LESSON E6_EN. TCP/IP SUITE OF PROTOCOLS. UNDERSTANDING ISO /OSI REFERENCE COMMUNICATION MODEL. TCP / IP' FEATURES.

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After studying this lesson, you will acquire the following knowledge::

- The understanding of the models of Data communication stacks and layers.
- The understanding of the ISO OSI -Open System Interconnection Reference Model.
- The understanding of elements of the TCP/IP suite of protocols and of hosting of protocols on layers of the stack.
- The understanding of the fluxes of Data inside stack, the procedures of work with the Ports and Sockets. Other.

CONTENT OF THE LESSON

LEARNING OBJECTIVES:

After studying this lesson, you will acquire the abilities to:

- Work with the stacks and layers of the communication protocols,
- Know and apply (the knowledge about) the ISO OSI-Open System Interconnection Reference Model.
- Know and apply elements of the TCP/IP suite of protocols and the hosting of protocols in the TCP/IP stack.
- Know and apply the fluxes of Data inside stack, the work procedures with the Ports and Sockets. Others.
- Know essential standards in the field of System Interconnection.

1. UNDERSTANDING THE COMMUNICATION REFERENCE MODEL ISO / OSI.

1.) Main definitions and aspects.

Placing the Data Packets in the right format, on the network transmission media, supervising the network is a complex activity.
The preparation of the Data to be sent and the processing of the received Data are performed by the software programs of OS (Operating System) of the device / machine.

On the Internet the processing is achieved by the preparation and passing of Data through the 4 layers of the TCP / IP suite of protocols.

In parallel with the TCP/IP, the ISO/OSI model of communication was elaborated at the international level.

The communication models, such as TCP/IP and ISO/OSI, define the functions of each layer, the rules and sequences for processing the Data on the emission and the reception.

Despite the fact that the ISO/OSI model of communication has not been applied (as an entirely practical model), it is still very important as a reference model.
The great majority of developments in Data Transmission refer to this ISO / OSI model.
The ISO/OSI model has become a universal tool for explaining and comparing different models and protocols in the digital transmission fields (including those related to the wireless applications).

Upon sending of the Data, the ISO/OSI communication model takes into consideration the essential targets of processing:

1. The Data must be sent toward a process of communication named protocol

2. The Protocol must prepare the Data of the application in order to be correct and compatible with the network.
In order to achieve this target, firstly, the Data is segmented into suitable Segments.

3. The resulting segmented Data must be encapsulated into Data structures which allow the identification of the Destination and of the Sources of the Data.
This Data structure may be a Data Packet or other structure.

4. The resulted Packets must be converted into serial bits to be transmitted through the physical media, which accept only serialized information.

5. The System must Control the Data fluxes, so as to avoid congestions of the network (the quantity of the Data to be transferred must not overpass the speed possibilities of the channel or of the involved devices).

At the reception of Data (of the Data Packets) the ISO/OSI process is reverse and takes into consideration:

1. The Control of the Data fluxes, in cooperation with the sending process, so as to avoid congestions

2. The mathematical checking of the received Data so as to detect alterations.

3. The request, when alterations are detected, to re-send the Data,. The control of the re-sent Data.

4. The re-assembly, using the segments, of the initial sent Message.

In order to systematize, in clear parts, the functions described by the protocols, the ISO /OSI communication model is divided into large hierarchic Building Blocks, named **layers**. The layers form one stack.

Each protocol is solved inside of one of the **layers**. Many protocols may be placed on the same **layer**.

Inside the **layers** software interfaces are at work, and they transfer the standardised Data between the correspondent **layers**.

The software packages, which support the protocols placed on the respective **layer**, work independently as software Building Blocks. These software Building Blocks are divided into other Sub- Building Blocks which solve the sub-functions of the respective **layer**.

The division of the communication model into precise and clear functions, functions to be accomplished by each of the protocols of each **layer**, has led to the separation, decoupling and isolation of the software Building Blocks.

The **layers**, organised, based on the very clearly established hierarchy and separate functions, into **stack of layers**, assure the processing of the Data to be sent and of the received Data.

On the Internet, the ISO /OSI complex communication model is not used, but the TCP/IP model.

Between ISO /OSI and TCP /IP suites of communication protocols there are similarities and differences.
- The ISO / OSI has become a theoretical communication reference model,
- TCP / IP has become the model that is successfully applied into practice, developed and used through the entire Internet, including the great part of the LANs – Local Area Networks.

2.) The model of Data communication:

- divides the functions of data processing related to the received and the sent Data Packages, respectively,
- collects the functions in the layers,
- lays out the layers in the hierarchy tower / stack.

The layers host software programs which process the Data Packages.
The software may be encapsulated in special hardware components.

The 2 lowest level layers of the OSI / ISO model:
- The Physical layer
- The Data Link Layer

may also include hardware elements.

Why was it necessary to develop the Layered Network Model ?
The Layered Network Model allows:

- The systematization, simplification, decoupling of functions and the reduction of the complexity of the Data processing,
- The application of **the separation principle and of the de-centralization principle.**
- The division of processes into small and clear parts.
- The activities on separate, decoupled, isolated Layers.
- The improvement of troubleshooting activities and actions.
- The creation of the standardized interfaces (between layers and between protocols).
- The possibilities to apply interoperable technology, responsive to control and assuring the visibility of the Data travel.
- The prevention of negative situations in which changes in one Layer generate changes in another Layer.
- The insurance of the clear presentation of processes and also of the conditions for teaching and learning in the field.
- The creation of the conditions for communication between different types of networks, software and hardware.

Each of the Layers solves a specific function of the respective level.

3.) The switched packets technology

In the case of the **packets switched technology**, the information which is transferred through the network is named:
- Data or Packet or Data Packet.

A Packet of Data is a logically (created based on rules and protocols) grouped unit of digital information.

This unit of digital information travels between the partner machines of the network (or networks such as Internet).

The Data Packet includes 2 parts:
- The control information Part,
- The Data part.

Among the elements of the Data Packet important for travel control there are:
- The Destination Address, that is, the address where the Data Packet must arrive.
- The Source Address, that is, the address of the sender of the Data Packet.

The final Data Packet for sending, that is the tram, is generated through the processing of information on the layers of the stack of the communication model.

4.) The Protocols.

The Data communication is possible only through the work based on precise rules.

The Protocol is an agreement which establishes a set of rules.

The protocol consists in a set of rules which determine the following:
- the transmission formats,
- the transmission conditions,
- the transmission sequences,
- the transmission control,
- other conditions,

Based on these, communication is possible on the network and inter-networks.

2. THE FUNCTIONS OF THE LAYERS OF THE ISO OSI COMMUNICATION MODEL.

1.) The communication models.
The generation process of the Data Packets is decomposed into functional phases / stages, corresponding to each protocol.
The layers with protocols are placed in hierarchical stack / town of layers including:
- the high level Layer, named of application,
- the intermediary Layers,
- the lowest level, named physical Layer.

The model works by the transfer of the Data, inside the stack, layer by layer:
- for the received Data, from the low layer to the top layer,
- for Data to be sent, from the top layer to the low layer.

2.) The ISO OSI model.

The ISO-International Standards Organization created, in the year 1984, the OSI - Open System Interconnect Reference Model. OSI signifies Open System Interconnection and is referred to as the Open System Interconnection Reference Model.

The ITU (International Telecommunication Union) has adopted OSI as Recommendation X.200.

The ISO / OSI communication model represents the internationally accepted standard for the communication reference models.

The ISO / OSI Open Systems Interconnection Reference Model describes the functions to be accomplished by each layer, so as to serve to the design, the implementation and the operation of the network.

The ISO / OSI model has a special theoretical importance.

The ISO / OSI model of data communication does not represent a collection of protocols which lead to the direct implementation of a specific network.

The ISO / OSI model is a framework and creates the general guidelines on how to achieve the specific protocols and standards of one category of networks (for each case).
The ISO OSI model is focused on the ways in which the transfer from one network node to other network node is managed.

The ISO / OSI Open Systems Interconnection Reference Model is a framework and creates the general guidelines on how to achieve the networks.

The ISO /OSI communication model is used:
- as a frame for the general reference to the mode of creation and use of the networks,
- as material for understanding the networks and networking concepts,
- as educational material.

The ISO / OSI Open Systems Interconnection Reference Model, a family of standards, defines the communication process as a set of 7 layers, placed in one stack.
Each layer has its own precise, separated and isolated functions.

The **model of communication** ISO / OSI, based on the division of processes of Data preparation in under-processes, placed in the stack of the hierarchical Layers, is illustrated in fig.2.1.

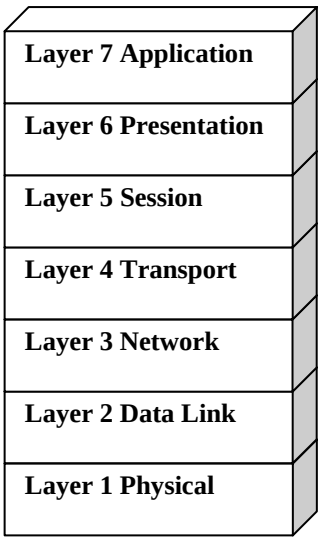

Fig. 2.1. The Layers of the stack of the ISO OSI communication model

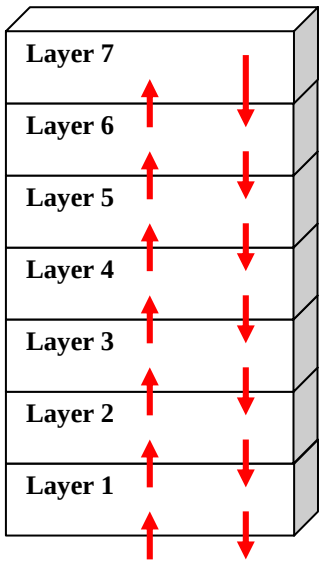

Fig. 2.2. The processing flux, from layer on receiving Data and on sending Data

The fluxes, inside the stack, for the processing of received Data and of the Data to be sent, are illustrated in the fig. 2.2.

The top level Layer in the stack is the Application Layer. The Application Layer deals with the high level aspects of the Data processing such as: the generation of communication session with another device, request of web pages etc.

The low level Layer is the Layer which physically transfers the Data to the network media (cables, optical cables, wireless communications etc).

Between the top Layer and the low level Layer there are intermediate layers, each with its clear precise functions.
The software hosted inside the Layer prepares and processes the Data for and from the network.

3.) Description of the functions of the ISO OSI Layers.

On the distribution of the functions on each Layer of the ISO/OSI layers it has been taken into consideration the fact that the following must be solved:

- **The ISO / OSI Layer1-Physical connection**: the connection to the media (cables etc), the binary serial transmission respectively.
  Layer 1 practically consists in the media of transmission and physical output elements towards this media.

- **The ISO / OSI Layer2-Data Link**: the preparation of the Data for the physical addressing inside the respective network.
  The Data Link Layer achieves:
  - The offering of the appropriate Data format in order to comply with the needs and the possibilities of Layer 1.
  - The serialized form of the Data Package, including procedures to correct transmission errors.
  - The assuring of the reliable delivery of Data.
  - The solving of the avoidance of transmission conflicts on the network.
  - Others.

  Because Layer 2, the Data Link Layer, is the point of contact with the physical media, the aspects related to this Layer are treated in the IEEE 802 family of Standards and includes:
  - reference to the sub-layer LLC- Logical Link Control: IEEE 802.1 and IEEE 802.2.
  - The LLC is active for the generation and the interpretation of commands related to the Data flow and the
  - correction of Data errors, and
  - reference to the sub-layer: treatment of the aspects related to the MAC- Media Access Control: IEEE 802.1, 802.3, 802.4, 802.5 and 802.12.
  - The MAC sub-layer solves the aspects related to the physical connections with the other machines from the same LAN network.

  The Standard IEEE 802.3., approached by the Data Link Layer includes the Standard 802.3 referring to the Ethernet.

  Therefore Layer 2 mainly deals with aspects related to:
  - **physical addresses and physical addressing**,
  - **flow control, and others**.

  Layer 2 uses the MAC Addresses (physical address burned inside the NIC – Network Interface Card).

- **The ISO / OSI Layer 3- Network**: the addressing between 2 devices connected to the network,
  The Network Layer solves the aspects related to the connectivity, such as:
  - the selection, based on the logical addresses (the virtual addresses such as the IP Address), of the logical (virtual) connection between the Source and the Destination (for instance between 2 devices placed in different networks).
  - the works of Layer 3 are focused on the creation of the conditions so that the Data Packet may navigate from Source to Destination, to respond to the routing requirements respectively.
  - others.

  For Layer 3 ITU protocols are defined, such as:
  - ITU X.25 **packet switching protocol**, which leads to the flow of Data under the form of Data Packets,
  - ITU X.75 Gateway protocol, which leads to the flow of Data between the networks.

- **The ISO / OSI Layer 4-Transport**: the assurance of the reliability and quality of transport of Data between 2 devices connected to the network, for instance 2 Hosts. The Transport Layer solves:
  - supervision and control of the transfer of Data.
  - achievement of the error controls, monitoring of the transmission sequences,
  - assurance of reliable End to End transmissions.
  - Others.

  The transport Layer is also responsible for the Quality of Service and reliability of communication (control and solving of errors etc).

- **The ISO / OSI Layer 5-Session**: the establishment, management and ending of the communication between 2 devices (hosts or other machines), connected to the network.

The Session Layer solves the management of the communication sessions:
- Handshaking (the establishment of the session of communication between 2 End to End machines):
  - The establishment and
  - The termination,
  - End to end data control,

  between 2 networking partners.
- Dialogue control and Security,
- Others.

- **The ISO / OSI Layer 6-Data Structure**: the establishment of the Data format, so that the Data are readable and re-constructed on reception. The Presentation Layer solves:
  - The sent messages are formatted (including the syntax) for Layer 5 Session Layer.
  - Conversion in the accepted format (by the Destination machine) on reception.
  - Possibly, ASCII to EBCDIC code conversions between
  - Data encryption/ decryption and
  - The received messages are formatted for Layer 7, Application Layer.
  - Others

- **The ISO / OSI Layer 7-Application**: the assurance of the conditions for the achievement of the respective service, such as sending mails or request of web pages etc. The Application Layer solves:
  The control of interfacing for essential high level functions such as file transfer, resource sharing etc.

* * *

The 7 layers of ISO / OSI model are divided into 2 groups:
- Top 3 Layers: 5, 6, 7 support the application, firstly.
- The bottom 4 Layers support the movement of Data from one network device to another network device.

Fig. 2.3. illustrates the correlations between the types of the ISO / OSI model, based on 7 Layers, with the Layers function classification in:
- Layers related to Network Protocols (3 layers: 1, 2 and 3).
- Layer related to the Transport protocol (1 layer: 4).
- Layers related to Application Protocols (3 Layers: 7, 6 and 5).

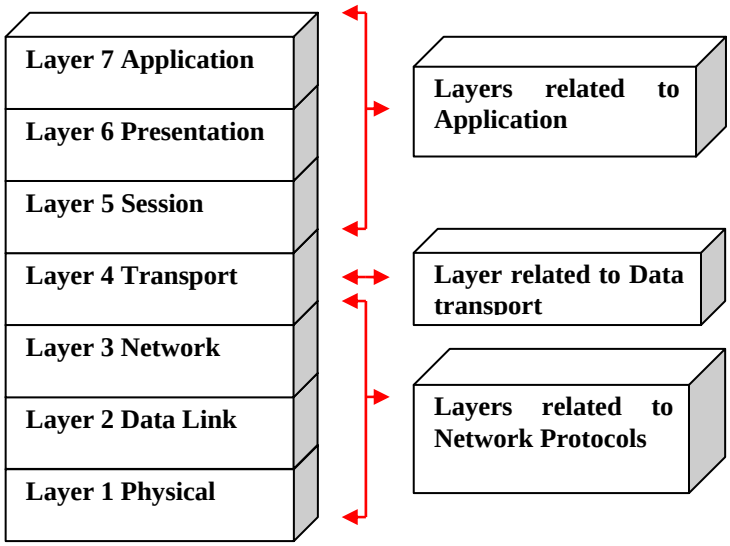

Fig. 2.3. The Layers of the ISO OSI stack

The connection between the Layers of the same rank of different devices.

Each layer (in ISO / OSI and also in TCP / IP) of a device communicates, cooperates and changes Data with the Layer of the equivalent rank of another device (despite the fact that, for this conversation, the Data pass through other inferior rank layers). This process bears the name Peer to Peer.

During this peer to peer conversation, the Data Packets travel from top to bottom, from the respective Layer, passing through inferior placed Layers of the same stack of Layers, and arrives at Layer 1 of the second stack of Layers. There, the Data ascend Layer by Layer up to the correspondent Layer, where they are passed on to the top Layer after processing.

This aspect is illustrated in fig. 2.4.

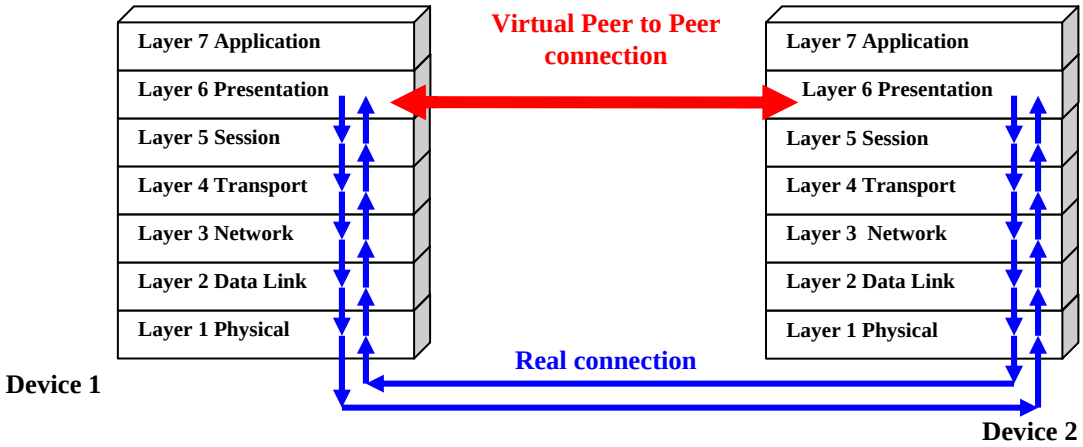

Fig. 2.4. The Peer to Peer conversation and connection

Despite the fact that Data travel through the Device 1, Layers 6,5,4,3,2,1, Device 2, Layers 1,2,3,4,5,6, **layers 6** of the Devices 1 and 2 **virtually** have a direct, Peer to Peer, conversation.

3. TCP/ IP. THE WINNER.

3.1. THE LARGE APPLICATIONS OF THE TCP / IP SUITE OF PROTOCOLS.

After you have learned about the ISO / OSI reference communication model and you have learned many practical components included in the TCP/IP suite of protocols, you will learn about the ensemble aspects of the TCP/IP suite of protocols.

The TCP / IP represents one suite of protocols of the related communication model.
The TCP/IP suite of protocols constitutes the base of the functioning of the Internet networks and of other types of networks.

Between TCP / IP communication model and ISO / OSI communication model there are many similarities.
TCP/IP is simpler, practically applied and assures the operation of Internet.

TCP / IP is today the winner of the competition between the different network protocols (including ISO /OSI).

The following are connected to the networks, sub-networks and inter-connected networks through TCP/IP:

- workstations,
- hosts,
- servers,
- routers,
- different devices such as:
  - home devices (refrigerators, cookers and other),
  - industrial devices (electrical motors drivers, elevators and others),
  - printers,
  - programmable systems,
- other equipments.

3.2. THE MAIN ADVANTAGES OF THE TCP / IP

Among the very important and positive features of the TCP/IP suite of protocols are:

1.).- Free and Open.
They are free and freely distributed standards. They are open Protocol standards. TCP/IP is not an owned suite of protocols. Because the TCP /IP is a free and open standard, it may be used by everybody.

2.).- Portability. Independence related to the type of hardware.
- The TCP/IP suite of protocols provides interoperable communication between mainly all types of hardware and all kinds of operating systems.
- TCP / IP is mainly applied **independently** from any specific computer hardware or physical network hardware.

- TCP / IP is mainly assuring the unified software interfaces with different types of hardware and software.
- TCP /IP creates the possibility of connection with devices which do not communicate over the Internet.

3.).- Universal support. The TCP /IP is running equally with the most widely applied operating system, including: UNIX, Linux, MS Windows, Novell and other.

4.). - Common addressing possibilities and scheme. The TCP/IP IP Addresses are unique regardless of where, in the entire world, these devices are placed.

5.). –The possibility of creation of networks of networks: the Internet.

6.). - Scalability and generalization. The possibility to be applied at different sizes and networks, from backbones, regional backbones to small rank networks etc. The following principles contribute to this important feature:

- **the SEPARATION PRINCIPLE,**
- **the DECENTRALIZATION PRINCIPLE,**
- **the NON-OWNERSHIP PRINCIPLE.**

Possibilities of separation (the entities involved in the Internet work in an independent mode), **isolation** and **rational segmentation.**

7.).- Adaptability. It includes protocols which can generally adapt to any process or function.

8.).- Offering of very efficient control and diagnosis tools for the network troubleshooting for network management.

9.)- Separation and cooperation between protocols.

10.).- Insurance of high reliability of transmission. The high reliability of transmissions is based on clear rules, controls, means of ensuring the correct Data reception, including the case of re-sending the Data Packets by mistake.

11.).- Insurance of efficiency and the diminishment of transmission costs. The assurance of the diminishment of the transmission costs, by using packets switching technology.

12.).-The adoption as successful protocol. The winner of networking standards.

13.).- The real, simplified and functioning application of the ISO OSI model (the TCP/IP was elaborated before ISO OSI model and uses a reduced number of layers.

14.) - Extensibility.

- Extensibility for new developments. The TC/P is extensible for new developments.
- Extensibility for new applications. The TCP / IP is used for different new applications. For instance TCP/IP has replaced the ownership standards in many LAN nets.

15.) - Interoperability: the possibility to work with different local networks, with different types of interfaces etc

16.) - Simplification of the communication procedures: Following the TCP/IP protocols and the game of IP addressing, all the equipment, regardless of type or supplier , may inter-communicate.

17.) - Others.

3.3. ESSENTIAL DEFINITIONS.

1.) The Message, in the TCP / IP, represents the Data on the output of the TCP/IP Layer 4, Application.

2.) The Segment, in the TCP / IP, represents the Data on the output of the TCP/IP Layer 3, Transport.

3.) The Datagram, in the TCP / IP, represents the Data on the output of the TCP/IP Layer 2, Internet.

4.) The Tram, in the TCP / IP, represents the Data on the output of the TCP/IP Layer 1, Access to the Physical Media, for instance of an Ethernet network.

5.) The Server is a software package (running on one equipment, for instance on a power PC or on another equipment), software which may be considered:

- as a resource for clients, or
- as a service to be shared by clients.

The Servers may be of different types:

- 5.1.) Web Servers: this is a software package which accepts requests from the clients (through the clients' browser).
- 5.2.) Web Applications Servers: a software package which allows remote collaboration, for instance in healthcare, financial services, advertising, entertainment etc.
- 5.3.) Commerce Servers, which allow the achievement of business over the Web and, possibly, the delivery of products through the Internet.
- 5.4.) File Servers share their disk space with other computers.
- 5.5.) Print Servers, used for printing services.
- 5.6.) Servers which achieve computing or other similar services.
- 5.7.) Servers which assist the network administration.
- 5.8.) DNS Servers, which store memory tables, for instance for addresses resolution: such as the equivalence between IP and DNS addresses.
- 5.9.) Other types of servers which store tables, for instance, inside LAN, the correspondence between the IP Addresses and the physical addresses etc.
- 5.10.) DHCP servers, which deliver to other machines the dynamic IP Addresses.
- 5.11.) Servers which supervise the network traffic and / or store the content of the traffic. For instance:
  - Servers which detect the spam's authors,
  - Servers which help the network diagnosis, such as for the protocol TCP/IP ICMP- Internet Control Message Protocol.
- 5.12.) Cache Servers. Servers that save the frequently accessed web pages (Normally frequently requested pages by clients). The saving is achieved in order to speed up the clients' access to these pages.
- 5.13.) Servers for other Internet services.
- 5.14.). Other types of Servers.

6.) The Browser (MS Internet Explorer, Netscape Communicator or others) is the software program which allows the Workstation or other device:

- the request of the Web objects,
- the interpretation of the texts arriving by the web through http protocol and communications, for instance the materials arriving in HTML language,
- the achievement of the hyper-connections,
- other functions.

7.) Packet Switching Network: a network based on the transmission of Data under the form of Data Packets.
The transmission based on the switched packets technology is an essential factor which has generated advantages such as:

- the lowering of costs of the Internet based communication and
- the improvement of the system reliability.

8.) Data Packets: are unitary configurations of processed Data, Data which are placed, in serialized form, on the physical communication media.

9.) The **socket** is the information formed from the couple: the IP address and the port number.

3.4. THE TCP/IP TOWER (STACK) OF LAYERS.

1.) TCP /IP and ISO OSI.
Despite the fact that the TCP/IP suite of protocols was developed before the elaboration of the ISO / OSI model, the TCP/IP protocol concepts comply, in many points, with the concepts of the ISO OSI.

From the TCP /IP suite of protocols, 2 protocols were firstly developed:

- the TCP protocol (connection oriented) and
- the IP protocol (non-connection oriented)

These are the elements which have generated the Internet network.

As you have learned above, the ISO OSI communication reference model has 7 layers grouped in:

- Application (3 Layers: Application Layer, Presentation Layer, Session Layer),
- Transport (1 Layer : Host to Host Layer),
- Network (1 Layer),
- Physical (2 Layers: Data Link Layer and Physical Layer).

Compared with the ISO OSI model, the **TCP/IP has only 4 Layers**, as illustrated in fig. 3.1.

The TCP/IP Layers are the following:

- **Layer 4: Application,** which consists in the applications that use the network, such as navigation, file transfer and others,
- **Layer 3: Transport,** which solves the End-to-End aspects of the data transmission and generates Data Segments,
- **Layer 2: Internet,** which defines the Datagrams and prepares the conditions, firstly the placement of the IP Addresses in the header of the Data Packet, in view of the future routing of Data toward the destination.
- **Layer 1, Network Access,** which solves the access at the physical levels, the communication inside the LAN respectively.

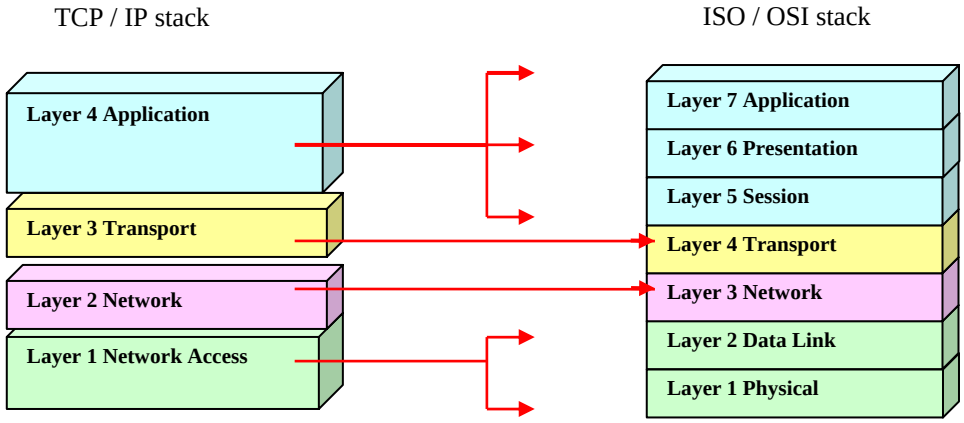

Fig. 3.1. Comparing the TCP/IP Model with the ISO /OSI model

As it is clear from fig. 3.1.above:

- Layer 1 of the TCP/IP protocols covers the functions of 2 Layers (1 and 2) from the ISO/OSI protocol.
- Also Layer 4 of the TCP/IP covers the functions of 3 Layers of the protocols.

The TCP/IP suite of protocols, following the above simplifications, generates robust, reliable and winning networking rules.

3.5. THE PLACES OF THE PROTOCOLS ON THE LAYERS OF ISO OSI MODEL AND THE CORRESPONDENCE WITH THE PRACTICAL TCP/IP PROTOCOLS.

The Data communication protocols for networking are divided into 3 classes:

- **Network Protocols,** focused on the preparation of network access,
- **Transport Protocol**s, focused on the preparation of the virtual End to End connection and the division of messages into Data segments,
- **Application Protocols**, focused on the achievement of complex functions such as navigation and others.

The following Table mainly indicates the placement of the different protocols, including the TCP /IP protocols, in correspondence with the ISO /OSI layers.

ISO OSI PROTO-COLS	THE ISO OSI LAYERS WHICH DEAL WITH THESE PROTO-COLS	Example of correspondent Protocols with the ISO
Network Protocols	ISO OSI Layers: 1,2,3,	1.1).- DLC (Data Link Control), used for the connection (through the net) with special devices (mainframe computers, HP printers), 1.2.). - TCP/IP member: IP (Internet Protocol) used for the achievement of addressing and routing. 1.3.).- Other Network protocols such as IPX (Internet Work Package Exchange) (Microsoft), NW Link (NetWare Link) (Novell), NetBEUI (NetBIOS Extended User Interface). Other protocols.
Transport protocol	ISO OSI Layers: 4	2.1.). - NetBIOS / NetBEUI (Network Basic Input / Output System) / (NetBIOS Extended User Interface) which manages communication between computers.

		2.2.). - SPX (Sequenced Packet Exchange), achieves, for the Novell NetWare network, similar functions with the protocol TCP and IPX. 2.3.). – TCP /IP member: **TCP (Transmission Control Protocol)**, assures reliable transport and delivery of the packets to the receiving devices. 2.4.) - TCP / IP member: **UDP (User Datagram Protocol)**, achieves the actions of transport and delivery of packets to the receiving devices, in the cases in which the reliability (for instance the lost part of information) has no high constrains or is accepted. UDP is one Protocol for the high speed service of the Datagram transfers. Other protocols.
Application Protocol	ISO OSI Layers: 7	3.1.) - TCP / IP member: **SMTP (Simple Mail Transfer Protocol),** used for transferring of e-mails. 3.2.) - TCP / IP member: **FTP (File transfer Protocol),** used for the transport of the files from one computer to another. 3.3.) - TCP / IP member: **SNMP (Simple Network Management Protocol)** used for the monitoring of the network. 3.4.) - TCP / IP member: **TELNET** used for remote action from one computer to another computer. Other protocols.

3.6. PROTOCOLS OF THE TCP / IP SUITE.

The TCP / IP suite of protocols includes a collection of services which are solved by protocols hosted in the specific layers and by cooperating with the protocols hosted in the inferior layers (of the respective stack / pile of layers).

The main protocols belonging to the suite of TCP/IP protocols are:

No. Cr.	**Abbreviation**	**Title**	**Belong to the type of TCP Layers:**
IV. GROUP: APPLICATION			
1	**DNS**	Domain Name System	Application
2	**FTP**	File Transfer Protocol	Application
3	**Telnet**	Explanation: Protocol for remote (through the network) work on other machine	Application
4	**SMTP**	Simple Mail Transfer Protocol	Application
5	**POP3**	Post Office Protocol	Application
7	**IMAP**	Internet Message Access Protocol	Application
8	**HTTP**	Hypertext Transfer Protocol	Application
III. GROUP: TRANSPORT			
	TCP	Transmission Control Protocol	Transport
	UDP	User Datagram Protocol	Transport
	ICMP	Internet Control Message Protocol	Transport
	DIAGNOSIS UTILITIES: PING, IPCONFIG, TRACERT, and other.	Tools for testing and diagnose the networks based on the TCP/IP protocols	Transport
II. GROUP: INTERNET			
	IP	Internet Protocol	Internet
	RIP	Routing Information Protocol	Internet
	ARP	Address Resolution Protocol	Internet
I. GROUP: NETWORK ACCESS			

	ODI/NDIS	Open Data-Link Interface / Network Driver-Interface	Network Access
	NIC driver	The Command of the NIC	Network Access
	OTHER PROTOCOLS	Other protocols	On the correspondent layer.

Fig. 3.2. illustrates the main protocols included in each TCP /IP layer.

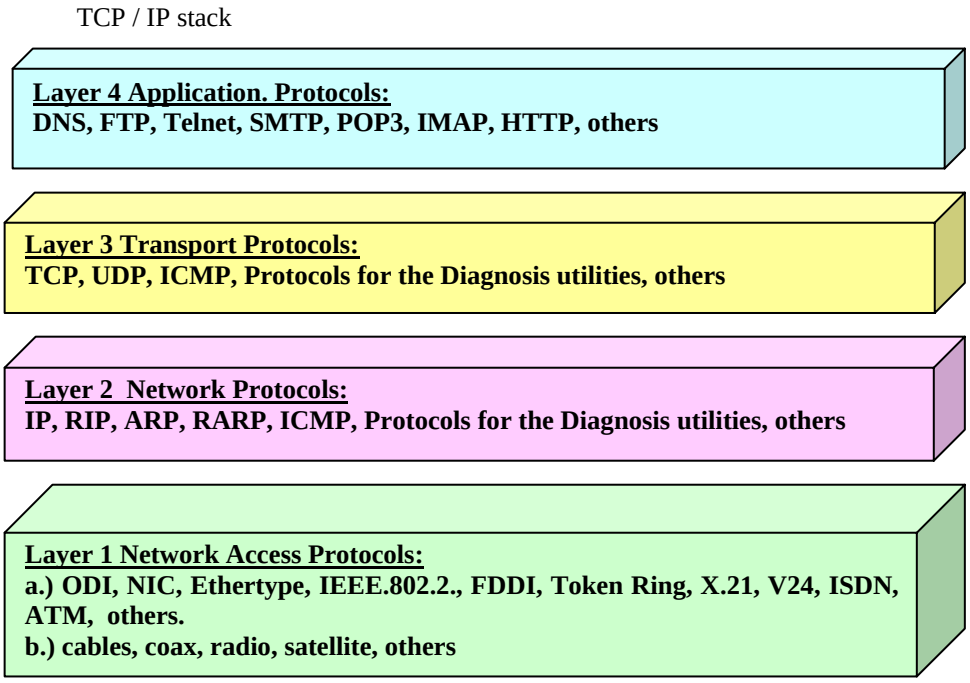

Fig. 3.2. The placement of the different protocols on the TCP/IP layers.

As it may be seen, the TCP / IP includes protocols developed by different bodies, for instance:

- by IEEE-Institute of Electrical and Electronic Engineering, which has developed the standards for LANs,
- by ITU-International Telecommunication Union, for WANs.

3.7. THE FLUXES OF DATA THROUGH THE TCP / IP LAYERS.

The cooperation of the TCP / IP protocols from different TCP/IP layers generates a hierarchy of TCP / IP implementation and solves the networking requirements.

The directions of the cooperation and of the Data transfer are:

- for the received Data, from bottom to top,
- for the sent Data from top to bottom.

The protocols from the superior layers cooperate with the protocols from the inferior layers in the processing of Data.
One implementation (system or server) may support only partial services, corresponding to the target of implementation.
For instance, fig..3.3. presents the TCP / IP hierarchy of services focused only on the SMTP (Simple Mail Transfer Protocol) and HTTP (Hyper Text Transfer Protocol) services and protocols.

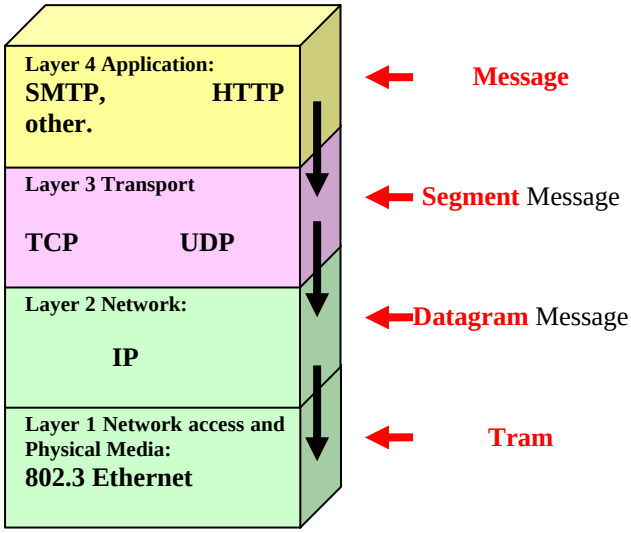

Fig. 3.3. Example of the real data transfer, which sustains the virtual Peer to Peer data transfer, at the implementation of TCP/IP protocols such as e-mail transmission protocol (SMTP) and the navigation protocol (HTTP).

The image illustrated above in fig. 3.2. indicates, also, the forms taken by Data on the way: Message → Segment → Datagram → Tram → the Physical Media.

Similarly, in fig. 3.3. illustrates, Layer by Layer, the flux of Data processing in the direction Layer 1 to Layer 4, for the arriving Data Packets (respective Trams), and the flux from Machine 2 to the Machine 1.

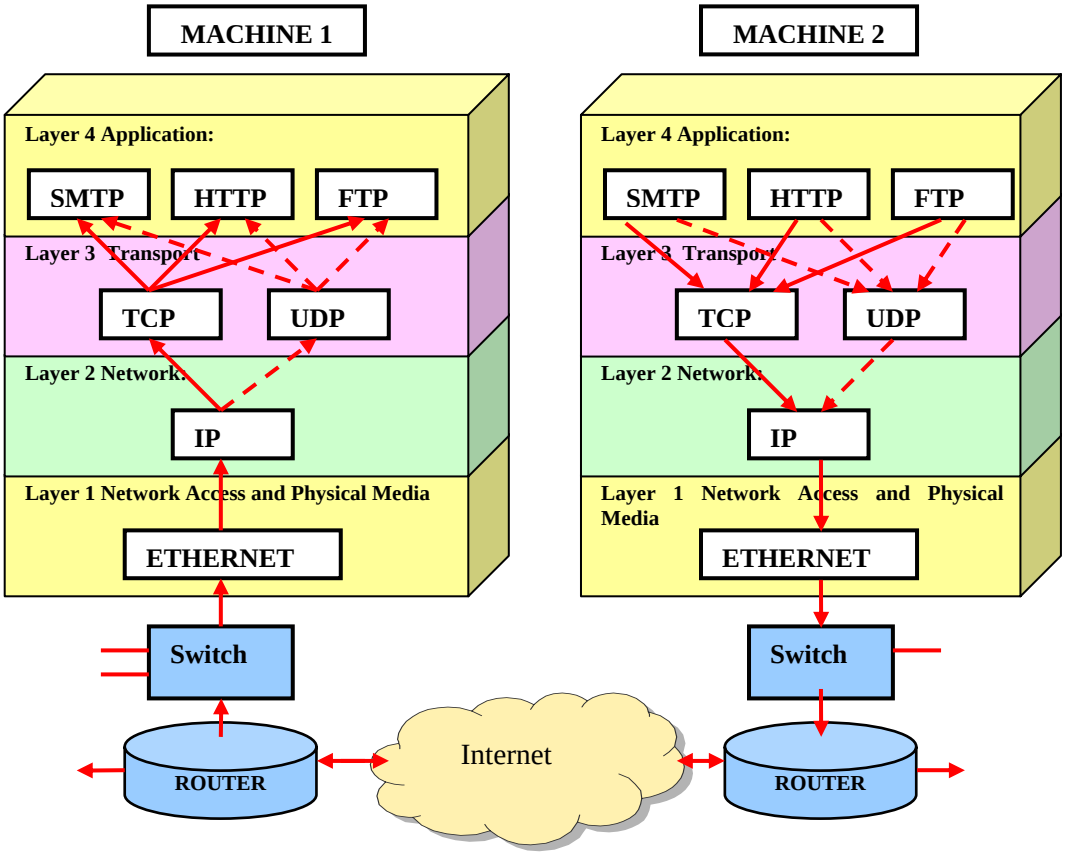

Fig. 3.3. The TCP/IP fluxes of Data between two machines.
The flux serves, in accordance with the requirements, one of the Protocols: FTP, or HTTP or SMTP or others.

The functioning in accordance with the above image must be taken into consideration for one of these protocols (HTTP, FTP, SMTP) even if the system may process in parallel different application protocols.

For instance if machine 2 intends to request a Web page from machine 1, it will launch the HTTP protocol in machine 2, which will initiate communication with the HTTP protocol (software packet) of machine 1.

So that the above 2 software programs of machine 2 and of Machine 1, to initiate communication, the Data must travel the following path:
Machine 2 Layer 4 protocol HTTP → Machine 2 Layer 3 Protocol TCP → Layer 2 Protocol IP → Layer 1 Protocol 802.3 Ethernet →Router → Internet → Router → Machine 1, Layer 1,Ethernet → Layer 2 IP → Layer 3 TCP → Layer 4 HTTP.

In the case of the HTTP protocol, for instance, the first step is to initiate, based on the exchange of Data Packets on the above path, the communication session between the HTTP protocol of Machine 2 and the HTTP protocol of Machine 1.
After the exchange of the HTTP session, the requested web page arrives to Machine 1.
After accessing the web pages of interest, the session is closed

4. PORTS AND SOCKETS.
THE MULTIPLEXING / DEMULTIPLEXING OF THE DATA PACKETS.

1.) The Multiplexing / De-multiplexing of Data towards and from protocols (software implementations).

On the processing of data through the components of the ISO / OSI Reference Model of Communication and also through TCP /IP Model:

- at the sending: the Data is passed, Layer by Layer, from top to bottom through the Layers (the protocols on the Layers are supported by the software programs) hosted inside the sending devices,

- at the receiving: data is passed, Layer by Layer, from the bottom to the top Layers of the stack.

When passing (towards the top or towards the bottom) through the Layers, upon entry to the following Layer, the Data uses the results of services from the preceding Layer and prepares the Data for the next Layer.

The placement of the protocols on the layers allows not only:
- the virtual, Layers' Peer to Peer communication (actually, for each Peer to Peer communication, the Data passes through the entire chain of Layers of both devices and through the Internet devices),
- the hierarchical distribution of protocols on specific layers,
  but also the multiplexing of protocols placed on adjacent layers.

The Data Packet, transferred through the network, after arriving in a Host, must be delivered to the respective application (the respective user or process which is involved in the reception of the respective Data).

The Data, from many applications, must be combined into a few transport protocols, **it must be multiplexed respectively.**
The multiplexing consists in the placing of Data from multiple sources into one single stream.

An application represents the specific service achieved for the specific user.

In order to be able to identify which Data Packet corresponds to which application, the following are used [9.]:
- by TCP/IP: protocol numbers, for the identification of the transport protocol,
  The protocol number is written in one byte in the 3-rd word of the header of the Datagram.
  The protocol numbers may be read, inside the UNIX systems, in the file: */etc/protocols*.

- by the transport protocols: port numbers, for the identification of application.

The multiplexing of protocols represents the process through which the Data Packets from different sources are streamed toward the appropriate protocol.
De-multiplexing is the process through which the resulting Data Units from one process/protocol are offered in parallel to the applications.

In fig. 3.3. above, inside Machine 2 Data are multiplexed, for instance, at:
- the passing from Layer 3 to Layer 2 and,
  for example Data is de-multiplexed in Machine 1 at:
- the passing from Layer 2 to layer 3 or from Layer 3 to Layer 4.

2.) The review of the essential addressing needs, in order to direct Data Packets inside the TCP /IP protocols.

The following image presents elements for directing the Data Packets towards the respective software packet which sustains the involved protocol.

Elements for directing the Data Packets (and which are treated inside the software which sustain the TCP/IP protocols):			
1. The Port Number which indicates which protocol will be appealed by TCP toward Layer 4 and vice-versa.	2. The Port Number which indicates which protocol will be appealed by UDP toward Layer 4 and vice-versa.	s3. The EtherType which indicate which protocol will be accessed between the Layer 1 and Layer 2 (IP, ICMP).	4. Other indicators for directing the Data package inside the TCP/IP software

Therefore the multiplexing represents the presentation of the data Packet to the appropriate protocol based on the indications present in the Data Packet:

- between Layer 1 and Layer 2, the indicator named Ether-type,
- between Layer 2 and Layer 3, the indicator named Protocol Identifier,
- between Layer 3 and Layer 4, the indicator named Port Number.

3.) **The Ports**. Example of the flux of multiplexing of the Data Packets arriving in one machine.
For instance, on the connection between 2 hosts, as in the example illustrated in fig. 3.3 above, the protocols from the top Layer 4 (Application) will be accessed by the protocol of the inferior layer.
Fig.3.3. presents the situation when the Protocol TCP IP (Layer 3, Machine 1) sends Data to the Protocol HTTP (Layer 4 Machine 1).

The TCP protocol access the HTTP protocol (from the Layer 4) for serving multiple, quite-simultaneously, arrived requests, from different machines.

We will start the example from the Layer 1 and will look at the flux in the Machine 1, from the above fig. 3.3..

From Layer 1 to Layer 2 (Machine 1).
The first identification, respective for the transfer between the Layer 1 and the Layer 2, is accomplished based on the information named EtherType (2 bytes). The EtherType is placed in the tram Ethernet (the tram Ethernet is the Data Packet arrived in the NIC of the above Machine 1, fig. 3.3.).
The value 800 (hex), already placed (by the sending machine) in the EtherType, indicates that the tram is necessary to be transferred to the IP protocol of the Layer 2, (of NOS-Network Operating System of Machine 1).
The indication named EtherType is used in the both senses (from the Layer 1 to the Layer 2 or vice-verso).

From Layer 2 to Layer 3 (Machine 2).
The identification of the protocol TCP or UDP, of the Layer 3 (Transport), to be selected by the protocol of the Layer 2, is achieved based on the existence, inside the header of Data Packet of one index of 8 bits, named Protocol Number or Protocol Identifier. The Protocol Identifier has, for instance, the following possibilities:

- If the value of the index is 6 then the Data packet will be directed toward the TCP protocol of the superior Layer 3,
- If the value of index is 17 then the Data packet will be directed toward the UDP protocol superior Layer 3.

From Layer 3 to Layer 4. **Ports and Sockets**.

The transfer of Data, from the output of the protocols (software packages which sustain the protocols) of Layer 3: TCP or UDP, towards the Protocols of Layer 4, and vice-versa, is achieved based on the 16 bits index, named Number of the Port.
For instance: The number corresponding to port 16 is assigned for the SMTP protocol,
80 is assigned for the HTTP protocol,
53 is assigned for the DNS protocol,
20 is assigned for the FTP protocol and
21 is assigned for the FTP control etc.

The Port is a pre-established internal address (virtual address) which indicates the path (which protocol will be appealed) between Layer 3 (TCP protocol and UDP protocol) and Layer 4, and vice-versa.
The access through the virtual ports is bidirectional.

The **Port Numbers** indicate, in view of the right Data Packet transfer, to which application (to which protocol of the Layer 4 Application) the respective Data will be sent.

One Port Number offers the channel between the Application Layer and the Transport Layer.

Port Numbers serve for multiplexing (at the transfer towards the Layer of a higher rank) and for de-multiplexing (at the transfer towards the Layer of a lower rank).

Port Numbers are pre-established by the ICANN. The number of pre-established Ports is high: over 1000 Ports.

4.) **Sockets**. In directing the Data packets, identifiers are used, which are named **sockets.**

One socket represents the combination (concatenation) between:
- **the IP Address of the source and**
- **the number of the port of the source where the response must arrive.**

For instance the socket of the IP Address **193.24.1.1** and of the Port Number **80** is: **193.24.1.1, 80**

Example of using the HTTP protocol.
Practically, at the communication between two Internet network partners (2 machines), fig. 3.4., Machine 1 (with the illustrative IP Address **193.24.22.2** and the Port Number where the response should be returned: **1001**) launches, in view of opening an HTTP session, the Data Packet towards Machine 2.
Therefore the Source's Socket (of the Data Packet sent by Machine 1) will be: (The IP address of Machine 1) + (the Own Port Number where the response should be returned) = **193.24.22.2,1001.**

By this information Machine 1 informs Machine 2 to which socket to respond, i.e. to the socket generated by Machine 1.
Machine 2 receives the requirement of Machine 1 and will respond towards socket **193.24.22.2,1001.**

Sockets permit the directing of Data Packets inside the TCP Layers.

The socket offers a unique entry point for one application on one machine.

The **sockets-based system** of addressing enables protocols to process data and to respond to arrived data.

How do the socket pairs achieve the unique identification and return the response?

Machine 1, which requires a service from machine 2, forms (through its own NOS – Network Operating System activities) its own sockets:
- Source Socket of Machine 1, formed from its own IP Address and its own Port Number from which is required the service, namely the socket: **192.24.22.2,1001**.
- Destination Socket (of the Data Packet sent by the Machine 1 toward the Machine 2), formed from the IP Address of destination and the port number of the required service in the Machine 2, respective the socket: **192,40.40.2,80** (for accessing the HTTP service).

To form this socket, Machine 1 knows in advance that the targeted Port Number is 80 (the well known Port Number of HTTP) and the IP Address of the targeted Host.

The Machine 2, upon generating the response, forms and sends (towards machine 1) the pair of response sockets:
- Source Socket of Machine 2, formed from its own IP Address and its own Port Number which responds, for which the service is required, that is the socket: **192,40.40.2,80**
- Destination Socket (of the Data Packet sent by Machine 1 towards Machine 2), formed from the destination IP Address and the port number of the required service in the Machine 2, that is socket: **192.24.22.2,1001**. (Machine 2 knows this socket because it arrived from Machine 1).

The machine which receives the service (Machine 2) knows, based on the socket of the client (Machine 1), the sender and the port to which it should respond.

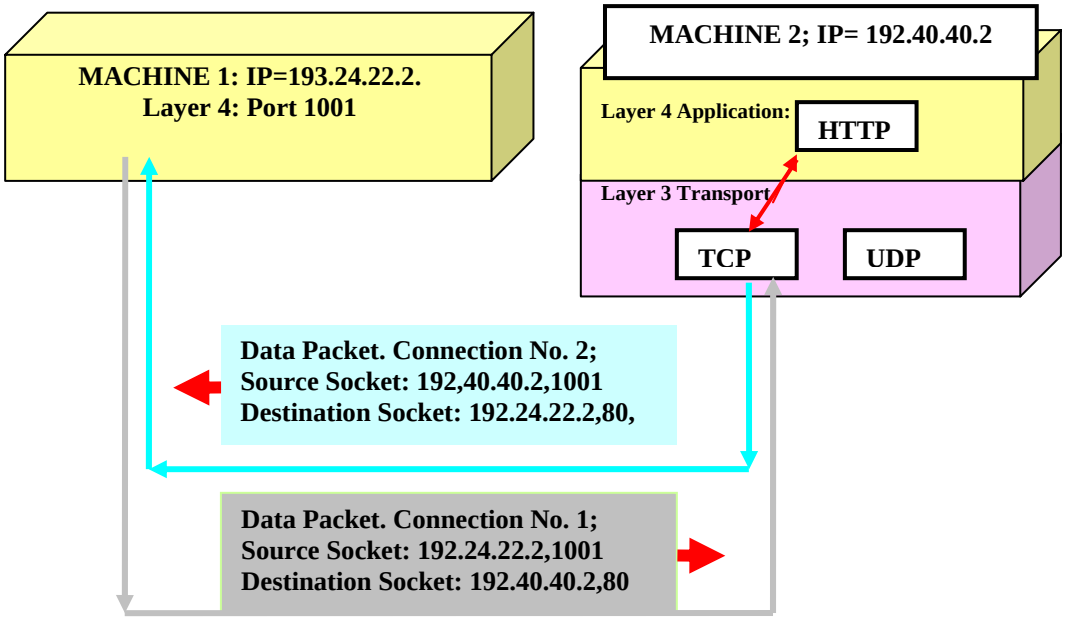

Fig. 3.4 The use of sockets

Key Point Summary Conclusions and Recommendations

The ISO / OSI communication model serves only for referencing the developments in internetworking and networking.
The TCP / IP model is a concrete, widely applicable and applicative model.
The TCP/IP implementations are accomplished based on a simplified and reliable TCP/IP stack with only 4 layers.
For networking it is necessary to know and apply the TCP/IP and ISO/OSI models. This knowledge creates the possibility to understand different developments and networking configurations.

Study Guide

ESSENTIAL QUESTIONS TO EVALUATE THE ACQUIRED KNOWLEDGE

1. Why is necessary to study and know the essential aspects of the ISO / OSI –communication model?
2. Which is the role of the multiplexing de-multiplexing, for instance in the TCP / IP?
3. Which are the functions/ names of the 7 layers of the ISO OSI -Open System Interconnection Reference Model and which are the names of the 4 layers of the TCP/IP model?
4. The ISO / OSI -Open System Interconnection Reference Model is in operation, as entire system, in one world place?
5. How is indicated the type of protocol of the TCP/IP Layer 3, with the view of the transfer of Data from the Layer 2?
6. How is indicated the type of protocol of the Layer 4 of the suite TCP/IP, for the transfer of Data from the Layer 3?
7. What is one Port, inside the transfer of data between the Layer 3 and the Layer 4?
8. What is one socket and how is used?
9. Please indicate 2 essential protocols of the Layer 3.
10. Please indicate some protocols of the Layer 4?

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IMPORTANT SUPPLEMENTARY BIBLIOGRAPHY. REFERENCES. (www)

[Supplem. 1.] http://www.prenhall.com/tanenbaum, Prentice Hall, Andrew S. Tanenbaum
[Supplem. 2.] www.cisco.com/univercd/cc/td/doc/cisintwk/idg4
[Supplem. 2.] www.cramsession.com

SUPPLEMENTARY INDICATIONS ABOUT THE CONTENT OF THE LESSON

It is recommendable to be consulted also the documentations from: www.cisco.com; www.cramsession.com; and other.

ANSWERS TO QUESTIONS

1. Because the net systems are referenced to and explained through the ISO / OSI communication model.

2. The multiplexing consists in the putting in series the elements which arrive in parallel. The de-multiplexing consists in putting in parallel elements which arrive in series.
3. The names of functions of the 7 layers of the ISO / OSI communication model are: Application (7), Presentation (6), Session (5), Transport (4), Network (3), Data Link / Media Access (2), Physical Level (1). The names of the TCP Layers are: Application (4), Transport (3), Network (2), Media Access (1).
4. Not, but the knowing of the model is important for understanding of many other models and systems.
5. By the indicator named Protocol Identifier, presents in the Data packet. Example: the value 6 for the transfer toward the toward the TCP protocol, and the value 17 for the transfer toward the UDP protocol.
6. The protocol of the Layer 4 is indicated by the number of port.
7. The Port is one pre-established internal address (virtual address) which indicate the path (which protocol will be appealed) between the Layer 3 (TCP protocol and UDP protocol) and the Layer 4 and vice-versa.
8. One socket is representing:
   - when is the Socket of Source: the combination (concatenation):between the IP Address of the source and the number of the port of Source at which is necessary to arrive the response,
   - when is the Socket for the Destination: the combination (concatenation): between the IP address of Destination and Port number of the targeted port inside the destination..

9. TCP and UDP.
10. FTP-File Transfer Protocol, HTTP- Hyper Text Transfer Protocol, DNS -Domain Name System, SMTP Simple Mail Transfer Protocol and other.

WORDS TO THE LEARNER: ***"… it is not required that you have the collective intelligence of all the network pioneers to be a network administrator"*** [10.].