Introduction to Computer Science Lesson 9

BSc in Computer Science University of New York, Tirana

Assoc. Prof. Marenglen Biba

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Networking and the Internet

- Today
 - Network Fundamentals
 - The Internet

- Next Lesson
 - The World Wide Web
 - Internet Protocols
 - Security

Networks

- The need to share information and resources among different computers has led to linked computer systems, called networks, in which computers are connected so that data can be transferred from machine to machine.
- In these networks, computer users can exchange messages and share resources — such as printing capabilities, software packages, and data storage facilities — that are scattered throughout the system.
- The underlying software required to support such applications has grown from simple utility packages into an expanding system of network software that provides a sophisticated network-wide infrastructure.
- In a sense, network software is evolving into a network-wide operating system.

Network Classifications

- Scope
 - Local area network (LAN)
 - Metropolitan area network (MAN)
 - Wide area network (WAN)
- Ownership
 - Closed versus open
- Topology (configuration)
 - Bus (Ethernet)
 - Star (Wireless networks with central Access Point)

LAN, WAN and MAN

- A LAN normally consists of a collection of computers in a single building or building complex.
 - For example, the computers in a university campus or those in a manufacturing plant might be connected by a LAN.
- A MAN is a network of intermediate size, such as one spanning a local community.
- A WAN links machines over a greater distance perhaps in neighboring cities or on opposite sides of the world.

Open and closed network

• Open network

- the network's internal operation is based on designs that are in the public domain, not owned by someone
- Closed or Proprietary network
 - the network's internal operation is based on innovations owned and controlled by a particular entity such as an individual or a corporation.

Examples of open and closed networks

- The Internet, the popular worldwide network of networks, is an open system.
 - In particular, communication throughout the Internet is governed by an open collection of standards known as the TCP/IP protocol suite.
 - Anyone is free to use these standards without paying fees or signing license agreements.
- In contrast, a company such as Novell Inc. might develop proprietary systems for which it chooses to maintain ownership rights, allowing the company to draw income from selling or leasing these products.

Figure 4.1 Network topologies

a. Bus



The machines are all connected to a common communication line called a bus.

Bus topology

 The bus topology was popularized in the 1990s when it was implemented under a set of standards known as Ethernet, and Ethernet networks remain one of the most popular networking systems in use today.

Ethernet

- Ethernet is a set of standards for implementing a LAN with a bus topology.
- Its name is derived from the original Ethernet design in which machines were connected by a coaxial cable called the ether.
- Originally developed in the 1970s and now standardized by IEEE as a part of the IEEE 802 family of standards, Ethernet is one of the most common methods of networking PCs.
- Indeed, Ethernet controllers have become a standard component in the PCs available in the current retail market.

Figure 4.1 Network topologies (continued)

b. Star



Star topology

- The star topology has roots as far back as the 1970s.
- It evolved from the paradigm of a large central computer serving many users.
- As the simple terminals employed by these users grew into small computers themselves, a star network emerged.
- Today, the star configuration is popular in wireless networks where communication is conducted by means of radio broadcast and the central machine, called the access point (AP), serves as a focal point around which all communication is coordinated.

Bus Vs Star

- Indeed, sometimes a bus network is created by running links from each computer to a central location where they are connected to a device called a hub.
 - This hub is little more than a very short bus.
 - All it does is pass any signal it receives (with perhaps some amplification) back out to all the machines connected to it.
- The result is a network that looks like a star network although it operates like a bus network.

Protocols

- For a network to function reliably, it is important to establish rules by which activities are conducted.
- Such rules are called protocols.
- By developing and adopting protocol standards, vendors are able to build products for network applications that are compatible with products from other vendors.
- Thus, the development of protocol standards is an indispensable process in the development of networking technologies.

Why protocols?

- As an introduction to the protocol concept, let us consider the problem of coordinating the transmission of messages among computers in a network.
- Without rules governing this communication, all the computers might insist on transmitting messages at the same time or fail to assist other machines when that assistance is required.

Protocols

- CSMA/CD
 Used in Ethernet
- CSMA/CA
 - Used in WiFi

CSMA-CD

- In a bus network based on the Ethernet standards, the right to transmit messages is controlled by the protocol known as Carrier Sense, Multiple Access with Collision Detection.
- This protocol dictates that each message be broadcast to all the machines on the bus.
 - Each machine monitors all the messages but keeps only those addressed to itself.
 - To transmit a message, a machine waits until the bus is silent, and at this time it begins transmitting while continuing to monitor the bus.
- If another machine also begins transmitting, both machines detect the clash and pause for a brief, independently random period of time before trying to transmit again.
- RESULT: The result is a system similar to that used by a small group of people in a conversation. => next slide

CSMA-CD (continued)

- If two people start to talk at once, they both stop.
- The difference is that people might go through a series such as, "I'm sorry, what were you going to say?", "No, no. You go first,"
- Whereas under the CSMA/CD protocol each machine merely tries again later.

Figure 4.2 Communication over a bus network



CSMA/CD not compatible with wireless star networks

- CSMA/CD is not compatible with wireless star networks in which all machines communicate through a central AP.
- This is because a machine may be unable to detect that its transmissions are colliding with those of another.
 - For example, one cause might be that the signals from the different machines are blocked from each other by objects or distance even though they can all communicate with the central AP (a condition known as the hidden terminal problem)

Figure 4.3 The hidden terminal problem



CSMA/CA

- The result is that wireless networks adopt the policy of trying to *avoid* collisions rather than trying to *detect* them.
- Such policies are classified as Carrier Sense, Multiple Access with Collision Avoidance (CSMA/CA), many of which are standardized by IEEE ("Institute of Electrical and Electronics Engineers") within the protocols defined in IEEE 802.11 and commonly referred to as WiFi.
- We emphasize that collision avoidance protocols are designed to avoid collisions and may not eliminate them completely.
- When collisions do occur, messages must be retransmitted.

CSMA/CA

- Approach to collision avoidance: give advantage to machines that have already been waiting for an opportunity to transmit.
 - When a machine first needs to transmit a message and finds the communication channel silent, it does not start transmitting immediately.
 - Instead, it waits for a short period of time and then starts transmitting only if the channel has remained silent throughout that period.
 - If a busy channel is experienced during this process, the machine waits for a randomly determined period before trying again.
 - Once this period is exhausted, the machine is allowed to claim a silent channel without hesitation.
- This means that collisions between "newcomers" and those that have already been waiting are avoided because a "newcomer" is not allowed to claim a silent channel until any machine that has been waiting is given the opportunity to start.

Combining Networks

- Sometimes it is necessary to connect existing networks to form an extended communication system.
- This can be done by connecting the networks to form a larger version of the same "type" of network.
- For example, in the case of bus networks based on the Ethernet protocols, it is often possible to connect the buses to form a single long bus.
- This is done by means of different devices known as repeaters, bridges, and switches.

Connecting Networks

- **Repeater:** Extends a network
- Bridge: Connects two compatible networks
- Switch: Connects several compatible networks
- Router: Connects two incompatible networks resulting in a network of networks called an internet

Repeater

 The simplest of these is the repeater, which is little more than a device that simply passes signals back and forth between the two original buses (usually with some form of amplification) without considering the meaning of the signals.



 a. A repeater or bridge connecting two buses

Bridge

- A bridge is similar to, but more complex than, a repeater.
- Like a repeater, it connects two buses, but it does not necessarily pass all messages across the connection.
- Instead, it looks at the destination address that accompanies each message and forwards a message across the connection only when that message is destined for a computer on the other side.
- Thus, two machines residing on the same side of a bridge can exchange messages without interfering with communication taking place on the other side.
- A bridge produces a more efficient system than that produced by a repeater.

Switch

- A switch is essentially a bridge with multiple connections, allowing it to connect several buses rather than just two.
- Thus, a switch produces a network consisting of several buses extending from the switch as spokes on a wheel.
- As in the case of a bridge, a switch considers the destination addresses of all messages and forwards only those messages destined for other spokes.
- Moreover, each message that is forwarded is relayed (passed) only into the appropriate spoke, thus minimizing the traffic in each spoke.

Switch



 $\boldsymbol{b}.$ A switch connecting multiple buses

Router

- The connection between networks to form an internet is handled by devices known as routers, which are special purpose computers used for forwarding messages.
- Note that the task of a router is different from that of repeaters, bridges, and switches in that routers provide links between networks while allowing each network to maintain its unique internal characteristics.

Figure 4.5 Routers connecting two WiFi networks and an Ethernet network to form an internet



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Local and internet address

- The reason that routers are so named is that their purpose is to forward messages in their proper directions.
- This forwarding process is based on an internetwide addressing system in which all the devices in an internet (including the machines in the original networks and the routers) are assigned unique addresses.
- Thus, each machine in one of the original networks has two addresses: its original "local" address within its own network and its internet address.

Forwarding table

- A machine wanting to send a message to a machine in a distant network attaches the internet address of the destination to the message and directs the message to its local router.
- From there it is forwarded in the proper direction.
- For this forwarding purpose, each router maintains a forwarding table that contains the router's knowledge about the direction in which messages should be sent depending on their destination addresses.

Gateway

- The "point" at which one network is linked to an internet is often called a gateway because it serves as a passageway between the network and the outside world.
- Gateways can be found in a variety of forms, and thus the term is used rather loosely.
- In many cases a network's gateway is merely the router through which it communicates with the rest of the internet.
- In other cases the term gateway may be used to refer to more than just a router.
 - For example, in most residential WiFi networks that are connected to the Internet, the term gateway refers collectively to both the network's AP and the router connected to the AP because these two devices are normally packaged in a single unit.

Interprocess communication

- The various activities (or processes) executing on the different computers within a network (or even executing on the same machine via time-sharing/multitasking) must often communicate with each other to coordinate their actions and to perform their designated tasks.
- Such communication between processes is called interprocess communication.

Inter-process Communication

Client-server

- One server, many clients
- Server must execute continuously
- Client initiates communication
- Peer-to-peer (P2P)
 - Two processes communicating as equals
 - Peer processes can be short-lived
Client/Server

- A popular convention used for interprocess communication is the **client/server** model.
- This model defines the basic roles played by the processes as either a client, which makes requests of other processes, or a server, which satisfies the requests made by clients.

Print server

- An early application of the client/server model appeared in networks connecting all the computers in a cluster of offices.
- In this situation, a single, high quality printer was attached to the network where it was available to all the machines in the network.
- In this case the printer played the role of a server, often called a print server, and the other machines were programmed to play the role of clients that sent print requests to the print server.

File Server

- Another early application of the client/server model was used to reduce the cost of magnetic disk storage while also removing the need for duplicate copies of records.
- Here one machine in a network was equipped with a high-capacity mass storage system (usually a magnetic disk) that contained all of an organization's records.
- Other machines on the network then requested access to the records as they needed them.
- Thus the machine that actually contained the records played the role of a server (called a file server), and the other machines played the role of clients that requested access to the files that were stored at the file server.

Peer-to-peer

- Whereas the client/server model involves one process (the server) providing a service to numerous others (clients), the peer-to-peer model involves processes that provide service to and receive service from each other.
- Moreover, whereas a server must execute continuously so that it is prepared to serve its clients at any time, the peer-to-peer model usually involves processes that execute on a temporary basis.
 - For example, applications of the peer-to-peer model include instant messaging in which people carry on a written conversation over the Internet as well as situations in which people play competitive interactive games.

Figure 4.6 The client/server model compared to the peer-to-peer model



a. Server must be prepared to serve multiple clients at any time.



b. Peers communicate as equals on a one-to-one basis.

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P2P and File Sharing

- The peer-to-peer model is also a popular means of distributing files such as music recordings and motion pictures via the Internet.
- In this case, one peer may receive a file from another and then provide that file to other peers.
- The collection of peers participating in such a distribution is sometimes called a swarm.

P2P, why?

- One reason that the P2P model is replacing the client/server model for file sharing is that it distributes the service task over many peers rather than concentrating it at one server.
- This lack of a centralized base of operation leads to a more efficient system.
- Unfortunately, another reason for the popularity of file distribution systems based on the P2P model is that, in cases of questionable legality, the lack of a central server makes legal efforts to enforce copyright laws more difficult.

P2P Network or Model?

- You might often read or hear the term *peer-to-peer network*, which is an example of how misuse of terminology can evolve when technical terms are adopted by the nontechnical community.
- The term *peer-to-peer* refers to a system by which two processes communicate over a network (or internet).
- It is not a property of the network (or internet).
- A process might use the peer-to-peer model to communicate with another process and later use the client/server model to communicate with another process over the same network.
- Thus, it would be more accurate to speak of communicating by means of the peer-to-peer model rather than communicating over a peer-to-peer network.

Distributed Systems

- Systems with parts that run on different computers
 - Infrastructure can be provided by standardized toolkits
 - Example: Enterprise Java Beans from Oracle
 - Example: .NET framework from Microsoft

Cluster computing

- Cluster computing describes a distributed system in which many independent computers work closely together to provide computation or services comparable to a much larger machine.
- The cost of these individual machines, plus the highspeed network to connect them, can be less than a higher-priced supercomputer, but with higher reliability and lower maintenance costs.





64 node/128 processor Ames Lab/ISU Cluster Environment

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Cluster computing, why?

- High-availability because it is more likely that at least one member of the cluster will be able to answer a request, even if other cluster members break down or are unavailable — and
- Load-balancing because the workload can be shifted automatically from members of the cluster that have too much to do to those that may have too little.

Clusters at NASA



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Grid Computing

- Grid computing refers to distributed systems that are more loosely coupled than clusters but that still work together to accomplish large tasks.
- Grid computing can involve specialized software to make it easier to distribute data and algorithms to the machines participating in a grid.
- PCs at work or at home, that can then volunteer computing power to the grid when the machine is not otherwise being used.
- Enabled by the growing connectivity of the Internet, this type of voluntary, distributed grid computing has enabled millions of home PCs to work on enormously complex mathematical and scientific problems.

Grid Computing*



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*From Adarsh Patil

Recent trend: Cloud Computing

- The latest trend in distributed systems is that huge pools of shared computers on the network can be allocated for use by clients as needed.
- Much as the spread of metropolitan electrical grids in the early twentieth century eliminated the need for individual factories and businesses to maintain their own generators, the Internet is making it possible for entities to entrust their data and computations to "the Cloud,"
- The Cloud in this case refers to the enormous computing resources already available on the network.

Cloud computing



Amazon and Google services

- Services such as Amazon's Elastic Compute Cloud allow clients to rent virtual computers by the hour, without concern for where the computer hardware is actually located.
- Google Docs and Google Apps allow users to collaborate on information or build Web services without needing to know how many computers are working on the problem or where the relevant data are stored.
- Cloud computing services provide reasonable guarantees of reliability and scalability, but also raise concerns about privacy and security in a world where:

we may no longer know who owns and operates the computers that we use.

The Internet

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The Internet

- The most notable example of an internet is the Internet (note the uppercase I), which originated from research projects going back to the early 1960s.
- The goal was to develop the ability to link a variety of computer networks so that they could function as a connected system that would not be disrupted by local disasters.
- Much of this work was sponsored by the U.S. government through the Defense Advanced Research Projects Agency (DARPA").
- Over the years, the development of the Internet shifted from a government-sponsored project to an academic research project, and today it is largely a commercial undertaking that links a worldwide combination of LANs, MANs, and WANs involving millions of computers.

Internet Architecture

- The Internet is a collection of connected networks.
- In general, these networks are constructed and maintained by organizations called Internet Service Providers (ISPs).
- It is also customary to use the term ISP in reference to the networks themselves.
- Thus, we will speak of connecting to an ISP, when what we really mean is connecting to the network provided by an ISP.

Figure 4.7 Internet Composition



Internet Architecture: Tier-1 ISPs

- The system of networks operated by the ISPs can be classified in a hierarchy according to the role they play in the overall Internet structure.
- At the top of this hierarchy are relatively few tier-1 ISPs that consist of very high-speed, high-capacity, international WANs.
- These networks are thought of as the backbone of the Internet.
 - They are typically operated by large companies that are in the communications business.
 - An example would be a company that originated as a traditional telephone company and has expanded its scope into providing other communication services.

Internet Architecture: Tier-2 ISPs

- Connecting to the tier-1 ISPs are the tier-2 ISPs that tend to be more regional in scope and less potent in their capabilities.
- The distinction between the tier-1 and tier-2 ISPs is often a matter of opinion.
- Again, these networks tend to be operated by companies in the communications business.

Access ISP

- Tier-1 and tier-2 ISPs are essentially networks of routers that collectivly provide the Internet's communication infrastructure.
- As such, they can be thought of as the core of the Internet.
- Access to this core is usually provided by an intermediary called an access ISP.
- An access ISP is essentially an independent internet, sometimes called an intranet, operated by a single authority that is in the business of supplying Internet access to individual users.
 - Examples include companies such as AOL, Microsoft, and local cable and telephone companies that charge for their service as well as organizations such as universities or corporations that take it upon themselves to provide Internet access to individuals within their organizations.

End Systems or hosts

- The devices that individual users connect to the access ISPs are known as end systems or hosts.
- These end systems are not necessarily computers in the traditional sense.
- They range over a multitude of devices including telephones, video cameras, automobiles, and home appliances.
- After all, the Internet is essentially a communications system, and thus any device that would benefit from communicating with other devices is a potential end system.

Connecting to access ISPs

- The technology by which end systems connect to access ISPs is also varied.
- Perhaps the fastest growing are wireless connections based on WiFi technology.
- The strategy is to connect the AP to an access ISP and thus provide Internet access through that ISP to end systems within the AP's broadcast range.
- The area within the AP's range is often called a hot spot.
- Hot spots and groupings of hot spots are becoming quite prevalent, ranging from individual residences, hotel and office buildings, small businesses, parks, and in some cases entire cities.
- A similar technology is used by the cellular telephone industry where hot spots are known as cells and the "routers" generating the cells are coordinated to provide continuous service as an end system moves from one cell to another.

Connecting to access ISPs

- Other popular techniques for connecting to access ISP's use telephone lines or cable/satellite systems.
- These technologies may be used to provide direct connection to an end system or to a customer's router to which multiple end systems are connected.
- This latter tactic is becoming increasingly popular for individual residences where a local hot spot is created by a router/AP connected to an access ISP by means of existing cable or telephone lines.

Connecting to access ISPs

- Existing cable and satellite links are inherently more compatible with highspeed data transfer than traditional telephone lines, which were originally installed with voice communication in mind.
- However, several clever schemes have been developed to extend these voice links to accommodate transmission of digital data.
- These make use of devices called modems.
- An example is DSL (digital subscriber line) in which the frequency range below 4 KHz (4,000 kilocycles per second) is reserved for traditional voice communication and the higher frequencies are used for transferring digital data.

Internet2

- Now that the Internet has shifted from a research project to a household commodity, the research community has moved on to a project called Internet2.
- Internet2 is intended as an academic-only system and involves numerous universities working in partnership with industry and government.
- The goal is to conduct research in internet applications requiring high bandwidth communication, such as remote access and control of costly state-of-the-art equipment such as telescopes and medical diagnostic devices.
- An example of current research involves remote surgery performed by robot hands that mimic the hands of a distant surgeon who views the patient by video.
- You can learn more about Internet2 at http://www.internet2.edu

Internet Addressing

- An internet needs an internet-wide addressing system that assigns a unique identifying address to each computer in the system.
- In the Internet these addresses are known as IP addresses. (The term IP refers to "Internet Protocol – discussed in next class)
- Originally, each IP address was a pattern of 32 bits, but to provide a larger set of addresses, the process of converting to 128-bit addresses is currently underway (IPv6 => next class).
- Blocks of consecutively numbered IP addresses are awarded to ISPs by the Internet Corporation for Assigned Names and Numbers (ICANN), which is a nonprofit corporation established to coordinate the Internet's operation.
- The ISPs are then allowed to allocate the addresses within their awarded blocks to machines within their region of authority.
- Thus, machines throughout the Internet are assigned unique IP addresses.

IP address

- IP addresses are traditionally written in dotted decimal notation in which the bytes of the address are separated by periods and each byte is expressed as an integer represented in traditional base ten notation.
- For example, using dotted decimal notation, the pattern 5.2 would represent the two-byte bit pattern 0000010100000010, which consists of the byte 00000101 (represented by 5) followed by the byte 00000010 (represented by 2), and
- The pattern 17.12.25 would represent the three-byte bit pattern consisting of the byte 00010001 (which is 17 written in binary notation), followed by the byte 00001100 (12 written in binary), followed by the byte 00011001 (25 written in binary).
- In summary, a 32-bit IP address might appear as 192.207.177.133 when expressed in dotted decimal notation.

Domains

- Addresses in bit-pattern form (even when compressed using dotted decimal notation) are rarely conducive to human consumption.
- For this reason the Internet has an alternative addressing system in which machines are identified by mnemonic names.
- This addressing system is based on the concept of a domain, which can be thought of as a "region" of the Internet operated by a single authority such as a university, club, company, or government agency.
 - The word region is in quotations here because, as we will soon see, such a region may not correspond to a physical area of the Internet.

Registration of domains

- Each domain must be registered with ICANN a process handled by companies, called registrars, that have been assigned this role by ICANN.
- As a part of this registration process, the domain is assigned a mnemonic domain name, which is unique among all the domain names throughout the Internet.
- Domain names are often descriptive of the organization registering the domain, which enhances their utility for humans.

Top-level domains

- As an example, the domain name of the Addison-Wesley publishing company is aw.com.
- Note the suffix following the period. It is used to reflect the domain's classification, which in this case is "commercial" as indicated by the com suffix.
- These suffixes are called top-level domains (TLDs).
- Other TLDs include edu for educational institutions, gov for U.S. government institutions, org for nonprofit organizations, info for unrestricted use, and net, which was originally intended for ISPs but is now used on a much broader scale.
- In addition to these general TLDs, there are also two-letter TLDs for specific countries (called country-code TLDs) such as au for Australia and ca for Canada.

Subdomains

- Once a domain's mnemonic name is registered, the organization that registered the name is free to extend the name to obtain mnemonic identifiers for individual items within the domain.
- For example, an individual machine within Addison-Wesley may be identified as ssenterprise.aw.com.
 - Note that domain names are extended to the left and separated by a period.
- In some cases multiple extensions, called subdomains, are used as a means of organizing the names within a domain.
- These subdomains often represent different networks within the domain's jurisdiction.
Subdomain example

- If Nowhere University was assigned the domain name nowhereu.edu, then an individual computer at Nowhere University might have a name such as r2d2.compsc.nowhereu.edu, meaning that the computer r2d2 is in the subdomain compsc within the domain nowhereu within the TLD edu.
 - We should emphasize that the dotted notation used in mnemonic addresses is not related to the dotted decimal notation used to represent addresses in bit pattern form

DNS

- Although mnemonic addresses are convenient for humans, messages are always transferred over the Internet by means of IP addresses.
- Thus, if a human wants to send a message to a distant machine and identifies the destination by means of a mnemonic address, the software being used must be able to convert that address into an IP address before transmitting the message.
- This conversion is performed with the aid of numerous servers, called name servers, that are essentially directories that provide address translation services to clients.
- Collectively, these name servers are used as an Internet-wide directory system known as the domain name system (DNS).
- The process of using the DNS to perform a translation is called a DNS lookup.

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DNS server

Internet Protocol Version 4 (TCP/IPv4) Properties	
General	
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.	
Obtain an IP address automatically	
Use the following IP address:	
IP address:	192 . 168 . 101 . 164
S <u>u</u> bnet mask:	255.255.255.0
Default gateway:	192 . 168 . 101 . 1
Obtain DNS server address automatically	
O Use the following DNS server addresses:	
Preferred DNS server:	80 . 78 . 66 . 66
<u>A</u> lternate DNS server:	80 . 78 . 66 . 67
Validate settings upon exit	Ad <u>v</u> anced
OK Cancel	

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Name servers, where?

- For a machine to be accessible by means of a mnemonic domain name, that name must be represented in a name server within the DNS.
- In those cases in which the entity establishing the domain has the resources, it can establish and maintain its own name server containing all the names within that domain.
- Indeed, this is the model on which the domain system was originally based.
- Each registered domain represented a physical region of the Internet that was operated by a local authority such as a company, university, or government agency.
- This authority was essentially an access ISP that provided Internet access to its members by means of its own intranet that was linked to the Internet.

Internet Applications

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Electronic Mail

- One of the most popular uses of the Internet is email (short for electronic mail), a system by which messages are transferred among Internet users.
- For the purpose of providing email service, a domain's local authority may designate a particular machine within its domain to play the role of a mail server.
- Typically, mail servers are established within domains operated by access ISPs for the purpose of providing mail service to users within its realm.
- When a user sends email from his or her local machine, it is first transferred to the user's mail server.
- There it is forwarded to the destination mail server where it is stored until the recipient contacts the mail server and asks to view the accumulated mail.

Mail Protocols: Sending

- The protocol used to transfer mail between mail servers as well as to send a new message from its author's local machine to the author's mail server is SMTP (Simple Mail Transfer Protocol).
- Because SMTP was initially designed for transferring text messages encoded with ASCII, additional protocols such as MIME (Multipurpose Internet Mail Extensions) have been developed to convert non-ASCII data to SMTP compatible form.

Mail Protocols: Receiving

- There are two popular protocols that may be used for accessing email that has arrived and accumulated at a user's mail server.
- These are POP3 (Post Office Protocol version 3) and IMAP (Internet Mail Access Protocol).
- POP3 (pronounced "pop-THREE") is the simpler of the two.
- Using POP3, a user transfers (downloads) messages to his or her local computer where they can be read, stored in various folders, edited, and otherwise manipulated as the user desires.
- This is done on the user's local machine using the local machine's mass storage.



- IMAP (pronounced "EYE-map") allows a user to store and manipulate messages and related materials on the same machine as the mail server.
- In this manner, a user who must access his or her email from different computers can maintain records at the mail server that are then accessible from any remote computer to which the user may have access.

Email address

- With the role of a mail server in mind, it is easy to understand the structure of an individual's email address.
- It consists of a symbol string (sometimes called the account name) identifying the individual, followed by the symbol @ (read "at"), followed by the mnemonic string that ultimately identifies the mail server that should receive the mail.
 - In reality this string often merely identifies the destination domain, and the domain's mail server is ultimately identified by means of a DNS lookup

FTP - File Transfer Protocol

- One means of transferring files (such as documents, photographs, or other encoded information) is to attach them to email messages.
- However, a more efficient means is to take advantage of the File Transfer Protocol (FTP), which is a client/server protocol for transferring files across the Internet.
- To transfer a file using FTP, a user at one computer in the Internet uses a software package that implements FTP to establish contact with another computer.
 - The original computer plays the role of a client. The computer it contacts plays the role of a server, which is usually called an FTP server.
 - Once this connection is established, files can be transferred between the two computers in either direction.

FTP use

- FTP has become a popular way of providing limited access to data via the Internet.
- Suppose, for example, that you want to allow certain people to retrieve a file while prohibiting access by anyone else.
- You need merely place the file in a machine with FTP server facilities and guard access to the file via a password.
- Then, people who know the password will be able to gain access to the file via FTP, while all others will be blocked.
- A machine in the Internet used in this manner is sometimes called an FTP site because it constitutes a location in the Internet at which files are available via FTP.

Anonymous FTP

- FTP sites are also used to provide unrestricted access to files.
- To accomplish this, FTP servers use the term anonymous as a universal login name.
- Such sites are often referred to as anonymous FTP sites and provide unrestricted access to files under their auspices.
- While FTP clients and servers remain widely available, most users now find their file transfer needs met through Web browsers using HTTP (next lesson).

Telnet

- One of the early uses of the Internet was to allow computer users to access computers from great distances.
- Telnet is a protocol system that was established for this purpose.
- Using telnet, a user (running telnet client software) can contact the telnet server at a distant computer and then follow that operating system's login procedure to gain access to the distant machine.
- Thus, by means of telnet, a distant user has the same access to the applications and utilities on the computer that a local user has.

Secure Shell

- Having been designed early in the development of the Internet, telnet has several shortcomings.
- One of the more critical ones is that communication via telnet is not encrypted.
- This is significant even if the subject of the communication is not sensitive because the user's password is part of the communication during the login process.
- Thus the use of telnet opens the possibility that an eavesdropper might intercept a password and later misuse this critical information.
- Secure Shell (SSH) is an alternative to telnet that offers a solution to this problem and is rapidly replacing telnet.

SSH

 Among the features of SSH is that it provides for encryption of data being transferred as well as authentication (explained also in next lesson), which is the process of making sure that the two parties communicating are, in fact, who they claim to be.

VolP

- As an example of a more recent Internet application, consider VoIP (Voice over Internet Protocol) in which the Internet infrastructure is used to provide voice communication similar to that of traditional telephone systems.
- In its simplest form, VoIP consists of two processes on different machines transferring audio data via the P2P model — a process that in itself presents no significant problems.
- However, tasks such as initiating and receiving calls, linking VoIP with traditional telephone systems, and providing services such as emergency 911 communication are issues that extend beyond traditional Internet applications.
- Moreover, governments that own their country's traditional telephone companies view VoIP as a threat.

Soft Phones

- Existing VoIP systems come in four different forms that are competing for popularity.
- VoIP soft phones consist of P2P software that allows two or more PCs to share a call with no more special hardware than a speaker and a microphone.
- An example of a VoIP soft phone system is Skype, which also provides its clients with links to the traditional telephone communication system.



- One drawback to Skype is that it is a proprietary system, and thus much of its operational structure is not publicly known.
- This means that Skype users must trust the integrity of the Skype software without third-party verification.
- For instance, to receive calls, a Skype user must leave his or her PC connected to the Internet and available to the Skype system, which means that some of the PC's resources may be used to support other Skype communications without the PC owner's awareness — a feature that has generated some resistance.

Analog telephone adapters

- A second form of VoIP consists of analog telephone adapters, which are devices that allow a user to connect his or her traditional telephone to phone service provided by an access ISP.
- This choice is frequently bundled with traditional Internet service and/or digital television service.

Embedded VoIP phones

- The third type of VoIP comes in the form of embedded VoIP phones, which are devices that replace a traditional telephone with an equivalent handset connected directly to a TCP/IP network.
- Embedded VoIP phones are becoming increasingly common for large organizations, many of whom are replacing their traditional internal copper wire telephone systems with VoIP over Ethernet to reduce costs and enhance features.

Smartphones

- Finally, the next generation of smartphones is using VoIP technology.
- That is, earlier generations of wireless phones only communicated with the telephone company's network using that company's protocols.
- Access to the Internet was obtained by gateways between the company's network and the Internet, at which point signals were converted to the TCP/IP system.
- However, the new 4G phone network is designed to be an IP-based network throughout, which means a 4G telephone is essentially just another host computer on the global Internet.

Generation of wireless tech: 1G and 2G

- The first generation wireless telephone network transmitted analog voice signals through the air, much like traditional telephones but without the copper wire running through the wall.
- In retrospect, we call these early phone systems "1G," or first generation, networks.
- The second generation used digital signals to encode voice, providing more effective use of the airwaves and the transmission of other kinds of digital data such as text messaging.

Generation of wireless tech: 3G and 4G

- Third generation ("3G") phone network provides higher data transfer rates, allowing for mobile video calls and other bandwidth-intensive activities.
- The 4G network objectives include even higher data transfer rates, and a fully packet-switched network using the IP protocol, which will provide the newest generation of smartphones with the capabilities currently available only to broadband-enabled PCs.

End of lesson 9

- Readings
 - Chapter 4