Network layer

Responsible for moving packets (data) from one end of the network to other, end-to-end communication.

Requires logical addressing such as IP address

To achieve its goals, the network layer must know about the topology of the network (i.e., the set of all routers and links) and choose appropriate paths through it, even for large networks.
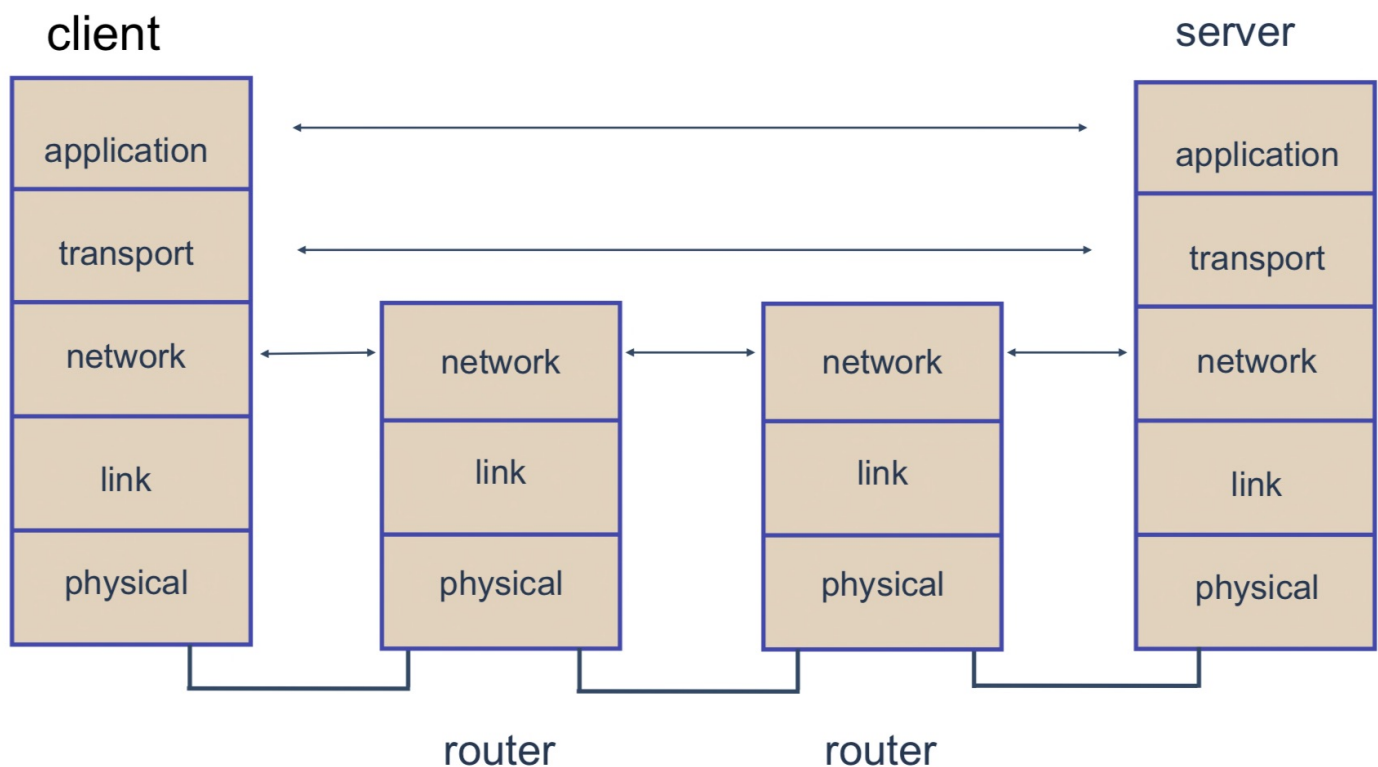
How Network layer is important?

Network layer

- transport segment from sending host to receiving host
- on sending side, encapsulates segments into datagrams
- on receiving side, delivers segments to transport layer

Network layer protocols in every host, router

Router examines header fields in all IP datagrams passing through it

client				server
application				application
transport				transport
network	network	network		network
link	link	link		link
physical	physical	physical		physical

router　　　　router

Key Network-Layer Functions

- Forwarding: move packets from router's input to appropriate router output.
- Routing: determine route taken by packets from source to destination.
- Connection service: before datagrams flow, two end hosts and intervening routers establish virtual connection

Network Layer Design Issues

1. Store-and-forwardpacketswitching
2. Servicesprovidedtotransportlayer
3. Implementationofconnectionlessservice
4. Implementationofconnection-orientedservice
5. Comparisonofvirtual-circuitanddatagramnetworks

1 Store-and-forward packet switching

A host with a packet to send transmits it to the nearest router, either on its own LAN or over a point-to-point link to the ISP. The packet is stored there until it has fully arrived and the link has finished its processing by verifying the checksum. Then it is forwarded to the next router along the path until it reaches the destination host, where it is delivered. This mechanism is store-and-forward packet switching.
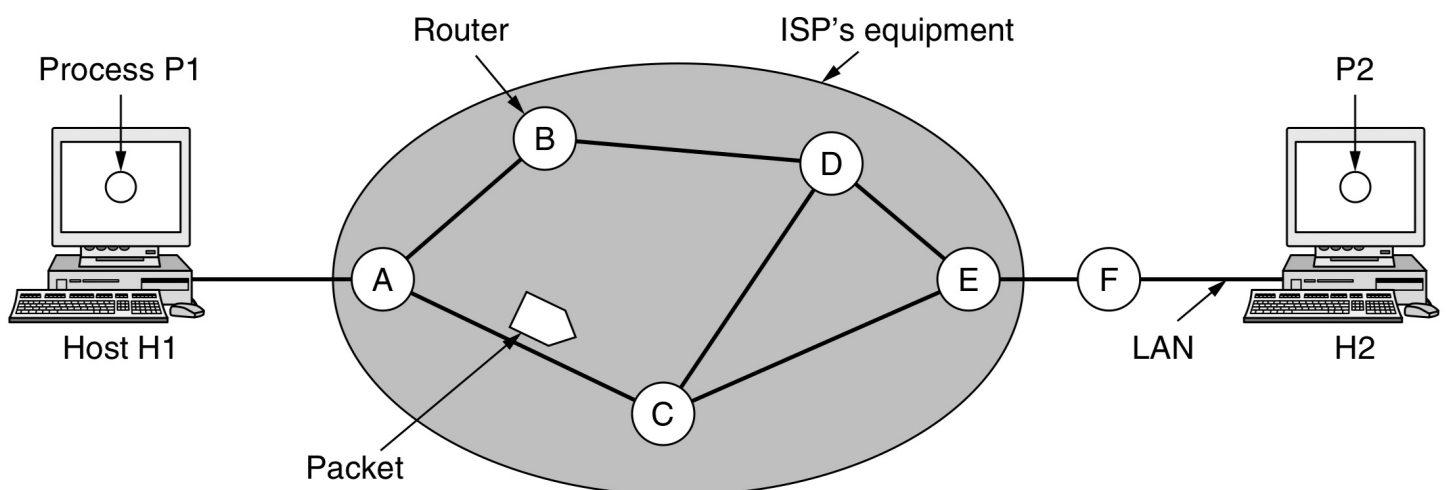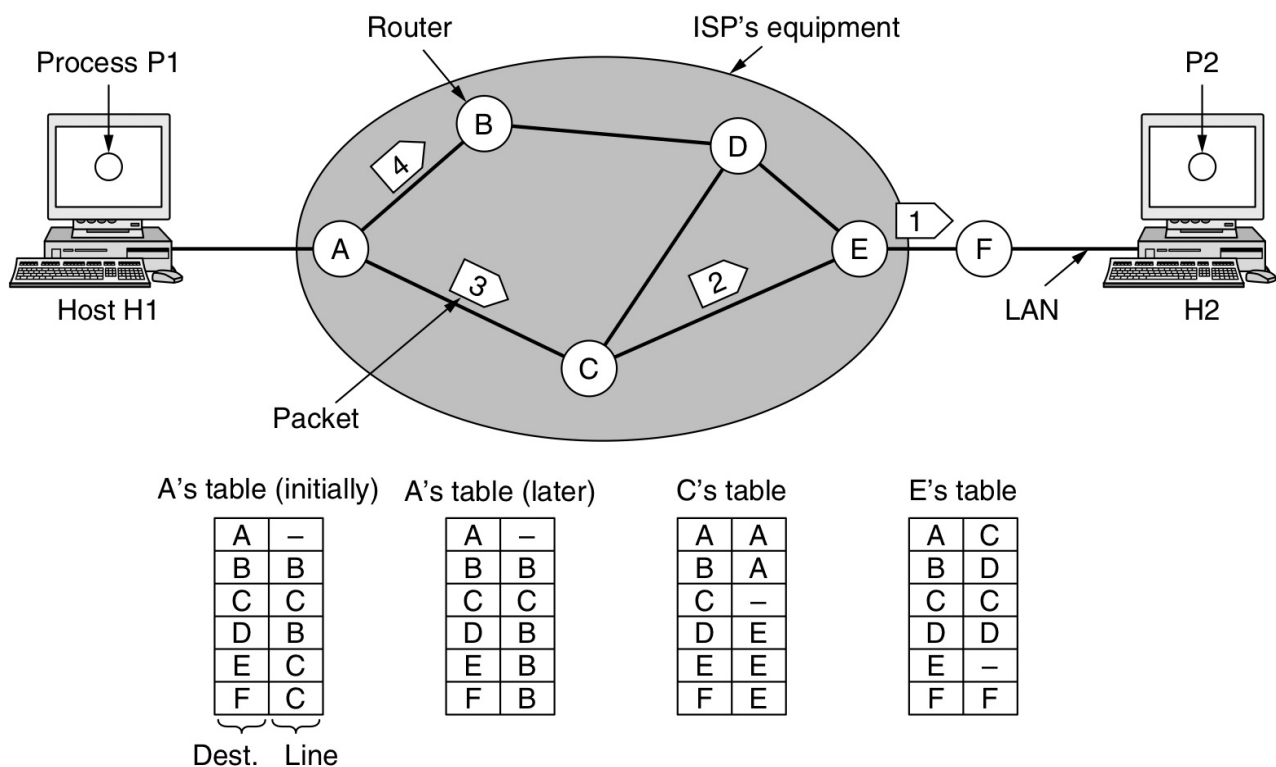
2. Services provided to transport layer

The network layer provides services to the transport layer at the network layer/transport layer interface. The services need to be carefully designed with the following goals in mind:
1. Services independent of router technology.
2. Transport layers shielded from number, type, topology of routers.
3. Network addresses available to transport layer use uniform numbering plan even across LANs and WANs

3 Implementation of connectionless service

If connectionless service is offered, packets are injected into the network individually and routed independently of each other. No advance setup is needed. In this context, the packets are frequently called datagrams (in analogy with telegrams) and the network is called a datagram network.

A's table (initially)		A's table (later)		C's table		E's table	
A	–	A	–	A	A	A	C
B	B	B	B	B	A	B	D
C	C	C	C	C	–	C	C
D	B	D	B	D	E	D	D
E	C	E	B	E	E	E	–
F	C	F	B	F	E	F	F

Dest. Line

Let us assume for this example that the message is four times longer than the maximum packet size, so the network layer has to break it into four packets, 1, 2, 3, and 4, and send each of them in turn to router A.

Every router has an internal table telling it where to send packets for each of the possible destinations. Each table entry is a pair(destination and the outgoing line). Only directly connected lines can be used.

A's initial routing table is shown in the figure under the label "initially."

At A, packets 1, 2, and 3 are stored briefly, having arrived on the incoming link. Then each packet is forwarded according to A's table, onto the outgoing link to C within a new frame. Packet 1 is then forwarded to E and then to F.

However, something different happens to packet 4. When it gets to A it is sent to router B, even though it is also destined for F. For some reason (traffic jam along ACE path), A decided to send packet 4 via a different route than that of the first three packets. Router A updated its routing table, as shown under the label "later."

The algorithm that manages the tables and makes the routing decisions is called the routing algorithm.

4 Implementation of connection-oriented service

A's table				C's table				E's table			
H1	1	C	1	A	1	E	1	C	1	F	1
H3	1	C	2	A	2	E	2	C	2	F	2
In		Out									
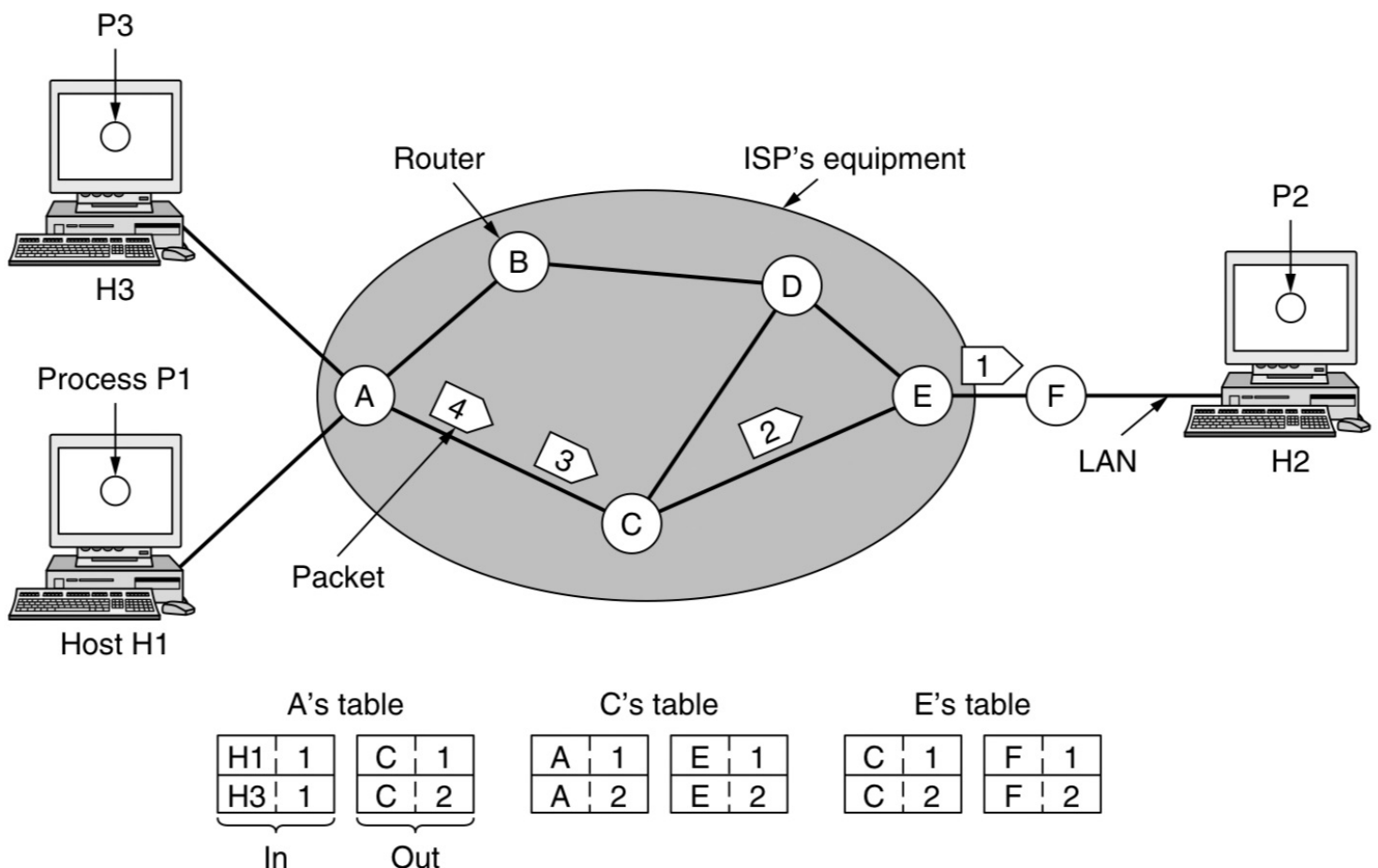
If connection-oriented service is used, a path from the source router all the way to the destination router must be established before any data packets can be sent. This connection is called a VC (virtual circuit), and the network is called a virtual-circuit network

When a connection is established, a route from the source machine to the destination machine is chosen as part of the connection setup and stored in tables inside the routers. That route is used for all traffic flowing over the connection, exactly the same way that the telephone system works. When the connection is released, the virtual circuit is also terminated. With connection-oriented service, each packet carries an identifier telling which virtual circuit it belongs to.

As an example, consider the situation shown in Figure. Here, host H1 has established connection 1 with host H2. This connection is remembered as the first entry in each of the routing tables. The first line of A's table says that if a packet bearing connection identifier 1 comes in from H1, it is to be sent to router C and given connection identifier 1. Similarly, the first entry at C routes the packet to E, also with connection identifier 1.

Now let us consider what happens if H3 also wants to establish a connection to H2. It chooses connection identifier 1 (because it is initiating the connection and this is its only connection) and tells the network to establish the virtual circuit.

This leads to the second row in the tables. Note that we have a conflict here because although A can easily distinguish connection 1 packets from H1 from connection 1 packets from H3, C cannot do this. For this reason, A assigns a different connection identifier to the outgoing traffic for the second connection. Avoiding conflicts of this kind is why routers need the ability to replace connection identifiers in outgoing packets.

In some contexts, this process is called label switching. An example of a connection-oriented network service is MPLS (Multi Protocol Label Switching).

5 Comparison of virtual-circuit and datagram networks

Issue	Datagram network	Virtual-circuit network
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Routing Algorithms

The main function of NL (Network Layer) is routing packets from the source machine to the destination machine.

There are two processes inside router:

a) One of them handles each packet as it arrives, looking up the outgoing line to use for it in

the routing table. This process is forwarding.

b) The other process is responsible for filling in and updating the routing tables. That is where

the routing algorithm comes into play. This process is routing.

Regardless of whether routes are chosen independently for each packet or only when new connections are established, certain properties are desirable in a routing algorithm correctness, simplicity, robustness, stability, fairness, optimality

Routing algorithms can be grouped into two major classes:
1) nonadaptive (Static Routing)
2) adaptive. (Dynamic Routing)

Nonadaptive algorithm do not base their routing decisions on measurements or estimates of the current traffic and topology. Instead, the choice of the route to use to get from I to J is computed in advance, off line, and downloaded to the routers when the network is booted. This procedure is sometimes called static routing.

Adaptive algorithm, in contrast, change their routing decisions to reflect changes in the topology, and usually the traffic as well.

Adaptive algorithms differ in
1) Where they get their information (e.g., locally, from adjacent routers, or from all routers),
 2) When they change the routes (e.g., every ΔT sec, when the load changes or when the topology changes),
3) What metric is used for optimization (e.g., distance, number of hops, or estimated transit time).
This procedure is called dynamic routing