INTRODUCTION

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This paper summarizes the customer needs that are shaping the network of the future. It describes AT&T's response to these needs in the form of Universal Information Services and surveys the technologies that are making the response possible. It examines the challenges in software productivity, quality, and standards that must be met to make the network of the future a reality.

The Network of the Future

The information network of the future will give anyone—anywhere, anytime—access to voice, data, images, and video, in any combination. Much as we now plug an appliance into an electrical outlet, the telephone user of the future will plug a terminal into a universal port, taking for granted that it will operate, and link to a worldwide bank of facts, information, advice, entertainment, and thousands of other functions.

The network of the future will boost our productivity as workers. Equally important, it will enrich our lives with a far wider range of social interaction. We will learn, we will play games, we will exchange ideas with people we choose from among billions of people from around the globe.

That future is not far away. If we think of the development of the network of the future in three phases, we are now well into phase 2 and preparing to enter the third phase. Phase 1 consisted of the buildup of an intelligent network. Over a 20-year period starting in the 1960s, we implemented digital transmission, digital switching, versatile signaling systems, and varied databases, making the telephone network a great distributed computer. In phase 2, we are implementing the Integrated Services Digital Network (ISDN), in which voice and data are combined on the same paths and travel via a small set of standard interfaces. Already, 200,000 lines in the United States are served by ISDN. Phase 3 will implement what we call Universal Information Services (UIS) and will take place in the 1990s. UIS will bring:

- Adaptive services in real time. An example is teleconferencing via multiple media—voice, graphics, video, electronic blackboard, and facsimile as they are needed.
- Bandwidth on demand; available bandwidth will rise and fall in ac-

cordance with users' needs.

- Convenient, user-friendly access to information resources and transaction services.
- Virtual private networking that will give users the benefits of communication links that operate as though exclusively theirs, but at the low cost of shared links.

Making It Happen

One of the keys to making it happen is integrated access and integrated transport. Photonics technology based on fiberguides will be exploited not only for long-distance transmission but also for short links from central offices to homes and businesses and within and among buildings. These links will make available to ordinary consumers the great bandwidths necessary for interactive video, for example. Current transmission rates of 3 to 4 Gb/s (gigabits per second) are only a tiny fraction—about one-tenth of 1 percent—of the potential bandwidth of fiberguides that will be fully realized over the next few decades.

Software, too, will be a vital part of UIS. Software will support such advanced features as multipoint subscriber lines, automatic rearrangement of customer stations, and on-demand packet switching. Software will ensure that users obtain the services they want and are billed only for the services they use.

Another key feature of UIS will be universal ports, the interfaces by which customers gain access to the network. There is much more to a universal port that its physical manifestation—the standardized outlet into which customers plug their terminals. Behind it is an array of software, distributed intelligence, and signaling abilities designed to accommodate and integrate disparate equipment.

Synergistic Technologies

It is fortunate that the available technologies are synergistic with evolving customer needs. This is not surprising; future networks will use the same digital technologies embodied in computers and consumer products. The same technologies that created the need will satisfy the need.

One such technology is photonic transmission. Glass fibers now carry voice, data, and video not just across oceans and continents, but also into homes. Each such fiber has the potential to carry more than 10 million telephone channels and thus can eventually provide the capacity needed for every combination of services.

Meanwhile, strides are being made in photonic switching technology, and we can expect complementary photonic transmission and photonic switching to eventually handle UIS signals from end to end, without converting signals from light to electricity for switching purposes.

Integrated circuits will continue their astounding growth in complexity and drop in cost. The number of components per IC chip doubled every year for a 20-year period. The current pace of doubling every 18 months can be expected to continue for the next 10 years. Now, chip manufacturers can place 8 million components on a chip. Eventually they will be placing at least 100 million components on a chip. To UIS users, this means that increasingly complex services can be provided at today's level of affordability.

Indeed, the low cost per function and low cost per unit bandwidth provided by modern integrated circuits and photonics make UIS economically practical. The first digital logic circuits cost about $10 per gate. Today, the cost is about one-hundredth of a cent per gate. Thus, many UIS functions that were technically feasible but too costly a decade ago are now affordable. Similarly, functions that cannot be offered economically today will be commonplace a decade from now. Information-processing systems and end-user systems will continue to benefit from the trend as increasingly complex, but affordable, microcomputers proliferate.

For microcomputers, processing power will continue to double each year. This growth comes not only from burgeoning chip functionality. It is also a result of networking many microcomputers into extremely power-

3

ful computing systems. For example, the 2500 microcomputers in AT&T's 5ESS™ switch are networked to yield a combined processing power about 5 times greater than that of a large mainframe computer. Microcomputer networking is like using a flexible fleet of trucks to haul more goods than a single locomotive. And there is no end in sight to the growth of microcomputer power through networking.

Packet switching, too, is an important technology for UIS. Although packet switching will not completely replace circuit switching, its flexible architecture can support the on-demand services that form the backbone of UIS.

Challenges

Intelligent systems create an insatiable demand for software, and herein lies a major challenge to UIS developers: to increase programming productivity so that software can be made available to users with much less delay and at far less cost. We are following several approaches to productivity improvement, such as designing standard program architectures and reusable software building blocks as well as exploring simplified, high-level languages that directly translate program requirements into software. We are confident that approaches such as these will eventually have dramatic impact on productivity to ensure the lowest possible software cost.

A related challenge is ensuring highest quality in every aspect of UIS—in software, in hardware, and in every other aspect of service realization and support. In systems of enormous complexity, only the most careful attention to quality can guarantee that users will be able to plug their terminals into the network and forget about the possiblity that they won't work.

Still another challenge is standards. The technology for UIS is evolving well, but the vision is global, with many interconnected service providers and many equipment vendors. Worldwide standards are required to assure interoperability. Toward this end, AT&T is committed to working with standards organizations and contributing effort and knowledge to forge mutually acceptable standards for the industry.

AT&T is also committed to working with users and service providers such as the regional Bell operating companies to sort out the maze of possible services to find those that truly bring value to users. This is the way to identify standard, practical means of meeting user needs, for the precise family of UIS products and services will be established in the marketplace.

This issue of the *AT&T Technical Journal* illustrates the company's commitment to UIS. In it, AT&T scientists and engineers discuss their achievements and plans. The papers reveal solid progress and hard work, but they represent only a fraction of the total effort that has gone into making the vision a reality.

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