Lecture 19: Network Layer & Internet Protocol

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Contents

1 Network Layer Outline

The network layer is responsible for packet forwarding and routing through intermediate routers.

2 Packet Forwarding

Send an incoming or previously buffered packet to the appropriate output port. Consult an identifier in the packet header and interpret it with respect to the:

- Connectionless (datagram) Approach
- Connection-Oriented Approach
- Source-Routed Approach

We will make a couple of assumptions:

- We identify nodes via globally unique addresses (such as Ethernet addresses).
- Each input and output port of a switch is given a unique number (relative to the considered switch).

2.1 Connectionless (Datagram) Approach

Every packet contains the full destination address. The decision of how to forward packets is made by a **forwarding table** (**routing table**).

2.1.1 Advantages:

- A host can send a packet anywhere anytime, i.e. all packets can immediately be forwarded by consulting the forwarding table.
- A switch or link failure must not have serious consequences as long as one may route around the failure (by modifying forwarding tables accordingly).

2.1.2 Disadvantages:

- A sending host does not know whether the network is capable of delivering a packet or whether the destination host is even up.
- Each packet is forwarded independently of other packets means that packets may be sent via different routs and, thus may reach the destination out of order.

3 Connection-Oriented Approach

Uses the concept of a *virtual circuit(VC), which requires that first a virtual connection from the source to the host is set up before any data can be transferred. Virtual circuits can be set up in different ways:

- Permanently/statically by the system administrator, leading to **permanent virtual circuits (PVC)**.
- Temporarily/dynamically by the sending host via sending appropriate messages into the network (signalling); this leads to **switched virtual circuits (SVC)**.

The second option is by far the most widely used out of the two.

3.1 Establishing VCs

Each switch needs to keep the following information **for each VC** (connection) in a **virtual circuit table**:

- An **incoming interface** (port) on which packets for this VC arrive.
- A **virtual circuit identifier (VCI)** that will be carried in the header of arriving packets.
- An **outgoing interface** on which packets for this VC leave.
- A VCI that will be used for outgoing packets.

Important remarks:

- The VCI is **not global**; it has significance only on a given link.
- When setting up a VC, the network administrator picks VCI that are currently unused.

Disadvantages:

- There is at least 1 RTT (round-trip delay) of delay before any data can be sent.
- A switch/link failure leads to a broken connection.
- Released/broken virtual circuits need to be torn down.

Advantages:

- Each data packet does not need to include the full address of the receiver, but just a small identifier (a VCI) that is unique relative to each link (the overhead caused by headers is reduced).
- When a virtual circuit is established, the sender knows that there is a route to the receiver, the receiver is willing and able to receive and there are enough resources along the route.

See slide 15 for very useful comparison table.

3.2 Source Routing

All information about network topology that is required to switch a packet across the network is provided by the source host.

1. Include an **ordered list of port numbers** in a packet's header.

2. Each switch forwards the packet to the port determined by the number at the front of the list.

3. Before forwarding, a switch must:

    - **Strip** the front number from the packet, or
    - **Rotate** the ordered list such that the next port number comes to the front. (At the last switch, the received list is then identical to the list originally sent by the sending host).

Disadvantages:

- Every host needs to know many details of the network's topology in order to be able to construct a packet header.

    - Similar to the problem of building forwarding tables in a datagram network, or determining how to route a setup messsage in a VC network.
    - Suffers from a scaling problem since getting complete path information is very hard in reasonably large networks.

- Headers have a variable size, probably with no upper bound.

Source routing is used in:

- Virtual circuit networks as a means for getting the initial request from the sending host to the destination host.

- Embedded systems and PANs (Personal Area Networks) where the topology is simple and unlikely to change.

- In the Internet protocol as an option (a *datagram* protocol).

4 Internetworking

Internetwork An arbitrary **collection of networks** using different technologies, which are interconnected via **routers** (**gateways**) to provide a host-to-host packet delivery service, i.e. an internetwork is a **logical network**.

The underlying networks, each based on a single technology, are often called **physical networks**, which might contain collections of Ethernets connects by bridges or switches.

*Simply put, an **internetwork** is a network of networks.*

The Internet Protocol glues the single network together, yielding a large, logical and heterogeneous network.

5 IP Service Model

The IP **service model** defines the host-to-host services which an internetwork should provide. Philosphy:

- The model is **undemanding** enough such that any existing and hopefully any future network technology is able to provide the services.
- The protocol assumes a **best-effort, connectionless service** of the underlying physical networks.
- Therefore it runs on virtually any network.

6 IP Addressing

To identify all hosts in an internetwork, a global addressing scheme is needed, giving each node a unique address. Problem:

- Ethernet addresses are flat, i.e. they have no structure that provides forwarding information to routing protocols.

Solution:

- IP addresses are hierarchical, reflecting the hierarchy of an internetwork.
  - `IP Address = <network part, host part>`

Each host is assigned an IP address; similary, every interface/port of a router is assigned an IP address.