Network Architectures for Distributed Computing

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(Arkhitektura vychislitelnykh setei)

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PREFACE

The development of electronic computers and the experience gained with them in economic, scientific, and technical applications have revealed that it is both necessary and efficient to employ remote data input (over data transmission channels) and remote output of the results. This gave rise to the first computer networks, which were initially intended to perform computations.

Over the last decade, there has been vigorous development of processes associated with logical processing of information. Data bases, information retrieval services, and services for processing text and graphic matter have appeared. Control of technological processes and scientific experiments is becoming more and more developed. Electronic mail, remote conferences, and digital telephony and television are becoming part of daily life. Computer networks have become complex information systems, in which computation, although increasing in volume, has ceased to be predominant, giving way to logical information processing.

As a result, the world's major manufacturers have changed over from individual computers to production of hardware for creating a variety of computer networks. The architecture of the SNA and DECNET networks, developed by IBM and DEC, have become well known. Control Data, Hewlett-Packard, Wang, and many other companies and organizations have contributed significantly to the creation of networks.

The Soviet Union manufactures three large groups of computers for network applications. For large users, the Elbrus installations and computers of the Unified System are employed. Minicomputers form another group, called SM computers. Finally, the third group encompasses microcomputers of the Elektronika series.

Present-day computer networks are expanding the types of computers. Not only is the number of terminals rapidly increasing, but entirely new types of devices are appearing and being extensively deployed: copying equipment, speech-recognition and speech-synthesis devices, fascimile equipment, image I/O hardware, and so forth. The number of computers in different computer networks is now to be reckoned in the many tens of thousands, while the number of terminals is approaching ten million.

The appearance of local networks has provided a new impetus to the development of networks. As a result of these networks, a base has been created for efficient automation of information activity at virtually all enterprises and institutions. Accordingly, a new approach to the creation of large global computer networks now presents itself. Such networks will increasingly become systems of large numbers of diverse local networks.

The appearance of information computer networks such as Teletex and Videotex, as well as the extensive assortment of personal computers, open up possibilities for providing network information to society at large.

In many countries, computer networks are becoming a highly productive branch of the economy, in which many millions of different users participate and cooperate with one another. In this respect, present-day computer networks are rapidly becoming bridges for friendship and collaboration linking different countries, through their industry, science, and culture.

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INTRODUCTION

Electronic computers performing complex mathematical operations have become universal information processing systems. The creation of large and ultralarge memories has led to the appearance of electronic libraries that are rapidly accumulating knowledge gained over the course of many centuries.

Conversion of telephone and telegraph networks into integrated networks for transmission of data, text, graphics, and speech opens up extensive possibilities for information exchange over enormous distances.

Development of methods of interacting with computers and of making most efficient use of their capabilities has led to the appearance of more and more complex multicomputer systems for acquisition, storage, processing, transmission, and delivery of information. The creation of these associations marks a qualitative advance in the development and use of computer technology, electronic libraries, and communications techniques [1–10]. In the near future, multicomputer systems will not only have a major impact on the development of science and of various branches of the national economy, but will also play a key part in processes associated with education, human intercourse, and other social problems of modern society. This book deals with one of the most important classes of multicomputer systems, namely, computer networks. In the near future, computer networks will not only determine the further development of the data-processing industry but will also be of great social significance, furnishing extensive sectors of the population with the ability to obtain information about political events, news, the functioning of transport and domestic services, and so forth. Local computer networks will raise to a qualitatively new level the management of institutions, production combines, and industrial and agricultural enterprises. The use of network architecture will give many users access to the most diverse information and computing resources.

Unfortunately, at present there is as yet no generally accepted terminology for multicomputer associations, and therefore a dictionary of terminology is included at the end of this book. Abbreviations and symbols are also listed; there is also a subject index to aid in using the book for reference purposes.

CHAPTER 1

OPEN SYSTEMS ARCHITECTURE

A basic characteristic of a computer network is its logical description, which enables us to examine and analyze the elements of the network and to determine the functions they perform. This description also includes a consideration of the interaction functions of the elements, the result of which is the computer network.

1.1. INTRODUCTION TO THE CONCEPT OF ARCHITECTURE

The complexity of automatic control systems is increasing rapidly. Even recently, integrated circuits contained just a few transistors. At present, complex electronic circuitry with tens or even hundreds of thousands of transistors can be created on a semiconductor chip. Many thousands of these integrated circuits interact in a large computer. Hundreds of computers may be combined into a computer network.

There is only one way to analyze and synthesize such complex installations, namely, to separate them into diverse elements and to investigate their set of interaction structures. These problems are reflected in a new line of scientific research, which has come to be known as **architecture of automatic control installations.** Depending on the object of study, it considers the architecture of computer networks, terminal systems, computers, or semiconductor chips (integrated circuits).

Architecture is an extensive concept, which includes three important types of interrelated structures: physical, logical, and software. In addition, in analyzing other aspects of architecture, structures of administrative management, service and repair, data-bank allocation, etc., are frequently considered. Each of these structures is defined by a set of elements and by the manner in which they interact. The mutual relationship of the structures forms the architecture of the installation under consideration.

Physical structure elements are technical objects. Depending on the tasks at hand, these objects may be semiconductor chips, parts of computers and computer hardware, the computers and hardware themselves, or systems made up of the latter. For example, if we are considering the physical structure of a computer, its interrelated elements are generally the processor, channel, I/O devices, printers, disks, and so forth. In addition to these physical-structure elements, there may also be an operator console, display, controller, data transmission device, and so forth.

Investigation of physical structure makes it possible to determine the physical resources of the installation under consideration, to determine the necessary number of computers, hardware, or devices, and to establish what their technical characteristics should be.

Everyone who undertakes an architecture analysis first sees and comprehends the physical structure. However, the creation of any installation begins by investigating another structure, namely, the logical one.

Logical structure elements are functions that determine the basic operations of input, storage, transmission, processing, or delivery of information files. Depending on the object of study and on the depth of the analysis, logical structures may be the operating system of the computer, terminal modules, groups of communications programs, and so forth. Logical structure elements are frequently called logical modules. In addition, the elements of this structure may be more complex entities incorporating several interrelated logical modules.

Analysis of the interaction of logical structure elements makes it possible to consider the operation of the entire installation, to investigate processes associated with processing of information flows, and also to determine the logical resources of the installation.

In most cases, the installation is characterized by extremely complex multipurpose software which performs various types of information tasks. A very important characteristic of the architecture of the installation, therefore, is its software or program structure. This structure is made up of interrelated programs: data processing, access to this process, hardware fault diagnostics, data transmission, channel control, and so forth. Interaction of software-structure elements ensures that the necessary information tasks are executed.

Thus, the architecture of the installation (computer network, terminal system, computer, semiconductor chip) is a concept of the interrelationship of a large number of elements of different types. It is basically characterized by the interlinking of the physical, logical, and software structures of the installation. This interlinking is determined by the arrangement of the logical modules in computers, by the synthesis of these models from sets of interrelated programs, by implementation of the programs in semiconductor chips, controllers, data transmission hardware, and so forth. Investigation of the architecture of a complex reveals its basic characteristics and makes it possible to create an integrated circuit, computer, terminal installation, or computer network that satisfies specified requirements ensuring that the necessary information processes are efficiently executed.

1.2. GENERAL CONCEPTS

A computer network is a distributed information and computing medium that is implemented by a large number of diverse hardware and software facilities. This medium (Fig. 1.1) can be divided vertically into a number of levels, called **layers.** The logical (N)-layer is made up of the (N)-part of the information and computing medium, which performs one of the fundamental tasks of the network (control of information channels, network control, and so forth). To implement this task, the (N)-layer is divided into logical (N)-entities (entities of the (N)-layer). Each such object is a local set of functions that are interrelated by a common purpose.

The same information and computing medium can be divided horizontally (Fig. 1.2) into local logical parts, called **open systems,** i.e., systems each of which meets the requirements and standards of open systems architecture. Systems that do not meet these requirements are called **closed.** Since we will not consider the latter systems in what follows, we will henceforth refer to open systems simply as **systems.** A computer network has a layered structure (see Fig. 1.1). Therefore, each system divides into the same number of layers (see Fig. 1.2), and all (N)-entities of the network are distributed over the (N)-layers of its systems. There can be one or more (N)-entities on each (N)-layer of the system.

The Reference Model of Open Systems Architecture [11-17] considers **interconnection functions** (Fig. 1.2) that support interaction of all application network processes via physical connection facilities. At the top, interconnection functions engage with application processes (Fig. 1.2) and incorporate the parts of them that deal with data transmission. The principal parts of application processes,

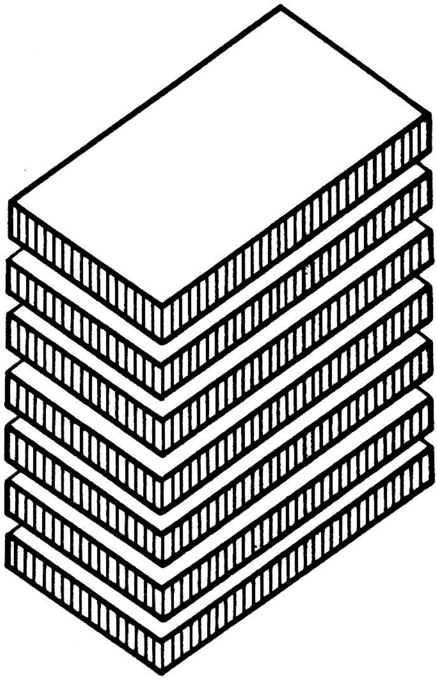

Fig. 1.1. Layered computer-network structure.

which perform data processing and storage, are not considered in the reference model. At the bottom, interconnection functions interact with the **physical connection facilities** over which data is transmitted between systems. The reference model does not deal with the topology, structure of characteristics, or parameters of these connections.

Each layer of the interconnection functions consists of entities, performs a certain task in the network, and provides service for the next higher layer. The set of interaction rules for (N)-entities (Fig. 1.3) is called an **(N)-protocol.** There may be one or more (N)-protocols at the (N)-layer. As for (N)-entities, each of them may employ any number of (N)-protocols.

Connection between an (N)-layer and (N – 1)-layer is described by an interlayer standard, called an **(N – 1)-interface.** The (N)-layer

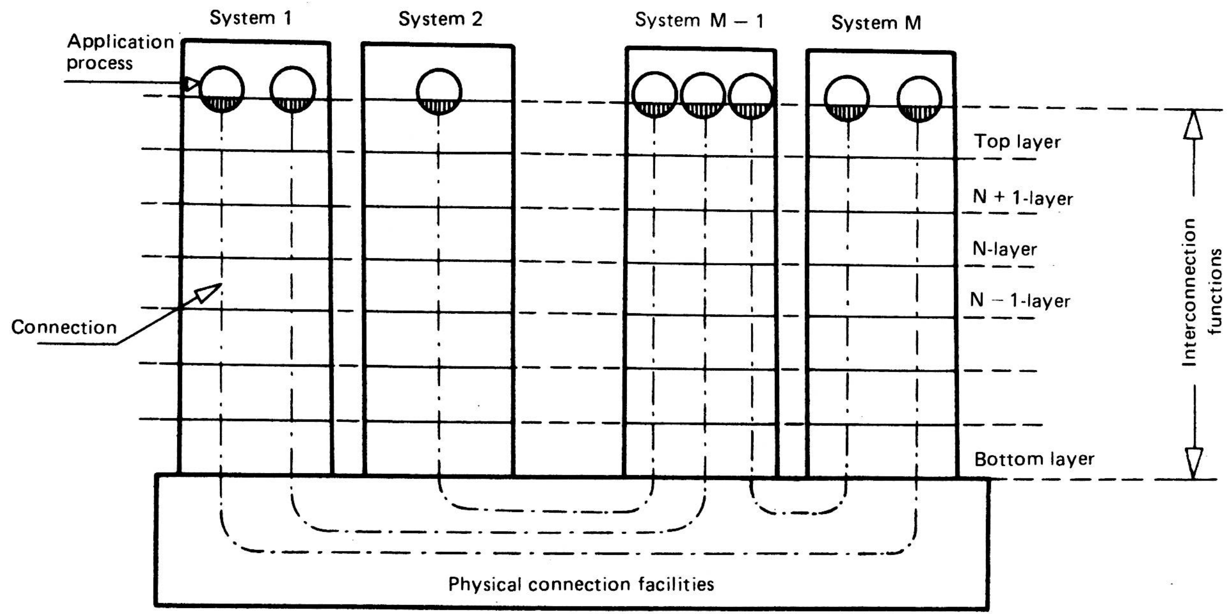

Fig. 1.2. Open systems interconnection.

receives **(N – 1)-service** (the service provided by the lower-lying layer) via this interface. The points (see Fig. 1.3) through which the (N)-layer interacts with the (N – 1)-layer are called **(N – 1)-service access points.**

An (N)-entity can interact simultaneously with one or more (N – 1)-service access points in one or more (N – 1)-entities. As a result, an (N)-entity is linked directly to any number of (N – 1)-entities.

Each (N – 1)-layer supports one or more forms of service furnished to (N)-entities. These forms may include the following:

- manipulation and reformatting of data files;
- management of data flows and confirmation of file delivery;
- establishment, maintenance, and termination of communication;
- choice of protocol from the available set of layer protocols;
- data-set addressing;
- opening (activation) of new objects and closing of unnecessary ones;
- routing of information;
- management of system resources, etc.

Entities at the same (N)-layer can interact with one another only via (N – 1)-entities of the lower-lying (N – 1)-layer. A line (dashed line in Fig. 1.3) connecting two (N)-entities via an (N – 1)-entity is called an **(N – 1)-connection.** Three types of connections are employed: one-way, two-way nonsimultaneous, and two-way simultaneous.

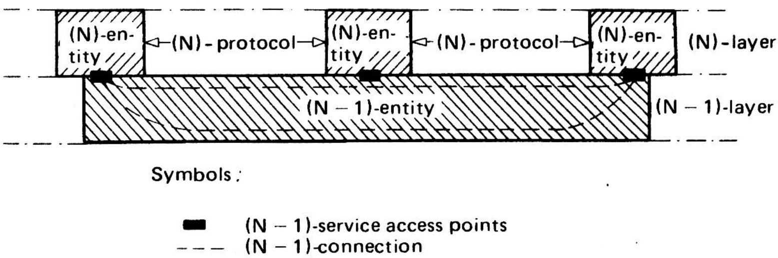

Fig. 1.3. Interaction of (N)-entities.