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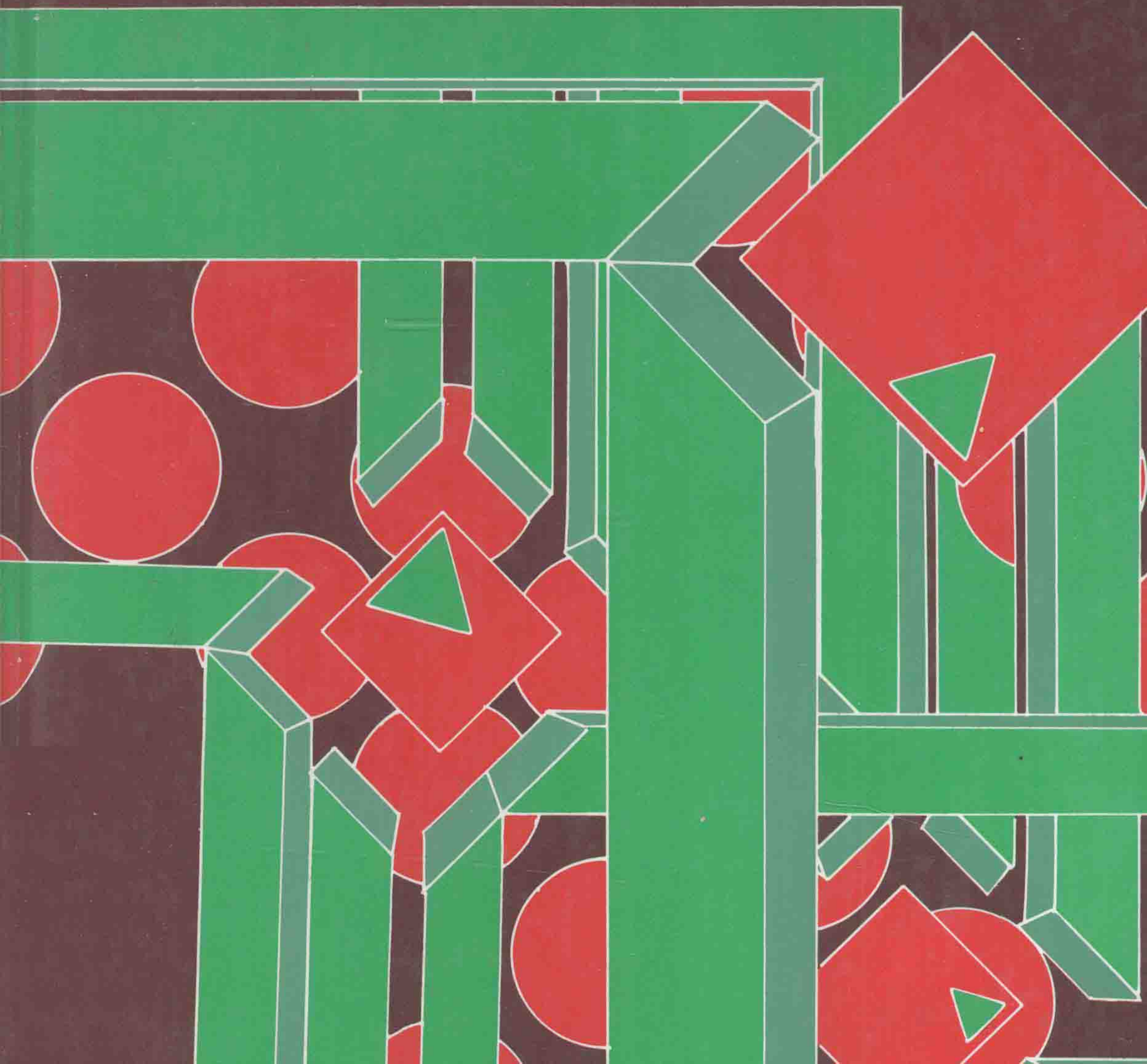
solution for broadband ISDN

Martin de Prycker



ASYNCHRONOUS TRANSFER MODE
Solution for Broadband ISDN

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To my wife Kaat
and my children Liesbeth, Thomas and Stefanie

To my parents

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Preface

The telecommunication networks of today are passing through a rapid evolution. In the early eighties, the first field trials with ISDN took place, with a commercial introduction in the late eighties. The breakthrough of ISDN is not yet achieved, maybe because of the lack of new attractive services.

This lack of attractive services can possibly be filled by a broadband network. This network can transport telecommunication services, like digital TV, digital HDTV, high quality videophony, high speed data transfer, video on demand, ... which are expected to be more attractive. To gain experience with those new services, researchers have already experimented with broadband networks and services since the beginning of the eighties.

The first standards for the broadband network have been defined by CCITT in the transmission domain. These are based on the SDH (Synchronous Digital Hierarchy) concept. This flexible transmission concept is also very interesting and directly applicable for the existing telecommunication networks.

Then the CCITT experts for broadband networks started with the definition of the broadband transfer mode. In 1988 there was only a very reduced recommendation with respect to broadband ISDN. It was already agreed then that ATM (Asynchronous Transfer Mode) would be the transfer mode for the future broadband ISDN (BISDN). Two years later, in 1990, CCITT SGXVIII prepared already 13 recommendations, using the accelerated procedure. These recommendations define the basics of ATM and determine most parameters of ATM.

The first ideas on ATM and related techniques were published in 1983 by two research centers (CNET, AT&T Bell Labs). In 1984, the Research Center of Alcatel Bell in Antwerp started working on ATM, and contributed actively to technical and standardization work on this subject.

This book benefited largely of the expertise which has grown since then in the Research Center of Alcatel Bell. The large team of experts on ATM in Alcatel Bell has a know-how on all ATM-related domains like the definition of ATM, ATM switching, ATM technology, ATM video coding, ATM traffic studies, ...

The purpose of this book is to cover all aspects related to ATM. Its intention is to help telecommunication experts, who will start working on Broadband ISDN, to acquire the needed experience on ATM and related issues. Seen the growing importance of telecommunications in graduate programs at universities, the book can also be used by graduate courses to build the basic ATM know–how and allow the students to start working on projects on more detailed topics like for instance ATM traffic studies, congestion control, ...

Contents

This book is composed of 6 Chapters, discussing each a particular item related to ATM. Every Chapter contains a detailed bibliography, to guide readers who want to study a particular topic more in detail. This bibliography contains a list of most of the recent published articles on that topic.

Chapter 1 describes the environment in which ATM has been defined. This means the requirements put forward by the market for a broadband network and the technology push, which shows a tremendous increase in performance of the available technologies.

Chapter 2 describes the history and evolution of ATM. Therefore, other possible candidate transfer modes for BISDN are first described. It is shown that ATM has a large number of benefits compared to the other candidate transfer modes. To define ATM in detail, a number of technical options have to be selected, with respect to functions and size of header and information field. These different options are described and compared.

In Chapter 3, a summary is given of the recommendation on ATM, as they are prepared by CCITT in June 1990. The most important functions and parameters are explained.

Chapter 4 describes an important system to be developed for an ATM network, namely ATM switching systems. First, the key options to be taken by an ATM switching system are explained : queueing and routing. Then a selected number of ATM switching systems, as described in the literature, are explained in detail.

In Chapter 5, it is shown that ATM also has an impact on the edges of the network in the terminals. Different important aspects are discussed : terminal synchronization, the possibility to use variable bit rate video coding, the statistical multiplexing and the requirement to cope with cell loss. In addition, different police functions are described.

Chapter 6 describes different MAN (Metropolitan Area Network) topologies. These are FDDI, DQDB and Orwell. In addition, performance characteristics of these 3 systems are given.

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1

Evolution towards an integrated broadband communication network

1.1. INTRODUCTION

In the evolution from the current telecommunication networks towards the Integrated Broadband Communication Network (IBCN) some important directions and guidelines have recently been made. IBCN is often referred to as the Broadband Integrated Services Digital Network (BISDN) since it is considered as a logical extension of the ISDN. The recent directions taken by the BISDN are influenced by a number of parameters, the most important being the emergence of a large number of teleservices with different, sometimes yet unknown requirements. In this information age, customers are requesting an ever increasing number of new services. The most famous teleservices to appear in the future are HDTV (High Definition TV), video conference, high speed data transfer, videophony, video library, home education and video on demand.

Each of these services will generate other requirements for the BISDN. This large span of requirements introduces the need for one universal network which is flexible enough to provide all of these services alike.

Two other parameters are influencing the directions taken by the BISDN : they are the fast evolution of the semiconductor and optical technology, and the evolution in system concept ideas, e.g. the shift of superfluous transport functions to the edge of the network. These system concept ideas are made possible by the technological progress which make it possible to put more functions on a chip operating at a higher speed and the higher quality and higher speed of transmission systems. Due to these rapid advances in technology, solutions not yet feasible some years ago, will become economically available in the near future if produced in large quantities.

Both the need for a flexible network and the progress in technology and system concepts led to the definition of the Asynchronous Transfer Mode (ATM) principle. This ATM concept is now accepted as the ultimate solution for the IBCN by CCITT (the International Consultative Committee for Telecommunications and Telegraphy), and plans are being made by different entities to realize experimental ATM pilots. A few examples of these experiments are RACE (Research for Advanced communication in Europe), the Belgian broadband experiment (De Prycker, 1988), the US multigigabit project, and an Australian experiment transporting ATM over satellite (Burston, 1990).

This book describes general technical problems related to ATM, independent of the private or public environment. However, seen the success of ATM in the public domain, it is more oriented towards the public domain.

Indeed in the public telecommunication world, most of the communication services and equipment are under control of the operating companies (USA) or PTT's (Europe, Japan, Australia, ...). These organisations very much require that the delivered equipment is in line with the CCITT Recommendations. So, ATM equipment will in the future easily find its way in the public telecommunication domain.

In the private telecommunication environment, the services and equipment are privately owned. Here, two large groups of players are present : the telecommunications industry, and the computer industry. There is a trend to align the private world to the public world, to guarantee an overall worldwide compatibility. This trend is recently reinforced, especially by the telecommunications industry.

This can be seen by the IEEE 802.6 standard. This standard, worked out by a professional society but with a large impact on computer manufacturers is as much as possible aligned to the ATM standards of CCITT. However, this is only a first step, and still non ATM compatible solutions are under definition by computer companies.

1.2. CURRENT SITUATION IN THE TELECOMMUNICATION WORLD

Today's telecommunication networks are characterized by specialization. This means that for every individual telecommunication service at least one network exists that transports this service. A few examples of existing public networks are described below :

- A telex network transports telex information, i.e. messages of characters, transported at very low speed (upto 300 bit/s). The characters are coded based on a specific 5 bit code (Baudot code).
- POTS (plain old telephone service) is transported via the public switched telephone network (PSTN). This ubiquitous network offers the customers classical two way voice conversation.
- Computer data are transported in the public domain either by a packet switched data network (PSDN) based on X.25 protocols, or in a very limited number of countries by a circuit switched data network (CSDN) based on X.21 protocols.
- Television signals can be transported in three ways : broadcast via radio waves using ground antennas, by the coaxial tree network of the community antenna TV (CATV) network or recently via a satellite, using the so-called direct broadcast system (DBS).

- In the private domain, computer data are mainly transported by LAN's (Local Area Networks). The most famous ones are Ethernet, token bus and token ring (IEEE 802 series).

Each of these networks was specially designed for that specific service and is often not at all applicable to transport another service. For instance, the original CATV networks did not allow the transportation of POTS; or the PSTN does not transport TV signals; or the transfer of voice over an X.25 network is very problematic because of a too large end-to-end delay and jitter on this delay.

Only in limited and special cases other service types than the one the network was originally designed for can be transported over it. This is for instance the case for the PSTN which is capable of transporting computer data at a limited speed, if modems are provided at both ends of the network.

An important consequence of this service specialization is the existence of a large number of often worldwide independent networks, each requiring their own design phase, manufacturing and maintenance. In addition, the dimensioning of each network must be done for every individual service type. Even if resources are freely available in one network, they cannot be used by another service type. For instance, the peak hours in the telephone network are between 9 a.m. and 5 p.m., whereas the peak hours in the CATV network are during evening. Since resource pooling is impossible each network must be dimensioned for its worst case traffic conditions which is the peak hour traffic.

A first step, albeit a limited one, towards a single universal network, is the introduction of NISDN (narrowband ISDN) in which voice and data are transported over a single medium. This network has no possibility to transport TV signals due to its limited bandwidth capabilities, so a special TV network is still required. Even in NISDN the integration of narrowband services such as data and voice can be considered as being rather limited : the user access to the network is fully integrated, either by a basic access or primary rate interface. However, inside the network there will still exist for some time a packet switched and a circuit switched network as two overlay networks incapable of transporting other traffic types and each dimensioned either for voice or X.25 data.

Another important consequence of this service specialization is the unability of the network to benefit highly from the progress made in technology and coding algorithms. For instance, current digital NISDN switches are designed for 64 kbit/s voice channels. However, with the current progress in speech coding and chip technology, bit rates of 32 kbit/s (ADPCM : Adaptive Differential PCM), 13 kbit/s (for the mobile network) and even lower will be used in the future. The existing switches and transmission systems are not directly suited and thus need an adaptation, or will not efficiently use their internal resources for these lower speed bit rates.

When designing the future BISDN network, one must take into account all possible existing and future services. Suppose a network is capable of transporting a specific service, e.g. a circuit switched service with a channel rate of 70 Mbit/s. Suppose also that it is specifically designed to transport this bit rate. Some years later a new teleservice of, for example, 40 Mbit/s appears on the scene. This would mean that the network designed for that service (i.e. 70 Mbit/s) will be capable of transporting the new teleservice, but with a large inefficiency : only 40 out of the 70 Mbit/s available will be used. This example is not unrealistic. It is very likely that in the future new services will emerge which have not yet been identified, and of which the requirements are not at all known today.

As can be concluded from the above examples, the networks of today are very specialized and suffer from a large number of disadvantages, the most important being :

- Service Dependence :
  Each network is only capable of transporting one specific service (information type) for which it was intentionally designed. Only in a limited number of cases and by using additional equipment (e.g. a modem) and with an inefficient use of its resources it can be adapted to other services.

- Inflexibility :
  Advances in audio, video and speech coding algorithms and progress in Very Large Systems Integration (VLSI) technology influence the bit rate generated by a certain service and thus change the service requirements for the network. In the future, new services with unknown requirements will appear. For the time being it is yet unclear what e.g. the requirements in terms of bit rate for HDTV (High Definition TV) will be. A specialized network has great difficulties in adapting to changing or new service requirements.

- Inefficiency :
  The internal available resources are used inefficiently. Resources which are available in one network cannot be made available to other networks.

Taking into account all these considerations on flexibility, service dependence and resource usage, it is consequently very important in the future that only a single network exists and that this network of the future (BISDN) is service-independent. This implies a single network capable of transporting all services, sharing all its available resources between the different services.

A single service-independent network will not suffer from the disadvantages described above, but it will have the following main advantages :

- Flexible and future safe :
  Advances in the state-of-the-art of coding algorithms and VLSI technology may reduce the bandwidth of existing teleservices. A network capable of transporting all types of services will be able to adapt itself to changing or new needs.

- Efficient in the use of its available resources :
  All available resources can be shared between all services, such that an optimal statistical sharing of the resources can be obtained.

- Less expensive :
  Since only one network needs to be designed, manufactured and maintained, the overall costs of the design, manufacturing, operations and maintenance will be smaller.

The evolution from the large number of existing networks to a single IBCN is possible through a large number of evolution scenarios. These evolution scenarios do not fall within the scope of this book.

However, to have a better overall picture of what might happen in the future, a possible evolution is shown in Fig. 1.1. This general diagram has been derived from RACE. It shows that initially the residential and business subscribers will continue to live apart. The residential subscriber has its analog CATV network together with a separate telephone and videotex network. First, some enhanced CATV services (pay TV, ...) will be offered, before digital techniques will be introduced such as digital processing in the TV set, and digital transport of the video information to the CATV head end. Simultaneously with the appearance of digital techniques in the TV world, the telephone network will gradually see an introduction of ISDN, including low speed videophones. The next step will then be the digital TV distribution, finally resulting in a full IBCN for all services.

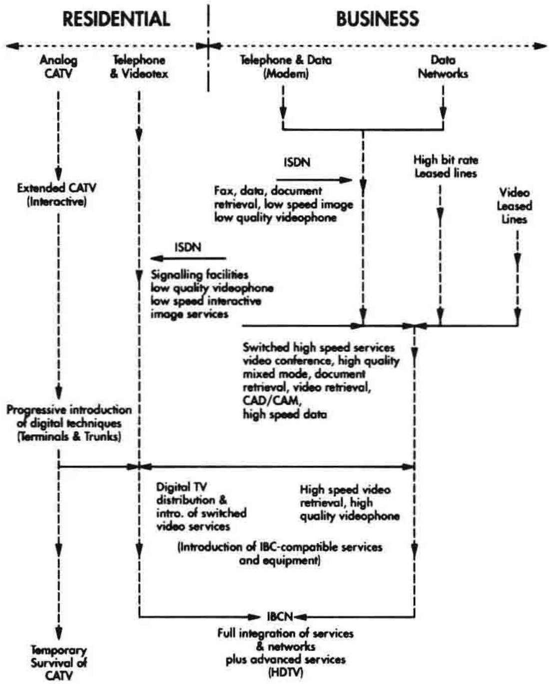

Fig. 1.1. – Integration of Interactive and Distributive Services for Business and Residential Customers