Routers

Routers are another class of device that link Ethernet/802.3 and token ring LANs that are in the same location or that are geographically separated over wide-area connections. While bridges operate at the Physical and Data Link layers of the OSI model, routers operate at a the Physical, Data Link and *Network* layers. The key point relates to addressing: bridges use MAC addresses (Data Link Layer) while routers use both MAC addresses *and* network (Network Layer) addresses.

Network Layer Addressing

While MAC addresses uniquely identify every station or device on a network, they cannot uniquely identify different *networks*. Network addresses generally contain a field that identifies every network, as well as every specific device on every network.

Routers Move Packets between Networks

Routers develop tables representing the many networks that make up the *internetwork*. This includes knowing how many routers (that is, *networks*) a packet would have to traverse to travel from itself to any particular destination network.

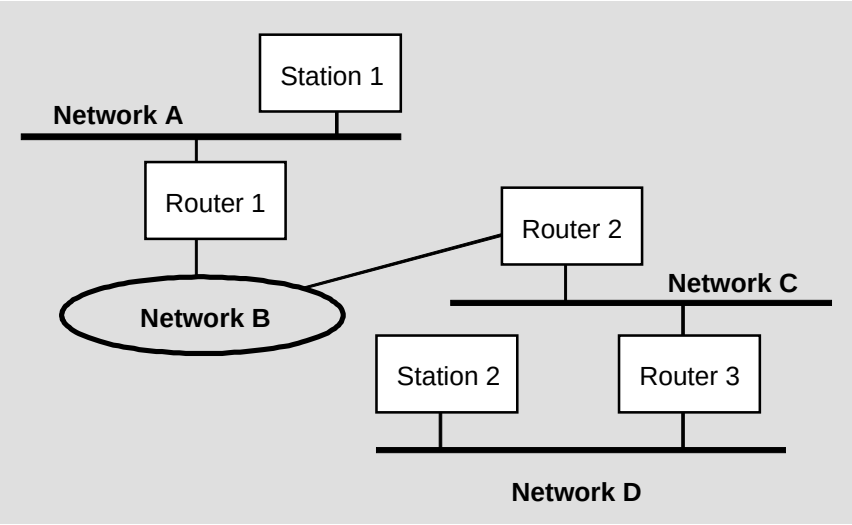

Figure 10. Router-Based Internetwork

Figure 10 shows a typical internetwork with four LANs, three routers and two end stations. Each router generates a table that provides a path to every network (A, B, C, or D) it knows about. The table in Router 1 would look something like Table 1.

Destination Network	Next Router	Number of Hops
A	none	1
B	none	1
C	2	2
D	2	3

Table 1. Router table

Address Resolution Protocols

Router tables (Table 1) do not contain the MAC address of any other router. But a MAC address is *always* required to move a packet across a LAN, even when the next device is another router. Routing protocols generally include an *Address Resolution Protocol* that routers use to figure out the MAC address of the next device to receive a packet from its network address. That is, the protocol provides a method for determining the MAC address of a device when you only know the network address of the device.

Routing: an Example Based on Figure 10

If Station 1 on Network A wants to send a message to Station 2 on Network D, the station would create a packet containing the network layer address of Station 2. This address has two parts: the network number and the station number (not a MAC address, a network layer address).

Most network layer protocols require that each end station either knows the MAC address of its local router or that it has a process that enables it find it. So, when Station 1 sends a packet to Station 2, it places the network layer packet into a data link layer packet (also called a *MAC frame*) whose destination MAC address is Router 1's MAC address.

Router 1 strips off the MAC addresses and examines the network identification part of the network layer destination address. It sees the packet is destined for Network D. It examines its table and sees that Router 2 is the next router on the path to Network D. It places the packet in a new MAC frame containing the destination MAC address of Router 2 (which it either already knows or can learn using its address resolution protocol).

Router 2 receives the packet and strips the MAC frame. It examines its table and sees that the next router is Router 3. It creates a new MAC frame with Router 3's MAC address (which again, it already knows or it now learns).

Router 3 receives the packet, strips off the MAC frame and examines the destination network address. It sees that it is directly attached to the destination network (Network D). Now it creates a new MAC frame for the packet with the actual MAC address of Station 2. It places the packet on Network D and Station 2 recognizes its own MAC address in the Destination MAC Address field of the MAC frame.

Routing Protocols

There are many routing protocols, but the most common is TCP/IP, often referred to as *IP*. IP was developed originally for the defense industry but is now widely used in private sector networks as well. Novell's IPX is another common routing protocol.

Note: Not all network protocol stacks have a network layer. So, not all protocol stacks can be routed (like IBM's SNA and its NetBIOS).

Figure 11 shows two end-stations using two TCP/IP routers to communicate. Every WAN link must have a router at both ends. This is always true, whether the link is carrying routed, bridged or some other kind of traffic.

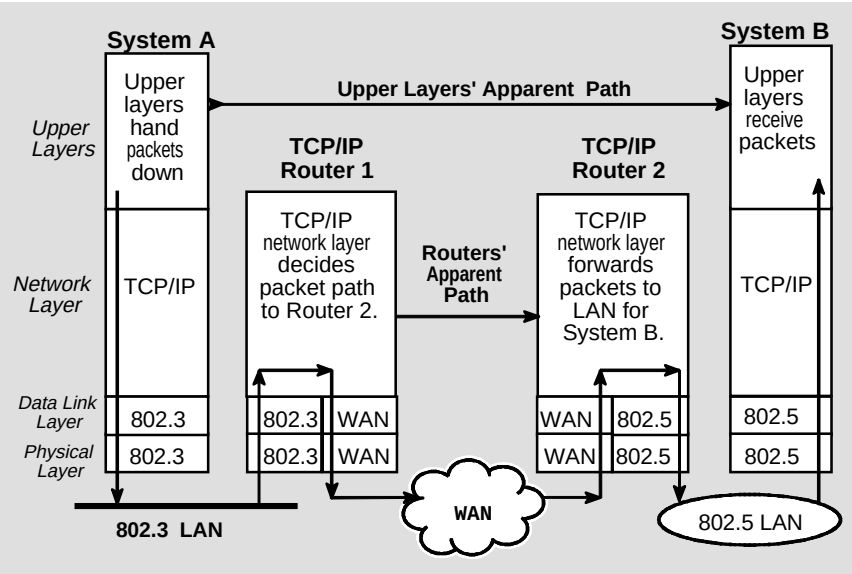

Figure 11. Apparent and Actual Data Paths between Linked Systems

Protocol *dependent* and protocol *independent* routers: There are two types of routers: protocol dependent and protocol independent. Both types use

sophisticated techniques for mapping the network to determine the best paths between LANs, but they differ in how they determine what the destination LAN is:

- *Protocol Dependent Routers* rely on network layer addresses and specific routing protocols to route packets across internetworks.
- *Protocol Independent Routers* use MAC addresses and automatic learning to route packets across internetworks. Because no network layer address is necessary and routing decisions are made based on the MAC address, the routing is *protocol independent*.