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Text Book

Data Link Layer and Associated Protocols

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I- GENERAL INTRODUCTION

Computer networks have become essential today. They are employed in all companies and even in individuals. They allow you to implement very diverse applications, from the simplest to the most sophisticated. The best known is the web browsing, i.e. the sharing of information through the Internet. Whether they are local networks, wireless networks, operator networks or small private networks, they all obey structuring principles that it is essential to understand. A communication subsystem is a complex piece of Hardware and software. Early attempts for implementing the software for such subsystems were based on a single, complex, unstructured program with many interacting components. The resultant software was very difficult to test and modify. To overcome such problem, the International Standards Organization (ISO) has developed a layered approach. In a layered approach, networking concept is divided into several layers, and each layer is assigned a particular task (figure 1). Therefore, we can say that networking tasks depend upon the layers.

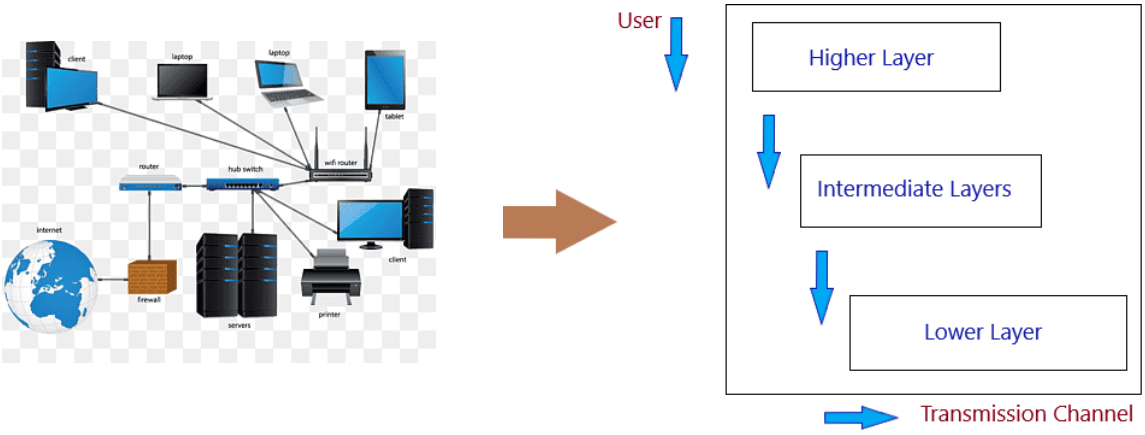

Figure 1: Layered view for networks design

I-1. LAYERED ARCHITECTURE IN COMPUTER NETWORKS

The importance of computer network layered architecture in computer network is as follows:

- ✓ The primary objective of layered architecture is to segment the design into manageable parts.
- ✓ To provide a complete set of services to manage communications and power the applications, each lower layer adds its services to the top layer.
- ✓ It offers modularity and distinct interfaces, allowing for interaction between different components.
- ✓ Offering services from lower to higher layers without specifying how they are implemented ensure independence between layers. As a result, changes made to one layer have no impact on those made to the others.
- ✓ Each network will have a different number of layers, functions, and contents. The goal of each layer, however, is to provide the service from a lower to a higher layer while concealing the specifics of how the services are performed from the layers.

The fundamental components or the core elements of layered architecture in computer network are services, protocols, and interfaces:

- ✓ Service: a group of tasks that a lower layer offers to a higher layer.
- ✓ Protocol: It is a set of guidelines used by a layer to exchange data with a peer entity. These guidelines mostly deal with the contents and order of the messages used.
- ✓ Interface: The interface serves as the channel for passing messages from one layer to another.

In a layer-n architecture, layer n on one computer interacts with layer n on another computer according to set rules known as layer-n protocols (figure 2).

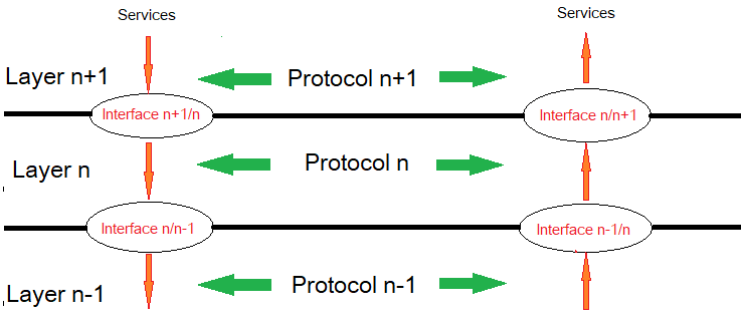

Figure 2: Services & Protocols

I-2. Types of layered architecture in computer network

Layered architecture is used for communication. There are two network models which use layering: OSI model and TCP/IP model.

I-2-1 OSI MODEL

The seven levels that computer systems employ to interact over a network are described by the Open Systems Interconnection (OSI) model. In the early 1980s, all significant computer and telecommunications businesses adopted it as the first universal architecture for network communications.
The seven layers of the OSI Model are given below (figure 3):

1. **Application Layer**: The application layer is in charge of giving the application users an interface. These protocols connect with the user directly through this layer.
2. **Presentation Layer**: This layer handles how the data appears and is formatted on the end devices.
3. **Session Layer**: The connections between distant hosts must be kept up by this layer. For instance, the remote host can keep the session once user/password authentication is finished and not ask for authentication again during that time.
4. **Transport Layer**: The end-to-end delivery between hosts is the responsibility of the Transport Layer.
5. **Network Layer**: This layer is in charge of giving hosts a network address and addressing them specifically.
6. **Data Link Layer**: Reading and writing the data from and onto the line are handled by the Data Link Layer. Problems with links are discovered at this layer.
7. **Physical Layer**: This layer provides information about the hardware, wiring, pulse rate, power output, and other components.

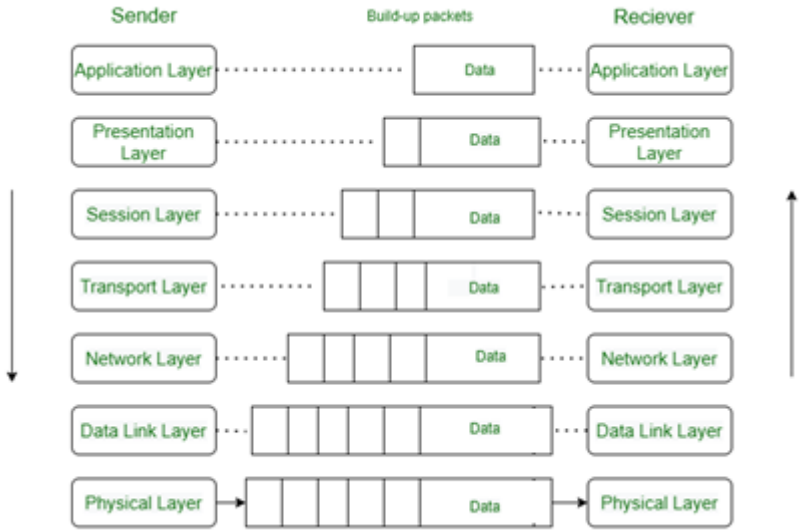

Figure 3 : The seven layer OSI model

We list in Table 1 some advantages and disadvantages of the OSI model.

OSI model advantages	OSI model disadvantages
Both connection-oriented services and connectionless-oriented services are supported	Setting up a model is a challenging task
It is quite flexible	Sometimes it becomes difficult to fit a new protocol into this model
All the layers work independently	It is only used as a reference model

Table 1: OSI model advantages and disadvantages

I-2-2 TCP/IP MODEL

TCP/IP stands for Transmission Control Protocol/Internet Protocol. It was designed and developed by the Department of Defense (DoD) in the 1960s and refined by Vint Cerf and Bob Kahn in the 1970s. It is based on standard protocols. The TCP/IP model is a concise version of the OSI model. It contains four layers, unlike the seven layers in the OSI model.

The number of layers is sometimes referred to as five or four. The Physical Layer and Data Link Layer are referred to as one single layer as the 'Physical Layer' or 'Network Interface Layer' in the 4-layer reference. The four layers of the TCP/IP model are as follows:

1. **Application Layer**: The protocol that enables network communication between users is specified at the application layer. Among them are HTTP and FTP.
2. **Transport Layer**: The Transport Layer explains how information should be transferred between hosts. The most crucial protocol at this tier is the Transmission Control Protocol (TCP). This layer is in charge of end-to-end delivery and ensures that data is delivered between hosts in the proper order.
3. **Internet Layer**: On this layer, the Internet Protocol (IP) functions. Host addressing and identification are made simpler by this layer. The routing is done by this layer.
4. **Network Access Layer**: This layer provides a way to send and receive actual data. This layer is independent of the hardware and underlying network architecture, unlike its OSI Model equivalent.

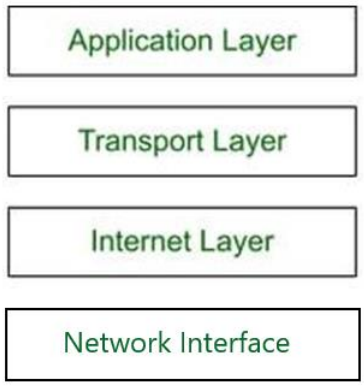

Figure 4 : The fourth layer TCP/IP model

We list in Table 1 some advantages and disadvantages of the TCP/IP model.

TCP/IP advantages	TCP/IP disadvantages
Many routing protocols are supported	Little difficult to set up
It is highly scalable and uses a client-server architecture	Delivery of packets is not guaranteed by the transport layer
It is lightweight	vulnerable to a synchronization attack

Table 2: TCP/IP model advantages and disadvantages

I-2-3 OSI MODEL VS TCP/IP MODEL

We will do a brief comparison between the two layered architecture models listing the advantages and disadvantages of each.

Similarities between OSI Model and TCP/IP Model

OSI and TCP/IP both are logical models. One of the main similarities between the OSI and TCP/IP models is that they both describe how information is transmitted between two devices across a network. Both models define a set of layers. Each layer performs a specific set of functions to enable the transmission of data (figure 5).
Another similarity between the two models is that they both use the concept of encapsulation, in which data is packaged into a series of headers and trailers that contain information about the data being transmitted and how it should be handled by the network.

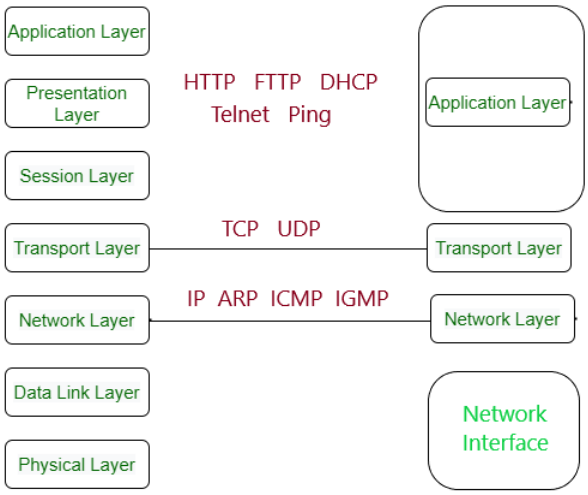

Figure 5 : OSI model vs TCP/IP model

Differences between OSI Model and TCP/IP Model

Despite their few general similarities, there are quite remarkable differences between the two models, in particular from some points of view (usage, functioning, etc.) as mentioned in table 3.

Parameters	**OSI Model**	**TCP/IP Model**
Full form	OSI stands for Open Systems Interconnection	TCP/IP stands for Transmission Control Protocol/Internet Protocol
Layers	It has 7 layers	It has 4 layers
Usage	It is a general model and it is low in usage	It is mostly used but cannot be used in any other application
Functioning	Provides layer functioning and also defines functions for all the layers	More based on protocols and protocols are not flexible with other layers
Connection	The network layer provides both connection-oriented and connectionless service	The network layer provides only connectionless service
Function separation	Defines services, protocols and interfaces very clearly and makes a clear distinction between them	Services, protocols and interfaces are not clearly separated
Transparency	Protocols are hidden and can be easily replaced if the technology changes	Replacing protocols is not easy
Delivery	Delivery of the package is guaranteed in OSI Model	Delivery of the package is not guaranteed in TCP/IP Model
Replacement	Replacement of tools and changes can easily be done in this model	Replacing the tools is not easy as it is in OSI Model
Reliability	It is less reliable than TCP/IP Model	It is more reliable than OSI Model

Table 3: Differences between OSI Model and TCP/IP Model

II- DETAILED OBJECTIVES OF THE COURSE

II-1 Introduction

Data Link Layer is the second layer of the OSI Model. This layer is one of the most complicated layers and has complex functionality and responsibilities. The data link layer hides the details of the underlying hardware and presents itself to the upper layer as the means of communication.
The philosophy of any network or a combination of networks (like Internet) is to glue together several network entities by connecting devices (routers or switches).
If a packet is to travel from a host to another host, it needs to pass through these networks. Communication at the data-link layer is made up of five separate logical connections between the data-link layers in the path.
Communication at the data-link layer is node-to-node. A data unit from one point in the Internet needs to pass through many networks (LANs and WANs) to reach another point. These LANs and WANs are connected by routers. It is customary to refer to the two end hosts and the routers as nodes and the intermediate networks as links.
Figure 6 is a simple representation of links and nodes when the path of the data unit is only six nodes.

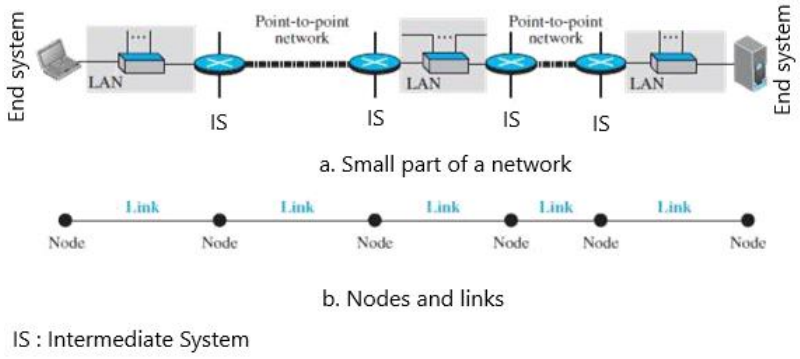

Figure 6 : Links and nodes

II-2 Objectives

Given the importance of the role played by the data link level in the overall architecture of computer networks, the objective of this course is to identify all aspects relating to its design and implementation. Thus and according to the figure 6 it is natural to consider three main concepts that allow this course to be divided into three fundamental parts, namely:

Part 1: Point-to-point and multipoint protocols
The basis of all activity in the entire network is the communication that takes place between two neighboring nodes i.e. point-to-point communication. It allows an intermediate basic exchange between adjacent nodes from the source until reaching the final destination. Note here that the transmission medium is dedicated to the two neighboring nodes and is not shared by other nodes.
However, when a packet traverses a LAN, then multiple paths are possible and the transmission medium becomes shared by all nodes. This is where multiple access protocols come in.
Therefore, the first part of this course addresses point-to-point protocols and presents the different aspects of multipoint protocols to then detail them in their context which are the LANs in the 2nd part of the course.

Part 2: Local area networks and switching
This part covers the essential notion of LANs which have become ubiquitous in everyday life. Intra-LAN switching and VLANs are also presented.

Part 3: Link Routing and Interconnection
In this part, we are interested in the inter LAN interconnection that can be encountered in computer network environments at the data link level and possibly at the adjacent network level by implementing interconnection tools such as bridges and switches or even routers.

III- GENERAL CONTENT

III-1 Introduction

As we have seen the pedagogical necessity of dividing this course "Data link layer and associated protocols" into three parts, we will present the potential and global content of these parts.

III-2 Three-part content

Part 1: Point-to-point and multipoint protocols
Since the data circuit can alter the information transported, the data link layer supervises it and defines a set of rules to ensure the reliability of exchanges on a data link.
We'll see how

- ✓ this level specifies the format of the data units exchanged (frames), their delimitation, the means of checking their validity (parity, polynomial code, etc.), as well as the mode of correction of detected errors;
- ✓ it sets the rules for dialogue between the two ends of the link by exercising two important functions: flow control (mechanism verifying the rate at which information is sent) and management of acknowledgments (mechanism validating the reception of information);

For this, the approach of increasing complexity is followed to present the link protocols until arriving at the HDLC (High level Data Link Control) protocol which is an example of a very widespread standardized protocol.

At the end of this part, we will see how the link layer is perceived by the local area networks and the Internet network.

Part 2: Local area networks and switching

As the transmission medium is no longer dedicated to only two neighboring nodes, the objective of this part of the course is to give an overview of the protocols which make it possible to control access to a shared medium. All of these protocols belong to a sub layer in the data-link layer called Media Access Control (MAC) and are categorized into three groups; random access controlled access channelization.
These protocols being the heart of Local Area Networks (LANs), in particular Ethernet, they will be presented in the introduction to this part. At the end of this part, the reader will have a somewhat precise idea of LANs (characteristics, components, functioning, switching, standardization, versions, etc.).
To separate traffic within the same LAN or within interconnected LANs for functionality or security purposes, we will also look at Virtual LANs or VLANs.

Part 3: Link Routing and Interconnection

The objective of this third part is to show how the network entities are routed and interconnected at the link level. Network interconnect device is a widely used term for any hardware that connects different network resources. Important devices that make up a network are mainly switches, routers, bridges, repeaters and gateways. Using either of these interconnecting devices, the following scenarios will be considered:

- ✓ Single LAN
- ✓ Two LANs connected to each other (LAN-LAN)
- ✓ A LAN connected to a WAN (LAN-WAN)
- ✓ Two LANs connected via a WAN (LAN-WAN-LAN)

IV- CONCLUSION

The interest of this course is that it dissects a layer that is both important and complex by presenting it in a simple, modular and practical way. Pedagogically speaking the best courses currently arranged in universities follow a top-down approach (Kurose, Tanembaum). This same approach is considered in this course but the at the data link level as defined by the standard layered architecture.
This introductory course is divided into three parts and provides an overview of all aspects relating to the data link level while structuring the different concepts necessary for its assimilation (figure 7).
At the end of this course, the reader is well prepared to study the three parts separately and preferably in the established order:
First sub-module: Point-to-point and multipoint protocols (Part 1)
Second sub-module: Local area networks and switching (Part 2)
Third sub-module: Link Routing and Interconnection (Part 3)

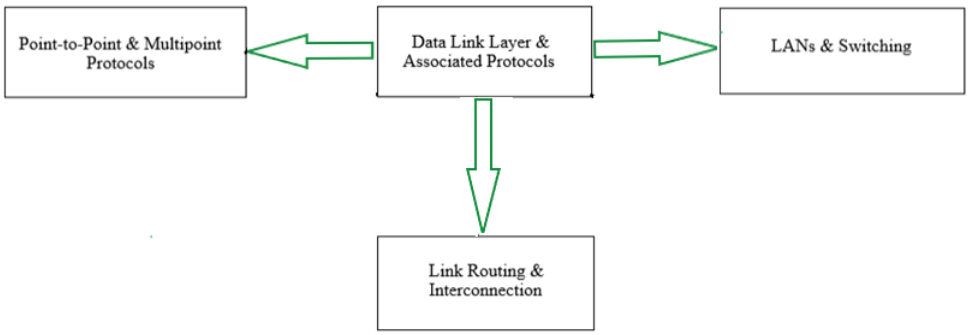

Figure 7: General overview of the content of this course.

At the end of the entire course, the reader will learn how issues related to the design and development of the data link level have been solved over the years, including:

- Error and flow control, frame identification and sequencing issues;
- The sharing of communication channels by local networks;
- The interconnection of different parts of networks to form large networks including the Internet;
- Standardization;
- etc.

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