Lecture 14

Inter-network, we require inter-network, so that any two stations on any of the constituent networks can communicate. However if each of the constituent network retains its identity and communicated with the other constituent network by hopping across multiple networks in between, this entire configuration is referred to as internet. Each constituent network consists of systems referred to as **End systems**, and each constituent network is referred as **Autonomous system**. Networks are connected by devices referred as intermediate systems (ISs). Interconnection of these intermediate systems forms a **subnet**.

Router is one such intermediate system which operates at layer 3 of the OSI architecture. Also Bridge is a intermediate system which operates at layer 2 of the OSI architecture.

The overall requirements for an internetworking facility are as follows

1. Provide a link between networks.
2. Provide for the routing and delivering of data between processes on different networks.
3. Provide an accounting service that keeps track of the use of the various networks and routers and maintains status information.
4. Should be compatible with the existing network architecture.
    - Different addressing scheme
    - Different maximum packet size
    - Different network addressing mechanism
    - Different timeout
    - Routing techniques
    - Security and User Access Control
    - Connection and Connectionless

1. Virtual Circuit
2. Datagram

Virtual Circuit is very much similar to circuit switching in data link layer. In Virtual Circuit, a route is established between the source and destination, prior to any transmission of packets. That defined route is given a *unique* **virtual Circuit number,** and each router which falls along the route, makes an entry in its table, called as **routing table**, about this virtual circuit number. When a packet sent through some source, it bears a virtual circuit number, which when received by the router, the router looks in the table for its virtual circuit number, and then generates or determines the outgoing line on to which that packet need to be placed. All the packets from source to destination thus follow the same path and reach in order. The over head with virtual circuit is maintaining a routing table, and since router memory is small, so a large table cannot be maintained.

There is another technique called as datagram, where routers do have a routing table, but this time routing table contains entry about which outgoing line to place the packet depending upon the destination address contained in the packet. So determination of route is still needed, but on the basis of destination address contained in the packet, in circuit switching it was virtual circuit number, so packets routed using virtual circuit does not contain the destination address, only they contain is virtual circuit number. Each datagram must contain the full destination address, so that makes the packet very long, if there are multiple routers in the way. Each packet may or may not follow the same route, packet may or may not arrive in the same order.

Issue	Datagram subnet	Virtual-circuit subnet
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

Comparison of datagram and virtual-circuit subnets.

There are two architectural approaches for building an Inter-network or internet architecture, one is connection oriented and second one is connectionless.

In connection-oriented approach, each network provides a connection oriented form of service. That is, a virtual circuit is established between the two entities, on different Autonomous systems. After the virtual circuit is established, data packets are exchanged on that established virtual circuit

A connectionless approach behaves very much similar to the packet switching network. Each data packet of end system is treated as an independent unit and routed through series of routers and networks. For each data unit transmitted by source, source makes the decision as to which router next on the path should receive the data unit, and then hops across the inter-network from one router to another until it reaches the destination or TTL times out.

Connectionless approach is preferred over connection oriented approach, as various different kind of networks may lie on the way, connection less or connection oriented, for a connection oriented network to route the packet on a connection less network, puts an extra overhead. Internet Protocol being a connection less protocol at the network layer is widely used, and we will discuss it widely.

- Advantages
  - Flexibility
  - Robust
  - No unnecessary overhead
- Disadvantages
  - Unreliable
  - Not guaranteed delivery
  - Not guaranteed order of delivery
  - Reliability is responsibility of next layer up (e.g. TCP)

Operation of Connectionless Internetworking scheme

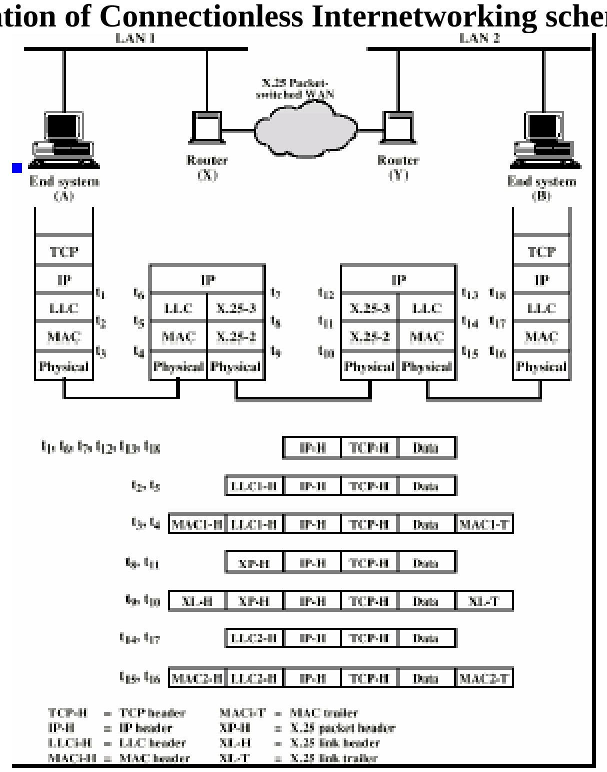


Diagram above shows the operation of connectionless Internetworking which uses IP protocol. There is host A on one LAN and host B on another LAN. They are exchanging data through the WAN between the two routers. The end systems and routers must share a common internet protocol. Each end system must share the same protocol above IP. The intermediate routers need to implement up through IP.

The IP at A receives blocks of data to be sent to B, from the upper layer. They from the datagrams by prefixing the network header and pass these datagrams to the LLC, which

attaches the LLC header and then to the MAC, which attaches the MAC header and finally to the physical layer for transmission.
Since the datagram contains the destination address of B, the IP module in A would like to send the datagram to the next hop router. This is what physical layer does physically. In this case router X (as shown in the diagram).

After reaching to router X, the router removes MAC and LLC header and analyzes the IP addresses to determine the ultimate destination of data (This we will discuss in more detail later, the processing of packets at the router). The router then makes a routing decision. There are three possibilities

1. The destination station B is connected directly to one of the networks to which the router is attached. If so the router sends the packet directly to the destination.
2. It may happen to reach the destination; packet may have to hop through one or two additional routers even more than that. To which router, packet need to be forwarded, this is decided by the router, and packet is placed on that corresponding outgoing line.
3. The router doesn't know the destination address. Then there are two possibilities, either router return the error message to the source, or he can forward the packet on the default route.

In the above example, packet must pass through router Y (intermediate router) before reaching the destination B. So router constructs a new packet by appending an X.25 header, and forwards it to router Y. When this packet arrives at router Y, it is stripped off, and destination IP address is extracted. On comparing the destination IP address with the contents of routing table, router Y determines that this destination address is on one of the networks to which the router is attached, so router Y directly forwards the packet to end system B.

Now this is how a packet travels through the inter network, but there are still very small intricate details that need to be covered, in order to gain a proper insight of operation of inter network.

Design issues of Inter-network

This topic discusses about the various issues that need to be implemented to realize the above example, or one can say, the issues that creep in or were considered during the implementation of above operation.

- Routing
- Datagram Lifetime
- Fragmentation and reassembly
- Error Control
- Flow Control

As discussed above, each router needs to do some processing with the packets it receives. He has to actually process the packet. Now what does this processing means? Processing here means that the router strip off the packet, extracts some information from the packet, and takes some decision. Router extracts information like

- What is the destination address and which outgoing line the packet should follow
- If there is any error in the received packet
- If TTL has expired or not.
- Is there any requirement to fragment, and If yes, can I fragment the packet.

All this information is contained in the packet, which network layer module tries to derive and with this information and routing table, router makes the decision on which outgoing line to forward the packet.

Routing

As briefly discussed, the decision on which outgoing line to forward the packet is what we call as routing decision. Now how do the routers maintain this routing table? There are various protocols, called as routing protocols, being used for maintaining routing tables. There are actually three terms widely used in networking scenarios: *routing, routed protocols,* and *routing protocols.*
There is story behind the difference between and rou**ted** and rou**ting** protocols.

The Story of Ted and Ting

Ted and Ting both work for the same company at a facility in Snellville, Georgia. They work in the same department; their job is to make lots of widgets. (Widgets are imaginary products; the term *widget* is used in the United States often to represent a product when the actual product is not the topic of discussion.)

Ted worked quickly and was a hard worker. In fact, because he was a very intense person, Ted tended to make more widgets than anyone else in Snellville, including Ting.

Ted also liked to have everything he needed instantly available when and where he wanted it so that he could make the widgets more quickly.

Ting, on the other hand, also worked very hard but was much more of a planner. He tended to think first and then act. Ting planned very well and had all supplies well stocked, including all the instructions needed to make the different kinds of widgets. In fact, all the information about how to build each type of widget was on a table by his door. He had a problem with the table getting "reallocated" (that is, stolen), so he applied a non-removable label with the words "Ting's Table" to the surface so that he could find the table in case someone stole it.

It turns out that Ted's productivity was partly a result of sitting next to Ting. In fact, Ted often was ready to make the next widget but needed something, such as the instruction sheet for a particular unique widget. By swinging into Ting's office, Ted could be back at it in just a few seconds. In fact, part of the reason Ting kept the instruction sheets on Ting's Table by the door was that he was tired of Ted always interrupting him looking for something.

Well, Ted got lots of bonuses for being the most productive worker, and Ting did not. Being fair, though, Ted realized that he would not be as successful without Ting, so Ted shared his bonuses with Ting. (Hey, it's an imaginary story!)

Then one day the president decided to franchise the company because it was the best widget-making company in the world. The president, Dr. Rou (pronounced like the word "ouch"), decided to create a manual to be used by all the franchisees to build their business. So, Dr. Rou went to the most productive widget maker, Ted, and asked him what he did every day. Along the way, Dr. Rou noticed that Ted went next door a lot. So, being the bright guy that he was, Dr. Rou visited Ting next and asked him what he did. The next day Dr. Rou emerged with the franchise manual. Being an ex–computer networking professional, he had called the manual "Protocols for Making Widgets."

One part of the protocol defined how Ted made widgets very quickly. Another part described how Ting kept everything needed by Ted at arm's length, including all the instructions that Ted needed.

It even mentioned Ting's Table as the place to store the instruction sheets. To give credit where credit was due—but not too much credit—the names of these protocols were as follows:

The "Rou-Ted Protocol"— How to make widgets really quickly

The "Rou-Ting Protocol"— How to plan and collect information so that the other guy can make widgets fast

The "Rou-Ting Table"— The place to store your widget-making instruction sheets

Similarly, with networking, the *routed protocol* is the one being routed, such as IP, IPX, OSI, DECnet, and so forth. The *routing protocol* is the one preparing the information needed to perform the routing process quickly, such as RIP, IGRP, OSPF, NLSP, and so forth. The *routing table* is where the information needed to perform routing is held, as built by the routing protocol and used by the routing process to forward the packets of the routed protocol.

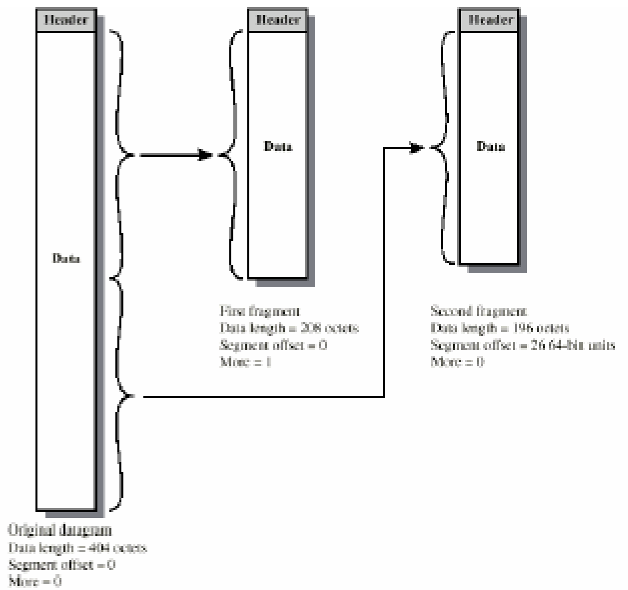
That's all just to distinguish among the terms *routed protocol, routing protocol,* and *routing table.*

Datagram Lifetime

Since a packet travels from one router to another, and in case a destination doesn't exist, it will keep on traveling, and thus a day may come in future, when there will be lots of packets traveling in the inter-network locating for their unknown destination. These wandering packets are of no use, infact they are utilizing the bandwidth of the network. To make efficient utilization of bandwidth and providing release to these packets, there is a field in the internet header, called as TTL field, which contains the number of hops a packet should take to reach the destination. TTL is an acronym for Time To Live. Every router who receives the packet, decrements the TTL value by 1, this value is initially set by the source. If the value reaches 0, then the router discards the packet.

Fragmentation and Reassembly

Each underlying can handle only a maximum size of the packet, or can only transmit some maximum size of the packet, called as MTU (Maximum Transferable Unit). If the length of the received packet exceeds the MTU, it is fragmented and these fragments may be reassembled at the converging Router or at the destination router? Can anyone suggest why is not suitable to reassemble all the fragments at the converging router?



We will discuss more about Segmentation and Reassembly during the discussion of IP header.

Error Control

Since the IP protocol is not a connectionless service, it means it is unreliable also. But routers that receive the datagram can check or determine if the packet is contaminated or not. If they come to know, they use ICMP (Internet Control Message Protocol) to send the error message back to the source.

Flow Control

Internet flow control allows the router and/or receiving stations to limit the rate at which they receive data. The best approach is to send control packets (this time again ICMP packets) to the intermediate nodes and source nodes to reduce their flow of data. We will talk in detail about ICMP in future lectures.