Chapter 2. Historical Highlights and Standardization Initiatives

2.1. Historical Developments of Communication Networks

Incredible advances and developments of individual and service-specific communications networks characterize telecommunications of the 20th century. In addition to the creation of separate and sophisticated networks, the close of the century has also witnessed a push toward integration of all these separate communication environments into a single network -- one that would offer higher capabilities for meeting the needs of newly emerging services while still offering the same or even improved quality of the existing services at a lower cost. The historical developments leading to the need of networks integration are presented in the following sections.

2.1.1. Telephone Networks

At the beginning of the telecommunications industry, copper wire was quickly accepted as a standard transmission medium, mostly due to its good conductivity and low production cost. However, it quickly became obvious that a single message or logical link per physical copper link was insufficient and economically nonviable. Ways of packing multiple channels onto one physical link emerged and the resulting system is referred to as the carrier system, or simply the carrier [3]. These carrier systems can be both analog as well as digital, and both are in use today. The analog carrier systems, however, are decreasing in importance.

In the 60's the telephone networks began their transition from analog circuit switched networks to all digital circuit switched networks. The first digital carrier system introduced in public switched networks was known as the T-1 carrier system, and was designed to operate over twisted copper wire pairs [3]. The rates and parameters of T-1 carrier reflect the fact that it was designed for carrying voice. The basic building rate for T-1 carrier was derived from a bandlimited analog voice signal sampled at the rate of 8000 samples per second and then 8 bit pulse code modulated to give a digital signal at the rate of 64 kbps. T-1 signal carries 24 simultaneous voice channels for the total capacity of 1.544 Mbps. Four T-1 signals can be time division multiplexed to obtain a 96 channel 6.312 Mbps T-2 signal and seven T2 signals can be time division multiplexed to obtain a 672 channel 44.736 Mbps T3 signal [3].

In more recent years telephone networks have been used for other applications, such as facsimile transmission, and the resulting increased network usage have forced the transition of main backbones of the telephone networks from copper and microwave radio to optical fiber. Also, using pre-existing networks for new applications lead to certain shortcomings. The T-carriers, for example, perform well in the circuit switched public telephone networks for carrying voice, but the constant bit rate channels are proving to be less efficient for the transfer of variable bit rate data traffic which is becoming a significant percentage of all telecommunications needs.

2.1.2. Cable Television Networks

Television, in addition to radio broadcast, is transmitted via broadcast networks which until recently were generally based on the use of coaxial cable as the transmission medium. Although cable networks are a more recent development than telephone networks, they have been very slow in transitioning from analog to a digital format. Due to the broadcast nature of TV networks and widely accepted analog transmission, there has never been a need to standardize certain "carriers," although channel assignment for both over-the-air and cable transmission are standardized. The common method of simultaneously packing individual 6 MHz TV channels into one cable uses the subcarrier-multiplexing (SCM) technique of amplitude modulated vestigial sidebands (AM-VSB) TV signals.

Inherently large bandwidths of video signals have also pushed cable television (CATV) distributors to include fiber and hybrid fiber-coax as transmission media of choice. The larger bandwidth of CATV networks makes them lucrative for transmission of data, but the broadcast nature of the networks make any transition to support new services a difficult option, although there is considerable work directed towards this.

2.1.3. Data Networks

At first computers were created for the sole purpose of aiding humans in numeric calculations and computing. As their processing speeds improved, the amount of calculations performed increased drastically. Large amounts of processing required large data bases and large storage files, and soon single computing machines were not adequate for performing all the desired operations while simultaneously storing all the desired information. Soon there was a need for file sharing, parallel processing and distributed computing; all of which require fast and reliable ways of transporting the data between the individual computers.

Faced with this problem throughout the 60's, a number of people began thinking about connecting computers to each other to improve performance, efficiency and overall capabilities for computing. However, it wasn't until the annual meeting in 1967 of the "principal investigators" of the Advanced Research Projects Agency (ARPA), an R&D agency funded by the U.S. Department of Defense, that the topic of networking was brought up and seriously considered as a future project [4].

The ARPANET Completion Report, as published jointly by BBN of Cambridge, Mass. and ARPA states the following from the meeting:

"At the meeting it was agreed that work could begin on the conventions to be used for exchanging messages between any pair of computers in the proposed network, and also on consideration of the kinds of communications lines and data sets to be used. In particular, it was decided that the inter-host communication 'protocol' would include conventions for character and block transmission, error checking and retransmission, and computer and user identification. Frank Westervelt, then of the University of Michigan, was picked to write a position paper on these areas of communication, an ad hoc 'Communication Group' was selected from among the institutions represented, and a meeting of the group scheduled" (ARPA draft, III-26) [4].

ARPA's Program Plan for the ARPANET was titled "Resource Sharing Computer Networks," and it was approved by the Director in June 21, 1968, the same month it was submitted [4].

ARPANET was created in 1971 as the first packet-switched network, connecting military and civilian locations as well as some universities [5]. This data network was the beginning of a major evolution of computer networking, eventually giving birth to today's Internet.

Along with the increased connectivity, interoperability and decreased size and price of computers, the Internet helped promote the transition from the use of computers as primarily computational machines to their implementation as a new form of personal device. However, David Clark observed, "It is not proper to think of networks as connecting computers. Rather, they connect people using computers to mediate. The great success of the Internet is not technical, but in human impact. Electronic mail may not be a wonderful advance in Computer Science, but it is a whole new way for people to communicate. The continued growth of the Internet is a technical challenge to all of us, but we must never loose sight of where we came from, the great change we have worked on the larger computer community, and the great potential we have for future change [4]."

The arrival of affordable Personal Computers (PCs), coupled with the recent creation of the World Wide Web, facilitated explosive growth of the Internet (Figure 2.1). According to an article in Nature dated 8 July 1999, the Internet doubled in the past year, causing the number of web pages to escalate to 800 million today [6, 7].

There was quickly a need for more bandwidth, and a switch to higher capacity optical fiber as the data transmission medium was inevitable, just as it was necessary for the telephone and cable TV networks.

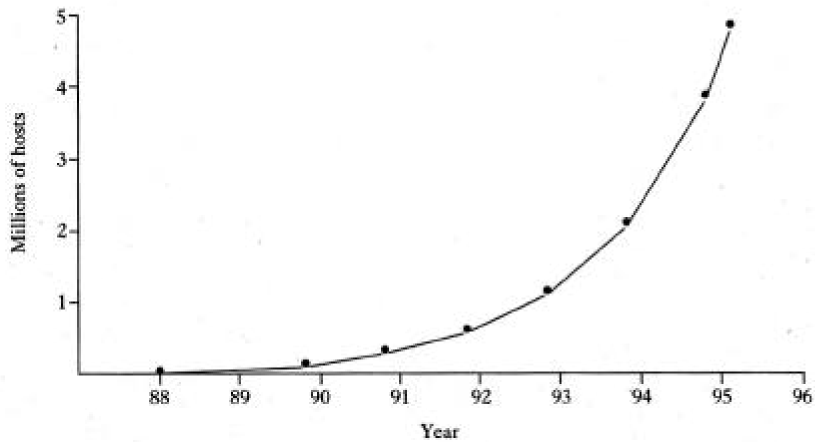

Figure 2.1 Growth in Number of Computers Connected to the Internet Since 1988 [6].

2.2. Standardization Initiatives

The transition of the three major communication environments (voice, video, data) to digital technology and the choice of optical fiber as the physical medium of choice for high speed communications in the wide area networks (WANs) exposed the issues of compatibility and interoperability as the main problems confronting global integration of these networks. At the beginning of commercial use of digital systems incorporating optical fibers as the transmission channel, there was no compatibility between vendors with regard to transporting signals over an optical network. Each vendor of optical transmission equipment, by necessity, produced proprietary signals. This problem was not limited to the U.S., and as other developed countries were running into similar problems, standardization of digital communication systems was becoming a global concern.

Two main avenues needed major work, and continue to require refinements, by the international standards setting community; first, it is necessary to implement a standardized method of transmitting the data no matter where it originates; second, a standard of procedures, rules and protocols needed to be developed. The adoption of both standards ensures the more efficient use of transmitted data by all geographically separated users.

The standardization initiatives concerning the integration of the disparate networks began with the adoption of concepts of Integrated Services Digital Network (ISDN) and Broadband-ISDN (B-ISDN), as well as the introduction of various protocol reference models such as the Open System Interconnection (OSI).

2.2.1. ISDN

Although the work on ISDN started in the mid 1970's, the first official standardization move toward integration of networks carrying different types of traffic came in 1984 [8]. That year, the adoption of the I series recommendations concerning ISDN was recommended by the Plenary Assembly of the Comité Consultatif International Télégraphique et Téléphonique (CCITT) which is now known as the International Telecommunication Union (ITU) [9]. (ITU-T is a sector of ITU, which is in charge of setting network standards for public telecommunications.) The goal of these recommendations was to provide a standardized set of multipurpose user-to-network interfaces, which would provide an end-to-end connectivity among users, as well as access to many voice and non-voice digital services [9]. The ISDN's building block rate of 64 kbps was derived in almost identical fashion to the T1 carrier for telephone networks, and the upper limit for ISDN channel rates was established at about 2 Mbps.

2.2.2. B-ISDN

Although the ISDN rates for network access were generally enough to support transporting voice and some lower grade video, they certainly were not enough for some multimedia applications such as high-resolution images and real-time video, which can require substantially higher rates. In addition, the ISDN rates are insufficient for connecting a LAN.

Thus, the CCITT/ITU-T began its work on extending the ISDN capabilities as early as 1985 [8]. This work eventually resulted in defining recommendations for B-ISDN by adding new high-speed channels to the existing ISDN rates, as well as new broadband user-to-network interfaces. However, the most important results to come out of this work were the establishment of new standards of synchronous techniques for transmission and asynchronous techniques for switching and multiplexing of broadband data services, now known as SONET and ATM.