References:


http://www.itweb.cellexgroup.com/telecommunication.aspx
Comparing Network to Shannon-Weaver Model

Minimum Data Comm Network
The Value of a Network

Metcalfe's law states that the value of a communications network is proportional to the square of the number of connected users of the network.

\[
\text{Value} \propto \eta^2; \quad \eta = \text{number of nodes}
\]

Metcalfe's law explains the advantage of larger networks in communication technologies such as the Internet, social networks, and e-commerce networks.

For example, increasing the number of nodes (or users) of a network by 10 times makes it approximately 100 times more valuable.

http://en.wikipedia.org/wiki/Metcalfe%27s_law
Network Categories or “Network Scale”

1. **Local Area Network (LAN)** – A network connecting computers and devices within a small restricted area. Usually privately owned and often used within a single building (e.g., hospital), a small campus, or a SOHO (small office/home office).

2. **Wide Area Network (WAN)** – A larger network used to interconnect multiple LANs over a large geographical area (such as county or state or even larger regions). The world-wide **Internet** is the largest public WAN.

3. **Metropolitan Area Network (MAN)** – A network connecting computer users in a particular geographic area or region larger than a LAN; often a large urban area. The MAN is typically owned and operated by a single entity such as a governmental body, large university or large corporation.

**Other network categories can include:**

- **PAN** – Personal Area Network  (Example: Bluetooth piconet)
- **NAN** – Neighborhood Area Network  (Example: smart meter network)

Note: If a network is wireless, then a “W” is added to the network category. Example, a Wireless LAN would become a WLAN.
Local Area Network (LAN) – A LAN is a computer network limited to a small area such as an office building, a factory, a school, or even a residence. An important attribute of a LAN is the network is shared among the users (called “nodes”).

- Sometimes called an **intranet**.
Metropolitan Area Network (MAN) – A MAN is a computer network links locations together from across disparate locations in a general geographic area. The terminology invokes the image of a large city and/or its suburbs.

Examples:

A network of fire stations in a suburban area

A group of community colleges

A newspaper/media company linking its branch offices in different locations allowing for the news coordination
Wide Area Network (WAN) – A long-distance communication network covering a wide geographic area, such as a state or country. Telephone companies and cellular carriers deploy WANs to service large regional areas or an entire nation. Other examples include military networks, banking networks, stock brokerage networks, airline reservation networks, etc.

- WANs interconnect individual LAN networks
- Provides communication over long distances.
- Must be reliable (generally uses route redundancy)
- The Internet is the world's largest WAN

http://lateforlunch.co.uk/blogs/lukasgoda/2010/05/19/chapter-8/
**Circuit-Switched Network vs Packet-Switched Network**

**Circuit Switching** originated in 1878 to serve telephone networks. Wires and switches used to make a dedicated wireline. “Dedicated” means the line remains connected from start to finish.

In **Packet Switching** the message is broken into limited-size data packets. These packets are sent over the network by special purpose computers called “routers.” Routers send packets over the network seeking the most effective path to travel as data links become available. Packets don’t necessarily travel by the shortest route, rather the paths chosen are the most efficient in terms of network utilization. Because each packet may travel by a different route than the other packets, they must be reassembled at the destination to put them in correct order.

Circuit-switched Networks and packet-switched networks use different technologies for sending data over the network.
Circuit-Switched Network

Many paths are possible, but only one is selected per call.

Once a connection is established, this connection is maintained until call is terminated.

PSTN = public switched telephone network

Full Duplex

Subscriber lines (or local loops)

Trunks (links between Exchanges)

Central Office

Caller

Telephone Switch

= Dedicated connection (point-to-point)
Circuit-Switched Networks

• **Circuit-switched networks** provide a dedicated *single connection* for the entire duration of the communication session.

• The traditional **public switched telephone network (PSTN)** is the premier example of a circuit-switched network.
  – The telephone company reserves a specific physical path to the number you are calling for the full duration of your phone call.

• Circuit switched communication requires 3 phases:
  – **setup, data transfer, termination**

• Provides fixed delay – good for voice transmission, but not for data networks because of setup and dedicated lines. As we shall see a **packet switched network** is better for data transmission.
Public Switched Telephone Network (PSTN)

• **PSTN** is the world's collection of interconnected voice-oriented public telephone networks, both commercial and government-owned, that was primarily designed for voice traffic.
  
  ➢ It's the aggregation of circuit-switching telephone networks that evolved from the beginning days of Alexander Graham Bell.
  ➢ Originally it was an analog system, the PSTN is now almost entirely digital, although most subscribers are connected (last mile) via analog circuits.
  ➢ It is analog at the local loop but digital in the backbone.

• Sometimes referred to as the **Plain Old Telephone Service** (POTS). However, POTS implies the analog embodiment of the network.

• But . . . the PSTN actually **furnishes much of the Internet's long-distance infrastructure**.

• As of end of 2010, the PSTN had **140,000,000 telephone subscribers**.
The “Signaling” Protocol in the PSTN

An example of a “protocol.”
Packet Switched Network

Message broken into packets and each addressed

Many paths possible for a single message as packets are routed to the destination.

Packets are routed according to the best path available at the time.

Huge array of routers and data links.

Sender (source)

Router or Switch

Internet

Packets sequentially reassembled to reveal message

Receiver (destination)

(Data Packet or “Datagram”)

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Packet-Switched Network Advantages

• **Adaptive routing** – routers chose best path by examining traffic loading along available paths. Routers create a “routing table” for the packet travel.

• **All users share the same network resources.**

• Packet-switching is more efficient than circuit-switching in networks when data is **bursty** (*i.e.*, variable delays interspersed with periods of data transmission). More “efficient” means a better utilization of the network resources.

This is an example of “bursty” data
## Circuit-Switched vs. Packet-Switched

<table>
<thead>
<tr>
<th>Circuit-Switched</th>
<th>Packet-Switched</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Connection-oriented”</td>
<td>“Connectionless”</td>
</tr>
</tbody>
</table>

### Bandwidth
- **Circuit-Switched**: Bandwidth is guaranteed once connected.
- **Packet-Switched**: Bandwidth is dynamically allocated (aka “adaptive routing”).

### Network Bandwidth
- **Circuit-Switched**: Has wasted Network Bandwidth.
- **Packet-Switched**: Better use of Network Bandwidth.

### Network Capacity
- **Circuit-Switched**: Not affected by other traffic; but limited # connections.
- **Packet-Switched**: Network Capacity independent of concurrent transmission of packets.

### Connection
- **Circuit-Switched**: Each connection is “dedicated”.
- **Packet-Switched**: Packet forwarding can use any route in the network (“store & forward”).

### Switches
- **Circuit-Switched**: Switches perform connections to establish dedicated circuit path for each call.
- **Packet-Switched**: Routers and protocols determine the packet routes and adjust to network conditions (“forwarding on the fly”).

### Failure
- **Circuit-Switched**: If a connection fails a new connection must be re-established to recover.
- **Packet-Switched**: If one router fails the network still functions by bypassing that router.

### Cost
- **Circuit-Switched**: Cost set by connect time.
- **Packet-Switched**: Cost set by number of packets.

---

*Today both network categories now handle both voice and data.*
A Fact:

Modern communication systems today are dominated by packet switched networks.
An Internet Packet and its Headers

<table>
<thead>
<tr>
<th>Internet Packet</th>
<th>Application Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP header</td>
<td>TCP/UDP header</td>
</tr>
</tbody>
</table>

- In IPv4, each packet is restricted to 1,500 bytes of data (*i.e.*, payload)
- Each packet consists of the application data and headers
- The headers contain control and routing information such as:
  - Source IP address and destination IP address
  - Packet numbering for reconstruction at destination
- Every computer on the Internet has the **TCP/IP program**. The client/server model is used on the Internet.
- **TCP** (Transmission Control Protocol) puts the data or message into packets at the source and reassembles the data or message at the destination
- **IP** (Internet Protocol) does the packet addressing for the routing over the Internet
- **IP** is a connectionless protocol.

## Header on an IP Packet (Format)

### Level 2-IP

<table>
<thead>
<tr>
<th>Word Offset</th>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0000</td>
<td>Version (0x4)</td>
<td>Type (0x0)</td>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>0x0010</td>
<td>Identification</td>
<td></td>
<td>Flags</td>
<td></td>
</tr>
<tr>
<td>0x0020</td>
<td>TTL</td>
<td>Protocol (0x1)</td>
<td>Checksum</td>
<td></td>
</tr>
<tr>
<td>0x0030</td>
<td>Source IP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0040</td>
<td>Destination IP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0050</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0060</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0070</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[https://people.ece.cornell.edu/land/courses/ece5760/FinalProjects/f2011/mis47_ayg6/mis47_ayg6/]
# Header on an UDP Packet (Format)

## Level 3-UDP

<table>
<thead>
<tr>
<th>Word Offset</th>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0000</td>
<td>Source Port Number</td>
<td>Destination Port Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0010</td>
<td>Packet Length</td>
<td></td>
<td>Checksum</td>
<td></td>
</tr>
<tr>
<td>0x0020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0030</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x0040</td>
<td></td>
<td></td>
<td></td>
<td>Data</td>
</tr>
</tbody>
</table>

TCP versus UDP Transmission

TCP is “reliable” because it has flow & congestion control, retransmission, & uses acknowledgements.

UDP does not use these because it is focused upon sending packets only.
Domain Name System (DNS)

The **Domain Name System (DNS)** makes using the Internet a lot easier by allowing a familiar string of letters (**i.e.,** known as the “domain name”) to be used instead of a “hard to remember” numerical IP address.

**Example:**
Instead of typing something like 207.151.159.3, you simply type in the domain name (**e.g.,** www.internic.net or www.sonoma.edu or www.disneyland.com). It is a "mnemonic" device that makes addresses easier for us to remember.

You are probably already familiar with the use of the **URL (Uniform Resource Locator)** for addressing Webpages on the World Wide Web.
Example of an IP Address (i.e., IPv4 format)

• Every Internet node must have an Internet address
• When you connect to the Internet over a broadband access, an IP address is assigned to your computer by your Internet Service Provider (ISP)
• This IP address is “dynamic” – when you disconnect from the network it can be allocated to another user

An IPv4 address (dotted-decimal notation)

Decimal: 172.16.254.1

Binary: 10101100.00010000.11111110.00000001

1 byte 1 byte 1 byte 1 byte

4 bytes = 32 bits in total
But IPv4 Addresses are Limited . . .

In **IPv4** an address consists of 32 bits which limits its address space to $4,294,967,296 (= 2^{32})$ unique addresses. (That’s only 4.3 billion addresses and the number of users of the Internet exceeds this.)

**IPv6** (**Internet Protocol version 6**) is a version of the Internet Protocol (IP) intended to replace IPv4. It will takes several years to accomplish this however.

**IPv6** uses 128-bit addresses, for an address space of $2^{128}$ (approximately $3.4 \times 10^{38}$) addresses.

Hey! Isn’t that **Vinton Cerf**, **Chief Internet Evangelist** at Google, and one of the “Fathers of the Internet”

IPv6 Addresses Give Unlimited Addressing

How do you say 340,282,366,920,938,463,463,374,607,431,768,211,456?

It is 340 undecillion, 282 decillion, 366 nonillion, 920 octillion, 938 septillion, 463 sextillion, 463 quadrillion, 607 trillion, 431 billion, 768 million, 211 thousand, 456.
A **Uniform Resource Locator** Example

The URL is a unique address for a file on the Internet.

```
http://www.starwars.com/education/seminars.html
```

**http://** -- **HyperText Transfer Protocol:**

*The protocol computers use to “talk” to each other on the WWW*

**www** -- **World Wide Web:**

*The collection of interlinked hypertext documents accessible via the Internet.*

**starwars** -- the domain name:

*A structured, alphabetic-based, unique name for a computer on a network*

**.com** -- top-level domain:

*One of the domains in the hierarchy of the DNS*

**education** -- a folder name:

*A folder within the Website*

**seminars** -- file name:

*A file within the folder*

**html** -- hypertext markup language:

*HTML is the computer language used to format documents*
Attributes/Characteristics of the Internet

- Uses computer-based technologies
- Both highly interconnected but very much distributed
- Networks interconnected through gateways and access points (i.e., routers, link-layer switches, etc.)
- Each network stands on its own (TCP/IP protocols do not dictate internal changes to network)
- TCP/IP is independent of the data type or the transport medium
- TCP/IP protocols are not proprietary (all can freely use it)
- Effectively little regulation applies to Internet (in fact, users of the Internet generally oppose regulation)
- No direct global control of the Internet