in the United States.

WORKSTATION: Workstation is a computer designed for a single user, built for network integration, and equipped with high-resolution graphics tasks [Smith, 1992]. It has revolutionalized the computer (desktop) conferencing.

Appendix B
REGISTERED TRADEMARKS

Ethernet is the trademark of Digital, Intel, and Xerox Corporations.

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