Chapter 10

The Internet

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CMP 110: Data Communications & the Internet
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An Introduction to the Internet

- **Brief History**
  - The Internet was born on Sep. 1, 1969 as the **ARPANET**
    - One computer at UCLA was connected to an AT&T carrier service network
  - Four locations connected by end of 1969; thirteen sites by end of 1970

An Introduction to the Internet

- **Brief History**
  - First international connection (to Norway, via UK) in 1973
  - Cerf and Kahn develop **TCP** in 1973
    - Establish communication session between hosts
    - Acknowledge the safe arrival of packets, and arrange for retransmission
    - Regulated flow of traffic between hosts

An Introduction to the Internet

- **Brief History**
  - **IP** split off from TCP in 1978; responsible for host addressing
  - ARPA had completely switched from NCP to TCP/IP by the end of 1982

An Introduction to the Internet

- **Brief History**
  - Supervision of ARPANET changed from ARPA to **Defense Communications Agency (DCA)** in 1975
    - In the event of failure in the circuit-switched AT&T telephone network, the military could still use ARPANET

An Introduction to the Internet

- **Brief History**
  - Supervision of ARPANET changed from ARPA to Defense Communications Agency (DCA) in 1975
    - Repercussions for academic researchers
      - Academic and research communities were comfortable with the open sharing of information and knowledge
      - Military personnel saw potential for compromise of security

An Introduction to the Internet

- **Brief History**
  - **MILNET** split off from ARPANET in April 1983
    - ARPANET remained under military control, but became more and more civilian-dominated
  - National Science Foundation's **CSNET**, a network of university Computer Science departments, was connected to ARPANET

An Introduction to the Internet

- **Brief History**
  - Emergence of PCs in the early 1980s led to demand for data sharing
  - Based on the success of ARPANET and CSNET, the NSF continued to fund research into computers and networking

An Introduction to the Internet

- **Brief History**
  - The NSF built five regional supercomputing centers, and linked them together into the **NSFNET** in 1985

An Introduction to the Internet

- **Brief History**
  - **NSFNET** centers:
    - **Princeton** (John von Neumann Center)
    - **UC San Diego** (San Diego Supercomputer Center)
    - **Illinois** (National Center for Supercomputing Applications)
    - **Cornell** (Cornell Theory Center)
    - **CMU & Pitt** (Pittsburgh Supercomputing Center)

An Introduction to the Internet

- **Brief History**
  - NSFNET was linked by T1 links by 1987
  - ARPANET was officially taken off-line at the end of February 1990, replaced by NSFNET
    - This ended military jurisdiction of the Internet

An Introduction to the Internet

- **Brief History**
  - When NSFNET replaced ARPANET in 1990, commercial business activities were not allowed
  - Several commercial TCP/IP networks were created that were not limited to academia and research
  - These commercial backbones had grown so much by 1991 that NSF could begin to plan for a smooth transition to the private sector

An Introduction to the Internet

- **Brief History**
  - NSF began turning Internet service over to private **Internet service providers** (**ISPs**) in 1994
  - NSFNET was officially decommissioned in April, 1995, making the Internet a private commercial enterprise, maintained by carriers and ISPs

An Introduction to the Internet

- **Internet Governance**
  - **Internet Society (ISOC)**
    - Formed in 1992
    - Created to expand financial support for Internet activities
    - Supports the publication activities of the IETF

An Introduction to the Internet

- **Internet Governance**
  - **Major Standards-Development Bodies**
    - **Internet Architecture Board (IAB)**
      - Defining Internet architecture and keeping the pulse of long-range Internet issues
    - **Internet Engineering Steering Group (IESG)**
      - Handles technical management of IETF activities

An Introduction to the Internet

- **Internet Governance**
  - **Major Standards-Development Bodies**
    - **Internet Engineering Task Force (IETF)**
      - Primary organization responsible for Internet standards development
  - **Internet Research Task Force (IRTF)**
    - Coordinates research activities involving Internet protocols, applications, and other Internet-related technologies; sponsored by **ISOC** and **IETF**

An Introduction to the Internet

- **Internet Governance**
  - **Internet Corporation for Assigned Names and Numbers (ICANN)**
    - Non-profit corporation that works on the behalf of the US government
    - Responsible for the allocation of IP address space Assigns Internet protocol identifiers
    - Manages the top-level domains (TLDs) such as .com, .org, .net, etc.

An Introduction to the Internet

- **Internet Governance**
  - **Internet Corporation for Assigned Names and Numbers (ICANN)**
    - Provides management functions for the domain name system (DNS)'s root servers
    - Vint Cerf is a former chairman of the board of directors

Accessing Information on the Internet

- **The Origin of the Domain Name System**
  - In the early days, each ARPANET host stored a **hosts file** in `hosts.txt`
    - Each time the ARPANET grew, each host's `hosts.txt` file grew
    - File was centralized at the Stanford Research Institute, which would propagate changes to all hosts

Accessing Information on the Internet

- **The Origin of the Domain Name System**
  - In the early days, each ARPANET host stored a **hosts file** in `hosts.txt`
    - *Each new host on the network necessitated broadcast traffic*
    - There were obvious limits on the scalability of this system

Accessing Information on the Internet

- **The Origin of the Domain Name System**
  - In 1983, Paul Mockapetris and Jon Postel created and tested a **distributed** database of host names and IP addresses
  - DNS was first described in RFD 882 and 883; current specification in RFC 1034 and 1035

Accessing Information on the Internet

- **The Origin of the Domain Name System**
  - Security, implementation, and administrative details updated in RFC 1535, 1536, and 1537
  - When a site adds a host, DNS distributes the host's information to other DNS servers around the network

Accessing Information on the Internet

- **The Origin of the Domain Name System**
  - Other hosts on other networks then access these distributed DNS servers remotely to resolve host names to IP addresses

Accessing Information on the Internet

- **Name Servers**
  - DNS servers are generally located in pairs at each local, regional, and national ISP
  - The client computer, called the "resolver", generates a resolve request and sends it to the IP address of the ISP's DNS server
  - If the DNS server can resolve the request, it does so; otherwise, the request travels up the DNS hierarchy

Accessing Information on the Internet

- **Name Servers**
  - DNS servers are configured to communicate with at least one other DNS server
  - DNS servers can *cache* requests for a configurable amount of time

Accessing Information on the Internet

- **Internet Domains**
  - The **Root Domain** serves as the top of the domain name hierarchy
    - The **Top-Level Domains** (**TLDs**) exist to organize all the assigned names
      - **.com** was originally intended for business presence
        - **rush.com, espn.com, amazon.com**

Accessing Information on the Internet

- **Internet Domains**
  - Other top-level domains exist for other organizational units
    - **.edu** for educational institutions like **ncc.edu**, **molloy.edu**, or **uvm.edu**
    - Other TLDs include **.org**, **.net**, **.mil**

Accessing Information on the Internet

- **Internet Domains**
  - More recent additions include country-code TLDs like **.ie**, **.it**, **.uk**, etc., and new organization types like **.museum**, **.info**, etc.
  - The maximum amount of layers under any TLD is 126
  - Domain names must be no longer than 255 characters (excluding dots); each part of a domain name is limited to 64 characters

Accessing Information on the Internet

- **Internet Protocols**
  - **Address Resolution Protocol (ARP)**
  - **Dynamic Host Configuration Protocol (DHCP)**
  - **User Datagram Protocol (UDP)**
  - **iSCSI**

Accessing Information on the Internet

- **Internet Protocols**
  - Many application-layer protocols
    - **HTTP** and **FTP/SFTP/SCP**
    - **Telnet** and **SSH**
    - **SMTP**, **POP3**, and **IMAP4**
    - **Real-Time Streaming Protocol (RTSP)**
    - IM protocols such as **XMPP** and **SIMPLE**

The Future of the Internet

- Remember those five supercomputing centers connected by the NSF in the 1990s?
  - They were connected by the **NSFNET**
  - NSFNET was decommissioned in April 1995, and was replaced by privately-run TCP/IP backbones
  - At the same time, NSF launched a new network backbone called vBNS

The Future of the Internet

- **Very High-Speed Backbone Network Service (vBNS)**
  - Connected the five supercomputing centers, government agencies, and research institutions with high-speed connections
  - Came to be called the **Next-Generation Internet** initiative, funded by the US government
  - Still operated by MCI; no longer funded by NSF

The Future of the Internet

- **Internet2**
  - Created by 34 US universities in 1996
  - Not a network infrastructure *per se*; it's a consortium of universities, government, and businesses to build and test advanced applications and technologies

The Future of the Internet

- **Internet2**
  - Incorporated in 1997 under the *University Consortium for Advanced Internet Development (UCAID)*

The Future of the Internet

- **Internet2**
  - The **Abilene Project** is the actual physical communications network that supports Internet2
    - Went live in February, 1999 on 2.4 Gbps OC-48 lines
    - Upgraded to 10 Gbps OC-192 in 2004
    - Not interconnected with the public Internet

The Future of the Internet

- **Internet2**
  - There exist many Internet2 Working Groups that support advanced service, application, and technology development, including:
    - **Campus Bandwidth Management**
    - **Digital Video**
    - **Integrated Infrastructure for Instant Messaging**
    - **IPv6** and more

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - Why?
    - The need to provide IP addresses to a growing number of devices
    - Next-generation business applications
    - Growing use of mobile and wireless devices
    - Increased exposure of data as it is transmitted across the Internet

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - Why?
    - We are running out of IPv4 addresses
      - This problem is partially solved by NAT and DHCP
      - However, NAT does not allow client devices to provide interactive services to the rest of the network
      - An IPv4-based solution to that problem is a significant challenge; implementing IPv6 will probably be easier

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - Why?
    - IPv4 does not scale well to large amounts of mobile devices; results in inefficient routing of network traffic
      - This problem is solved by IPv6's **autoconfiguration** feature
    - Security is an add-on feature to IPv4 (through IPSec); security is built in to IPv6

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **IPv6 Addresses**
    - An IPv6 address is 128 bits long (compare to 32 bits in an IPv4 address)
    - The address is broken into eight 16-bit sections

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **IPv6 Addresses**
    - For simplicity's sake, each 16-bit section is represented by four *hexadecimal* digits
      - 0 through 9, and then A through F (A = 10, B = 11, etc.)
    - Example IPv6 address:
      FE80:0000:0000:0000:ABCD:FF32:030C:1234

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **IPv6 Addresses**
    - There are no classes of IPv6 addresses; the first bits are the **Global Routing Prefix** bits
    - These are followed by subnet ID bits, and then **Interface ID** bits, derived from the MAC address

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **IPv6 Addresses**
    - FE80:0000:0000:0000:ABCD:FF32:030C:1234 can be abbreviated a couple of ways
      - Remove leading zeros to create FE80:0:0:0:ABCD:FF32:30C:1234
      - Represent a string of zeros with two colons, such as FE80::ABCD:FF32:30C:1234 (This can only be done once per address)

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **IPv6 Addresses**
    - FE80::ABCD:FF32:030C:1234/**10**, with that "/10" at the end, means that the first ten bits are the global routing bits (this is called **prefix notation**)

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **Types of IPv6 Addresses**
    - **Unicast** addresses identify individual, unique network interfaces
      - Network cards
      - Wireless access points
      - Switch ports or router ports

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **Types of IPv6 Addresses**
    - **Global Unicast** addresses are unique across the entire IPv6 Internet
      - Start with bits 001
      - Each group of bits 4-16, 25-48, and 49-64 represent different organizational bodies like the ISP, or are assigned locally
      - The last 64 bits comprise the interface portion

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **Types of IPv6 Addresses**
    - An **anycast** address is a unicast address that is assigned to more than one interface
      - Imagine a network with access to the Internet through many routers
      - Each router can be configured with the same anycast address, used as a destination by the internal machines
      - No one really cares which router sends data out to the Internet

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **Types of IPv6 Addresses**
    - A **link-local unicast** address can be used on a network that doesn't require routing
      - Addresses must start with bits 1111 1111 10
    - **Multicast addresses** can be used to send packets to groups of interfaces

The Future of the Internet

- **Internet Protocol Version 6 (IPv6)**
  - **Types of IPv6 Addresses**
    - The **loopback** address in IPv6 is **0000:0000:0000:0000:0000:0000:0000:0001**
      - Which can be abbreviated as **::1**
      - Analogous to the IPv4 loopback address **127.0.0.1**