PACKET-SWITCHING NETWORKS

In Circuit switching the resources allocated for a particular user can not be used by other users at the same time. This approach is inefficient when the amount of information transferred is small or if information is produced in bursts, as is the case in many computer applications. Networks that transfer blocks of information called packets. Packet-switching networks are better matched to computer applications and can also be designed to support real-time applications such as telephony.

1.1 Packet networks can be viewed by two perspectives:

One perspective involves an external view of the network and is concerned with the services that the network provides to the transport layer that operates above it at the end systems. Ideally the definition of the network services is independent of the underlying network and transmission technologies. This approach allows the transport layer and the applications that operate above it to be designed so that they can function over any network that provides the given services.

A second perspective on packet networks is concerned with the internal operation of a network. Here look at the physical topology of a network, the interconnection of links, switches, and routers. The approach that is used to direct information across the network: datagrams, or virtual circuits. The first perspective, involving the services provided to the layer above, does not differ in a fundamental way between broadcast and switched packet networks.

The second perspective, however, is substantially different.

In the case of LANs, the network is small, addressing is simple, and the frame is transferred in one hop so no routing is required. In the case of packet-switching networks, addressing must accommodate extremely large-scale networks and must work in concert with appropriate routing algorithms. These two challenges, addressing and routing, are the essence of the network layer.

NETWORK SERVICES AND INTERNAL NETWORK OPERATION:

The essential function of a network is to transfer information among the users that are attached to the network or internetwork. In Figure 1.1 we show that this transfer may involve a single block of information or a sequence of blocks that are temporally related. In the case of a single block of information, we are interested in having the block delivered correctly to the destination, and we may also be interested in the delay experienced in traversing the network. In the case of a sequence of blocks, we may be interested not only in receiving the blocks correctly and in the right sequence but also in delivering a relatively unimpaired temporal relation.

Figure 1.2 shows a transport protocol that operates end to end across a network. The transport layer peer processes at the end systems accept messages from their higher layer and transfer these messages by exchanging segments end to end across the network. The figure shows the interface at which the network service is visible to the transport layer. The network service is all that matters to the transport layer, and the manner in which the network operates to provide the service is irrelevant.

The network service can be connection-oriented or connectionless. A con- nectionless service is very simple, with only two basic interactions between the transport layer and the network layer: a request to the network that it send a packet and an indication from the network that a packet has arrived. The user can request transmission of a packet at any time, and does not need to inform the network layer that the user intends to transmit information ahead of time.

A connection-release procedure may also be required to terminate the connection. It is clear that providing connection-oriented service entails greater complexity than connectionless service in the network layer.

It is also possible for a network layer to provide a choice of services to the user of the network. For example, the network layer could offer:

i) best-effort connectionless service

ii) low-delay connectionless service

iii) connection-oriented reliable stream service

iv) connection-oriented transfer of packet with delay and bandwidth guarantees.

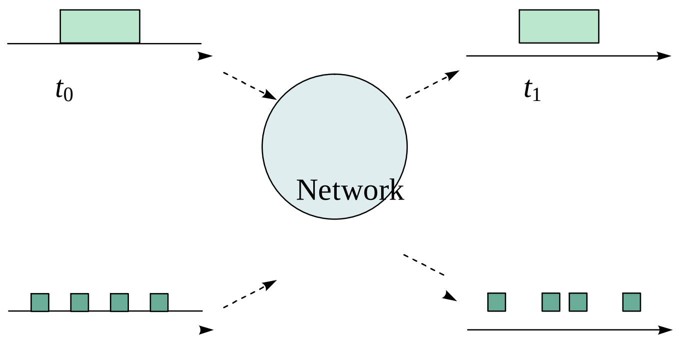

FIGURE 1.1 A network transfers information among user

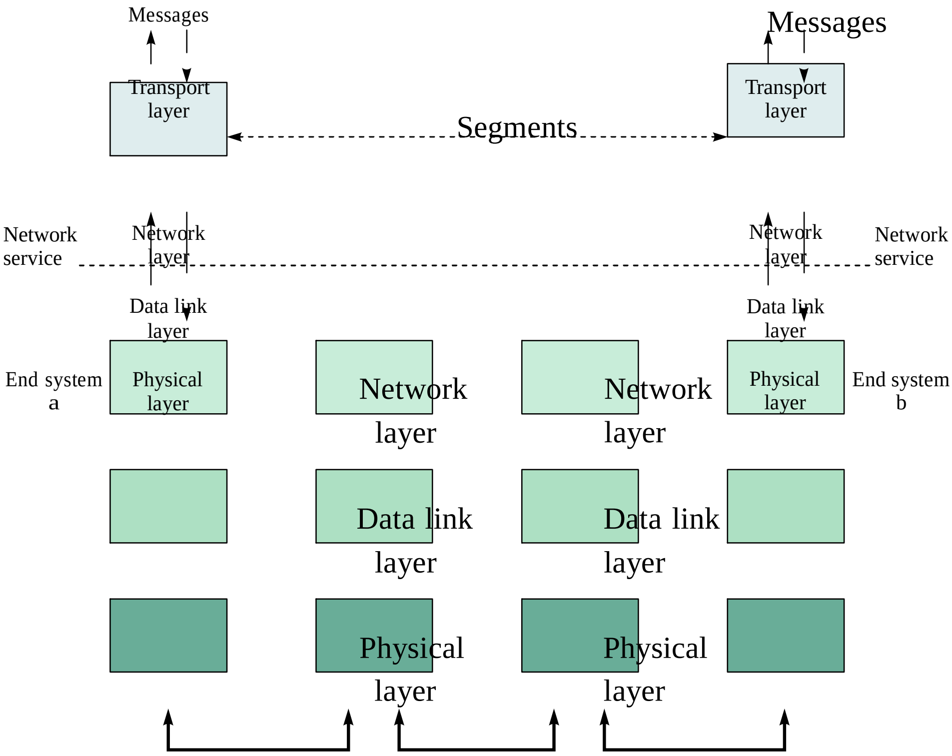

FIGURE 1.2 Peer-to-peer protocols operating end to end across a network protocol stack view

It is easy to come up with examples of applications that can make use of each of these services. However, it does not follow that all the services should be offered by the network layer.

When applied to the issue of choice of network services, the end-to-end argument suggests that functions should be placed as close to the application as possible, since it is the application that is in the best position to determine whether a function is being carried out completely and correctly. This argument suggests that as much functionality as possible should be located in the transport layer or higher and that the network services should provide the minimum functionality required to meet application performance.

Consider the internal operation of the network. Figure 1 .3 shows the relation between the service offered by the network and the internal operation. T he internal operation of a network is connectionless if packets are transferred within the network as datagrams. Thus in the figure each packet is routed independently. Consequently packets may follow different paths from to and so may arrive out of order. We say that the internal operation of a network is connection-oriented if packets follow virtual circuits that have been established from a source to a destination. Thus to provide communications between and, routing to set up a virtual circuit is done once, and thereafter packets are simply forwarded along the established path. If resources are reserved during connection setup, then bandwidth, delay, and loss guarantees can be provided.

The fact that a network offers connection-oriented service, connectionless service, or both does not dictate how the network must operate internally.

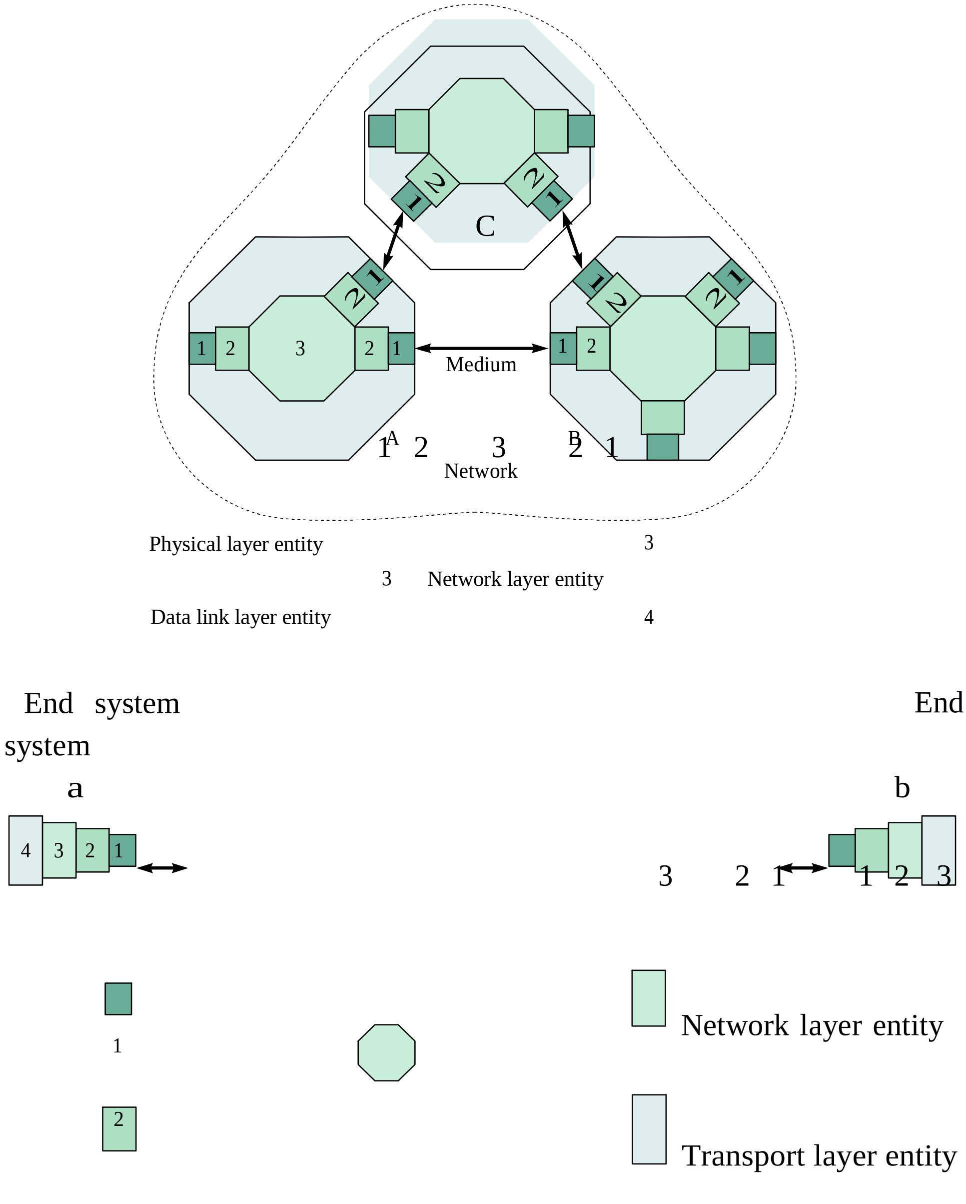

FIGURE 1.3 Layer 3 entities work together to provide network service to layer 4 entities

This reasoning suggests a preference for a connectionless network, which has much lower complexity than a connection-oriented network. The reasoning does allow the possibility for some degree of ``connection orientation'' as a means to ensure that applications can receive the proper level of performance. Indeed current research and standardization efforts can be viewed as an attempt in this direction to determine an appropriate set of network services and an appropriate mode of internal network operation.

We have concentrated on high-level arguments up to this point. Clearly, functions that need to be carried out at every node in the network must be in the network layer. Thus functions that route and forward packets need to be done in the network layer. Priority and scheduling functions that direct how packets are forwarded so that quality of service is provided also need to be in the network layer. Functions that belong in the edge should, if possible, be imple- mented in the transport layer or higher. A third category of functions can be implemented either at the edge or inside the network. For example, while con- gestion takes place inside the network, the remedy involves reducing input flows at the edge of the network. We will see that congestion control has been imple- mented in the transport layer and in the network layer.

The network layer may therefore be called upon to carry out segmentation inside the network and reassembly at the edge. Alternatively, the network could send error messages to the sending edge, requesting that the packet size be reduced. A more challenging set of functions arises when the ``network'' itself may actually be an internetwork. In this case the network layer must also be concerned not only about differences in the size of the units that the component networks can transfer but also about differences in addressing and in the services that the component networks provide.

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