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# Organization of the network connection in the Industry 4.0

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*Abstract.* The methods of organization of a computer network in the context of its application to Industry 4.0 are analyzed. The most optimal methods of network organization within the workshop, enterprise and cascade of enterprises located at a considerable distance are determined.

*Keywords:* Industry 4.0, computer network, increasing the speed of data transmission

## INTRODUCTION

We are currently experiencing the end of the third industrial revolution, which is characterized by automation and robotization of production processes. However, the fourth industrial revolution is steadily holding the top spot in the leading industrial countries of the world. Industry 4.0 is characterized by complete automation of production, and all processes are controlled in a real-time environment taking into account all the external conditions. Cyber-physical systems produce exact copies and virtualize all physical objects that are involved in production, control all physical processes as well as make decisions on the change of production algorithm; they exchange data via the network. Computer network is a system of distributed information data processing among devices or devices assisted by communication facilities; it is a total of geographically dispersed devices capable of exchanging messages among themselves through the data transmission medium.

Information transmission among devices occurs by means of electric signals that can be digital or analog. Digital signals in binary form are used within a computer, while analog ones are used during information data transmission over a network. Frequency of analog signal is the number of wave occurrences per specified unit of time. Devices connect to the network via switching nodes, which are interconnected by means of communication channels. Switching nodes along with communication channels make data transmission medium. In the literature network-connected devices are called nodes, user terminals or workstations. Computers performing a function of network management or providing any network services are called servers.

Added reality is a mixed reality that is created with the help of additional graphic elements displayed on the screen of the device. Man receives the bulk of information about the outside world through the visual channel and effectively processes, analyses, and interprets the information received from the outside. Therefore, the question arose as soon as possible to implement a similar video processing system for computing. Technologies of computer vision and added reality are used in quite popular areas of science and technology, such as production equipment control, mobile control systems, biomedical research, product quality improvement, etc.

## THE LITERATURE OVERVIEW

Industry 4.0 involves designing real-world production in a virtual world. To implement such a plan, you need to use a huge amount of sensors that will transmit a lot of information. This will increase the network load. The problem is that networks may not be able to withstand such a load. Therefore, it is necessary to analyze the possibilities of different implementations of networks, which is carried out in this publication.

## THE AIM AND OBJECTIVES OF THE STUDY

The purpose of the accomplishment is to optimize the networks used within the Industry 4.0. Because we have many sensors that provide real-time information, which entails the transmission of a large amount of data, it is necessary to clearly divide the roles of different networks.

## AN OVERVIEW OF VARIOUS METHODS FOR ORGANIZING COMPUTER NETWORKS AND THEIR RESEARCH INTO APPLICATION CAPABILITIES IN INDUSTRY 4.0

**Computers or hardware using the services of servers are called clients**

Every network-connected computer, whether it is measuring or control device, has its address. Computer networks can exchange information among themselves in the form of messages. These messages can be of various natures (a letter, a programme, a book, etc.). In general, the message passes several switching nodes on the way to the destination station. Each of them, analyzing destination address in the message and being familiar with network configuration, chooses the communication channel for further message passing. Thus, the message "travels" over the network until it reaches its destination station. In order to connect to the network computers or hardware must have:

- hardware facilities connecting computers with

data transmission medium;
- network software by means of which access to network services is carried out.

There are thousands of various computer networks in the world. The most fundamental features determining network type are degree of territorial dispersion, topology and applied switching methods.

## CLASSIFICATION OF COMPUTER NETWORKS

Depending on the principles of network construction there are local and worldwide networks. Local networks are meant to be used in the same room or on the premises of one organization. Worldwide networks are created to connect computers or hardware located at long range from each other. Local networks are divided into peer-to-peer and client-server ones. In a peer-to-peer network all users have equal rights. Users of such a network can exchange data among themselves using shared resources (printers, disks, access to various sensors).

Client-server network is distinguished from the peer-to-peer one by using one or several (if a large number of sensors, control stations, etc. is used) higher-power computers called servers. All the other computers of such a network are called workstations. Server is meant for network management and shared information storage. The advantage of this type of networks is the possibility to carry out rights management of the network users. Data transmission medium in the local network can be wired or wireless. In the wired environment information is transmitted across the wire, and in the wireless one – by means of electromagnetic waves of different nature: infrared, radio waves, etc. In contact local networks three types of cable are used: twisted pair, coaxial and optical fiber. Two computers connected through parallel or serial ports may be an example of the simplest network. In order to create a full scale local network, we need to use an additional device – a network adapter. Network topology defines physical location of network cables and physical connection of clients to the network. Nowadays three network construction schemes are used: bus, star, and ring [1-4].

However, local networks cannot fully meet all the requirements regarding information data exchange among the devices. Local networks of different organizations can be interconnected by means of communication channels (telephone, radio-relay, satellite and other), hence creating distributed computer systems and networks of various application. Utilization of various information resources by users from different organizations, cities and countries is the main purpose of worldwide networks. Worldwide networks are divided into regional and international. Regional networks are intended for users of specific region. There are several well-known worldwide networks. They are the following: FidoNet, InterNet, EuroNet, system of interbank payments SWIFT. One of the most popular is the worldwide network InterNet – the largest global computer network connecting tens of millions users in more than 170 countries of the world. Both local and worldwide networks are important for Industry 4.0. Local network is important in view of communication of sensors, servers, workstations within one enterprise. On the other hand, worldwide network is suitable for the communication of local networks of enterprises among themselves and cloud services.

### *Network architecture*

Division into levels, or level architecture, is a form of functional modular one, which is central in the design of modern digital data transmission systems. The concept of functional modular (but probably not the term itself) is as old as technical hardware. Hereafter the word “module” is used to indicate both device and process in a certain computer system. Significantly, a module performs a certain specified function. Module developers should have a deep understanding of internal components and operation of the module. However, he who uses the module as a component when constructing a more complex system, will consider it to be the “black box”, that is the user is interested in inputs, outputs, and particularly, functional relationships between outputs and inputs rather than internal workings of the module. Therefore, black box is a module that is described by the input-output feature. It can be used along with the other black boxes to build a more complex module, which again will be considered as a big black box on higher levels [7-9].

This design approach obviously leads to hierarchy of nested modules. Complex system must be constructed as a related set of high level modules and maybe some additional simple modules necessary for implementation of interconnections and performance of additional simple functions. From the viewpoint of the highest level – the level of the entire system – each of these modules is considered to be the black box but on the next lower level every high level module is considered as a related set of modules of the next lower level that again can be appended with simple modules. A simple module is a module that is not split into modules of lower level. Every module of the next lower level is again split into modules of lower level, and so forth until the lowest level of the hierarchical chain. As an example of hierarchical approach, a computer system can be presented as a set of processor modules, a set of memory modules and a bus module. Whereas a processor module can be presented as a set of a control device, an arithmetic unit, an instruction fetch device and a conclusion input device. Likewise, an arithmetic device can be split into adders, accumulating registers, etc.

In the majority of cases, a black box user doesn’t need to know detailed response of output for input action. For example, it does not matter when exactly output signal will change in response to input signal change until it has been used. Thus, modules, i.e. black boxes, can be described by permissible deviations rather than precise values. This leads to standardized modules and further, to the applicability of a number of identical, already-existing (in other words, ready-to-use) modules within the same system. Furthermore, such standardized modules can be

easily replaced with new, functionally equivalent modules that are cheaper and more reliable [1,3,9].

All these advantages of the functional modular (that is design simplicity, understandability and standard, interchangeable, widely used modules) give grounds for the introduction of level sensitive architecture of data communication networks. Level architecture can be considered as a hierarchy of nested modules or black boxes, as described above. An unusual feature of level architecture is that communication lines are represented by black boxes on the lowest level of hierarchy. The result is that black boxes on each higher level are actually distributed black boxes. Therefore, a black box of each higher level consists of a set of simple modules (usually one for every switching node or external point included into the system) plus one or several black boxes of lower level. Simple modules from the black box on the given level are called parity processes or parity modules.

In a simple case the black box consists of two parity processes, one for each of two nodes and the black box, located on the lower level and representing communication system connecting these two parity processes. Each process communicates a message to the parity process in another node through the lower level, which is via the black box, representing communication system. The black box of the given lower level may consist of two parity processes of lower level that belong to different nodes and are connected by the communication system – the black box of even lower level. As an example, we can describe a situation when two heads of the state speak different languages. Each head can transmit a message to the parity leader by means of his translator (an interpreter) who conveys it in the language known to the parity translator, and he then delivers the message using the language of the parity head of the state.

It should be noted that the process of information transmission between two parity modules of level “n” that belong to different nodes has two completely different aspects. The first one is a protocol (or a distributed algorithm) with the help of which parity modules exchange messages in order to assure the required maintenance for the subsequent higher level. The second one is a description of exact interface between the module of the level “n” of the given node and the module of the level n — 1 of the same node; actual exchange of the specified messages between the level “n” and the black box (communication system of the lower level) is carried out through this interface [10,11]. The first of the above-mentioned aspects is more important (and more interesting) for conceptual understanding of the level architecture operation, and the second one is essential for the design and standardization of the system. In the previous example about the communication of the two heads of the state the first aspect is associated with negotiations between the heads of the state while the second one is associated with the fact that each head of the state must be confident that the translator can really translate the message correctly.

## Networking

### *Bus*

The cheapest scheme of networking is bus topology that presumes immediate connection of all network adapters to the network cable.

All computers in the network are connected to one cable. The first and the last computers must be decoupled. A simple resistor is used for decoupling, as it suppresses the signal at the end of the network in order to prevent obstacles. Besides, one and only one end of the network cable must be grounded, which will allow avoiding ground loops.

The major disadvantage of bus topology is the probability that the entire network will shut down if there is a break in any section of the network cable. In order to discover the problem area it is necessary to split the bus into two separate parts that makes it possible to figure out in which of them there is a breakdown. Then, the segment of the cable in which a breakdown was spotted is also split into two parts, and the same procedure is repeated until the breakdown has been localized. This process is very time-consuming. However, it does not exclude the possibility of bus topology usage [2,13,15]. It is in the best way suitable for combining sensors within one department at the enterprise and creating small networks where cables can be laid in easily accessible places and where it is impossible to use routers, for example because of dustiness of the premises.

### *Star*

At the present time, star topology is used for the organization of most networks. In this case, the disadvantage associated with the probability of breakdown in the general cable is resolved by using individual cables to connect every control or measuring hardware to the main network cable. Every workstation is connected to the repeater that has several ports and is called a hub or a concentrator. The hub, in turn, is connected to the main network cable. The main purpose of the hub is to transmit signals from the main network cable to separate workstations. If the cable connecting the hub and a workstation breaks, only this station is disconnected. The other ones can operate in the network without obstacles. However, in case of the hub breakdown all the involved users of the stations are disconnected. Of course, such kind of failure is easily discovered because all the users involved in this hub, will draw attention of the network administrator to the fault encountered. As distinguished from the bus topology where one spends a lot of time and makes a lot of efforts to find the breakdown, broken down hub literally makes it clear itself.

In case of such a breakdown, it is necessary to have an extra hub in reserve to replace the broken down hub. Thus, it seems reasonable to fit the entire network with the hubs of the same type. Besides, the application of smart hubs shows good performance. Such hubs support SNMP protocol that can be used for remote management

and testing of the hub without leaving one's working place. It is the most expedient to use such network organization along with the ring organization for the communication of departments within one enterprise and among enterprises.

### *Ring*

Ring topology is mostly used by the IBM Company for organization of token-ring networks. The structure of the network built upon this topology reminds the structure in case of star topology. Instead of a hub, station users are connected to the multistation access unit (Multiple Access Unit) that performs logical connection of the network computers into a ring. Ring topology has the same advantages as star topology because physical organization of these two network types is identical. It follows that ring topology also has the same disadvantages because multiple access unit breaks down most frequently. At the present time, depending on hardware implementation, such local networks as Ethernet and TokenRing have become the most widespread [4,7,8].

### *Local network of Ethernet type*

Networks of Ethernet type appeared in the early 1970's. Networks of such class usually have bus topology. Data transmission medium in the Ethernet network is a twisted pair or coaxial cable with resistance of 50 Ohm. Two types of coaxial cable are used: thick one about 1 cm in diameter and thin one about 0,5 cm in diameter. Bus access method is random with carrier sense and collision detection. For hardware operation in the network an Ethernet network card is required. Connection of the network card to the bus for the thin cable – 195 m, for the thick one – 500 m. Not more than 30 or 100 stations or sensors can be connected to such a bus. If it is necessary to provide the Ethernet network on the territory larger than coaxial cable allows, additional devices (repeaters) are used. Their purpose in the network is to relay all the incoming information restoring amplitude, phase and form of signal. There can be up to 4 repeaters in the network. This allows increasing maximum bus length to 925 meters for thin and 2500 meters for thick cable, which means that the longest distance between sensor and data collection device may be 925 and 2500 meters accordingly [2,4,14,15]. Twisted pair is used mainly in the Ethernet networks of star topology. Sensors or computers are connected into the network with the help of concentrators. Every device is connected to the concentrator via relevant connectors.

### *Networks of TokenRing type*

Networks of TokenRing type appeared in the early 1980's. Networks of such class have ring topology. Data transmission medium – twisted pair, coaxial cable, optical fiber cable. Mixed types of cable may be used in the ring. Access method to the transmission medium is determined with the transfer of rights. The TokenRing network provides data transmission rate of 4-16 megabits per second. Taking into consideration the information above, this method of network organization is optimal for departments with very frequent sensor polling and where performance plays major role.

## Global community of computer networks Internet

### *Stages of formation*

The Internet is a worldwide famous global network that makes it possible to realize computer-assisted communication among all the world continents. The prototype of the Internet network was created in the late sixties on request of the United States Department of Defense. At that time there were very few powerful computers and it became necessary to make those machines accessible to a number of scientists so that they could carry out scientific research. In addition to the above, it was stipulated by the Ministry of Defense that the network should keep working even after its part has been destroyed, so the increased reliability of the Internet was embedded when it was created. January, 2, 1969 may be considered to be the birthday of the Internet. On that day the Agency of advanced research (ARPA – Advanced Research Projects Agency), which is one of the subdivisions of the United States Ministry of Defense, started working on the project associated with communication among computers of defense organizations. The result of the research work was the creation of the APRANET network based on the principles that will later provide the basis for the Internet. The next step of the Internet development was creation of the network of the National Science Foundation of the USA (NFS). The network called NFSNET connected scientific centers of the United States. In that case, 5 supercomputers interconnected by means of high performance lines became the basis of the network. All the other users could connect to the network and take advantage of such devices. NFSNET network quickly took the place of ARPANET, and the latter was liquidated in 1990. Network development required its reorganization, so in 1987 NFSNET Backbone (basic part or the network backbone) was created. The backbone consisted of 13 centers interconnected with each other by means of high speed communication channels. The centers were located in different parts of the USA. In such a way, the Internet network appeared in the USA.

At the same time, nationwide networks were created in the other countries. Computer networks of various countries started uniting, and in the nineties the Internet as it is today appeared. At present the Internet combines thousands of various networks located throughout the world. Tens of millions users have access to it [3-8]. The Internet growth and development continues, and the increase of its role in all information technologies can be evidenced.

### *Internet structure*

Like any other network, the Internet consists of a lot of computers or measuring devices interconnected by means of communication lines (channels) and programs installed on these devices. There are several access methods to the Internet network that are determined by the selected channel. The simplest channel alternative among private users is the so-called dial-up line or, in

other words, a separate usual telephone line where the data can be transmitted by means of modem. The advantage of such a channel is its cheapness: if telephone communication is available at user's place, the channel is ready for use. The disadvantages here are low speed and communication quality, for communication quality depends on the fact whether an exchange station, which the computer is connected to, is modern or outdated. It is also preferable to ensure that the user's computer or data collection device is connected to the same station as provider's server. Data transmission rate is limited by one of the two values, notably the one that is smaller: maximum rate that the dial-up line can "endure" (in fact, we have 28,8 Kbit, and in some cases – 33,6 Kbit) and modem speed [15]. Such implementation of communication is possible between a separately standing department in a remote location and enterprise or corporate server.

A leased (or non-switched, that is personal) line is the most common channel by means of which computers or measuring/control devices, which work in the network on a permanent basis, are connected. The drawback of such a channel is primarily high price of laying and a bit higher price of network services. The benefits are practically perfect quality and notably higher speed. A straight-through cable (Ethernet) may be used for the leased line, though the use of optical fiber cables is very promising. Such implementation is optimal in terms of network stability; it can be easily implemented within one plant or corporation. This scheme is quite convenient and relatively easily customized.

If it is problematic "to lay the cable" due to natural obstacles or political hurdles, then the satellite channel is used. As stated about, Internet users connect to the network via computers of special organizations called the Internet service providers (provider – supplier). A separate computer or control/measuring system as well as local network of such devices can be connected to the network. In the latter case it is considered that all computers and devices of the given local network are connected to the Internet, though only one computer is connected to the Internet by means of communication line. The connection can be permanent or temporary. All organizations interconnected by the fastest communication lines make the basic part of the network or the Internet backbone. In fact, the distinction between users and providers is quite conventional. Every user that has connected his computer or local network to the Internet and installed the necessary software can provide services of network connection to other users, which is to say, become a provider.

Generally speaking, the Internet provides information exchange between two arbitrary devices connected to the network. Internet-connected computers are often called Internet nodes. The nodes positioned at the provider's afford users' access to the Internet; there are also nodes specializing only in supplying information. A distinctive feature of the Internet is its high reliability. Even if some computers and communication lines break down, the network is still in operation. Such reliability is achieved by the fact that the Internet does not have a single control center [10-14]. If some communication lines or computers break down, messages can be transmitted through other communication lines because there are always several ways of information data transmission. Therefore, the Internet is a conventional name of a system of interconnected networks that includes a great and variable number of computers from all over the world characterized by common features. Firstly, they are all interconnected by means of specific channels, and secondly, they can exchange information according to custom-designed rules – protocols.

### *Addressing system of the Internet network*

Every computer connected to the Internet has its own unique address even in case of temporary connection. At any specific time all computers connected to the Internet have different addresses. Internet address uniquely specifies computer location in the network. A special address system, referred to as an IP (Internet Protocol)-address, is used for this purpose. Internet address is a set of four integers, each of which is within the interval [0; 255] separated with dots, for example: 194.44.90.33. The first two numbers of the address specify the part of the Internet to which a computer is connected, and the last two – the address of the computer in that network part. Let us imagine a person who uses the network and regularly visits not one but several dozens or even hundreds of Internet computers. Such a user must remember a large number of numeric sets so a special literal addressing has been developed to help him – DNS (Domain Name System). According to DNS-addressing, all computers have address names which consist of a set of letters, separated with dots, for example, www.if.ua. Firstly, it is easier to remember letters; secondly, on detailed account, DNS-address structure has a clear logic. Thus, computers transmit information by means of digital addresses, and users, while working with the Internet, use basically address names. There are organizations that verify and provide addresses. That is why one may not assume any address on his own. Let us consider the structure of the address name in detail.

The Internet network uses domain addressing method, when the whole space of users' addresses is divided into areas called domains [3,9,11]. Such an address is read from right to left, and on the rightmost position there is a top-level domain that gives us the most common information. It can be of two types: indicates the type of organization being the owner of the computer or the geography, or the country where the computer is located. There are seven variants of domains indicating organization type:

com – the most common domain, indicates that the computer belongs to a commercial organization;

org – owner – a non-commercial organization;

edu – owner – a university or any other educational institution;

mil – the computer belongs to a state military institution in the USA;

gov – owner – a state non-military organization;

int – owner – a certain international organization;

net – organizations that perform certain works related to the networks.

The domain indicating the country consists of two letters which, as a rule, duplicate the international state code: ua – Ukraine, us – the USA, uk – Great Britain, fr – France.

Any number of domains is allowed in the name but the names with three to five domains are prevalent. Every domain owner can create and change addresses that are under his control. For example, if a new department of analytical investigation has been created at an enterprise with the address firm.ua, the enterprise does not have to receive any permission in order to name it; all it takes is to add a new name to the description of one's own domain address, for example store. Consequently, every Internet user can access this group at the following address: store.firm.ua. The leftmost part of the name in the address quite often explains the information type which this address indicates. For example, the address www.toyota.com indicates the page in WorldWideWeb, and the address ftp.toyota.com refers to ftp-server, where the files are stored. Such an addressing rule is not mandatory, and is used only to make the information search easier. Universal resource locators called URL Universal Resource Locator) instead of just domain addresses are most commonly used in the Internet. URL is an address of any Internet resource together with the indication according to which protocol it should be addressed. This is the general form of the URL: <type of informational space>://<server name>/<directory name>/<subdirectory name>/<file name>.

Thanks to the Internet there is a possibility to communicate control or measuring devices, servers, data stores, means of data accumulation, etc. Thanks to the Internet it is possible to obtain all the data we are interested in on a real time basis as well as make adjustments to the algorithm of production located, for example in Europe by an engineer who performs correction being in the USA.

***The concepts of server program, client program, ports***

In order to provide the users with the Internet possibilities specific programs running on the network computers are used. Besides, for the purpose of ensuring any service, for example WWW, FTP or other, two programs are always necessary. One of them is a server program, which receives, processes, stores and transfers information on demand of other computers; another one is a client program, which is installed on the user's computer (workstation) and is meant for sending requests on the server, receiving and displaying information on the user's computer. For example, a WWW server stores Web-pages and supports special hyper text transfer protocol (HTTP) for traveling around the World-wide web. Web-page viewer is a client for a WWW-server. Notice that a server is also known as a computer on which programs providing access to network resources are operating. Servers usually have large resources (hardware, software, informational) that can be allocated for network use and are in permanent working state ensuring data transfer.

So that a client program could know which server program it is working with, the so-called ports are used. A port in the Internet is a number connecting programs in the network. Operating in the Internet, a workstation sends a port number, specifying which server program should be launched, to the network node [10-13]. Do not confuse port number with the computer port, which is an information input/output device. In most cases port number is specified in the client program, and it is not necessary for the user to know it.

***Information security in the Internet***

The question of privacy is very important while working in the Internet. Let us say, you e-mail a message intended only for the recipient, though, while it is on its way, malicious users may intercept and control your correspondence. In order to protect their messages some users use programs that allow encrypting the content of secret letters before e-mailing them. Recipients also need such programs to decrypt the message. Practically all encryption/decryption programs perform encryption/decryption of texts by means of the key (password). In such a way data communication privacy over the Internet is ensured. When accessing resources of certain computer system passwords are also often used, as long as password is precisely what guarantees personal login. From the viewpoint of software, a person initiating login using your password is you, so he or she obtains authority to perform any manipulations with your data [3,7,9,15]. Let us outline those troubles that may occur in case of unauthorized use of user password.

User will have to pay for the time did not actually use.

Malicious use will change the password, and the user will not be able to log in.

Malicious user can change the user's files.

Malicious user will send a provocative letter on behalf of the user or will be able to control the user's private correspondence.

It is possible to change user's signature.

A hacker can do malicious actions in regard to the system on behalf of the user.

To avoid such troubles, it is necessary to change the password from time to time. Password length should not be too small for in such a case it can be figured out with the help of the computer through the creation of certain possible combinations. It is preferable not to use words that can be guessed if somebody knows your preferences,

for example favorite rock group name, year of your birth, and, above all, it is necessary to choose such a password you will not later forget. If somebody else has access to the computer you work on, do not leave the connection open; close it before you leave your workplace. This applies especially to the places of public access. When it comes to Industry 4.0, it is possible to protect data communication not reducing the performance with the help of special encryption/decryption devices. Their logic lies in data encryption and IP address change at appropriate intervals. Such a system is widely used when transferring secret or confidential data, for example among military formations, network stations of election committees, etc.

## CONCLUSIONS

Classification of networks, their topology, software and hardware implementation means have been examined. The issues related to the "Internet" computer network use have been examined in more detail: its features, services, possibilities. The issues of computer networking in the form of multilevel hierarchical structure that forms methodical basis of modern informational systems have also been outlined. An analogy of using computer networks in terms of their application within Industry 4.0 has been drawn. They have been divided into levels which are expedient to be used within enterprises, corporations, etc.

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