CHAPTER 1

ORGANIZATIONAL PRINCIPLES OF COMPUTER SYSTEMS

1.1. MODERN DEMANDS TO THE MIDDLES OF COMPUTER TECHNOLOGY.

Information processing always played an important role in the development of science and production. Reconstruction of economy and administration of national budget, application in design, planning, and control of automated middles, performance of qualitatively new demands in the sphere of services, execution of scientific-technical calculations every time more complex, and elaboration of projects, are impossible without the new high technologies based on the middles of computer technology. A significant volume of information, obtained of different sources, stimulates an intense scientific execution of researches in the environment of elaboration of new and important methods and mediums of automated information processing.

At present, obtained volume of information enlarges and is continuously stored without ceasing. The development of information networks, computer systems of multiprocessing, and terminal systems of accessing to them, conducts to that great part of information, overcoat of scientific-technical, social-economic, and political information, be transferred to the computer memory and there be processed and transformed. Besides, in the development of computer technology a qualitatively new leap was given, namely: the automated operation of computers in complex systems with direct introduction of information from subsystems of measurement of objects that are found to any distance, with processing of this information and with supply of control commands to the object execution mechanisms in a real-time, was created. Thus the development of the middles of computer technology is dialectically related to the growth of the demands imposed to it by the technology of information processing.

The analysis of the 80-90s' scientific-technical problems allows to conclude that the largest computer resources are employed in the solution of problems of nuclear and thermonuclear energy, aerodynamics and hydrodynamics, planning and control of large economic systems, and control in a real-time of multi-parametric objects, etc.

Conditions to the problems that are necessary to resolve in the 90s are changing. It is necessary an integrated research of objects and phenomena (for example, the static research of the conjugated state of the model of flight cosmic devices), on time that before models of either elements or construction nodes were studied. Since the investigated objects possess large geometrical dimensions (for example, the hydrodynamic model of circulation of the Atmosphere and the Ocean is researched world wide), it is necessary to resolve space problems. Thus, in one of the phases of the Earth's vibration radiation problem is necessary to resolve a dynamic problem of space of elasticity theory, which cannot be reduced to a problem of research in the plane. Now, more frequently, object of study becomes not only the static, but also the dynamics of the investigated objects. If before, fundamentally, linear models were researched, now the need of studying non-linear models arises. At the present moment of large resources, which surpass the possibilities of the modern computers, it is required of calculations in optimum distribution of technical and material mediums, composition of schedules for the middles of transportation, and operating control of job optimum distribution of technological equipment.

With the introduction of simplified hypothesis, scientific-technical problems are reduced to physical models, which at the same time, can be described with the help of mathematical models. Most of the scientific- technical problems are reduced to a standard solution of classes of mathematical problems that require for their resolution of a significant number of arithmetic operations.

At present, upon presenting an entire series of problems, it is necessary to resolve algebraic equations systems with non-square matrices (their number of variables is on the order of 10^5 and their number of equations is a little greater than thousand) and with symmetrical matrices (their order can arrive at the million). In the resolution of the generalized problem of eigenvalues with non-square matrices and respective symmetrical matrices A and B, whose orders reach 10^4 and number of rows constitutes 600-800, is required of the calculation of some minimum eigenvalues and eigenvectors belonging to them. In the resolution of non-linear differential equations by the method of finite elements, enormous non-linear algebraic systems of equations arise, whose number can reach thousand, and using the method of finite differences, their number reaches a few thousands.

In the numerical integration of Cauchy's problems for the case of design of deformed systems is necessary to resolve ordinary differential systems of equations, whose number reaches 10^4, and in the case of rigid systems, 10^3. In the description of a series of applied problems, some contour problems for ordinary differential systems of equations, whose number can reach some hundreds, arise.

The development of computer technology conducted, on the one hand, to the creation of large computer systems of multiprocessing, and on the other hand, to the union of the last ones in computer networks. A computer system represents an interconnected collection of middles of computer technology coordinated by its own parameters, which can be utilized by the user more effectively in the automated solution of problems. A computer network represents a computer system of distribution that is formed by the union of different computers, located structurally in the space, and interconnected in a network especially built for data transmission. Solution of the following problems is vital in the development of the middles of computer technology:

1. Elaboration of topologies of computational middles, keeping in mind the criteria of productivity, security, and cost.
2. Organization of the interaction of processors' (computers') groups to solve a complex problem.
3. Effective use of common resources of interconnected computer mediums.
4. Organization of data recollection, parallel processing, and information output operations in complex computer systems from the topological view point.

At present, the tendency to that the computer systems are divided into the following three classes is observed:

1. Supercomputers, built according to the principles of network operation, which are oriented to the processing of enormous volumes of information with maximum permissible speed.
2. Wide area and local area computer networks, oriented to the storage and parallel processing of distribution information arrays.
3. Computer systems of multiprocessing, oriented to information processing to moderated speeds.

Therefore, it is observed an interrelation and an interdependence of computer mediums of the classes before indicated, what in perspective, form new classes of computer systems.

We will analyze the possibilities of the modern mediums of computer technology, applied to the most present and most perspective problems in science and production.

Let us examine a vector of parameters of an applied problem belonging to a certain class

$$P^I = P^I (p_1, p_2, p_3), \qquad (1.1)$$

where I is the number of class of the problem; p_1 is the computational power of the problem, bit/s; p_2 is the volume of stored information that is necessary to resolve the problem, bytes; and p_3 is the required mean time of continuous resolution of the problem that guarantees its correct solution.

Let us examine also the vector of parameters of the computational middle, belonging to the class

$$S^J = S^J (s_1, s_2, s_3), \qquad (1.2)$$

where J is the number of a conditional class for a computational middle; s_1 is the computational power of the middle, bit/s; s_2 is the maximum capacity by memory of the computational middle, bytes; and s_3 is the permissible time of continuous solution of the problem in the computational middle. Let V be the symbol of the operator of comparison.

As criterion we will choose the following expression:

$$E = P^I \ V \ S^J \begin{cases} \text{If } p_1 > s_1,\ p_2 > s_2,\ p_3 > s_3, \text{ the problem of class I cannot be resolved in the computational middle of the chosen class J, } E = 0, \\ \text{If } p_1 \le s_1,\ p_2 \le s_2,\ p_3 \le s_3, \text{ the problem of class I can be resolved, } E = 1, \\ \text{In all the other correlations between } p_k \text{ and } s_k \text{ the criterion cannot be utilized.} \end{cases}$$

To characterize the level of development in computer technology, let us choose $P^I \in \{P\}$, where $\{P\}$ is a collection of perspective problems in science, economy, industry, or military matters. Let $S^J \in \{S\}$ be, where $\{S\}$ is a set of representatives of the most perfect computer devices already elaborated, or already launched to the market by the hardware industry.

To calculate the coordinates of the given vector, we will utilize the following procedure. The computational power p_1 of the problem is calculated keeping in mind limitation factors that are accessible to the whole analytic calculation. The computational power s_1 of the computer equipment is determined of the owner's manual. The volume of information p_2 processed upon resolving the problem is determined utilizing known methods. The maximum capacity by memory s_2 of the devices of computational middles is determined of the owner's manual. The parameter p_3 is the required time of continuous solution of the problem proposed by a user.

The permissible mean course of time of continuous solution of the problem for a real existing computational middle, is determined approximately using the exp ression

$$s_3 \leq \bar{T}_{neg}, \qquad (1.3)$$

where $\bar{T}_{neg}$ is the necessary mean time of negation to process the information (mean time of refuse), which requires the computational device.

Let us examine information characteristics of a set of problems proposed by the modern science and practice, utilizing one of the possible conditional classifications of the whole scientific set of systems and production.

A. Automatic public stations of information with extensive designation for scientific and industrial uses. Particularities: Intense and varied dialogue with different types of terminals in combination with processing executed by specialized software, instability of mathematical methods, large specific weight of individual funds, and extensive set of demands to the computational power.

These particularities can be illustrated with a series of examples. Behavior simulation of an object or process for an influence appraisal of change of entry parameters in the behavior of an investigated system, finds extensive use in radio-physics. As a result, the control quality rises upon the object or process. For this application, a propagation model of acoustic or electromagnetic field in a non-homogeneous middle is used. This model allows selecting optimum parameters (inclination of the directional characteristic, solvent, radiation frequency, etc.) of the radio-acoustic and radio-localization stations.

The propagation of acoustic or electromagnetic field is described with the equation of wave. The non-homogeneity of the middle is expressed as a dependence on the propagation speed of wave in function of the space coordinates (quasi-linear problem), or in function of the coordinates and the amplitude of field (non-linear problem). A model of propagation field is obtained by means of the resolution of the initial equation of wave with conditions of border given. Without doing a detailed exam, we will indicate that the solution of the equation of wave by methods of differences in order to obtain a propagation model of acoustic wave in a real-time, requires of a speed of execution equals to 10^{12} oper/s, and the solution of the equation of electromagnetic wave - a speed equals to 10^{17} oper/s.

By means of the execution by cosmic devices of the photograph of the territory of certain region with a surface of 100 million hectares, twice in a year, the total volume of video information is composed from 300 to 400 magnetic tapes of higher revealed density, or approximately 50 to 60 thousand images (512 x 512 elements). It can be analyzed 30 to 40 thousand of them. The volume of the obtained photographic information with the help of airplanes, provided with multi-zonal MKF-6 equipment, is still larger. Besides, the video-information obtained from artificial satellites, in the execution of numerous scientific-technical experiments in the Earth's conditions, daily a large quantity of photographs with the help of microscopes, telescopes, rays X devices, laser technology of movies and television, radio-localization devices, etc., are registered. To obtain an image of quality of a picture of 35-mm-roll of movie is necessary more than 45 Mbytes of information. In 1986, in the course of a distant research of the Earth's natural resources, was obtained 25 x 10^9 Mbytes of information from satellites. The speeds of information transmission are cited in table 1.1. Mean time of the problem's solution 1-10 hours.

Table 1.1

Functions of the middles of computer technology.	Speed of information transmission.
Output operations of data processed by a computer.	10 Mbytes/s.
Transmission of information to the central operating memory.	1 Mbit/s.
Control upon distant objects.	10 Kbits/s.

Table 1.2

Functions of the middles of computer technology	Speed of information transmission.
Information reception from the instruments of measurement.	10 Kbits/s.
Information distribution by each node of processing.	1 Mbit/s.
Dialogue of informative character.	10 Mbits/s.

B. Automatic public stations of information of the industrial branches of urban centers (automated systems of control of the respective branch and automated systems of control of large urban economies). Particularities: regular predominance of calculations carried out by sets comparatively limited of complex programs, large files with intense exchange through the communication lines, and constant dialogue of informative character.

The type problem "control of railways" is one of the most important problems in the administration of urban economy. The presence of a large flow of information (10^{70} – 10^{100} variants to choose) in order to make control decisions does not give any possibility to use classical mathematical methods for its resolution. Besides, heterogeneity, abundance, confusion of information, and impossibility of its recollection with frequency, accuracy and required reliability, always put in doubt the quality of obtained control decisions based on the knowledge of the specialist that must make these decisions. The mathematical methods utilized in the control of railways are represented by rigid algorithms to what the information is delivered from instruments of measurement (controllers), located in inductive limits along the railway line, as rule near crossings. The algorithms used in the analysis of railway transportation accidents (RTA) are algorithms of statistical processing of information. It is natural that the analysis of RTA should consider the state of trip traffic. This problem is complex and is still open as much in the national jobs of elaboration, as foreigners.

Because of large number of variants to choose in order to solve the problem in a real-time, the speed of the computational middle should exceed 10^{10} – 10^{15} oper/s. The volume of stored information is greater than 10^{10} Kbytes. The speeds of information transmission are cited in table 1.2. Mean time of the problem's solution 0.003 - 1 hour.

C. Databanks and commutation centers (automated fund of patents and standardization, computational centers of the upper section of the automated state system of recollection, storage, and information processing). Particularities: Enormous files with simple algorithms of processing in combination with extremely complex middles of identification supply, security, accuracy and defense of information; large load of job of communication lines.

It is calculated that for the problem's resolution of present planning and control, to national scale, are necessary computational middles whose speed exceeds 10^9 oper/s at the whole operation without exception.

Objections about the optimum distribution of assignments to the production of pipes of large diameter among metallurgic businesses, conduct to a problem of linear programming with a number of variables over 500 thousand and a number of restrictions of around 50 thousand. Future planning problems are reduced to either dynamic models of linear programming or mixed models of discrete-continuous type. In both cases, the number of computational operations, which is of order over to that one of present planning, constitutes near 10^{10} oper/s.

Problems of production location, location and unity of technical mediums, synthesis of transmission, pipe-conductor, and computer networks, etc. are reduced to models of multiple criteria of discrete-continuous type with a large number of variables. For example, for the network synthesis problems with convex functions, in which a source and various users participate, the dimension of the linear programming appraisal problem constitutes approximately 10^3 variables and restrictions. It is required of large resources of computation for the solution of continuous dynamic models and multiple provisions that generalize known macro-models for the formal description of complex systems in development. In order to make the most useful decisions of control in the national economy of a country, it is necessary to store simultaneously around 10^{12} Kbytes of information. The speeds of information transmission are cited in table 1.2. Mean time of the problem's solution 10-100 hours.

D. Automatic systems of real-time with rigid cycle of information registration and transmission of control signals. Particularities: a large flow of homogeneous information, intense parallel calculations, measurement instruments controls and varied middles of reflection, stability of states with possibilities of quick action switch installation, demands of highest security, presence of a critical path of calculations that imposes demands to the speed of processing.

Toward the year 2000, it is expected the introduction to the radio-electronic equipment of flight devices of a new computational technological generation on board, which by its functional designation, can be divided into two categories. The first one includes control systems of information and expert systems. The second one assumes the installation of middles that will be able to execute an intellectual processing of data, which supplies a control of greater accuracy upon the weapons and objective persecution.

In a predictable time, it is expected an intense development of input/output devices of spoken information, which should supply a natural and simple communication between the pilot and control middles of flight devices. Here, the fundamental problem consists of the most perfected creation of input devices of spoken information.

In table 1.3, it is reflected the level and development perspectives of the technology of input operations of spoken information, and the demands imposed to the speed of the middles corresponding to the digital processing of signals.

Table 1.3

Recognition possibilities	Syntax	Dictionary, number of words	Required speed of digital processing, millions of oper/s.
Isolated words (in dependence on the speaker).	Restricted	200	1-10
Conversation without pause (it does not depend on the speaker). Isolated words (in dependence on the speaker).	Non- restricted	1,000 5,000	100 300
Isolated words (in dependence on the speaker).		20,000	1,000
Conversation without pause (it does not depend on the speaker).		20,000	10,000

Toward the year 2000, the improvement of the radio-electronic equipment of flight devices will go accompanied of a growth of the specific weight of the instruments of measurement, which will supply a signal registration (radio-localization, acoustic, infrared, and other signals). The intellectual processing of these signals allows carrying out an adequate and detailed picture of the state of things around, and in correspondence with it, to take the necessary cautions. In table 1.4, the fundamental demands to the speed of signal processors are cited. They will be used in different systems on board of aircrafts. The volume of stored information does not exceed 25 x 10^2 Mbytes. The average speed of information exchange in dependence on the information process type is 1 - 100 Mbits/s. Mean time of the problem's solution 0.01 – 50,000 hours.

Table 1.4

Computational process	Bearer	Speed, millions of oper/s
Remote-control of a rocket with wings toward the last part of the trajectory.	Rocket	50
Processing of signals in radio-localization systems.	Airplane, Cosmic Device	100-500
Processing of signals in the remote-controlled system.	Airplane, Cosmic Device	1,000-10,000
Processing of (electro-optical, infrared) images.	Airplane, Cosmic Device	200-1,000
Transmission of data by communication line of stable interference, little powerful, and wide-band.	Rocket with wings, Rocket, Airplane, Cosmic Device	500
Transmission of data by communication lines of wide-band.	Cosmic Device	500

E. Large automated systems of operation control distributed territorially (reservation and sale system of air tickets, automation of banking operations). Particularities: a large number of terminals of equal type, large files, higher demands of security, alternated functions of dialogue with massive statistical or optimization calculations. In this class turn out to be interesting the problems of operating accounting, quarterly and annual projects composition control of load transportation planning and determination of territorial transportation control, prognostic of routes that passengers follow with election of airline network plan, composition of schedules of airplane traffic, process systems of load in railway transportation, and others. Most of the enumerated scientific-technical problems are reduced to the mathematical solution of problems of standard classes, which require of significant volumes of arithmetic operations. These last ones are reduced to the solution of algebraic linear systems of equations with non-square matrices (their number of variables is on the order of 10^5 and their number of equations is greater than thousand) and with symmetrical matrices (their order arrives at the million). The common productivity of the computer medium of such an automated system of control should constitute about 3×10^9 oper/s, memory capacity, (4 to 10) x 10^8 Kbytes. The speeds of information transmission are cited in table 1.5. It can be considered that the mean time of the problem's solution is approximately found in a range of 1 - 1000 hours.

Table 1.5

Functions of the middles of computer technology	Speed of information transmission
Task division among the computational middles.	1 Mbit/s.
Reception of information from distant terminals.	10 Kbits/s.
Information transmission by networks.	10 Kbits/s.
Administration and distant control of devices and objects.	10 Kbits/s.

F. Collective systems of experimental control (conditional designation): information systems of medical diagnostic in large clinics, distant automatic mobile laboratory control systems (underwater stations, orbital laboratories), automatic systems of design, simulation complex systems. Particularities: presence of a complex process in development that is controlled for a computational system, or that happens in the own system. The process is carried out, controlled, and observed by a large group of experts whose actions and interactions are coordinated by the computational system. These systems have a common series of characteristics with the systems of type A, D, and E.

In spite of their heterogeneity, the enumerated systems of information processing impose to both hardware and software a common series of conditions:

1. Resources capacity calculations need to be combined through an operating service of a large number of external influences.
2. Large arrays of information of easy access, which include storage and defense systems of higher reliability, are necessary.
3. A large variety of external devices and language mediums are required.
4. Capacity of quick concentration of resources to satisfy the excess of job in the rush hours is another requirement.

5. Demands to the volume of stored information are similar to the demands formulated for the systems of type A, D, and E, and constitute around 25 x 10^9 Mbytes.
The speeds of information transmission are cited in table 1.6. Mean time of the problem's solution 1 - 1000 hours.

Table 1.6

Functions of the middles of computer technology	Speed of information transmission
Transmission of the information flow of components separated of the experimental installation.	10 Mbits/s.
Filtration of the information.	10 Mbits/s.
Processing of the information stored in the central processor.	1 Mbit/s.
Discrete analysis.	100 Kbits/s.
Administration and control.	10 Kbits/s.
Exchange of information with an effective system of control.	10 Kbits/s.
Distribution of tasks among the machines of the complex of computation.	1 Mbit/s.
Transmission of communications and on-line conferences.	10 Kbit/s.
Administration and control of distant objects, teleprocessing.	10 Kbits/s.

In order to form the vectors of values of the applied problems of the different classes A to F, we will build table 1.7 of final results. In the table construction, all the calculations were executed, according to the expressions cited by different authors. The last columns of the table determine the values of the parameters of the vector P, applied to the problems of the classes A to F.

Table 1.7

Classes of problems	Characteristics of the processor's speed				p_1 bits/s.	p_2 bytes	p_3 hours
	v_{cc} bits/s.	V_{cd} Bits/s.	V_{io} bits/s.	v_m bits/s.			
A	10^{20}	10^{20}	10^7	$2x10^{20}$	10^{20}	$25x10^{15}$	1 - 10
B	10^{18}	10^{18}	10^6	$2x10^{18}$	10^{18}	10^{13}	0.003 - 1
C	10^{12}	10^{12}	10^6	$2x10^{12}$	10^{12}	10^{15}	10 - 100
D	10^{10}	10^{10}	10^8	$2x10^{10}$	$\approx 10^{10}$	$25x10^8$	0.01 - 50 000
E	$3x10^{12}$	$3x10^{12}$	10^6	$6x10^{12}$	$3x10^{12}$	10^{12}	1 - 1000
F	10^{20}	10^{20}	10^7	$2x10^{20}$	10^{20}	$25x10^{16}$	100 - 1000

Remarks: cc = computational center; cd = control device; io = input/output device; m=memory.

Now, let us examine the vector S of general characteristics for some classes of computers (table 1.8). The comparison of the vectors P and S shows that the personal computers of a single processor cannot satisfy the demands that arise at present in different branches of science and production.

Table 1.8

Computer	s_1 bits/s.	s_2 bits/s.	Mean time of refuse, hours	s_3 hours
B550	$0.5x10^9$	$\approx 10^8$	14.7	≤ 14.7
Chi/05	$1.1x10^9$	$\approx 10^8$	17	≤ 17
IBM 370/165	$9x10^7$	$0.16x10^8$	8.86	≤ 8.86
SLAC	$3.2x10^8$	-	20.2	≤ 20.2
CMU-A	$1.2x10^8$	-	10	≤ 10
CRAY- 1	$1.3x10^{10}$	$32x10^6$	4	≤ 4
EC-1065	$4x10^8$	$0.16x10^8$	-	-
ELBRUS-2	$1.2x10^9$	10^9	≈ 200	≤ 200

The increase of the possibilities of multi-computer and multiprocessing systems is the unique and perspective way of computational middles.

1.2. COMPUTATIONAL SYSTEMS: FOUNDATIONS OF CONSTRUCTION OF DATA PROCESSING SYSTEMS.

Data processing consists of their storage, transmission and transformation. Any data processing system consists of a group of hardware and software of processing. Any structure of hardware includes: computers for input, storage, transformation, and output operations of data, interconnection of computers with objects, devices of data transmission, and finally, communication lines. Software is a group of programs that carry out assignments to a system of functions.

Functions of a data processing system consist of a necessary execution of actions in information processing: input, storage, transformation, and output operations.

Base of a data processing system is hardware since its security and productivity in greater degree determine the effectiveness of processing.

At present, data processing systems can be divided into five classes. The one-computer class of data processing systems, historically, is the first one, and not a long time ago, the most extensively diffused in different spheres of science and production. The one-computer systems of data processing are built based on a single computer. In fig. 1.1 the logical construction of a computer is described, whose traditional structure is composed of a single processor. Along their development, computers defeated a series of phases which are normally called generations. The successive character of command execution of calculation programs represents one of the essential particularities of organization of the computers belonging to the first two generations, what conducted to the ineffective use of hardware of computers, and their low productivity. Practically, in any timed interval, job functions were carried out by a single computational device and the remaining time it should be found in wait state. At the time of input/output operations in some computers their digital codes were transmitted through a logic-arithmetic installation, while hardware of this installation was utilized partially. Input/output operations were executed very slowly on account of the lower velocity of operation of input/output installations.

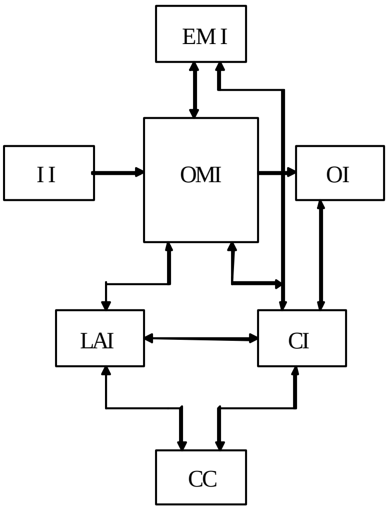

Fig. 1.1. Logical structure of a first-generation computer.
EMI - external memory installation;
II - input installation; OI - output installation;
OMI - operating memory installation;
LAI - logic-arithmetic installation;
CI - control installation; CC - control center.

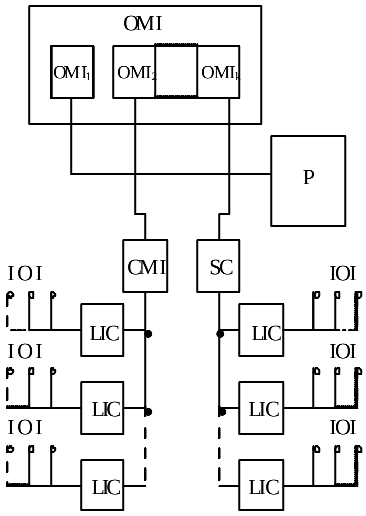

Fig. 1.2. Logical structure of a third-generation computer.
P - Processor; CMI - channel of multiple interconnections;
SC - selector channel; LIC - local installation of control;
IOI - input/output installation.

The use of computers of first generations allowed putting in clear two problems that determined the inefficient utilization of hardware of computers:

The contradiction among the high speed of information transformation in the logic-arithmetic installation and the lower speed of input/output installations was the first problem.

The consecutive character of job of computer main installations was the second one.

To free the logic-arithmetic installation of the direct participation in input/output operations was necessary to develop local installations of control of operating memory, and to carry out the input/output operations by chains in order to not utilizing the logic-arithmetic installation. For a third-generation computer (Fig.1.2), the effectiveness of hardware and computer productivity was substantially increased. In the logical structure of a third-generation computer, the following installations and groups of installations can be distinguished: processors normally called central processors, operating memory sectioned installations conformed by some installations functionally finished; selector channels and channels of multiple interconnections; local installations of control of input/output devices.

However, the productivity and security of the existing set of computers are satisfactory for a restricted utilization, only in the case when a relatively not high productivity is

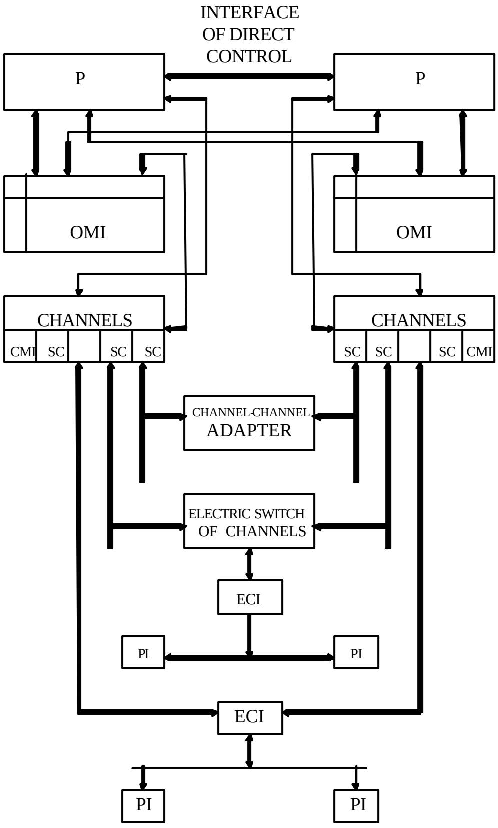

Fig. 1.3. Levels of interconnection of two computers joined in a single computational system.
ECI - external control of installations.

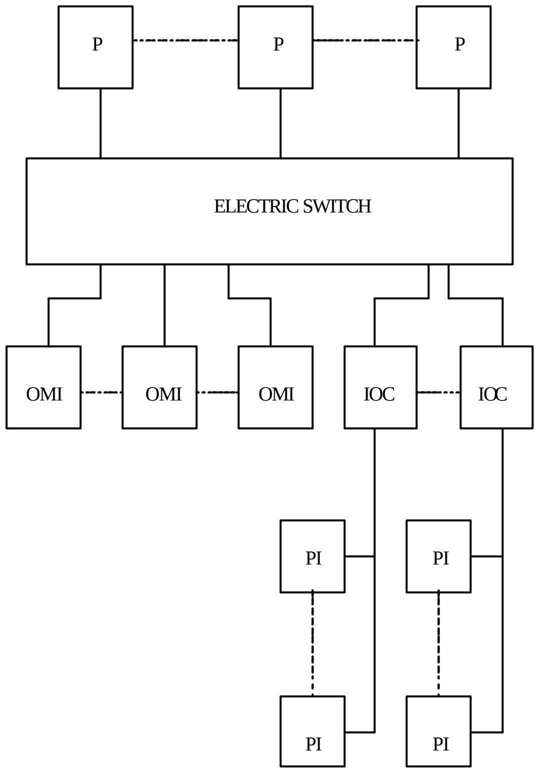

Fig. 1.4. Computer system of multiprocessing.
IOC – input/output channel.
PI - peripheral installation.

required ($\leq 10^8$ oper/s) and the use of a simple computer in the course of some hours of job because of hardware refuse, is allowed. The value of cited productivity of one-computer systems of data processing is limited. Any technology based on the utilization of one-computer systems of data processing does not exclude the possibility of losing their capacity of job. Consequently, one-computer systems of data processing partially satisfy the conditions imposed by science and technology.

The following class of data processing systems is the class of computational systems that gather the resources of different computers for the execution of a common problem of processing, supplying with this higher indices of productivity and security. The interconnection of individual computers can be carried out to the level of any system component with the help of determined technological middles:

to the level of channels, with the help of a channel-channel adapter;

to the level of external control devices of installations with the help of a switch of double channel and an electric switch of channels;

to the level of common operating memory;

to the level of processor with the help of middles of direct control.

For the organization of a computational system, a connection installation of any of the indicated types, a combination of these, or all of them, is utilized (Fig.1.3). The fundamental property of any type of connection installation consists in the possibility of utilization, on the part of the interacting processors, of common arrays of information and programs.

In computational systems with many computers, the interaction of states of data processing is guaranteed to account of the cut signal exchange and data transmission through the channel-channel adapters, or by installations of common operating memory of computers, each of which can set in motion one or various processors.

The best conditions for the interaction of processes are given in the case when each processor has access to the entire volume of data stored in the OMI, and is able to interact with all of the system peripheral installations (PI). A computational system that contains various processors joined by an interface of direct control with common operating memory, and with external PI is called system of multiprocessing. The principle of construction of such systems is illustrated in fig. 1.4. Processors, modules of the OMI, and input/output channels (IOC), to which the PI are connected, are joined by a complex of interconnection supported of a hardware of commutation which guarantees the access of each processor to any module of operating memory, and any input/output channel, as well as the possibility of their interaction.

A computational system oriented to a concrete branch of utilization is called complex of computation (Fig. 1.5). This is the third class of data processing systems (DPS).

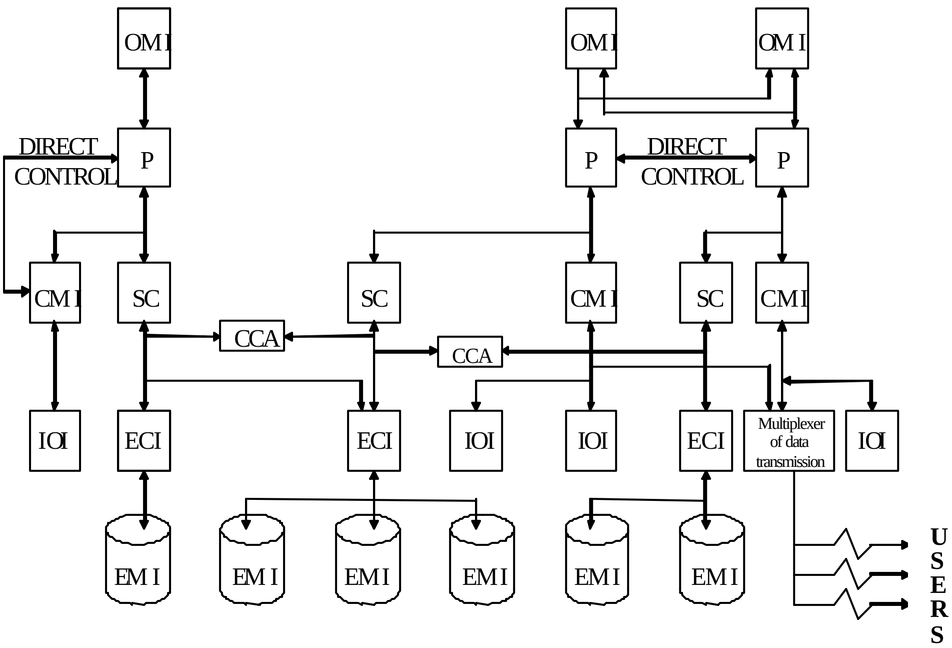

Fig. 1.5. A specialized complex of computation.
CCA - channel-channel adapter.

There are two ways of orientation of the complexes of computation. In the first place, a complex of computation can be built based on a common use computational system and the orientation is executed to account of software. In the second place, the orientation to the given class of problems can be reached to account of the utilization of a specialized hardware of the computational system. In the last case, high productivity is reached, while equipment expenses are moderated. The structure of a complex of computation, as well as that one of a computational system, can dynamically be adapted and installed in correspondence with the demands of problems to resolve.

The fourth class of DPS corresponds to the computational systems destined to data processing where these data are received from distant terminal stations (points of users), or directed to them by communication lines. This system is called system of teleprocessing (Fig.1.6). The communication lines are an individual part of specialized networks of data transmission, but can also be leased lines.

A system of data teleprocessing should include the following fundamental hardware: a computational system, multiplexers of data transmission (MDT) (a multiplexer is a functional block that allows to two or more lines to utilize jointly the middles of transmission), installations of data transmission (IDT), points of users (PU). The fundamental links of each system of data teleprocessing are computers, which execute functions of teleprocessing, storage, and information exchange control by communication lines.

The fifth class of DPS corresponds to the computer networks. They represent the solution to the interaction problem of a large number of computers or groups of computers located among them to a long distance.

A computational system (one or several computers with their peripheral installations, adapters, terminals, and specialized software) is the fundamental element of a computer network. Computational systems are joined by lines of information transmission, which form a network of lines of data transmission. Each network is open since it satisfies the common demands of interaction architecture of open systems of the International Organization of Standards (IOS). The structure of a computer network is represented in fig. 1.7. The set of computational systems and individual computers, as well as the network of data transmission (NDT), which is conformed by network adapters, lines, and complexes of communication, constitutes the nucleus of every network. Complexes of terminals are connected to computational systems with the help of communication lines through which users interact with the network. The set of terminals and communication lines used for the connection of these terminals with computers forms a network of terminals. Thus a computer network represents a composition of a fundamental network of data transmission; these data are processed in the computational system and the network of terminals. This computer network is called either wide area network (WAN) or distribution network [unlike a local area network (LAN)].

Computer networks based on computational systems constitute the most effective way of construction of wide area DPS. The utilization of computer networks allows to automate the control of production, transportation, and technical-material supplies, and to join efforts of scientific organizations to scale of large regions of a country.

A local area network (LAN) represents a group of computers located to a short distance, which are consecutively joined to interface, and equipped with specialized software that supplies the information interaction among processes in different computers. The number of computer processors can be greater than one, what allows to

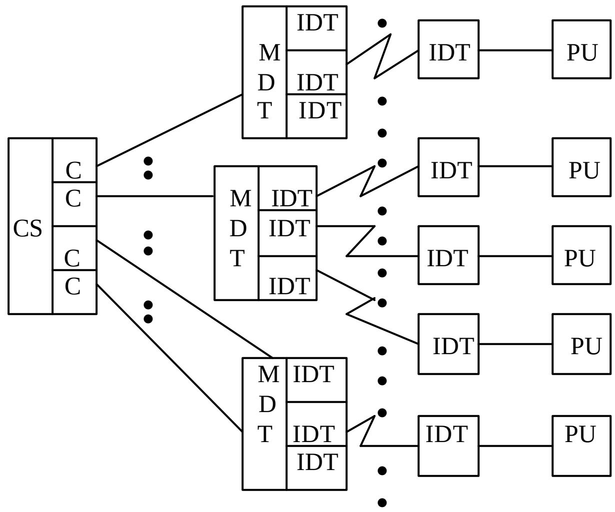

Fig. 1.6. A system of data teleprocessing.
CS - computational system.
C - computer.

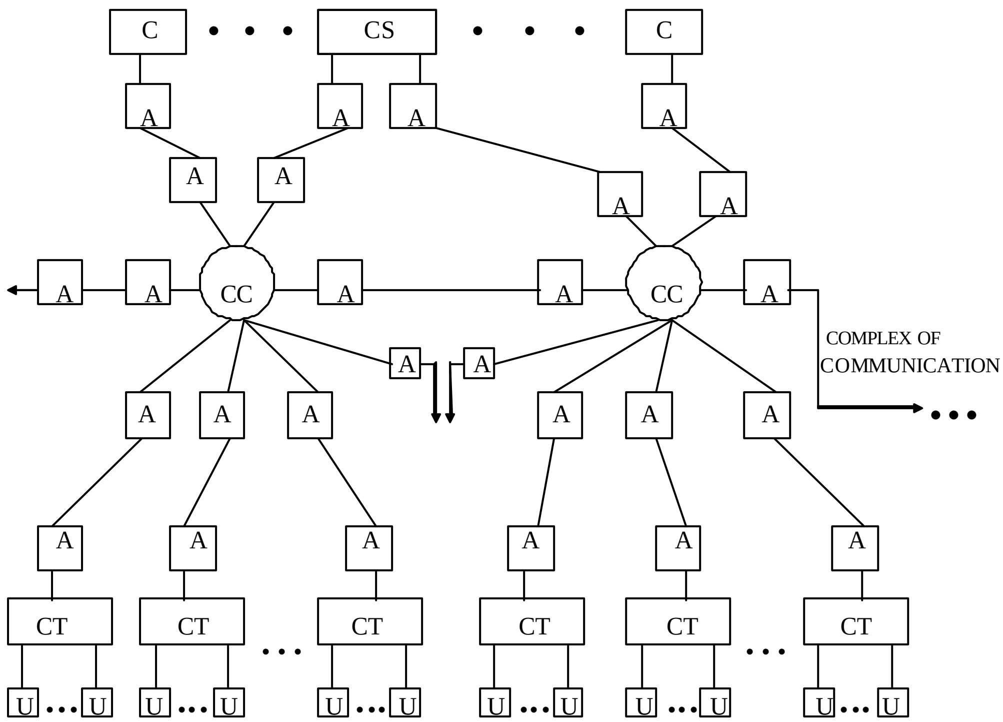

Fig. 1.7. Structure of a computer network.
A - network adapter.
CC - complex of commutation.
CT - complex of terminals.
U - user.

examine the LAN as the union of either computational systems or complexes of computation. This union of computers in a LAN is carried out through especial adapters (EA) which are connected to a single line of data transmission.

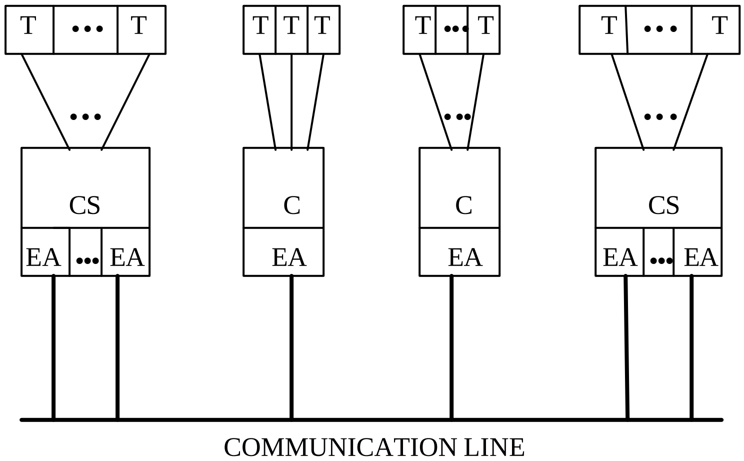

Fig. 1.8. A local area network (LAN).
T - terminal.

The presence in the LAN (Fig. 1.8) of a single communication line for data exchange among computers considerably simplifies communication establishment procedures and exchange of information. The network software is simpler in a LAN than in a WAN since the last one contains a NDT. As consequence, in a LAN, microcomputers and minicomputers can easily be connected.

In the class of LANs can be distinguished the subclass of computer networks called small LANs that are characterized for their reduced functional possibilities: lower cost and simplified protocols of interconnection. LANs and small LANs can be universal and oriented, according to their functions. The orientation to a specific branch of utilization is expressed in the following aspects: in restrictions of network dimensions, in restrictions of the number of users, in the lower speed of transmission, and in the specialization of protocols of interconnection.

LANs obtained extensive diffusion in design automated systems, in systems of production control, transportation, execution and provision, as well as in automatic systems of control of technological equipment, which are based on microcomputers, minicomputers, and flexible systems of production.

DPS are classified in dependence on the way of construction (Fig. 1.9).

In section 1.1 is proved that the demands to the practical utilization of computer mediums (the need of higher speed of calculation, security, and large volumes of memory) surpass abruptly the possibilities available in the modern middles of data processing. Roots of such contradiction are generated in the structural organization of computers.

The base of construction of a computer is determined by Von Newman's machine of five blocks, which carries out a universal consecutive algorithm. A computer possesses centralized control and a few installations of hardware are required for its construction.

This construction corresponds to the model of a single block of calculation, which possesses the following three characteristics: consecutive execution of operations, unmodified structure, non-homogeneity of component elements and interconnection among them.

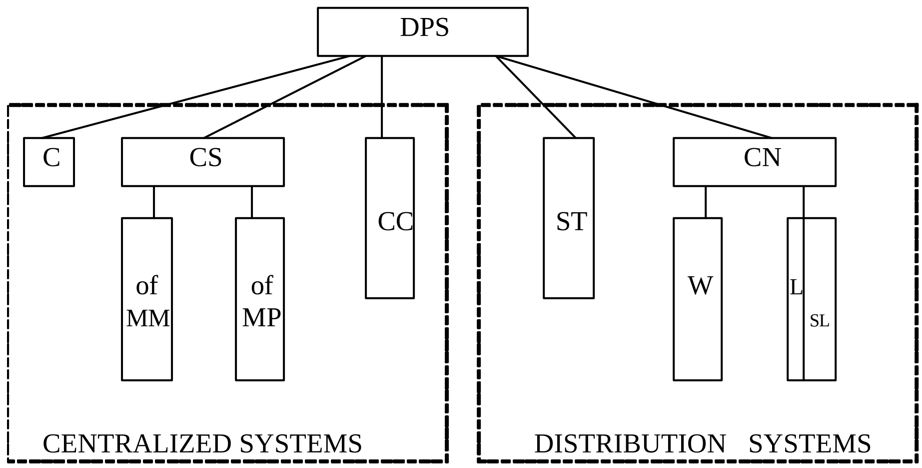

Fig. 1.9. A DPS classification.
CC - complex of computation; MM - many machines; MP- multiprocessing; ST – system of teleprocessing; CN - computer networks; W - wide area networks; L – local area networks; SL - small local area networks.

The execution of these three principles engendered structures of computers, whose development of orientation in order to reach high productivity, security, and vitality has found serious obstacles. The analysis of computers, whose model of construction is based on a single block of calculation, shows that is not possible to obtain qualitatively new properties. The utilization of this model provides only an insignificant qualitative improvement of computer technical characteristics non-comparable to the expenses in execution of the corresponding project jobs.

In this way the DPS based on the model of a single block of calculation have restricted productivity and security, and are not economic when producing them en masse. For that reason, the part of one-computer DPS, in the general volume of produced middles of computer technology, is reduced.

The restrictions that characterize to the computers, whose model of construction is based on a single block of calculation, disappear when the DPS, whose model of construction is based on a set of blocks of calculation, are utilized.

By set of blocks of calculation is understood the set of blocks of calculation able to work in parallel and interconnected in order to coordinate hardware and software for the solution of a general problem.

The definition previously enunciated does not exclude the possibility of simultaneous job of the set of blocks of calculation upon different problems that are not related. In fact, part of this set represents a set able to coordinate efforts in the resolution of a general problem, including a simple problem.

Three principles constitute the base of the model set of blocks of calculation: parallel execution of operations (parallelism), variability (programmability) of structure, and homogeneity of construction. It is easy to realize that the principles previously established are dialectically the negation of the principles of the model of a single block of calculation.

The parallelism of executio n of operations in a set of blocks of ca lculation is based on the possibility to represent the solution process of a complex problem by means of a parallel program. The programmability of structure is guaranteed with the introduction of specialized hardware and software, with which is possible to establish interconnection programs among blocks of calculation. The homogeneity of construction consists in the representation of such a set in form of subsets of equal blocks of calculation constantly interconnected.

In order to organize the operation of these blocks of calculation, it is required not only an algorithm A of individual job, an individual program P, and a data array D, but also an interaction algorithm of the respective block with the remainders. The variety of technical materializations of the model set of blocks of calculation is consequence of different ways of execution of interaction algorithms in such blocks and varied structures and rules of algorithmic composition of these blocks. In this way the organization of computational systems and networks is based on the model set of blocks of calculation. In conditions of needs of demand of higher productivity, security, vitality, and technical-economic effectiveness to the computational middles, the elaboration and utilization of computational systems, whose model of construction is based on a set of blocks of calculation, is the alternative that allows solving the problems mentioned already.

1.3. ORGANIZATION OF COMPUTATIONAL SYSTEMS (CS).

A CS consists of hardware and software. Designation of the CS hardware consists of input, storage, transformation, and output operations of information. The CS software is a set of programs that provide a function execution order of assignment to the system in terms of commands that are carried out for the CS hardware. These programs control the job of the entire computational installation in order to obtain the results corresponding to the designation of DPS.

Since CS will be here examined as a fundamental middle in order to create DPS of different designations, in the conformation of CS, hardware and general system software is admitted to include, but not application software related to a concrete branch of the system's utilization.

A CS interacts with the external mediums, obtaining from them the necessary information, and delivering to them the information produced by the programs. The CS hardware can be here examined as a space oriented to the execution of a set of operations upon the information. The computational processes engendered by the programs are developed in this space. The program execution initiation is produced for signals of a timer in specific moments of time, or by signals from outside and by commands of other programs, and also in the case when particular conditions in the own CS arise because of signals emitted from the CS installations.

A CS interacts with the external mediums as a whole, and executes resolution of problems that enter to the system; activating software in form of computational processes that happen themselves in such a CS.

By different reasons the possible classifications of CS (that one of greatest diffusion was the classification by structure-functional criteria of information parallel processing) are fundamentally based on Flynn's classification.

The fundamental idea of Flynn's classification consists in systems division by criteria of either uniqueness of command flows or sets of command flows (the same for data flows) through central processors and control installations, on the one hand, and central processors and fundamental memory, on the other hand. The pair of criteria of ambivalence before mentioned [the flow of either uniqueness of commands or sets of commands (UC or SC), and the flow of either uniqueness of data or sets of data (UD or SD)] determines four fundamental classes of CS:

(1) UCUD – systems with flows of uniqueness of commands and uniqueness of data. This is the class of computer mediums, corresponding to the modern CS of a single processor which, by their organization, are similar to the systems of multiprocessing. That similarity is due to that in the modern CS of a single processor, different phases of information processing stop in different moments of time (Fig. 1.10).

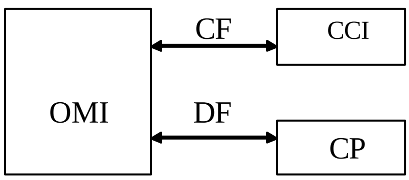

Fig. 1.10. Organization of a CS of multiprocessing, according to the principle UCUD.
CCI - central control of installations; CP - central processor; CF- command flows; DT - data flows.

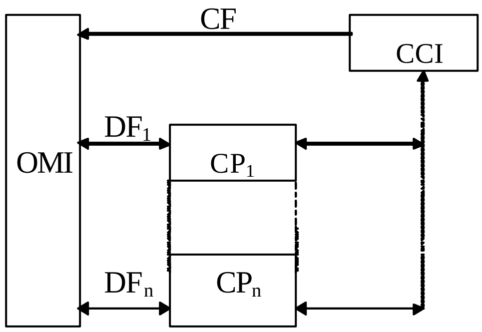

Fig. 1.11. Organization of a CS of multiprocessing, according to the principle UCSD.

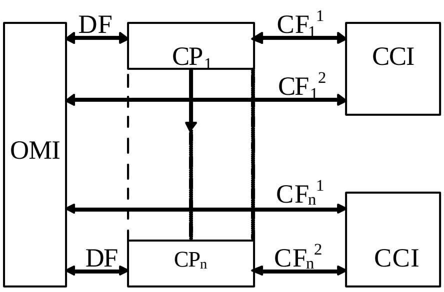

Fig. 1.12. Organization of a CS of multiprocessing, according to the principle SCUD.

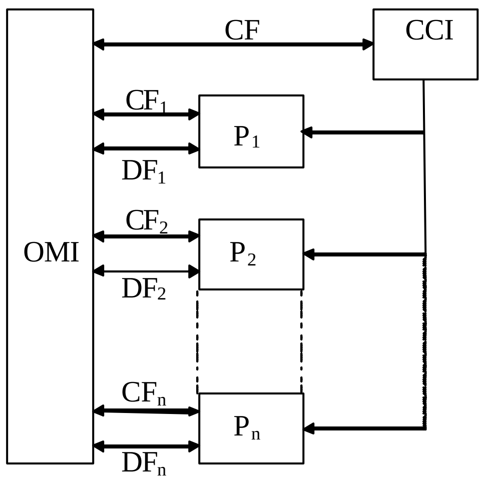

Fig. 1.13. Organization of a CS of multiprocessing, according to the principle SCSD.

(2) UCSD – system with flows of uniqueness of commands and sets of data (Fig.1.11).

(3) SCUD – system with flows of sets of commands and uniqueness of data (Fig.1.12).

(4) SCSD – system with flows of sets of commands and sets of data, in which simultaneously various programs P that work upon different data arrays are executed. These systems have various accessible modules of OMI (Fig. 1.13).

Microprocessors and complexes of microprocessors with large integrated circuits open essentially new possibilities in the creation of systems of multiprocessing of different type. A microprocessor has small dimensions, but great power of computation. The future development of microelectronic technology will allow manufacturing universal and specialized microprocessors of highest effectiveness. This opens new possibilities in the creation of homogeneous and non-homogeneous CS of multiprocessing. The large integrated circuits manufactured, using semiconductors, and with which are built the OMI, resolve the problem of the creation of memory with multiple location in a CS. The variety of large integrated circuits of commutation and control of input/output installations (IOI) gives the possibility to carry out a flexible control of information flow distribution inside the complex, and among external mediums and CS.

The installations that compose the CS hardware are part of the computer hardware, which at the same time, is part of this CS.

Central installations: a basic series of processors of different productivity, OMI with different capacities, input/output channels.

Peripheral installations: EMI which utilize collectors that work with disks and magnetic tapes, set of input/output installations which include printing middles of different productivity, keyboards and installations that include graphic and digital monitors, installations of interconnection with control devices and installations for interconnection supply among groups of devices of CS.

Processors, main memory, and input/output channels represent elements, whose concepts are opposite to those ones of the PI (and to those ones of their control installations) by the functions that perform, and their interfaces. The term "central installations" represents a joint designation for processors, main memory, and input/output channels.

The central installations can be directly connected each other or through peripheral installations, for example through EMI with output devices in several directions.

The particularity of interconnection of peripheral installations gives a formal criterion of division in composition subsystems of technical mediums. The central section of computer technical mediums is called subsystem. It is composed of central installations that interact among themselves without participation of PI. In the composition of computer technical mediums should have, at least, a central section. To interconnect the central sections (that is to say, to carry out the common exchange of data among machines) is used a common operating memory field, middles of exchange of data among communication lines, and middles of direct transmission of information. The following classes of CS can be distinguished, keeping in mind the commutation control of the system's computers:

(1) Systems with fixed structure (trunk, matrix, associative, and with distribution control).

(2) Systems with programmable structure.

The systems of the second class have more perspective.

The computational systems of many machines are divided into homogeneous and non-homogeneous. According to researches carried out by one of the Institutes of Mathematics associated to The Russian Academy of Sciences, parallel principles of processing could be materialized, in a more complete way, using homogeneous computational systems (HCS). Their possibilities are essentially better in comparison with the remaining classes of CS. Therefore, we will examine problems applied to the HCS. Topology of a CS can be represented by means of a graph (Fig. 1.14). Graph's edges, that is to say, connections among computers, correspond to the communication lines, and vertices correspond to the machines or processors (that is to say, the elementary machines) of the given CS. At the same time, other graph may correspond to each vertex of the original graph, what is equivalent to the enlargement of a CS in which instead of computers, computational systems of a subordinate level are installed. The Graph of the topology of a CS is part of the composition of other graphs, showing in this way, the interconnection of the examined CS with systems of higher level.

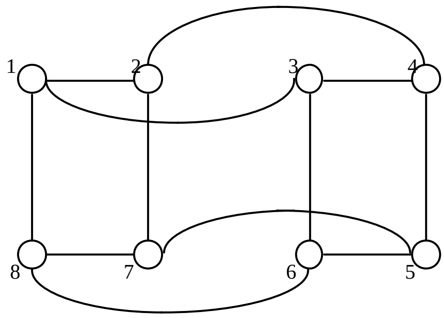

Fig. 1.14. Graph of the topology of a CS.

Summarizing, we can conclude that the CS hardware can be represented for a scheme that is represented in fig. 1.15. Representing the given CS in element way, it is possible

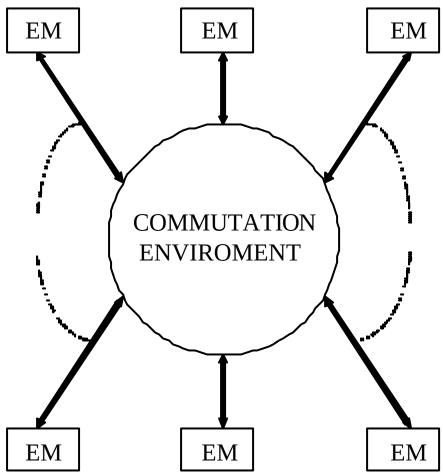

Fig. 1.15. Topology of a CS.
EM – elementary machine.

to build collectives or super collectives of CS, which at the same time, are also systems of many machines, or computer systems of multiprocessing.

Software of programs is the second component element of a CS. A program is a set of data appointed for controlling the system components in order to carry out a specific algorithm.

Software represents an organized set of programs and data. There are two types of software: the first one is called system software, and the second one – specialized software.

The system software is appointed for carrying out the following tasks: control of technical resources and CS information, control of the execution process of programs; on the part of users, programs automation creation, and finally, technical service for CS. The specialized software is appointed for the solution of different problems proposed by the user: scientific and engineering calculations, data processing, automated and automatic control of different objects, etc.

The variety of connections among modules and branches of the CS software can be reduced to the following six groups:

(1) Exchange of transmission (ET) in which the information is directed from a branch to the other remainders.

(2) Cyclic exchange of transmission (CET) which carries out an ET in cycle by branches.

(3) Exchange by displacement (EBD) when the information is transmitted from the i branch to the $i + 1$ one, or to the $i - 1$ one.

(4) Differentiated exchange (DE) in which the information is transmitted from the i branch to a specific group of branches.

(5) Collector exchange (CE) when the information of all of the branches is joined in one.

(6) Generalized conditional step (GCS), in which the natural order of the sequence of operations in all of the branches under the execution of a generalized condition, is changed. This operation, besides the control transmission to the given signal, guarantees the synchronization of all of them.

The enumerated procedures guarantee the direct access to the general data, and the interaction of the programs executed in different computers. In order to represent programs and algorithms, oriented graphs are utilized. Their vertices correspond to the commands (that is to say, to the elementary algorithmic operations), and their arcs correspond to the sequential conditions. That objects are called data flow diagrams.

The data flow diagram for a concrete program is built following certain simple rules, but with certain degree of demand in details. A trivial solution of the problem consists in the representation of each language command (that is to say, of each machine command, each line, and each fragment recognized like a unit of language) by a specific vertex. In this way, two vertices are adjacent if among each pair of language commands there is a control transmission. More precisely, a command, after whose execution a control transmission is produced, is represented for a tail of arc; the command, to which the control is transmitted, is represented for a head of arc, while each control transmission is represented for the corresponding arc. Using this approach, the graph dimensions grow to account of the formation of long chains of vertices which correspond to the lineal parts of the program. In order to reduce the number of vertices, such chains can be represented by means of a single vertex. More complex approaches consist in the separation of program parts, and in the introduction of vertices and arcs with weight. Representing the program structure, using graphs, it is possible to examine separately the program properties, thus facilitating the programmer's job.

Software includes itself different complex structures. Consequently, the elaboration of software can be carried out, using different types of hierarchy. Representing the CS software in form of an element, collectives and super collectives of complex software can be built.

Software includes sets of data examined here as one of its particular components. The sets of data represent groups of data elements logically interconnected, organized according to specific rules, and supplied of a description accessible to the programming system (that is to say, accessible to the data control middles). The sets of data are supplied of names with the help of which the programs call to the corresponding sets of data, and to their elements.

Just as it happens with the programs, the models of sets of data can be represented in network way. The same sets of data can be used for many application programs. To exclude the need of representation of the same data in different ways and combinations, oriented to different programs, is indispensable the data independence supply and programs. This is achieved to account of the data organization in a special way of structures (databases and databanks), and to account of the use of software groups (database management systems) appointed for the election, modification, and addition of data.