Chapter One

Network Architecture

Communication is based on transfer of information having a wider scope. For establishing a meaningfull communication a functional requirements should be identified. A man to man communication is an example from which these functional requirements can be identified.

In the context of these requirements, a model for communication in a computer network is developed. The model is based on the concept of the layered architecture. Open System Interconnection (OSI) reference model is the earliest one of the layered architecture, this model will be explained in detail in this chapter.

1.1 Topology of a Computer Network

A computer network consists of end systems which are sources and sinks of information, and which communicate through a transit system interconnecting them, Figure 1.1. The transit system is also called an interconnection subsystem or simply a subnetwork.

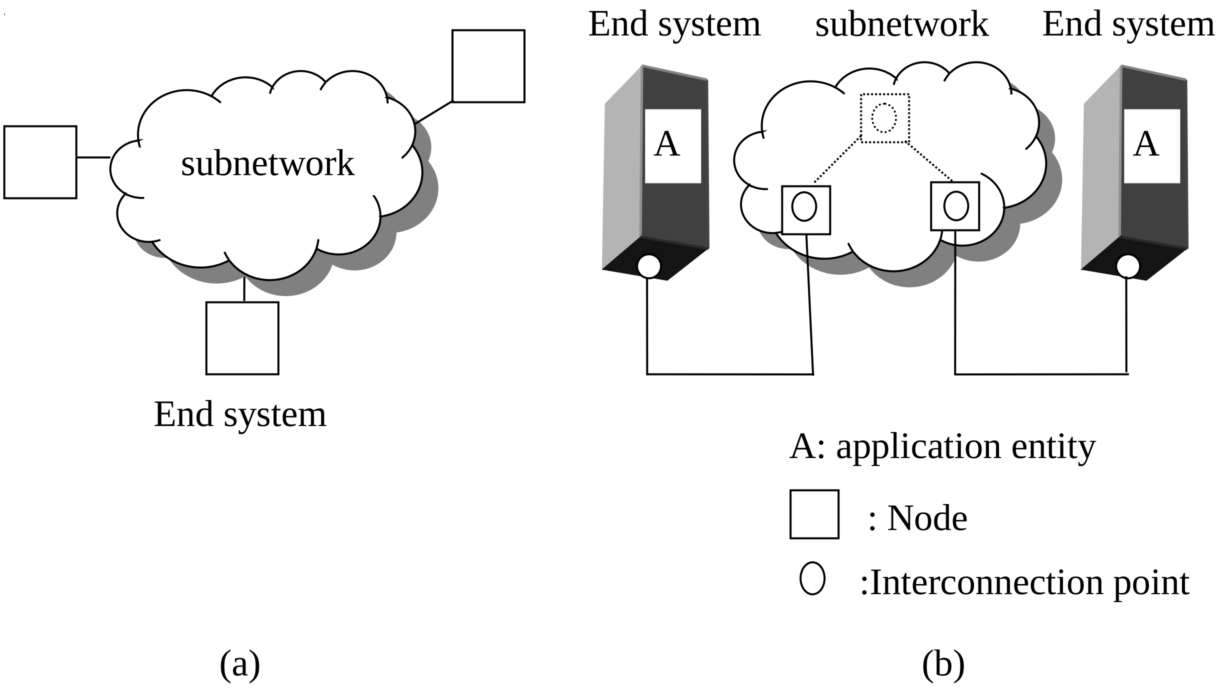

Figure 1.1 Computer Network

An end system consists of computers, terminals, software, and peripherals (e.g. disk drive, CD, HDD) forming an autonomous whole capable of performing information processing. Each end system has an interconnection point through which it is physically connected to the transmission medium. The interconnection point has an address by which the end system is identified. Each end system hosts one or more application entities. It is due to these application entities that communication takes place between the end systems. They determine the subject and the duration of their communication.

The subnetwork, (with out any application entity), performs all transmission and switching activities required for transporting messages between the end systems. Subnetwork consists of nodes that process the messages for routing them towards their destination. Nodes are interconnected to the end systems at the edges of the sub network through a transmission medium that carries electrical signals.

1.2 Elements of Meaningful Communication

The purpose of communication between the application entities is not served just by exchanging bits. The communication needs to be meaningful. Meaningful communication is always done with a purpose and aims at enlarging common understanding between communicating entities. Physical transfer of bits is transmission not communication.

There are some basic elements of the communication process which must be present in any communication to make it meaningful. This is true for any type of communication, between human beings or between computers. A human communication will be taken as an example to understand the elements of meaningful communication between two end systems of a computer network.

Consider that a young Egyptian, May, would like to tell her friend Menna who lives with her mother in Britain, about her visit to Egypt during vacations. Menna is learning Arabic for her forthcoming visit. May decides to call Menna over the telephone and dials here telephone number. Menna's mother picks up the telephone handset. The conversation which ensues is as follow:

May : Hello, May speaking. **Authentication**

Mother: Hello May, mama here. (Identification of communication entities.)

May : Mama, could I speak to Maiar?

Mother: Please wait. I will call her.

….(*Mother calls Maiar*)

Menna : Hello May, Menna here.

May : Hello, I have made plans **Common Theme**

for your visit to Egypt (Agreement on the common theme.)

Menna : Thanks.

May : Are your Arabic lessons continuing? **Common Language**

May I speak in Arabic (Agreement on the common language.)

Menna : No. I am still not at ease with Arabic. Please continue in English.

May : O.K.

(*May tells her the program*.)

Menna : Yes, fine.

Synchronization (Forward)

(Point of common understanding and Indication of willingness to proceed.)

(There is some disturbance on the line)

Menna : Please repeat the dates.

I did not hear you clearly. **Error Recovery**

May : …..(May repeats)…... (Recovery of the lost messages.)

Menna : Yes.

Menna : Please speak slowly. Let me take **Flow Control**

It down. (Control of the flow of messages.)

…..(May slows down)

Menna : I could not follow after the visit Alex. **Synchronization (Backward)**

May : …..(May repeats and continues) (Loss of the point of common understanding. Going back to to the last point of common understanding.)

May : Good by, Maiar.

Menna: Bye, May.

The above communication involved three communicating entities, May, Menna, and her mother. The entire process involved several steps:

- Establishing connection through a telephone network.
- Identification of the communicating entities.
- Understanding on the common theme and common language for communication.

- Disciplined dialogue exchange which required flow control, error control, and synchronization.

  Common theme, common language, and an orderly session are essential elements of any type of meaningful communication.

The elements of meaningful communication discussed above are also applicable to a distributing computing system where application entities residing in different end systems communicate. There is need to establish connection between the communicating entities through the subnetwork. Authentication (user password), login, syntax, and orderly exchange of messages with markers for dialogue synchronization are built into an end system. For each incidence of communication, these elements must be decided and agreed upon explicitly by the communicating entities for the communication to be meaningful.

1.3 Transport- Oriented Function

Communication results in generation of messages which are to be truthfully transported between the communicating entities. In a computer network, the subnetwork provides means of transporting the messages. But some additional functions must also be built into the end systems for enabling transport of the message through the subnetwork without any error. These functions are assigned for:

- Interaction with the subnetwork
- Quality of transport service
- Conversion of signals
- Error control

1.3.1 Interaction with the Subnetwork

In the man-to-man communication, the communicating entities interacted with the telephone network by lifting the handset of the telephone instrument, waiting for dial tone, dialing the telephone destination number, and answering the ring. A computer network is somewhat analogous in this respect. The end systems need to interact with the subnetwork for transporting the messages to the destination. This interaction is in the form of specifying the address of the destination, answering an incoming call, and releasing the connection.

It is also possible that a subnetwork may offer message transport service that is equivalent to the postal service. In this case, an end system merely releases a message in the subnetwork. The message bears source and destination addresses and the subnetwork delivers the message to the destination.

1.3.2 Quality of Transport Service

In a computer network, the end system needs to set up an appropriate transport connection of the required quality of service. Quality of Service (QoS) is specified in terms of error rate, transit delay of message delivery, throughput, and the cost.

1.3.3 Conversion of Signals

In digital devices, messages are in the form of bits. The bits need to be converted by the end systems into electrical signals having suitable voltage levels for the transmission media.

1.3.4 Error Control

Computer communication is very sensitive to the errors. Errors are introduced due to noise and distortion of electrical signals during transmission. Some mechanism in the end systems to control these errors is required.

1.4 Components of a Computer Network

From the above analogy of man-to-man communication, we can deduce certain functional capabilities that must be built into an end system for meaningful communication. These capabilities are listed below. This list is not exhaustive but it does indicate broad categorization of the required capabilities.

- Authentication and login.
- Common syntax.
- Establishment of an orderly exchange of messages with markers for forward and backward synchronization.
- Establishing transport connection of required quality, flow control.
- Interacting with the subnetwork.
- Error control.
- Conversion of bits into electrical signals and vice versa.

The above communication functions are implemented using hardware (physical) and software (logical) components in a computer network. All the components of a computer network function in a coordinated fashion to realize the functional requirements of meaningful communication between the end systems.

1.5 Architecture of a Computer Network

The architecture of a system, whether it is a building, organization or computer system, describes how the system has been assembled using its various components. It defines the specifications of the components and their interrelationship.

The architecture of a computer network specifies a complete set of rules for the connections and interactions of its physical and logical components for providing and utilizing communication services.

Designing the architecture of a computer network requires a model. After the model is ready, design specifications of the components and their standardization can be taken up. We need only an orderly reference model of the computer network.

The approach usually adopted for modeling a complex system (e.g. computer network) is to partition it into meaningful pieces (components). After identifying these functional pieces, their interrelationship, interfaces, services, and functionality are so defined that on integration they form a complete model.

1.6 Layered Architecture of a Computer Network

Decomposition of the organization into offices and each office into hierarchical functional levels and the interaction procedures define the coverall organization architecture.

A computer network is also portioned into end systems interconnected using a subnetwork and communication process is decomposed into hierarchical functional layers, Figure 1.2.

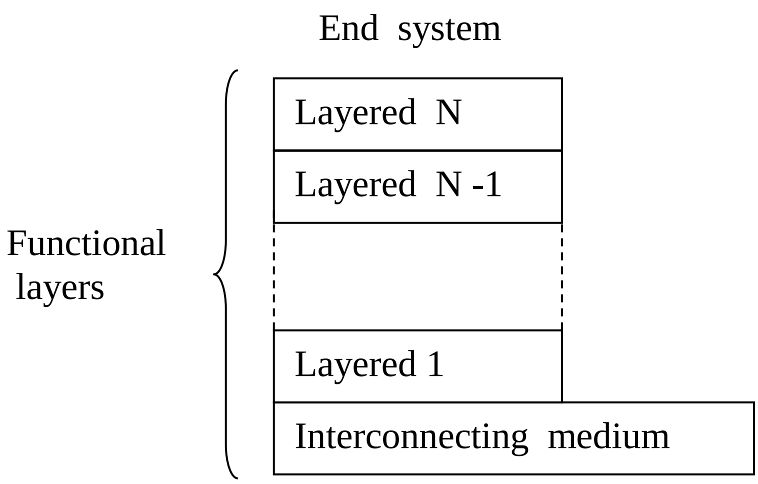

Figure 1.2 Layered Architecture of an End System

Just like in an office:

- Each layer has a distinct identity and a specific set of functions assigned to it.
- Each layer has an active element, (a piece of hardware or software), which carries out the layer functions. It is called layer entity.

The criteria for defining the boundaries of a layer are:

- Each function is distinctly identified and implemented precisely in one layer.
- Functions are carried out in logical sequential manner by proper design of the hierarchy.

- Volume of communication between adjacent layers is minimized by suitably choosing the layer boundaries.
- Boundaries of a layer are defined by considering the existing acceptable implementation.
- The implementation details of a function in a layer are hidden so that any change in the implementation does not affect other layers.

In section 1.4, we examined the basic capabilities to be built into an end system for meaningful communication. Each of these functions is assigned to one of the layers of the model. Functions can not be assigned in any arbitrary order.

1.6.1 Need for Standardization of Network Architecture

The layered architecture concept was built into many computer systems (e.g. computer networks) but different vendors defined proprietary protocols and interfaces. The layer partitioning also did not match. As a result, there was total integration incompatibility of architectures developed by different vendors. In the case of incompatible architectures, we have what is called "closed systems".

Standardization of network architecture makes us move from "closed systems" to "open systems". Standardization can solve many problems and solve a lot of effort required for developing interfaces for networking different architectures.

There are several network architectures developed by manufacturers and by standardization organizations. Some of the important network architectures are:

- IBM's System network Architecture (SNA)
- Digital's Digital Network Architecture (DNA)
- Open System Interconnection (OSI) reference model developed by ISO (International Organization for Standardization) and ITu-T.
- Internet architecture.

SNA and DNA are vendor-specific layered architecture (closed systems). The OSI reference model and Internet are two vendor-independent architectures. Between the two, Internet architecture is more widely developed.

1.7 Open System Interconnection

Open System Interconnection (OSI) represents a generalization of concepts of inter-process communication so that any open system may be technically able to communicate with another open system. Systems achieve openness by following certain architecture and obeying standard protocols. These standards are open for anybody to use and implement.

The OSI architecture is the first step towards standardization. It decomposes the communication process into hierarchical functional layers and identifies the standards necessary for open system interconnection. It does not specify the standards but provides a reference model for development of standards. The OSI architecture is, therefore, called *reference model* for open system interconnection.

1.8 Layered Architecture of the OSI Reference Model

In the OSI reference model, the communication functions are divided into a hierarchy of seven layers as shown in Figure 1.3.

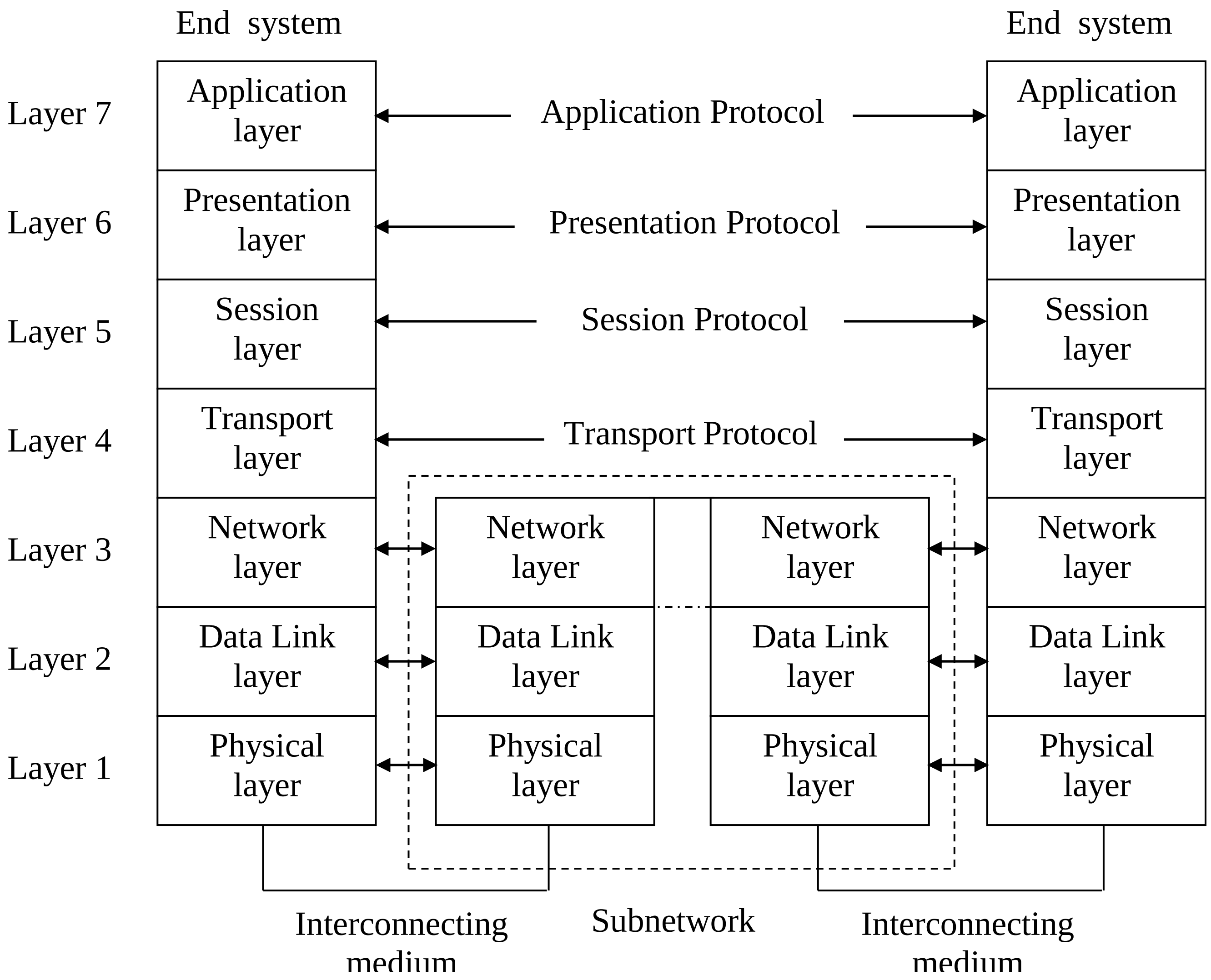

Figure 1.3 Layered Architecture of the OSI Reference Model

The computer network is portioned into end systems and subnetwork. The end systems are the computer systems that house the applications. The subnetwork has at most three layers as shown in Figure 1.3. These three layers interface with the corresponding peer layers of the end systems to carry out functions relating to the transport of the messages of one end system to the other.

1.8.1 Application Layer

The application layer provides a means for application programs to access the OSI environment, in other word, the application layer is the interface for the distributed applications (programs). Some examples of the applications programs; Internet explorer, File transfer, Electronic mail, Terminal access to remote computer, and the World Wide Web (WWW).
Each one of the above mentioned applications has a part of it that resides in the application layer, for example:

- Internet explorer: It uses HTTP protocol of the application layer for exchanging messages.
- File transfer: It uses File Transfer protocol (FTP).
- Electronic mail: It uses Simple Mail Transfer (SMT) protocol to send message.
- Remote login: It uses Telenet. The protocol for remote login.
- World Wide Web (WWW): It uses the application protocols mentioned above with some additional components.

In addition to information transfer, the application layer provides such services as:

- Identification of the intended communication partner(s) by name or by address.
- Establishment of authority to communicate.
- Agreement on privacy (encryption) mechanisms.
- Authentication of an intended communication partner.
- Agreement on responsibility for error recovery.

1.8.2 Presentation Layer

The purpose of the presentation layer is to present the information to the communicating application entities in a way that preserves the meaning while resolving the syntax (code and data format) differences.

There are three syntactic versions of data being transferred, syntax used by the application entity of the originator of the data, the syntax used the application entity of the recipient of data, and the "transfer" syntax used to transfer the data between the presentation entities, Figure 1.4.

The syntax may be same or different. When they are not same, the presentation layer contains functions necessary to transform the transfer syntax to the required syntax used by the application entities preserving the meaning.

There is no fixed transfer syntax, and is to be negotiated by the presentation entities. Encryption of data, if required, is also carried out by the presentation layer.

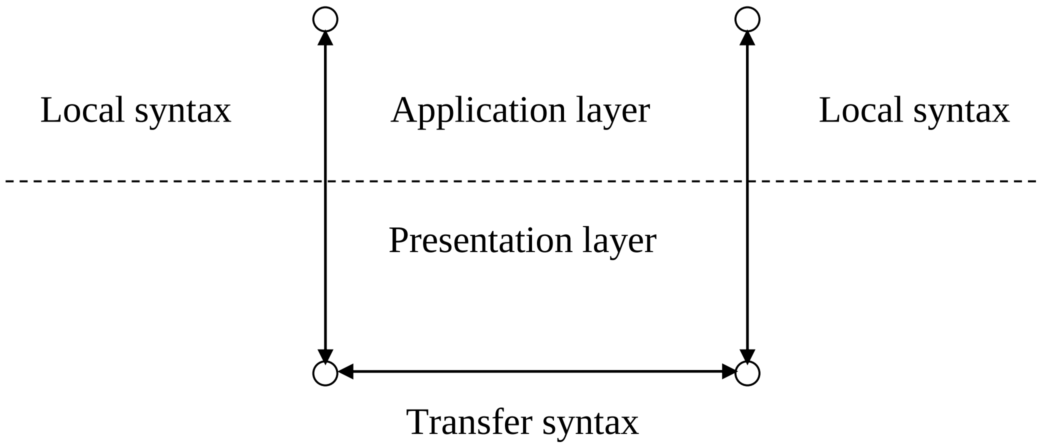

Figure 1.4 Local and Transfer Syntax of the Presentation Layer

1.8.3 Session Layer

The session layer provides the necessary means for the two cooperating application layer protocol entities to:

- Organize their dialogue (session),
- Synchronize their dialogue (data exchange), and
- Mange their data exchange (interaction management).

Session organization

For session organization, the session layer provides functions which are necessary for setting up (opening) and clearing (terminating) the session (dialogue).

Dialogue synchronization

A lengthy transaction-processing application might require checkpoints in the data transfer stream to permit backup and recovery. The session layer provides a check pointing mechanism (e.g. –ve & +ve ack), so that if a failure of some sort occurs between checkpoints, the session entity can retransmit all data since the last checkpoint.

Interaction management

The data exchange associated with a dialogue may be full duplex (two-way simultaneous) or half duplex (two-way alternate). In the half duplex the session layer protocol provides facilities for controlling the exchange of data (dialogue units) in a synchronization way.

1.8.4 Transport Layer

The overall function of the transport layer is to provide transport service of the quality required by the session entities in a cost-effective manner.

The basic function of the transport layer is to accept data from the session layer, split it up into smaller units if need be, pass these units to the network layer, and ensure that the pieces (the small units) all arrive correctly at the session layer of the other end system. Furthermore, all this must be done efficiently, and in a way that isolates the upper layers, from the inevitable changes in the hardware technology.

Under normal conditions, the transport layer creates a distinct network connection for each transport connection required by the session layer. If the transport connection requires a high throughput, however, the transport layer might create multiple network connections, dividing the data among the network connections to improve throughput. On the other hand, if creating a network connection is expensive, the transport layer might multiplex several transport connections onto the same network connection to reduce the cost. In all cases, the transport layer is required to make the multiplexing transparent to the session layer.

Two types of transport service are provided by the transport layer to the session layer, and ultimately, the users of the network. These two types are concerned with the type of the transport connection:

- *Connection-oriented* transport service, which ensures that data are delivered error free, in sequence, with no loss or duplications.
- *Connectionless* transport service, where the transported messages have no guarantee about the order of delivery.

The type of service (connection-oriented or connectionless) is determined when the connection is established.

The transport layer is a true end-to-end layer, from source to destination. In other words, a program on the source machine carries on conversation with a similar program on the destination machine, using the messages header and control messages

In the lower layers (from the physical layer to the network layer), the protocols are between each machine and its immediate neighbors, and not by the ultimate source and destination machines, which may be separated by many nodes.

Also the transport layer provides a mechanism to regulate the flow of information, so that a fast end system can not overrun a slow one. Such a mechanism is called flow control.

1.8.5 Network Layer

The network layer provides the means to access the subnetwork for routing the message to the destination end system. Network layer relives the higher layers (from transport layer to the application layer) of need to know anything about the underlying data transmission and switching technologies used to connect end systems.

The network layer of an end system interacts with the network layer of the access node of the subnetwork, Figure 1.5. This interaction represents the dialogue between an end system and the subnetwork to specify the destination address and to request certain network facilities, such as priority.

An access node of a subnetwork facing the end system must support the three lower layers of the OSI model. The packets that are created by the end system pass through one or more network nodes that act as relays between the end systems. The network nodes implement layers 1 through 3 of the architecture. Routing decisions at each node are taken by the network layer, Figure 1.5.

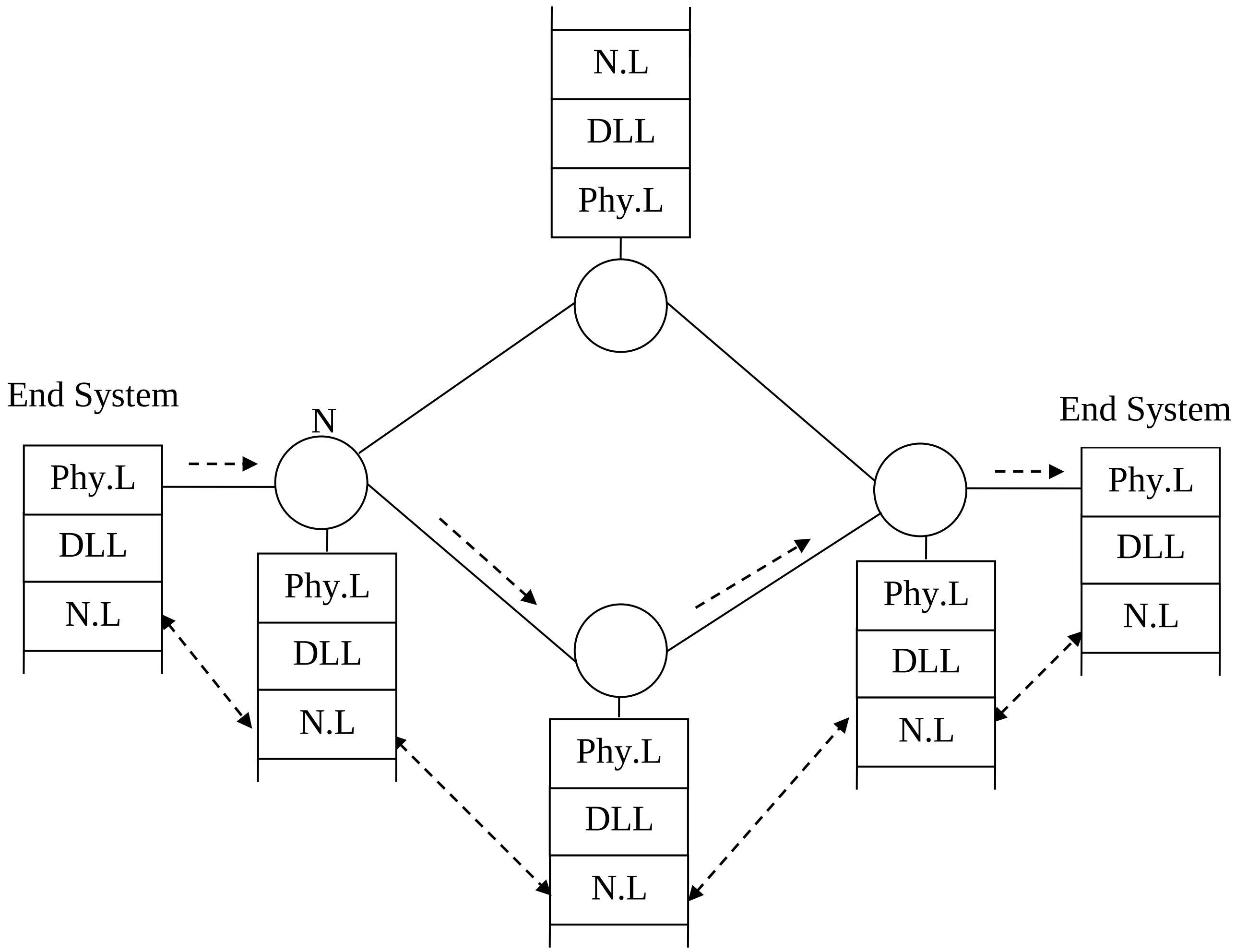

Figure 1.5 Routing of Packets by the Network Layer

When a packet has to travel from one network to another (different) one, to get to its destination, many problems can rise. The addressing used by the second network may be different from the first one. The second one may not accept the packet at all because it is too large. The protocols may differ, and so on. It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected. This can case requires the use of some sort of interconnecting technique. Also the congestion control is carried out by the network layer.

1.8.6 Data Link Layer

The main task of the data link layer is to take a raw (a stream of bits) transmission facility, from the physical layer, and transform it into a line (a frame) that appears free of undetected errors to the network layer. It accomplishes this task having the data link layer, (at the sender; which may be end system or Node), breaks the incoming data unit (packet), from the network layer, into up data frames, and transmits the frames sequentially (using the physical layer).

Since the physical layer merely accepts and transmits a stream of bits without any regard to the meaning or structure, it is up to the data link layer to create and recognize frame boundaries. This can be accomplished by attaching special bit patterns to the beginning and end of the frame.

Another important function of the data link layer is error detection and correction. For detecting and correcting the errors which are introduced during transmission of electrical signal. Data link layer appends "error detection bits" the frame before handing it over the physical layer for transmission. These bits are used for detecting the errors in the frame received by the data link layer at the other end.

Another function that arises in the data link layer is how to keep a fast transmitter from drowning a slow receiver in data. Some traffic regulation mechanism must be employed to let the transmitter know "how much buffer space the receiver has at the moment". This flow control mechanism and the error handling are integrated.

The data link layer performs another function that specific to local area networks. In local area networks, the users (end systems) are having a common transmission medium. Medium Access Control (MAC) function is carried out by the data link layer. MAC determines which user can use the media for its transmission.

1.8.7 Physical Layer

The physical layer is concerned with transmitting raw bits over a transmission medium. The design issues have to do with making sure that when one side sends a "1" bit, it is received by the other end as a "1" bit, not as a "0" bit.

Typical questions here are how many volts should be used to represent a "1" and how many volts for a "0", how many microseconds a bit lasts, how many pins the network connector has and what each pin is used for, and what is the type of the used transmission medium.

To the end systems, the physical layer carries out the following functions:

- Conversion of the bits into electrical signals having characteristics suitable for transmission over the medium.
- Signal encoding, if required.
- Relaying of the digital signals using intermediary devices, like modems.