EEC 687/787 Mobile Computing
(Spring, 2007)

Fundamentals of Data Networks

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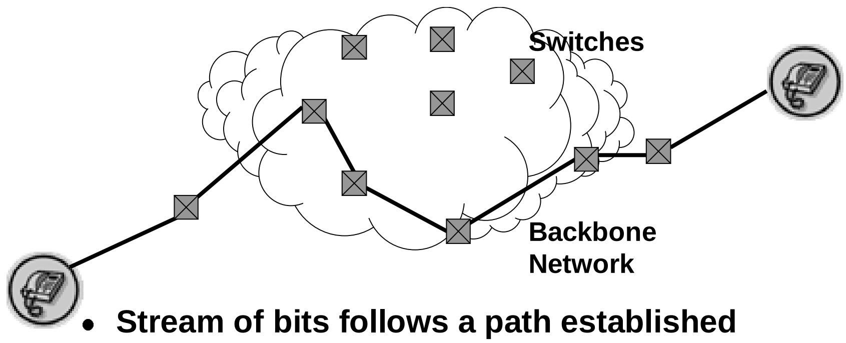
Fundamentals of Data Networks

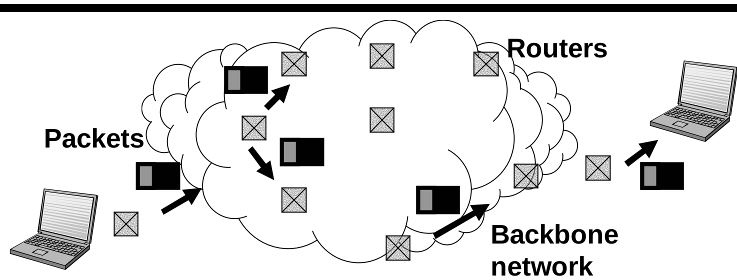
- Circuit and packet switching
- Protocols and layered architecture
- The OSI model

Circuit Switching



- Stream of bits follows a path established during call set-up
- Resources reserved for the duration of the call
- Inefficient for exchange of data
- Example: traditional telephone network

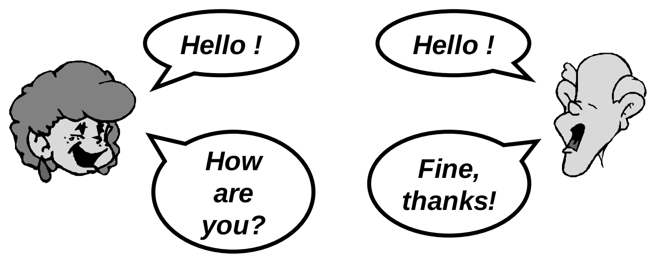
Packet Switching



- Data are sent in blocks: data + control information = a "packet"
- Resources not necessarily reserved in advance
- Increased efficiency through statistical multiplexing
- Example: the Internet

Protocols

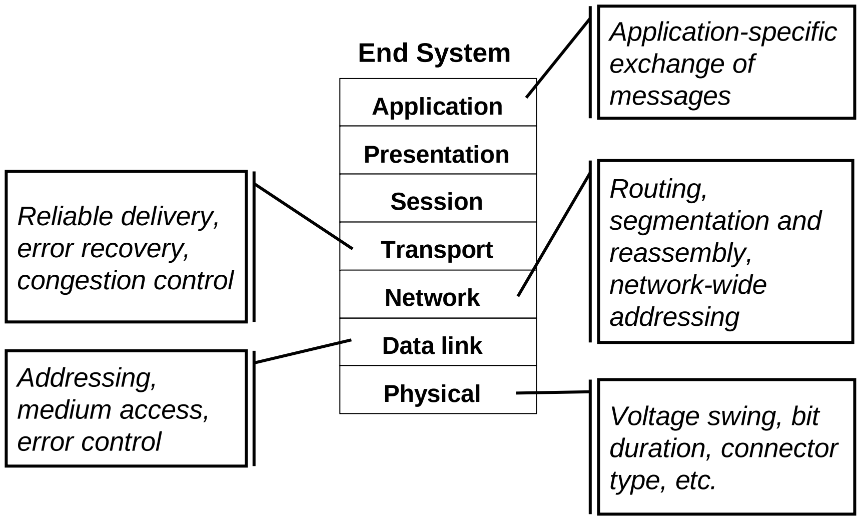
- Define the format and order of messages exchanged between two entities in the network
- Define the actions to be taken upon transmission or arrival of messages or some other event
- Examples: IP, HTTP, DHCP, etc.



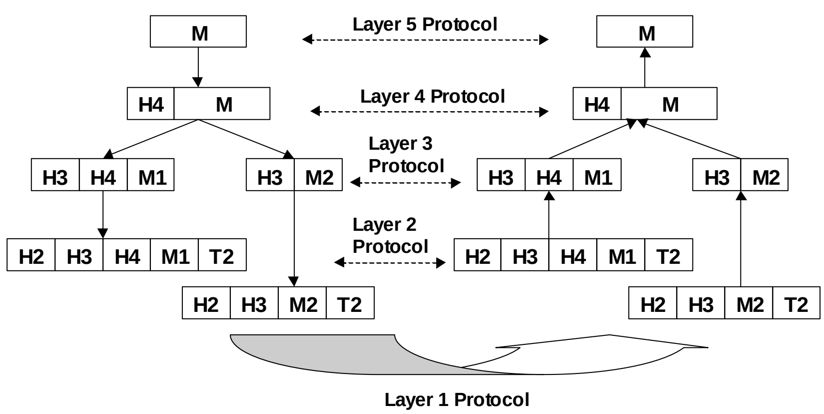
Layering

- Start with services provided by the hardware, then add a sequence of layers, each providing services to the layer just above it
- Why?
  - Decomposes the very complex problem of providing networked communications into more manageable pieces
  - More modular design (easier to add a new service or to modify the functionality of a layer)
- Example of protocol layering
  - HTTP (for web browsing) uses services from TCP (for instance, reliable delivery of packets), which uses services provided by IP (for instance, globally unique addressing)

OSI Model



Encapsulation

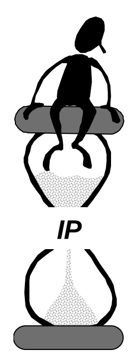


IP Protocol Suite

- IP stack
- Basic characteristics and reasons for ubiquity of IP
- ICMP

Why is IP so successful?

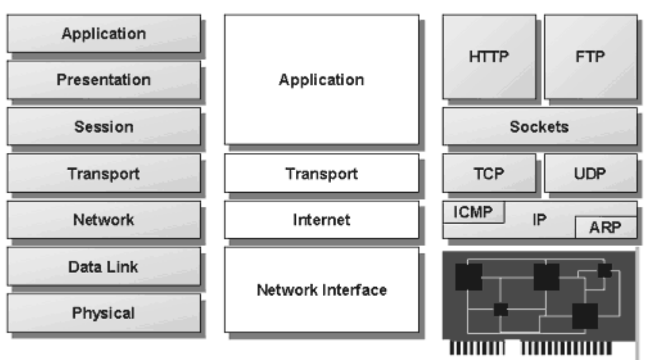
- Hourglass shape of the protocol stack
  - Many protocols run “over” IP
  - IP runs “over everything”
- Architectural principles
  - Minimalism, autonomy
  - Best effort service
  - Stateless routers
  - Decentralized control



IP Protocol Stack

Application	***e.g.*** **TELNET, FTP, SNMP, DNS, HTTP, etc.**
Transport	**TCP, UDP**
Internet	**IP**
Physical + Data Link	***e.g.*** **Ethernet, 802.11, SONET, ATM, etc.**

OSI and the IP suite

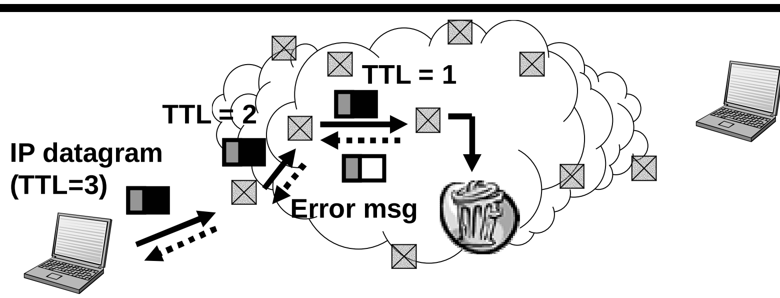


OSI and TCP/IP

Essential Characteristics of IP

- **Connectionless**
  - **Each IP <u>datagram</u> is treated independently and may follow a different path**
- **Best effort**
  - **No guarantees of timely delivery, ordering, or even delivery**
- **Globally unique 32-bit addresses**
  - **Usually expressed in dot-decimal notation: 128.17.75.0**
  - **Each interface has its own IP address**
  - **Later, we will see that there are ways to use non-unique addresses**
- **Typical IP datagram contains payload + a 20-byte header with control information (addressing, redundant bits for error detection, etc.)**

Time to Live (TTL)



- **IP datagram headers contain a TTL field**
  - **At each router, this field is decremented; if it reaches 0, datagram is discarded and an error message is generated**
- **Original purpose was to prevent datagrams from endlessly circulating within the network**

ICMP

- Internet Control Message Protocol (ICMP)
  - Used by hosts, routers and gateways to communicate network layer information to each other
  - Typically used for error reporting
- Uses the services of IP
  - ICMP messages are carried as IP payload
- ICMP messages have a type and code and contain the first 8 bytes of the IP datagram that caused the ICMP message to be generated
- Many of the utilities we will use in this course (ping, traceroute, etc.) are implemented by processing ICMP messages

Introduction to Addressing

- IP addresses
- MAC addresses
- Address translation: DNS and ARP

IP Addresses

- 32-bit addresses

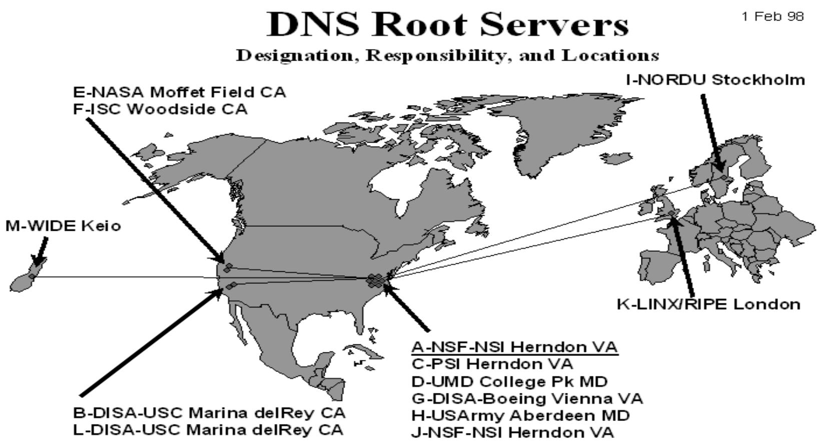
  01001000 11000001 00000001 00001001
- Usually expressed in dot-decimal notation for convenience

72 . 193 . 1 . 9

Address Translation: DNS

- From a domain name or URL (application layer) to an IP address (network layer)
  - Use Domain Name System (DNS)
  - Root and authoritative name servers provide the translation between any possible domain name and an IP address
  - Translation is cached locally

DNS Root Servers



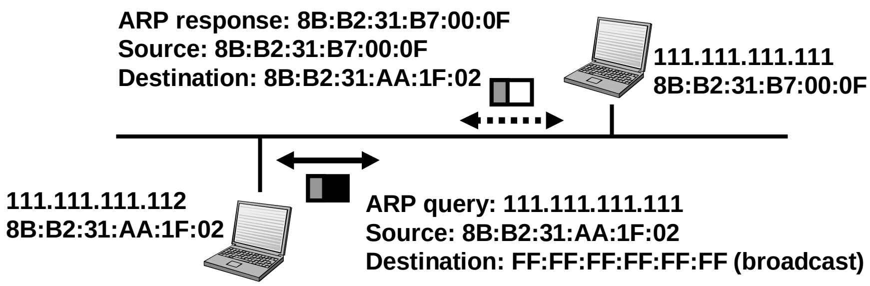
MAC addresses

- LAN adaptors have hard-coded Medium Access Control (MAC) addresses
- These are 6-byte globally unique addresses
  - First 3 bytes identify the vendor
  - Expressed as hexadecimals separated by ":"
- Example:
  - 02 : 60 : 8C : E4 : B1 : 02

    (02 : 60 : 8C = 3COM)

Address Translation: ARP

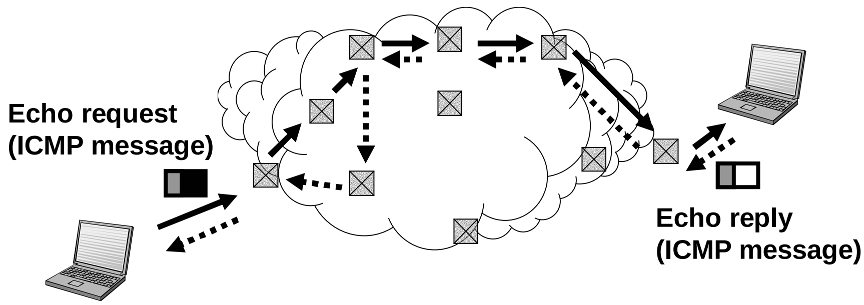
- From an IP address (network layer) to a MAC address (link layer)
  - Use the Address Resolution Protocol (ARP)
  - Results from an ARP query are kept locally in an ARP cache



Some Basic Tools for Performance Monitoring

- Ping
- Traceroute
- Ethereal

Ping

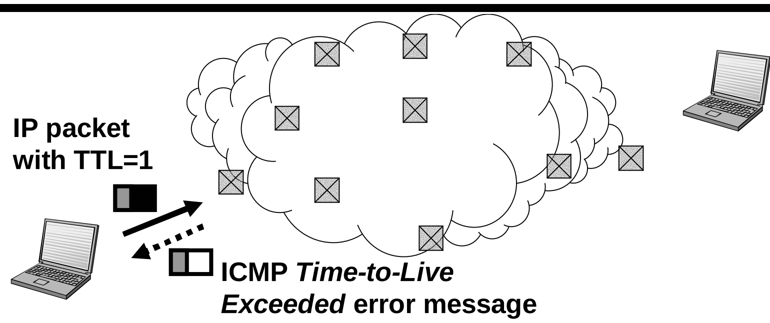


- **Measures the round-trip time (RTT) between two nodes**
- **Source node generates echo request(s), destination node responds with echo reply (replies)**

Ping Example

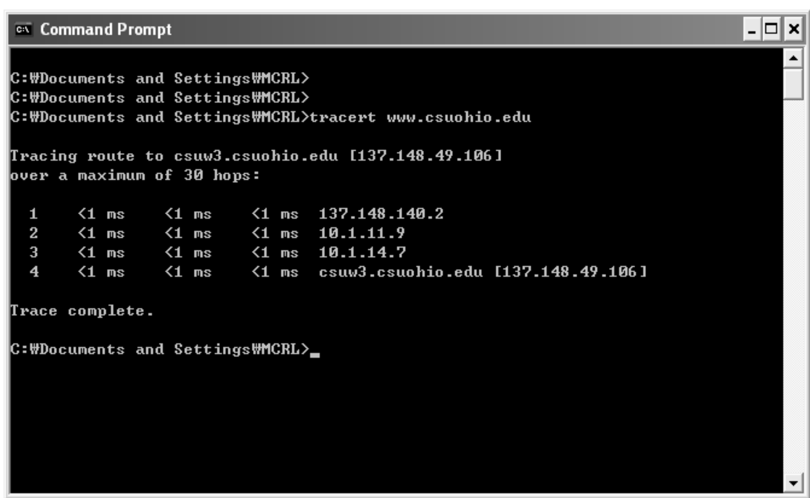
```
Command Prompt
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\MCRL>ping www.csuohio.edu

Pinging csuw3.csuohio.edu [137.148.49.106] with 32 bytes of data:

Reply from 137.148.49.106: bytes=32 time<1ms TTL=252
Reply from 137.148.49.106: bytes=32 time<1ms TTL=252
Reply from 137.148.49.106: bytes=32 time<1ms TTL=252
Reply from 137.148.49.106: bytes=32 time<1ms TTL=252

Ping statistics for 137.148.49.106:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Documents and Settings\MCRL>
```

Traceroute



- **Lists all routers between source and destination**
- **Send consecutive IP datagrams with TTL = 1, 2, …**
  - **Each of these will "die" at one of the intermediate routers, which will respond with an ICMP error message**
  - **Source will learn the identity of every router on the path**

Traceroute Example



Ethereal

- A "GUI protocol analyzer" that display, organizes and filters the results of packet sniffing
- A wide variety of packet types and protocols are supported by Ethereal
  - ATM, ARP, BGP, DNS, FTP, HTTP, IP, POP, TCP, UDP, and many others (even Quake…)
- Each packet is shown with source, destination, protocol type, and comments
  - A HEX dump shows you exactly what the packet looked like as it went over the wire
- Many more features to be explored in the homework
  - For more info, go to www.ethereal.com

Ethereal Example