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Modern Internet Based Production Technology

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1. Introduction

Recent a globalisation of technology and economics world causes that possibility for Internet applications are moved from off-line data processing to on-line data streaming. Internet is often becoming a part of real production processes that thanks to Internet can grow into more efficient and better distributed. A typical example of an implementation of modern production technologies using modern information and communication technologies (ICTs) can be a company with headquarters in one country but having chain of production sites all over the other countries. Internet in this case can be used not only for data transfer from e.g. economics, management, logistics and marketing, but also for data flow regarded to quality of production, failures and others. It enables to achieve recent information about technology used. Moreover, it allows interfering with production system, e.g. in case of need it is possible to actively interact into production system.

2. Modern production topology – recent development and future directions

Higher demands on quality growth and productivity of production processes lead to necessity of integration within information and control systems. It tackles whole production system from top management to the most modern technology, sensor systems and integrated production unit. This is called also Computer Integrated Manufacturing (CIM). In order to create CIM, to provide only simple connection of the all technical devices using communication interfaces to connect them mutually is not sufficient. However, it is necessary to compose reasonable control and information architecture. In general the architecture is divided into 4 levels based on 4R principle as it is displayed on Fig. 1 (Yang et al., 2002).

The principle of 4R is an abbreviation of 4 particular levels of the information pyramid: *Response time, Resolution, Reliability and Reparability.*
Response time.

In direction to top part of the information architecture requirements on fast time response decrease. While on the level of sensors and activators it is necessary to update the information in milliseconds, on the level of management the average update made in hours is sufficient.

Resolution.

It covers level of data abstraction that occurs on each of the levels of the information pyramid. The highest level of the pyramid, management and planning, works with the most abstract data.

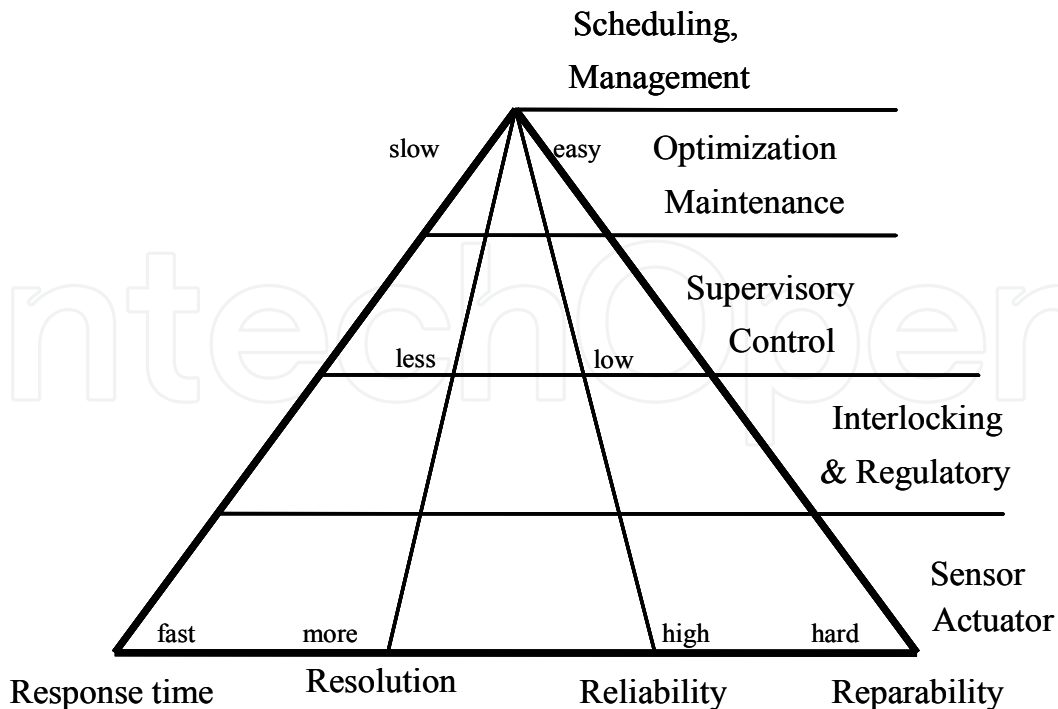


Fig. 1. An information pyramid

Reliability.

In direction of top to basis of the information pyramid, not only the requirements for fast time response of the system are decreasing. Also the requirements on reliability of system decrease. For example in case of computer blackout on the level of management and planning, system can be safely turned off in the time interval of hours but even days with slight loss only. However, if the network blackout occurs for few minutes on the level of control and/or on lower level, this can lead to breakdown, emergency situation and/or blackout of the entire production system.

Reparability.

This term describes the ordinary process to conduct the repairs and maintenance of computer devices on the particular levels of information pyramid. Technical devices on the level of the production line are mostly more complicated from the maintenance and repair point of view that those applied on the level of management and planning.

2.1 Internet applications in production technologies

For technical design of the information pyramid it is necessary to use provide appropriate type of the communication bus besides the particular technical and information devices with suitable communication inputs and outputs.

2.1.1 Strong and weak points of Internet usage

An analysis of strong and weak points of Internet as bus that connects particular levels of information pyramid can be seen in Table 1.

From the analysis in the table above the text it can be concluded that in the technological production chain it is possible to use Internet as bus for data (data bus line).

The most significant problem that occurs is the need of data flow in real-time especially in case of transferred data have transfer time period shorter than hundreds of milliseconds. It

occurs due to fact that the delay in data transfer via network can fluctuate from few milliseconds to hundreds of milliseconds. In case of periodic data transfer with periodicity of higher than few seconds this problem can be neglected.

Existing information level	Information exchange	Strong points	Weak points
Management level	System of commercial data	Enables to share and exchange information between management and clients /customers/	Not suitable for real-time monitoring and control
Level of plant-wide optimization	Global database	Enables to gather information about processes in the company easier	Not suitable for real-time monitoring and control
Level of supervisor	Process database	More comfortable to reach the real-time control, suitable for extended control implementation	Does not dispose with information from management
Level of regulation	PLC, control units	Enables connection of control units directly to Internet	High risk in case of hackers' attacks
Level of sensors and actuators	Intelligent devices	Possibility of direct monitoring and control of intelligent devices via Internet	High risk in case of hackers' attacks, high demands on speed and security of connection

Table 1. Options of interconnection of control levels via Internet

Another, relatively recent issue in this field is the security of the transfer, authorized access to information (Tomčík & Tomčíková, 2008). In case of the connection of technological production devices to global network - Internet (not only on isolated LAN network) there is a danger of unauthorized access. Therefore, people not authorized to have an access to the data could reach information not for their usage.

In spite of the mentioned problems, the advantages that Internet offers are far more dominant than the disadvantages.

One of the most important advantages is the possibility of huge distance data exchange. Internet is the most wide-spread computer network and it enables users to connect to it from any place on the world. Nowadays, speed of Internet connection is so advanced that the data transfer delay between two continents is hundreds of milliseconds. Because of the fact that Internet is generated by license-free protocols, its usage is very strong and economically lucrative tool in process of data transfer.

Another strong advantage of Internet is its versatility and availability of Internet protocols that are applicable as for small closed networks as for large-scale networks. Hence, it is possible to find application for the same data acquisition chain and control process for technologies in distance of meters or thousands of kilometres (theoretically it can be applied for unlimited distances). However, it had to be taken into an account that longer the distance, higher the data transfer delay and also greater the uncertainty, unpredicted fluctuations in timing of data transfer).

One of the advantages is the number of nodes connectable to the network. While in case of the other bus types the number of the nodes that are able to be connected is limited, e.g. for RS-232, Profibus, MPI and others where the number of nodes is ranging from 32 to 128 depending on the bus type, in case of Internet the number of nodes is restricted with number of IP addresses. When the Ipv4 (Internet Protocol version 4) protocol is used, theoretically 2^{32} addresses can be created and therefore, 4. 10^9 nodes can be connected. In the case of IP protocol of newer generation, e.g. IPv6 it is possible to use 2^{128} addresses, which enables to connect more than $3 \cdot 10^{38}$ devices to the network. Therefore, Internet has no competition in the situation when it is necessary to connect higher number of devices to one bus.

One of the practical advantages is the transmission capacity of the Internet. Most of the local networks nowadays operate with data transfer rate of 10Mb/s or 100Mb/s, respectively. However, in case of higher bitrate demands, it can be increased to reach value of bus data transfer rate up to 10Gb/s.

Last advantage to be mentioned, but not the last one in general, is the independence on the type of the transmission medium. It means that data can be transmitted no matter the type of the transmission is using wire-based or wireless connection or even using the combination of both. When the system for control and monitoring production technology is developed based on the Internet, it can be equally reliably functioning with no regards on the type of the transmission channel. The condition is that data transfer rate of the slowest way of connection was sufficient to requirements of the control system. This advantageous feature of the Internet in case of both types of buses is very complex and difficult for realisation. In this way control system based on the Internet can be fully adjustable to the environment, in which it is implemented.

Nowadays, Ethernet communication is a worldwide standard. Therefore, many of technical devices produced recently have already the interface for network connection integrated. It enables direct communication via Internet with central control system without need of the indirect connection to computer.

2.1.2 Methods of application of Internet into production technologies

There are several architectures that can be applied in the technological chain based on Internet. To answer the question which of the architectures is the most suitable depends on the particular situation.

Regarding the connection of particular device to control and information technological network 2 main ways of connection can be distinguished:

- indirect connection - using PC (Fig. 2)
- direct connection - without using PC (Fig. 3)

In case of indirect connection is the Internet connection realized by local computer that communicates with technical device via interface, e.g. RS-232, LPT, USB and others. Local computer is functioning as converter of the interfaces. It also can carry function of security firewall that controls authorization of the particular access to data, enables data encryption, data compression, filtration or pre-processing of data. It can serve as database of history of the processed data. In case it is required, it is possible to connect several devices to one node in the same moment while computer has function of multiplexer. Indirect connection is preferred mostly in controlling of devices on greater distances.

Second type of the connection requires that there is interface for direct connection to network implemented in the technical device. Except of the various programmable logic controllers (PLC), oscilloscopes and other multifunction devices, there are nowadays also intelligent sensors equipped with this interface.

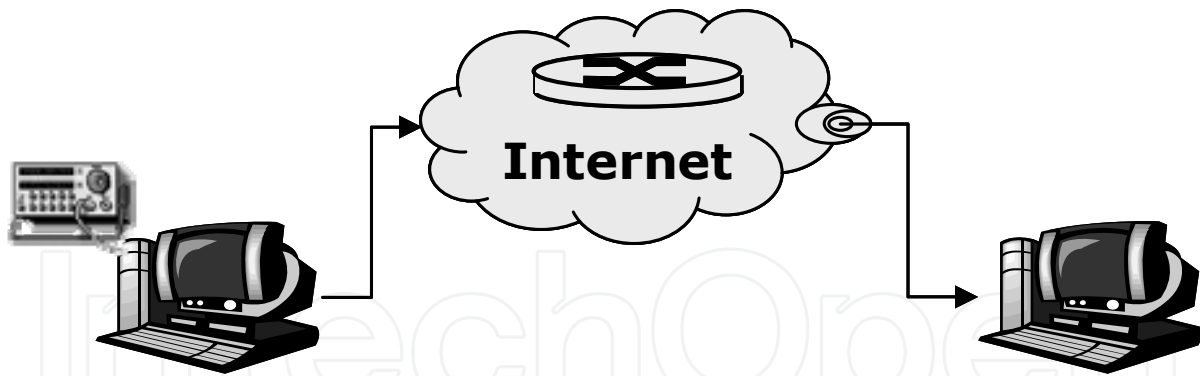


Fig. 2. Indirect connection to Internet

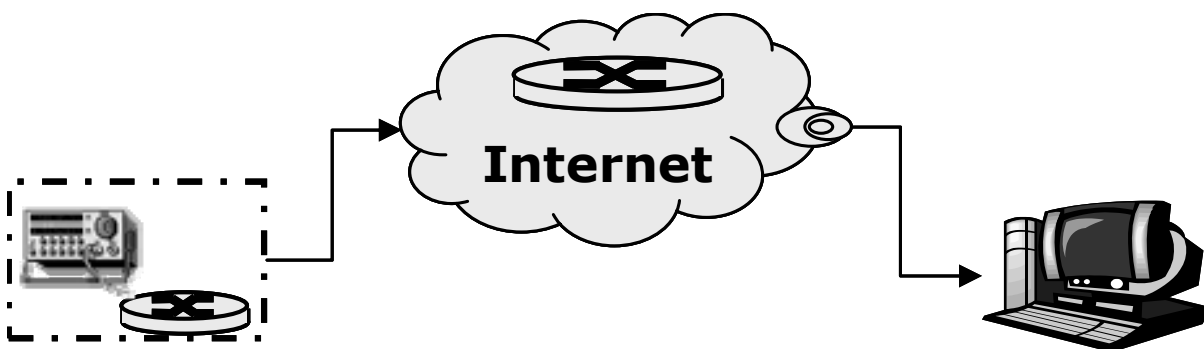


Fig. 3. Direct connection to Internet

The most important advantage of this type of connection is no need of another computer included in the control chain. In many devices there is next to hardware interface also software interface implemented. For example it is web server, ftp server, OPC server and others. Direct connection is financially and spatially not demanding, also technically less difficult to operate for end user. It is more suitable for distant control of systems in the LAN networks (for shorter distances).

According to the interaction between (client and server) computer and controlled device we can classify:

a) Device in the role of server (Fig. 4)

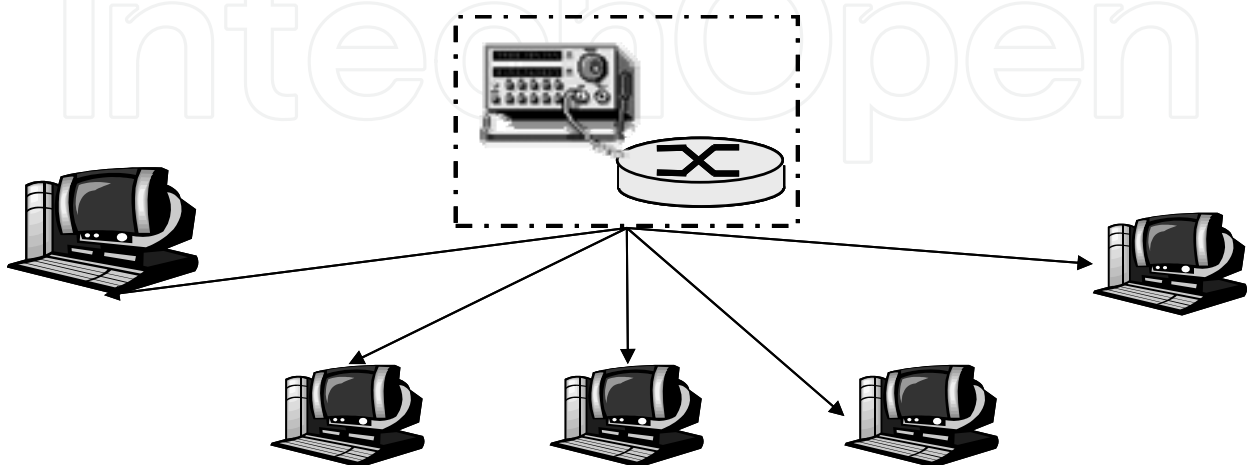


Fig. 4. Device works as server

b) Device in the role of client (Fig. 5)

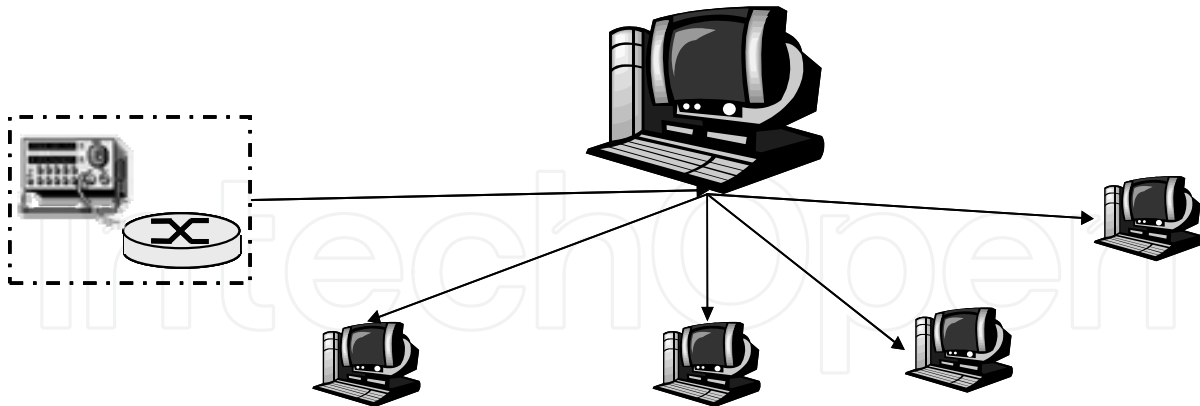


Fig. 5. Device works as client

When device has function is the server, all the computers that require technical data connect to this device that is sending required data using multicast messages (from on or several sources the message is sent to several targets). The biggest advantage of this architecture is that it is not necessary to have powerful server and users have the most recent updated information. This type of the architecture is suitable especially for decentralized systems. A disadvantage is that the faster data transfer is necessary on the line on which the device is connected and it is also higher intelligence of device necessary in order to manage and fulfil several tasks in the same moment. Other disadvantage is the time of the response that can vary depending on the number of the requests.

When device has a function of the client, there are data required that are transferred to one computer, which provides the further distribution on demand. In case of this architecture it is necessary to have computer in role of server. However, there are not high requirements on data link transfer rate, on which technical devices are connected to (because the data are provided to one target). Thanks to written about system has relatively constant time response. Server provides better security and data administration. This type of architecture is suitable for centralized systems.

2.2 Computer network

Computer network creates a connection of several computers, technical devices and nodes of the network. It enables transfer of the information among of them. There are various types of networks: Token Ring, Novell, Ethernet etc. Interconnecting those particular local networks composes Internet.

2.2.1 Network layers classification

In consequence of the fact it would be practical if several devices from different producers can communicate with each other via Internet connection and it would be necessary to create certain communication standard. With intention to build up structured communication model in computer networks, an international organisation ISO (International Organization for Standardization) established system OSI/RM (Open Systems Interconnection Reference Model). The aim of the OSI/RM was to design how the different parts of the network communication system should cooperate and interact. This model determines what is necessary to do generally, not what has to be done particularly during

realization of the tasks. Model OSI divides communication services to 7 categories. Generally, system OSI/RM creates a complete model with 7 layers of network communication (Seven-Layer Model - SLM):

1. Application layer - consists of a set of the different protocols for upper level of application, specifies background in which network application communicate with network services as electronic mail, file transfer, connecting distant terminals and others.

2. Presentation layer - it is also theoretical and not used widely. It is devoted to semantics of particular bits and controls formatting of the data transfer. It consists of specification for encryption and decryption of symbols' sets. It enables communication of computers with different internal representation. This layer is the most suitable for occasional implementation of cryptography.

3. Relation layer - is the most spread transport layer. It provides services that control data and synchronization. It processes errors of transmission and transfer and stores reports about the transfers made. This layer is purely theoretical and it is used only exceptionally and with few applications. The set of Internet protocols does not support this layer.

4. Transport layer - provides functions for creating particular connections, initialize data transfer and release the connection after end of the transfer. It does not deal with lost messages. Transport layer ensures reliable network services. It divides the message (from relation layer) to smaller particles (packets) and match them sequence numbers (for purposes of repeatable composition of the message) and send it over. The most used protocols of transport layer are protocol X.25 and protocol IP. In case IP protocol the packets must be repeatedly put in order according to the sequence because it could happen that due to delayed of the packets the order of them could change.

5. Network layer - is devoted transferring of the packets. It describes processes that divide data into network addresses and control whether the messages were send entirely and in time. Network layer finds the best path for sending the packet, it is described as process called routing, and that can be rather complexion large network as Internet. There are several types of routing: short or fast (it means whether the packet will go to the shortest or the fastest way), static or dynamic routing and others. The most used protocols at the secure transfer connection are X.25 (contact oriented - example of fax line) or IP (contract-free oriented).

6. Contact layer - is correcting errors that occur in physical layer, describes processes that detect and correct errors on the level of data during data transfer between physical and layer and layers above physical layer. It configures bits into the frames and controls its correct transfer. Contact layer adds certain bits plus called check sum in each frame. On the side of the receiver the check sum is verified whether damage of the frame occurred during the transfer. If check sum does not match, contact layer requires a retransmission of packet. It sends control message to the source of the damaged packet. Contact layer consists of sublayers:

Logic Link Control (LLC) - defines how the data are transferred using medium and provides services of data connection to higher layers.

Medium Access Control (MAC) - defines who can use the line where there are several computers attempting to connect in the same time (for example Token passing, Ethernet [CSMA/CD] etc.).

7. Physical layer - is aimed to transfer the particular bits, it describes electrical, mechanical and functional requirements on processing transfer data. It characterizes processes that control data as bits passing through the hardware. There are topics of voltage levels of logic zero and logic one, transfer bitrate, one-way and two-way transfer, protocols of data transmission (for example X.21, RS-232 for serial communication and others), topics solved

on the level of physical layer. Because of the fact that relation and presentation layer are only theoretical and they are used not very frequently, we will focus more on the 5 layers (5-layer model). The activity of the particular layers is displayed on Fig. 6.

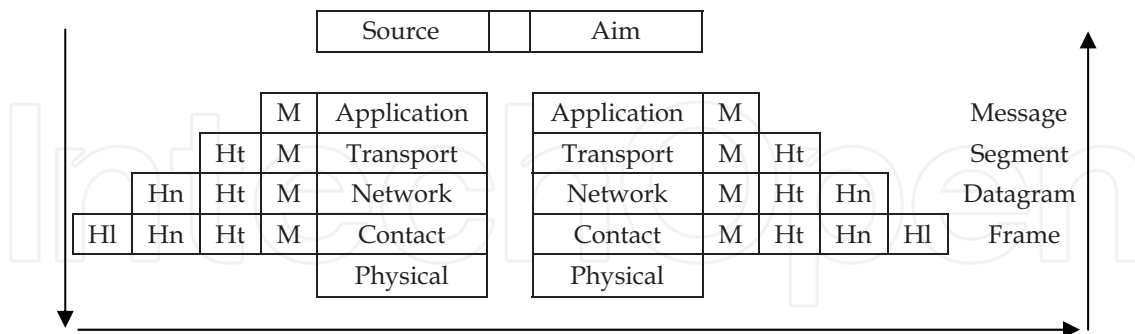


Fig. 6. Activities of the particular layers OSI/RM

Message is sent from the application layer of the source to the transport layer. In the transport layer the message is divided into the segments of appropriate size and each part of the message will be matched with Transport layer Head (Ht) by transport layer. This is the process how segment is made. Segment is removed to network layer. In the network layer the most optimal route to send the message is selected according to the target address, this calls routing. In the network layer the Net layer Head (Hn) is added to segment in order to create datagram. Datagram is moved from the network layer to contact layer, where Link layer Head (Hl) is paired with datagram in order to create frame. Frame is decomposed into particular bits, which are transported with physical layer using suitable medium (coaxial, optical fibre or using microwaves). After the frame is transported to the target, message M is forwarded from physical layer back to application layer by inverse functions. It means integrity of transferred frame is inspected, instead of the decomposition the message is recomposed once again. In each layer head is removed and information is passed to higher level. For example in the transport layer net layer head is removed from the particular segments. They are composed into one compact message and then the message is send to application layer. Application layer transmit the message to particular application for further processing (Tanenbaum, 2003).

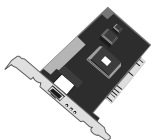
2.2.2 Network components

For exact and reliable functioning of the network, there are besides the transfer medium and computers also large number of other components included in the computer network. Correct recognition and application of these components and these features allows composing better computer network. Because Internet as global network made by local networks, it means it is necessary to take into the account communication requirements of other types of networks with their different structure and topology.

The network includes these components from physical point of view:

- nods
- transfer routes

Basic nods of network



Network adapter – it is an interface between computer's motherboard and transfer medium. Each technical device connected to network must dispose with appropriate network adapter.



Repeater - 2-port electronic device that reproduces only what it receives on input port into the output port. It is used for instance when the data are transported on bigger distances.



Bridge - more sophisticated repeater with option to filter the packets (it is disposing with contact layer - OSI level 2). It means that except of the sending packets from one port to the other, it enables to inspect the packets and allows transporting only undamaged packets (frames). In case of damaged packets bridge send a request to source of damaged packets to send the undamaged packet.



Hub - is a multiport repeater.



Switch - is a multiport bridge.



Router - connects two or more networks (also different types of networks), conducts references with appropriate "routing" information. It operates on the level of network layer (OSI level 3). It has to include wide range of information about internal network (routing table). It is usually used in distant networks that interconnect networks with different communication protocols. Router stores the routing table, routes between the nodes and it is able to select optimal route for data transfer. If the error occurs in one-way data transfer, it will try to find an alternative. There are static and dynamic routers. Static router includes table of directions that is static. Only network administrator can change it, e.g. when the structure or network topology is changed. Dynamic router can find on its own how the particular branches of the network loaded and adjust the table of directions in order to send packets in the most optimal (fastest) route.



Gateway - similarly as the router, it connects two networks of different type. It can operate on OSI level higher than 3rd. It enables to convert instruction file of the sending network to corresponding instruction file of the receiving network. These instructions about the way of data processing are required by some of the network systems, mostly mainframe and minicomputer systems. For example gateway converts the request for accepting the file form the connected computers into the command that is readable by mainframe computer. In praxis for gateway can be computer with more network cards where each card serves for different type of the network. It also can provide function of bridge and router.

Data flow routes

Data can be transferred by three main ways:

- telephone line
- wired media
- wireless media

Telephone line

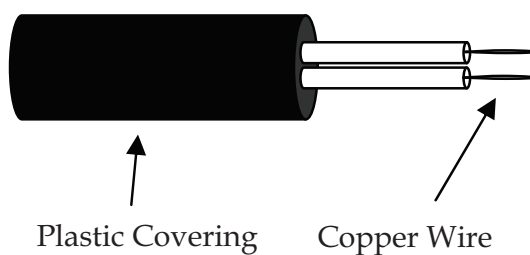
It belongs to the oldest way to connect computer to network. In spite of this way of connection is still wide spread and used, it is slowly in regression. There are several types of the telephone connection. The most wide-spread are following:

Classic modem connection - direct connection on router using telephone modem. The data transfer rate is up to 56 Kbps (kilobits per second).

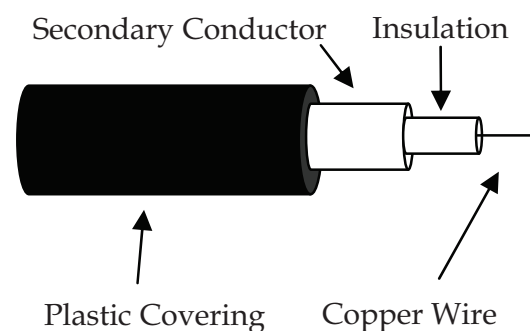
ISDN connection (Integrated Services Digital Network) - digital connection with router. The transfer rate can be up to 128Kbps for both-way digital connection.

ADSL connection (Asymmetric Digital Subscriber Line) - is asymmetric digital connection. It enables connection with bitrate 1Mbps in direction PC -> Router and bandwidth 8Mbps in direction Router -> PC.

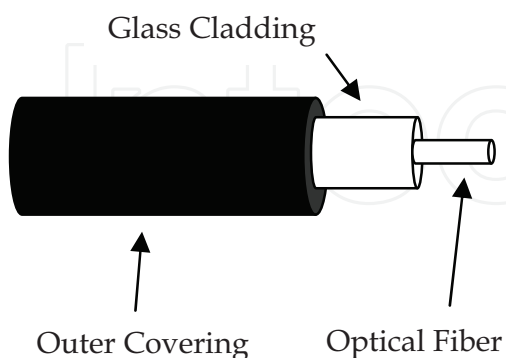
Wired media



Twisted pair: is used often in telephone wiring where several fibres are twisted together. Twist pair is characterized by low bitrate: 250 KHz and low relation of signal and noise. It can cause signal skip, which results to low data rate. This type of the medium is suitable for short distance communication. Therefore, they are used especially in the LAN networks.



Coaxial cable: is used especially in LAN networks. It is simple central line surrounded round isolation layer and conductive shadow. In comparison of twisted line wire coaxial cable has higher data rate: up to 400 MHz, higher quality of transfer (higher relation of signal and noise distance) and maximal bandwidth - 100 Mbit/s. When higher frequencies are reached, loss of signal can occur.



Optical cable: is suitable for high quality and high-speed data transfer. Optical impulses are used for transfer of particular bits instead of the electrical impulses. This enables wide range of frequencies (20,000 MHz) and data rate: 400 Mbit/s and more. Optical cable is used for intercontinental lines. It becomes more and more often popular connection for LAN networks. Extremely low noise and very problematic tapping the line (high level of security) increases advantages of this medium. Main recent disadvantage is relatively high costs.

In project 802 IEEE the specification for cables for transferring Ethernet signals was established. IEEE - Institute of Electrical and Electronic Engineering is American organization that defines standards relating the networks and other areas. IEEE 802.x are probably the most known standards in the field of computer networks. There are series of the standards, recommendations and information documents related to computer networks

and communication. Names 10Base5, 10Base2, 10BaseT and 10BaseF (FOIRL [Fibre Optic Inter Repeater Link]) label thick coaxial, thin coaxial, unshielded twisted double line, cables with optical wire, respectively. Number "10" means Ethernet data transfer rate - 10Mbit/s. "Base" describes basic band, 1 communication channel for each cable. Last number was originally naming maximal length of cable in hundreds of meters. After implementation of codes 10BaseT and 10BaseF, the last letter is used to distinguish type of the wiring: T is used for twisted double line (twisted pair) and F indicates optical fibre (fibre-optic).

Table 2 shows names and characteristics of some selected medium types. Above-mentioned wiring (twisted pair, coaxial cable and optical fibre) belong to the most wide-spread and most often used.

Cable label	Type of medium	Maximal segment length	Maximal number of nodes
10Base5	Thick coaxial	500 m	100
10Base2	Thin coaxial	185 m	30
10BaseT	Twist pair	100 m	1024
10BaseF	Optical fibre	2.000 m	1024 k

Table 2. Table of features of wire medium

Wireless media

In case of the medium without line wire the signals are transferred using electromagnetic spectrum. To ensure the signal transfer there is no physical wire or cable used and the signal is transferred both-ways. The main disadvantages of the media without wire line are the effects related to electromagnetic field and signals: reflection, blocking the signal by objects, interference.

Nowadays, there are several ways of wire free line connection used. The basic types of the wireless connection are:

Shared microwave network - it connects router with end-users. Bitrate of particular channels is up to 54 Mbps.

Wireless local network- physical fibres are replaced by radio spectrum. Data rate e.g. in network Lucent Wavelan that can represent this type of wireless network is 10Mbps.

Wider wireless network - e.g. DCPD (Cellular Digital Packet Data) is wireless access to ISP (International Standardized Profile) connecting router via cellular network. Bitrate of this connection reached tenths of kbps.

Satellite connection - enables wireless connection in the channels up to 50 Mbps, or more channels with lower permeability. Final delay is maximally 270ms. The greatest advantage of satellite connection is that end-user does not need to be close to basis connected to network using cables, wires and in spite of it the connection can be made anywhere on the globe. Extremely high costs are the main disadvantage.

Nowadays, it is possible to reach relatively high speed of the data transfer using physical media. However, those higher transfer rate causes lower quality of transferred data. In case of the analogue image or sound transfer it can cause only graininess or noise, in case of packets it would mean devaluation of the whole packet if only one of the bit is changed within the packet. It would result to situation that when using high-speed data transfer, the ratio of number of successfully received packets and entire number of sent packets would decrease.

Therefore, very high data transfer rate can cause connection failure. It is very important to realize that transfer parameters from producer are conditional by "ideal conditions". To reach them is practically impossible in praxis. It is the reason why while designing the network it is necessary to take into the account relatively big difference between data transfer rate given from producer and real speeds that are reached in practical usage.

2.2.3 Internet protocols

Internet protocols are among the network communication protocols used worldwide the most. They are "open-system" protocols and they also are universal. They are used in the local (LAN) but also wide (WAN) networks and they can be applied as well as independently on the network type (Ethernet, Token Ring, etc.). They consist of complex of protocols, the most known and most often used are TCP (Transmission Control Protocol) and IP (Internet Protocol). They include not only protocols of lower layer as TCP a IP but also protocols of common applications as electronic mail, protocols for file transfer, hypertext data transfer and others.

First protocols were developed in half of seventies by DARPA (Defence Advanced Research Projects Agency). They were interested in the network based on the packets' exchange that enabled communication among various computer systems in the research agencies. With the aim to create heterogenic interconnection DARPA funded the research at Stanford University, Bolt, Beranek a Newman (BBN). As a result of this research was set of the Internet protocols finished at the end of seventies.

TCP/IP was later connected with Berkley Software Distribution (BSD) UNIX and since then it became a background on which Internet and World Wide Web are based on. Documentation of Internet protocols, including new and sophisticated protocols and their policies are specified in the technical documentation, technical reports called Request for Comments (RFC). They are reviewed and published by Internet community. Any improvement of protocols is then published in the new RFC.

Fig. 7 displays an overview of the most spread protocols classified according to the OSI reference model, depending on the OSI level, in which they operate.

Physical layer: on the level of physical layer there are not specified any protocols yet. Transfer of particular bits is purely task of the network layer and transfer media.

Contact layer: on the contact layer there are mainly 2 protocols active: ARP and RARP. In order to ensure that 2 devices could communicate, the physical address of the paired devices has to be known (so called MAC address).

- Address Resolution Protocols (ARP) is a protocol that help host to find out MAC address corresponding the IP address. After accepting MAC address, IP device remembers temporarily and stores cache in order to avoid sending ARPs once again in case of restoring the connection. If the contacted device does not react for certain time interval, cache record is deleted.
- Reverse Address Resolution Protocols (RARP) has reverse function, finds IP address that correspondents with particular MAC address. RARP protocols represent logical inversion of ARP are used at workstations without disks that reply on RARP server with mapping table MAC-IP because they find out IP address while booting.

Network layer: disposes mainly with 3 protocols: ICMP, Routing protocols and IP protocol.

- ICMP protocol provides information packets back to the source, reports about errors and other information related to the IP packets processing. Packets of protocol ICMP

are generated in several situations, including inaccessibility of the target, echo requirement and reply, diverting, time-out etc. The typical feature of the ICMP protocols is that if ICMP packet does not reach the target, other one is not generated in order to avoid an incomplete cycle of sending the packets.

OSI reference model

Application layer	FTP, Telnet, SMTP, SNMP, HTTP	NSF
Presentation layer		XDR
Session layer		RPC
Transport layer	TCP, UDP	
Network layer	IP, Routing Protocols, ICMP	
	ARP, RARP	
Datalink layer	not specified	
Physical layer		

Fig. 7. Overview of different protocols classified according to OSI model

- Routing protocols - routers inside the Internet are organized hierarchically. Routers used in the autonomous systems are called internal routers. The use Interior Gateway Protocols (IGPs), e.g. Routing Information Protocol (RIP). Routers that transfer information among autonomous systems are called external routers. External routers use for information exchange among autonomous systems Exterior Gateway Protocols (EGPs), e.g. Border Gateway Protocol (BGP).
- IP protocol - includes address information and some of the control information that enables alignment of the packets. IP is main protocol in complex of Internet protocols. Together with TCP protocol it presents main keystone of Internet protocols. IP has two primary functions: provide the most powerful delivery of datagram via computer network and provide a fragmentation and rebuilding datagram to support data connection with different Maximum Transmission Unit (MTU).

Transport layer: uses one of the most known Internet protocols TCP and UDP. These protocols play key role in the control and regulation processes via Internet. Both mentioned protocols, TCP and UDP, use the most known and most often used protocol IP for their operations. Protocol TCP transports data using TCP segments that are addresses to particular applications. Protocol UDP transports data using so called UDP datagram. Protocols TCP and UDP ensure connection between application running on distant computers. Difference between protocols TCP and UDP is in fact that protocol TCP is linking service, receiver confirms the received data. In case of data loss, loss of TCP segment, receiver requires resending the message. Protocol UDP transfers the data using datagram, sender sends datagram but is not interested in the information whether it was successfully received or not.

All the protocols of transport layer, including TCP and UDP, use IP protocol for their basic functions. IP is on itself not reliable protocol. It does not provide any guarantee that

datagram or packet will be successfully delivered. It happens that packet is lost or damaged, e.g. due to overload of the network. Also a situation that packets are not received in correct order can occur. For applications that require certain level of guarantee of successful delivery of undamaged packets, e.g. Telnet, Email and others, is the uncertainty of delivery unacceptable. These applications need the guarantee that sent data will reach target in initial, unchanged form. This reliability is assured using virtual circuit, when two applications based on TCP need to communicate with each other. In this circuit every data exchange is monitored between the particular applications. Receiver confirms sender that each message was received. Message that was sent and there was no delivery report about will be resent again.

- Fig. 8 displays particular fields of packet in TCP protocol. The meaning of the particular fields is following:

Source port is 16-bit number that indicates number of sender's port.

Target port is 16-bit number that indicates number of receiver's port.

Sequence number helps receiver to restore the received data from the segments in case they arrived not in initial order.

Acknowledgement code is byte that sender of the message expects as confirmation that packet was successfully received.

Data offset is number of 32-bits words in the header (place where data begin).

Reserve is made for usage in the future (recently it does not have any function).

Flag means control bits that are used e.g. when initializing the connection.

Window specifies size of window of sender (size of buffer that should be in disposition for incoming data).

Urgent is index that indicates the 1st urgent data byte in the packet.

Option specifies different TCP settings.

Data includes data from higher layer.

Header of TCP packet is mostly in size of 20 bytes. However, maximal size of header is up to 60 bytes.

TCP provides 5 key services: virtual circuit, managing input/output (I/O) applications, managing I/O networks, controlling flow and reliability of delivery.

Every time two applications need to communicate one with the other using protocol TCP, there is a virtual circuit created between them. If it is necessary to provide communication among more computers in the same time, there is virtual circuit created for each coupled pair of computers separately. Virtual circuit is basic for all other services provided based on TCP.

Source port		Target port	
Sequence number			
Acknowledgement number			
Data offset	Reserve	Flag	Window
Check sum		Urgent index	
Options			
Data			

Fig. 8. Fields of TCP packets

Applications communicate among each other sending data to local TCP that transfer data using virtual circuit on the other side where they are delivered to the target applications. TCP provides I/O buffer for applications. It enables them to send and receive data as fluent data flow. TCP converts data to individually monitored segments and it sends them using IP protocol of network layer.

TCP provides also managing I/O of network for IP, creating segments that can effectively flow through the IP network and particular segments repeatedly transfer to data flow appropriate for applications.

Different hosts in the network have different characteristics, including memory, width of network band, capability and other. For this reason not all the hosts are able to send data with the same data transfer rate and TCP have to be able to cope with those differences. TCP has to conduct all these services continuously without performing any activities from the side of applications.

TCP provides reliable transfer by monitoring of data that have been sent. TCP uses sequence numbers for monitoring of particular bytes of data, acknowledgement numbers in case of loss of any packet and acknowledgement numbers for own control of the data. All the services make protocol TCP robust transport protocol.

- UDP packet is displayed on Fig. 9.

Source	Target
Length of UDP	UDP control sum
Data	

Fig. 9. Fields of UDP packets

As it is visible from Fig. 9, packet UDP is much simpler in comparison with TCP packet. Protocol UDP is often named as simple interconnection of network layer (IP protocol) with higher layers, e.g. with application layer. UDP provides transfer services for applications that don't need to or cannot use services connection oriented services provided by TCP. The term connection oriented services is mutual dialogue of sender and receiver in data transfer. It is characterized by successful delivery of each one of the packets. UDP is the most used by applications that often send packets with updated information or in cases when it is not necessary to deliver each one of the packets.

At UDP protocol that sends UDP packets, immediately after sending protocol "forgets" the packet and does not care of it anymore. While TCP provides high level of reliability using virtual circuit, UDP offers high level of network performance (Hall, 2000).

Application layer: (together with Presentation and Relation layer) uses protocols to support particular application e.g. for applications of electronic mail, protocol SMTP and so on.

- Network File System (NFS) - distributed file system developed by Sun Microsystem for simplification of work with files on distant system.
- External Data Representation (XDR) - abstract (not depending on machines) syntax for data structures description. XDR was developed as part of NFS.
- Remote Procedure Call (RPC) - transparent mechanism. Using this mechanism one procedure called on one computer by program running on other computer. This mechanism provides simple way how to implement relation client-server.
- File Transfer Protocol (FTP) - is a protocol that allows user transfer of files from one computer to the other. For this purpose it is using protocols of lower layer of TCP/IP.

- Simple Mail Transfer Protocol (SMTP) – provides simple service of electronic mail. It is using protocol TCP for sending and receiving messages.
- Simple Network Management Protocol (SNMP) – is applied to control services of network management and data transfer connected to network management.
- Telnet – has ability of emulation of the terminal and enables log in from distant network.
- Hypertext Transfer Protocol (HTTP) – fast and object oriented protocol used mainly in World Wide Web (WWW). HTTP enables agreement between Web client and server.

2.2.4 Latency in network

Power of computer network is characterized by several existing and mutually interconnected parameters. One of parameters is latency in the network. Latency is time that is needed for transfer of the empty message (a packet without any data) between two computers. It is entire sum of the latency due to software of the sender, software of the receiver, latency of the access to the network and latency of the network transfer.

Other parameter is data transfer rate. It is a speed that data are transferred between sender and receiver via network. Size of the parameter is given in Bits/s.

Time required for transfer of packet then can be calculated:

$$MTT = L + ML/TS \quad (1)$$

where: MTT – message transfer time, L – latency, ML – message length, TS – transfer speed
Bandwidth is also very important parameter. Bandwidth is entire volume of the transfer that can be transported through the net. Maximal speed of data transfer can be then calculated:

$$MTS = BW * \log_2 (1 + (signal/noise)) \quad (2)$$

where: MTS – Maximal Transfer Speed, BW – Bandwidth of transfer medium

The maximal transfer speed calculated in this way is purely theoretical and it cannot be practically used. It can be regarded as higher limit for transfer speed of given network.

All the parameters describing power of the network show that the main disadvantage of Internet when the point of view is an application of Internet in the technological chain is latency. Certain latency occurs in every type of remote control (RS-232, Profibus and others). However, latency that occurs in Internet connection is very dynamic parameter that can change its value in wide range (from few milliseconds to seconds). While packet is passing through the network there are 4 types of latency in each nod:

- Latency that results from processing packet in the nod (control whether the packet arrived without damage and according to the target address forwarding to appropriate output channel),
- Latency due to queue (waiting while transmission line is occupied),
- Latency due to transfer (time from transmitting packet to medium),
- Latency due to dataflow (time that signal needs in order to change position from one to next nod using medium).

The greatest latency is caused by latency due to queuing that is becoming significant especially at more loaded networks. How the network is loaded it can be calculated:

$$TI = L * A / W \quad (3)$$

where: TI – Traffic Intensity, L – average length of network, A – average number of incoming packets, W – link bandwidth (bps).

When relation L^*A/RP is close to zero, latency from queuing is very small. If it reaches value 1, latency due to queuing increases exponentially. If the value is greater than 1, latency due to queuing is becoming “infinite”, as there are more packets incoming to the nod than it is able to process (Tanenbaum, 2003).

3. Modern production topology – future challenges

All mentioned circumstances are nowadays only a recent premise for designing future automated technological complexes that will be reconfigured via Internet (Fig. 10). The main advantage of such modern solutions is their adaptability and variability that will assure higher efficiency of production and competitiveness. Herewith, other activities connected to production process and its modifications can be also automated and so eliminate the subjective human factor that was responsible for performing mentioned activities.

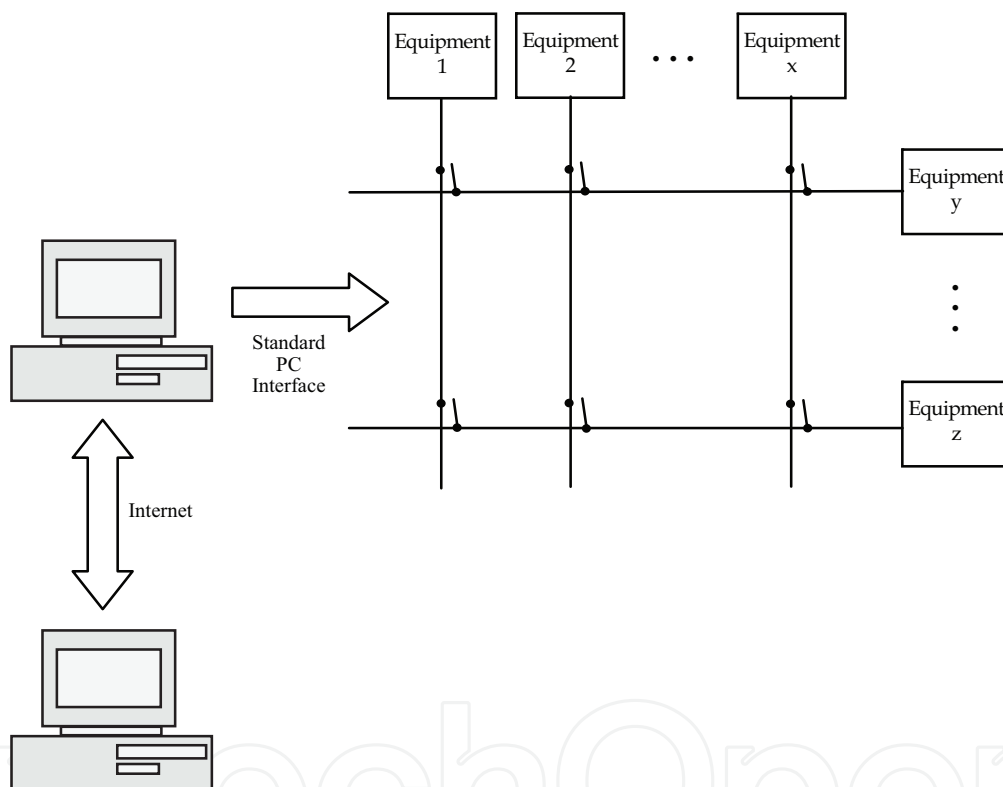


Fig. 10. Production line based on matrix topology and configurable via Internet

Basic assumption of the matrix production line configurable via Internet is fact that all or most of parts of production technology must be designed in advance and constructed as mobile or universal devices. In that case it is possible to control change of topology of production line, and so also production character and its quality and productivity via Internet. For this purpose it is possible to use reconfigurable mobile transport systems remotely controlled via Internet. If they exist, particular parts of the production line can be stationary.

There is detailed example of Virtual Measurement Laboratory (VML) realised on matrix topology basis. It is also the first workplace designed in this manner. It serves for expert measurements of various applications; at the moment Slovak patent application (Kováč et al., 2009) is pending. It is necessary to underline that VML (Fig. 11, Fig. 12, and Fig. 13) is not only a virtual workplace.



Fig. 11. Real part of VML

However, it is a real laboratory equipped with excellent measurement technologies based on above-mentioned principle of complexes that can be reconfigured via Internet. It is available for wide range of clients, users with no regard on their location and time. Due to these facts the expensive expert measuring systems enabled to utilize the equipment effectively and provide better access to technology. Therefore, this laboratory became a background for building a centre of excellence in the field of electrical engineering in the wide scope of application.

Work with the system starts in program VM LAB, in which user chooses in the roll-down menu "Type of element" from the catalogue of devices (those that are available in given laboratory). After selecting device user places it on the right side of the window of the program. After selecting all the devices that user is planning to work with and the ones that user wants to use for measurements. Then these devices are connected according to the electric circuit designed by user. In order to compose this circuit, user can choose all necessary components from the catalogue, e.g. cable, crossing, nod etc. in this way user can create scheme of electrical circuit that user has intention to perform practical measurement. In the moment user finished editing of circuit topology, user can send it to server using main menu. After connection with server, server accepts the request and interconnects particular measuring system according to the circuit scheme designed by user. If this is finished, left lower part of the program window becomes accessible for user. There user can change settings for required parameters of particular sources used in the measurement system in order to be able to modify parameters of the circuit according to user's ideas and the technical description of the devices. Output measured parameters are displayed in form of the graphical output as it is displayed on the particular measured instrument.

Real-time work with system is finished in the moment user disconnect from server and closing the program VM LAB, in case of working in off-line mode. User can save all edited schemes on disk of computer for purpose of the future use.

Design of measuring system begins in the program VM Lab developed at department of Theoretical Electrical Engineering and Electrical Measurement, Technical University of Kosice (Fig. 12). Left part of the program window serves for selection of component from the catalogue. The component is then added to designed system as part of it, e.g. direct current or alternating current power source, resistance, coil, voltmeter etc. After selecting category of the component, program offers user list of the components from selected type

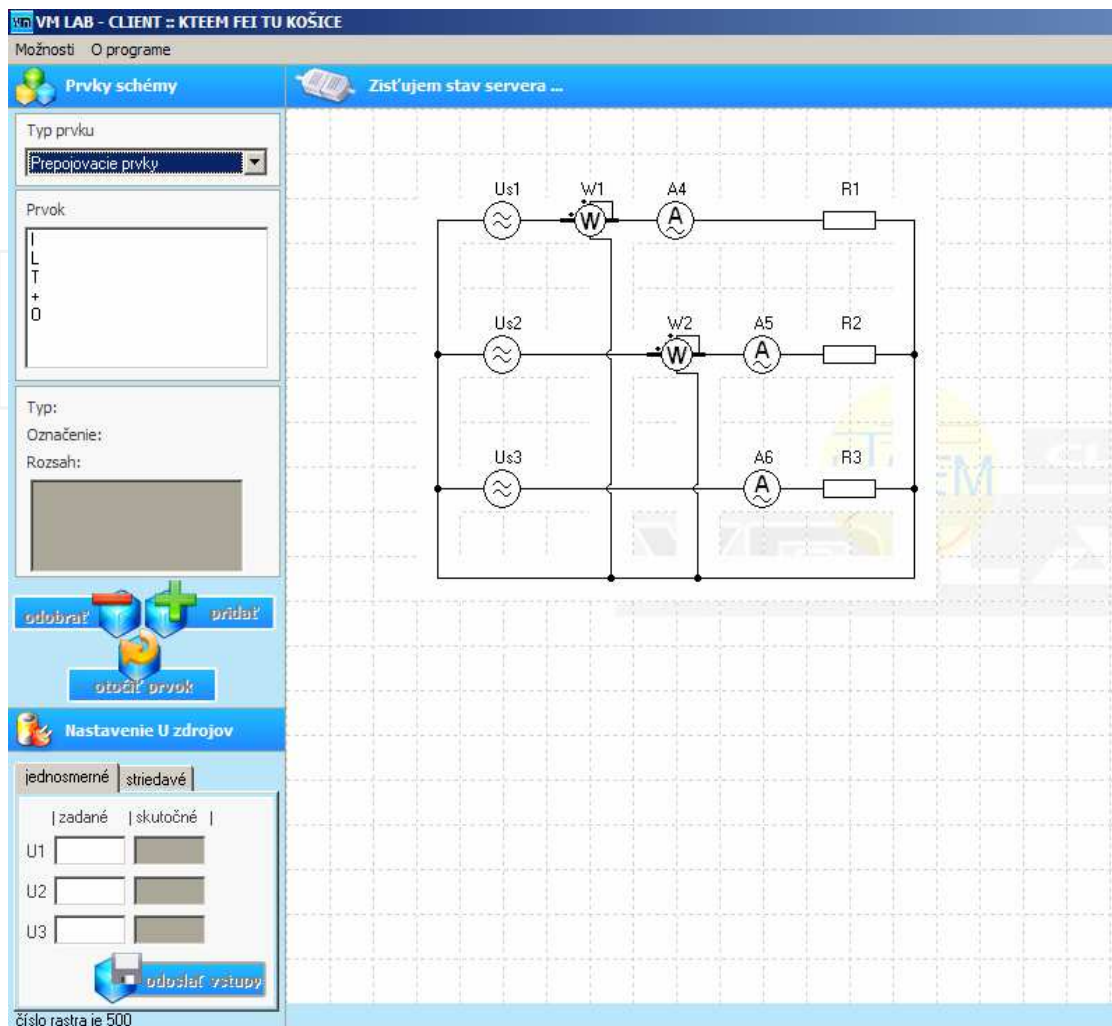


Fig. 12. Virtual part of VML

including the parameter's description. For example, if the selected component is resistance, then program will offer certain number of different resistances with their parameters and additional information, e.g. value of resistance, dimensioning power, technological form (ceramic, resistance wire etc.). If the selected resistance meets requirements, user will add it to right side of the program window. After all the components are selected, user connects them with lines. In this way the entire system is designed. For example Fig. 12 shows Aron's set/up for three-phase power measurement. After the scheme of the circuit is created, program connects to the server where there is real hardware as a part of the measurement laboratory (Fig. 11). In this way all selected components are physically interconnected according to the design in the program VM Lab. In this moment it is possible to change the input settings for adjustable sources and to see values achieved from measuring devices. Designed measurement circuit can be saved into the files and they can be later reloaded in case of need. In this way it is possible to create whole library with the circuits and edit schemes that have already been created.

It is necessary to emphasize several important facts related to unique workplace:

- Program does not serve for simulating of measurement systems. Displayed output from measurements does not result from calculations but they are resulting from real measured data.

- Hardware does not work as switch between limited set of pre-defined connection but it enables creating any real circuits with components available in VML. Circuits can be created from any computer connected on Internet.

For these features developed system is unique.

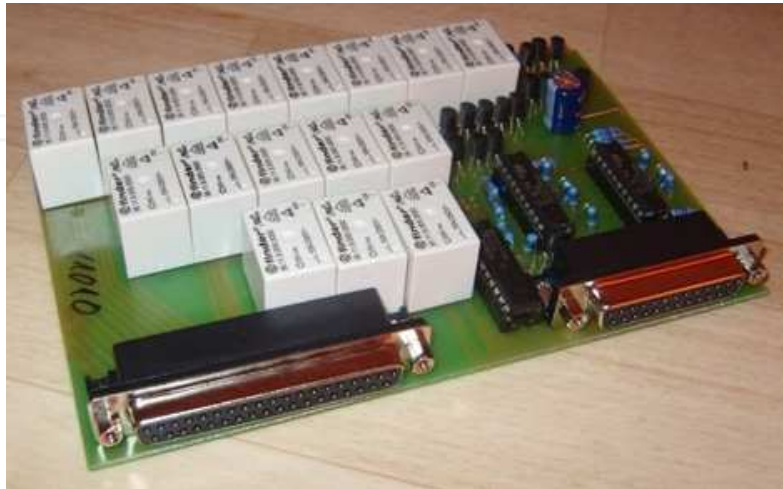


Fig. 13. Communication board

4. Conclusion

All the information included in the chapter can be implemented also in the area of manufacturing technologies. For this purpose it will be necessary, besides the modern technical devices, to provide also sufficient human resources. Design, realization and administration of these technologies will require wide multidisciplinary knowledge in the field production technologies, mechanical engineering, electrical engineering, automation, informatics, artificial intelligence, management and logistics, but also mathematics, physics, material engineering. Due to this fact their practical applications are not easy and they become a challenge for coming decades.

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