Routing, WANs, Protocol Layering

INFO 341

1

Intro - Objectives

- What is a WAN?
- What are some common WAN interconnections?
- What are some WAN characteristics?
- What is a protocol?
- What is a protocol stack?
- What are some function of different layers in the Internet Reference model?
- What is a sliding window?
- What is ARP, what does this protocol do?

2

Building ever larger networks

- Routers facilitate traffic control
- Routers use multiple interfaces (NICs) to connect different types of networks
- Routers allow for the scalable construction of ever larger networks
- Which gets us to WANs

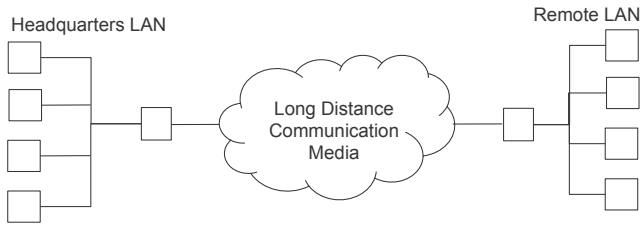
3

What is a WAN?

- Wide Area Network (WAN)
  - Extend the reach of a LAN
  - Connect remote offices, within a city or cross country
  - It is the routers that have to be connected
  - There are different types of connections with different characteristics

4

A Basic WAN



5

WAN/Router Connections

- Commercial
  - T1, T3, OC1, OC3
  - ISDN
  - Frame Relay
  - ATM
  - Business DSL
- Consumer
  - Cable
  - DSL
  - Dial-up
  - WiFi

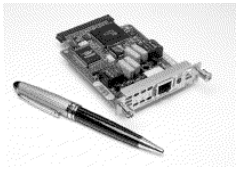
6

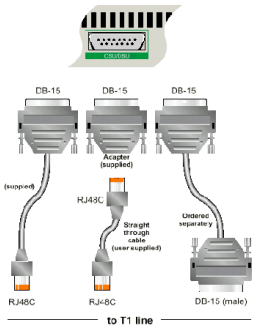
T- Carrier Lines

- Often used for PBX phone systems
- Deployed as point-to-point connections
  - Between business and phone company
  - Between remote business locations
- T1 & T3 are common
  - T1 = 1.5 Mbps, T3 = 44Mbps
- Related are the Optical Carrier lines (OC)
  - OC1 = 51 Mbps, OC3 = 155Mbps
- A DSU/CSU is required on each end (Data Service Unit/Channel Service Unit) to translate the signaling used by the phone company to the local network signaling

7

CSU/DSU





8

T- Carrier cost a large factor

- While a T1 is a slow link at 1.5Mbps compared to a local Ethernet running 10 or 100Mbps, costs for such connections are VERY expensive
  - $800-$1200 per month are typical – again the cost will vary with distance
  - Phone companies often price based on voice traffic that they are familiar with, not data traffic
  - Since a T1 is the equivalent of 24 voice lines we should of course charge the same as 24 individual voice lines. Or a T3 is equivalent to 672 voice lines so it should be 672 times as much as a single voice line right?
    - $20/month voice line * 672 = $13,440 per month
  - Some companies now will give you a base amount of bandwidth you can use, and if you have more traffic charge you extra
    - Typically see $4,000/month type costs with this type of service for T3

9

High Capacity Circuits

- STS (Synchronous Transport Signal), also commonly called OC (Optical Carrier) circuits as they require optical fiber
  - STS-1 or OC-1 51.84 Mbps
  - OC-3 155.52 Mbps
  - OC-12 622.08 Mbps
  - OC-24 1,244.16 Mbps
  - OC-48 2,488.32 Mbps

10

ISDN

- Integrated Services Digital Network (ISDN)
  - Initially planned as a service that would extend to individuals and small business
  - Typically 64Kbps per data channel
  - Basic service provides 2 data channels and 1 control channel of 16Kbps
  - Fairly old technology, not widely used except for some niche applications such as video-conferencing
  - Cost still high, over $100 a month typical, per minute charge as well close to $1/min per channel
  - Not that fast by today's standards
- Many joke that ISDN stands for *It Still Does Nothing*

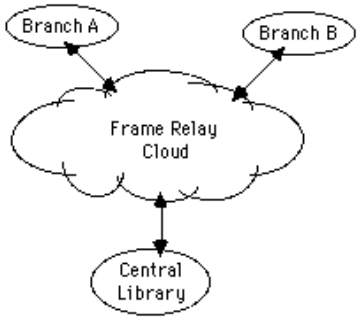
11

Frame Relay

- Designed to connect LAN segments across wide areas
- Can operate at various data rates from 1 – 100Mbps
  - In practice, usually offered at 1.5Mbps rates
  - Usually priced much less than T1
- Supports Virtual Circuits for dedicated connections among several sites
  - PVC's (Private Virtual Connections) that are always setup
  - SVC's (Switched Virtual Connections) that are setup as part of the "call"
- Big advantage - you only pay for the distance to the carrier's POP and not for the total distance, as in T1 lines
- Frame relay works with frames, at **Layer II** of the OSI model

12

Sample Frame Relay Cloud



13

Frame Relay Advantages

- Ability to easily add additional circuits
- If you have multiple locations, unlike T1 where you would have to install a dedicated connection between each site in a “mesh”, with Frame Relay each site connects to the “cloud” and through the cloud to any other site
- Large potential cost savings as a result
- Connection oriented (guaranteed delivery of packets)
- Supports specification of Quality of Service (QoS)
- You pay for the Committed Information Rate (CIR) of 256Kbps but get a T1 line at 1554Kbps, for example

14

Asynchronous Transfer Mode (ATM)

- Sold as the next generation network
  - Small fixed sized frames called “Cells” (5 octets header, 48 octets payload)
  - Extremely fast switching of cells, reduce transmission delay (reduce jitter)
  - Data, voice & video transmissions
  - LAN & WAN implementations
  - Multi-gigabit transmission speeds

15

Cable Modem

- Cable company has reserved 1-3 channels for data
- Symmetric or Asymmetric service (depends on the switches at the cable company)
- Speeds are typically 3-50Mbps
- Service is shared in a bus with your local distribution nodes (your neighbors)

16

Digital Subscriber Line (DSL)

- Digital Subscriber Line
- Uses standard phone lines
- Symmetric and Asymmetric service
- DSL-Modem splits the line into multiple digital channels (CSU/DSU), one for transmit, the other for receive, and reserves the lower voice band for .. voice
- Service is switched, single line per subscriber, so bandwidth is not shared with your neighbors
- Telcos run DSL so it's very reliable

17

WAN Characteristics

- Connection Model
- Connection Type
- Ownership
- Performance

18

Connection Model

- A circuit is a dedicated connection between locations
  - Old telephony model
  - Resource intensive (possibly $O(n^2)$ wires) to connect all nodes
- Virtual circuits
  - Give the perception of dedicated wire by multiplexing/sharing a single wire
  - Works because often there are big gaps where no data is sent (bursty traffic)

19

Connection Types

- Connection Oriented
  - Guarantee delivery of packets
  - Provide reliable communication (QoS)
- Connectionless
  - No guarantee of delivery
  - Assumed unreliable communication

20

Ownership

- Private
  - Own the network outright, but often it is impossible to own the actual WAN connection
  - A packets' "right to pass" is often restricted
- Public
  - All packets have a "right to pass" through the network
- Virtual Private Network (VPN)
  - Special equipment on each end of a WAN connection validates packets (often through encryption)
  - Now this can often be done in software

21

Network Performance

- Bandwidth (capacity)
  - The theoretical speed of transmission (frequency) measured in Hertz
- Throughput (capacity)
  - The volume of data per unit time accounting for the handling of the data
- Delay
  - How long data stays in a network
- Packet loss may occur

22

Making the Hardware Useful

- Wiring
- Transmission
- Packets
- Hubs, Switches, Routers
- LANs, WANs

- Hinted at the need for software to make it all work - to make it useful

23

Networking: A Logical Model

- How do applications use the network?
- How do endpoints communicate?

- A logical model for the network is defined by protocols, protocol stacks, and layers

24

Protocols

- Protocol - an agreement about how endpoints will communicate
  - Protocols are an end-to-end concept
- Protocol Suite - a set of protocols that handle a full range of communication details and error handling (also 'stack')

25

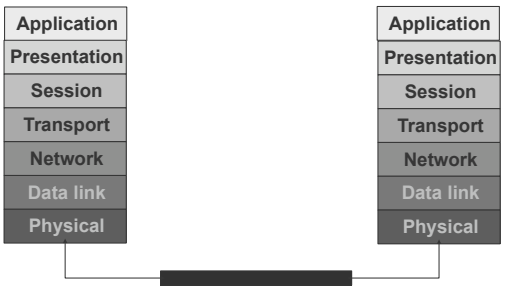
Layering

- Layers - a logical separation of concerns among the parts of a protocol stack
  - A layer often defines an interface (API) for the functions that compose that protocol level

26

ISO 7 Layer Model

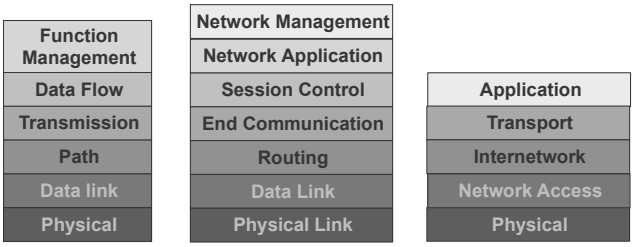
- Client app



Server app

27

Other Layered Models

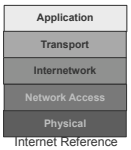


IBM SNA | DECnet | Internet Reference Model

28

What happens in a layer? Network Access

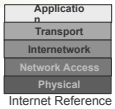
- Consider the Internet Reference Model
- Network Access
  - The functions of this layer are largely hidden from the 'user'
  - Often tied to the specific network hardware (e.g. Ethernet, Token Ring, etc)
  - The Address Resolution Protocol (ARP) exists here, to map physical addresses to internet addresses



Internet Reference Model

29

What happens in a layer? Internetwork

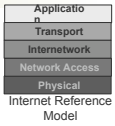


Internet Reference Model

- Internetwork
  - Facilitates delivery of internet packets
  - This is often considered the Internet Protocol (IP) layer
  - Defines the basic datagram (packet)
  - Facilitates fragmentation & reassembly
  - Defines the addressing scheme
  - Facilitates routing to remote machines

30

What happens in a layer? Host-to-Host Transport

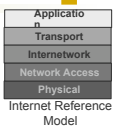


Internet Reference Model

- Host-to-Host Transport
  - User Datagram Protocol (UDP)
    - Unreliable packet delivery
    - No built-in acknowledgment of packet
    - Very low overhead from the network
  - Transmission Control Protocol (TCP)
    - Reliable, connection-oriented service
    - Attempt to guarantee delivery, packets are acknowledged, additional overhead
    - Byte stream, like reading files

31

What happens in a layer? Application



Internet Reference Model

- Application
  - File Transfer Protocol (FTP)
  - Telnet
  - Simple Mail Transfer Protocol (SMTP)
  - Domain Name Service (DNS)
  - Network File Service (NFS)

32

Problems for protocols

- As you can see, protocols at different levels must handle different problems
  - Out of order delivery
  - Too many packets delivered at once
  - Packets lost in transmission
- Sliding Window
  - A common packet transmission and acknowledgment technique that facilitates solutions to all of these problems

33

Our first protocol … ARP

- ARP solves the problem of associating physical MAC addresses with Internet Protocol (IP) addresses
- ARP is a Network Access layer protocol, just above the Physical layer
- We've not really introduced and discussed IP addressing, that will happen later …

34

ARP – Address Resolution Protocol

- ARP provides a mechanism for one device to discover the MAC address of another device when all you know is an IP address
- ARP works by sending a "broadcast" packet
- Every NIC receives that packet and the Network Access layer processes it and checks it if is 'this' device.
- If it is, 'this' device responds with a packet giving the requesting machine 'this' devices' MAC address

35

ARP tables

- Each device maintains an ARP table that lists MAC addresses and IP address that it has recently used to control the number of broadcasts required
- You can use the "arp –a" command to display the arp table
- Let's try…
  - First try arp –a
  - Now ping 128.208.100.140
  - Now arp –a again to see the new table
  - Now ping 128.208.100.140 again – did we have to ARP again to deliver the packet?
- Let's look with tcpdump … or Ethereal
- Also try ping 128.208.100.255 - what does this do?

36

Delivering packets to a different network

- We want to find a device on another network such as a PC on the UW Computer Science network. That PC has an IP address 128.95.1.56
  - Do we just sent out an ARP broadcast looking for the device?
    - Recall that different networks are connected to each other using routers
    - Recall that routers do not pass broadcast traffic
    - ARP is broadcast so ARP will not pass through a router, the NIC on the PC in Computer Science will never see an ARP packet from the PC on our network and be able to respond
    - What if routers did pass broadcast, would this be good?
    - No! Every computer on the Internet would get an ARP broadcast packet every time an Ethernet device needed to use ARP. That would be a LOT of broadcast traffic! So much that the Internet would fall to pieces
    - Plot spoilage: Proxy arp and routing tables anybody?

37

Solution …

- Next week we'll discuss this as we get into TCP/IP

38

Summary

- WAN construction, characteristics
- Connection types
- Layered models
- Protocols, protocol suites
- ARP

39