

Fundamentals of Computer Networking



Fundamentals of Computer Networking

- Computer networks are an integral part of the modern computing infrastructure
- The local network (LAN) is usually Ethernet
- LAN's are inter-connected with other LAN's in a hierarchical fashion eventually forming the Internet

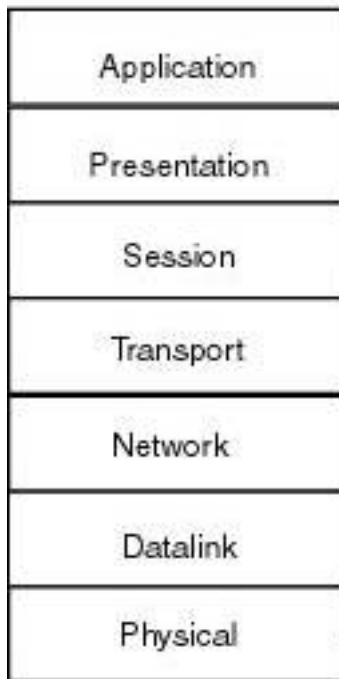
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- The operation of computer networks is governed by hardware and software protocols
- There are two standard network models
 - The 7-layer ISO model
http://en.wikipedia.org/wiki/OSI_model
 - The 5-layer TCP/IP model
http://en.wikipedia.org/wiki/TCP/IP_model
- These models are abstract representations of the division of labor

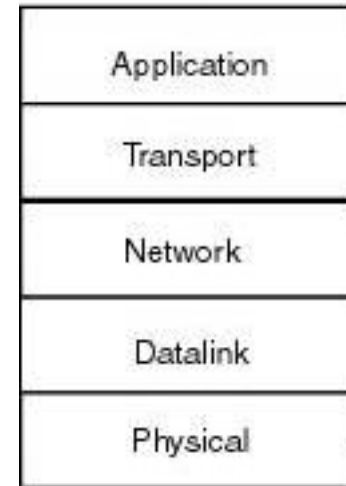
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Network Models

ISO



TCP / IP



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Network Model

- Layer 1 (Physical) is the electrical specification
- Layer 2 (Data Link) defines the interface to Layer 1
- Layer 3 (Network) is generally responsible for transferring data between networks
- Layer 4 (Transport) is generally responsible for packaging data into packets for transfer between computers
- Layer 5 (Application) is generally responsible for communication between applications

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Ethernet

- The networking protocol of the Local Area Network is Ethernet <http://en.wikipedia.org/wiki/Ethernet>
- Ethernet is defined in layers 1 and 2

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TCP/IP Suite

- The networking protocol of the Internet is TCP/IP
<http://en.wikipedia.org/wiki/TCP/IP>
- The functionality of TCP/IP resides in layers 3, 4, and 5

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Layer 2 - Ethernet

- Ethernet was invented by Xerox in 1970's
- Speeds are currently 10, 100, 1000 Mbps
- Data is packaged in frames
- The major contents of a frame are
 - source address (6 bytes)
 - destination address (6 bytes)
 - payload (up to 1500 bytes)

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Layer 2 - Ethernet

- An ethernet is 48 bits in length and each device has a unique address
- An ethernet address is usually referred to by the terms
 - MAC address
 - Physical address
- The address is normally written as
 - XX:XX:XX:XX:XX:XX
 - XX-XX-XX-XX-XX-XX
 - “x” is a hexi-decimal digit, 0-f

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Layer 2 - Ethernet

- The ethernet address space is flat
- Addressing is not scalable
- Ethernet transmissions are “unreliable”, the receiver does not acknowledge receipt

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Layer 3

- Three common layer 3 TCP/IP protocols are
 - IP the inter-networking protocol
 - ICMP the IP control message protocol
 - ARP the address resolution protocol

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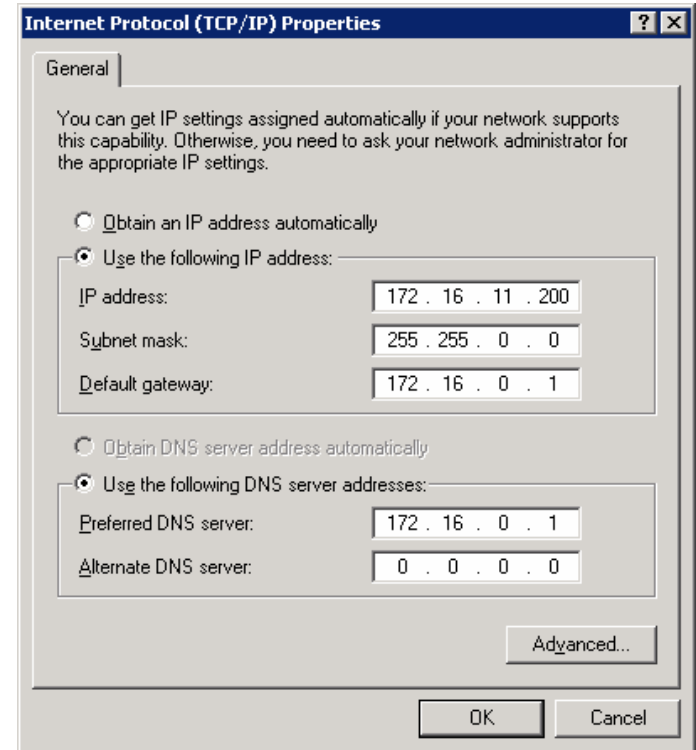
Layer 3 - IP

- Data is packaged in packets
- Contents of an IP packet are
 - source address (4 bytes)
 - destination address (4 bytes)
 - payload
- IP addresses are hierarchical
- Written as
 - ddd.ddd.ddd.ddd
 - where ddd ranges from 0-255

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Layer 3 - IP

- An IP address consists of a network part and a host part
- Displayed as address and subnet mask
- Can also be displayed as 172.16.11.200/16
- IPv4 addresses are 64 bits
- IPv6 addresses are 128 bits



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Layer 3 - ICMP

- These messages convey information about an IP connection
 - Host unreachable
 - Route not found
- This is also the carrier for the ping command
 - ping www.ae.gatech.edu

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Layer 3 - ARP

- Address resolution protocol
- Fits between layers 2 and 3
- Creates and maintains the mappings between ethernet addresses and IP addresses

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Layer 4 - UDP

- User Datagram Protocol
- Connectionless, send and forget
- Packet ordering not guaranteed
- Does not provide a reliable connection between nodes
- Less expensive to setup than TCP
- Uses source and destination ports for addressing
- Requires IP addressing to locate remote computer

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Layer 4 - TCP

- Transmission Control Protocol
- Connection oriented, creates a virtual connection between computers
- Packet ordering is guaranteed
- Does provide a reliable connection between computers
 - will retransmit as necessary
- Uses source and destination ports for addressing
- Requires IP addressing to locate remote computer

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Layer 5 - Application

- There are many application level protocols
 - http, smtp, pop, telnet, ssh, smb, nfs, ...
- These all rely on the capabilities of the lower levels
- Most are TCP but some are UDP

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Packaging Data

- Each layer will add additional content to the data to be transmitted
- For example, an HTTP request will consist of,
 - An HTTP request enclosed in a TCP packet, which in turn is enclosed in an IP packet, which is finally enclosed in an ethernet frame
 - Each level add its own functionality and addressing scheme

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Example

- `http://www.ae.gatech.edu/`
- HTTP request (5) – GET / HTTP/1.0
- TCP packet (4) – specifies port 80
- IP packet (3) – specifies address of web server (128.61.191.2)
- Ethernet frame (2) – puts request on the wire to server (00:50:da:b9:4b:c5)

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IP Addresses

- To uniquely identify a connection requires
 - source IP address (3)
 - source port number (4)
 - destination IP address (3)
 - destination port number (4)
- Sometimes written as 128.61.191.2:80

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IP Addresses - Ports

- The addressing scheme of TCP and UDP uses a source and destination port number
- Both TCP and UDP are point to point in nature – they see only the other computer – they identify a resource on the other end
- Port numbers are assigned and well-known
 - 22 ssh
 - 25 smtp
 - 80 http
 - 3389 rdp
- Source port is usually randomly selected

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IP Addresses - Names

- The Domain Name System (DNS), a layer 5 protocol, provides a mapping service between names and addresses
- A name consists of *name.domain*
- The naming system is hierarchical
- Examples
 - www.gatech.edu - 130.207.165.120
 - www.ae.gatech.edu - 128.61.191.2
 - asdlserver.asdl.ae.gatech.edu - 172.16.0.100

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IP Addresses – Obtaining

- A computer will usually acquire its IP address from
 - manual configuration
 - from a DHCP (dynamic host configuration protocol) server (a UDP layer 5 protocol)

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IP Addresses - Routing

- IP addresses are partitioned into network and host parts
- Computers in the same network are usually on the same ethernet LAN – they do not require routing, they use ARP
- Computers on different networks require a router to reach each other
- Ethernet frames are not routed, only IP packets
- IP configuration will specify a default router address

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IP Addresses – Reserved

- The internal loopback address – traffic that stays in the host
 - 127.0.0.0/8
- The private addresses – not routed to the Internet
 - 10.0.0.0/8
 - 172.16.0.0/16 – 172.31.0.0/16 (172.16.0.0/12)
 - 192.168.0.0/24 – 192.168.255.0/24 (192.168.0.0/16)
 - 169.254.0.0/16 - randomly assigned by host

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IP Addresses – Reserved

- The non-routed Link Local addresses
 - 169.254.0.0/16
 - 169.254.1.0/24 – 169.254.254.0/24
- A computer that has been configured to acquire its IP address from a DHCP server will select an address from this range after a suitable time-out period has expired

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Terms – protocol

- frame – the sequence of bytes in an ethernet transmission
- packet – the sequence of bytes in IP based protocols
- TCP/IP – the DoD created protocol suite used for the Internet
- ethernet – the Xerox created protocol used for LAN's
- tcp stack – refers to the software implementation of the network model
- DNS name – the name associated with an IP address
- IP address – the address of a host using TCP/IP
- MAC address – the address used by ethernet frames

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Terms – network devices

- firewall – a device that filters packets based on content or addresses, usually also an IP router
- router – a device that connects IP network segments
- bridge – a device that connects ethernet segments
- proxy – a device that connects to a network service on your behalf
- vpn – virtual private network, a device that creates a virtual network on a public network (Internet). It is usually encrypted.

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Windows Network Commands

- `ipconfig` – a command that will display configuration of all network devices (see `ipconfig /help`)
 - `ipconfig /all`
 - `ipconfig /release` and `ipconfig /renew`
- `route` – a command that will configure and display the current route tables on your computer (see `route help`)
 - `route` – `route add 192.168.10.0 mask 255.255.255.0 192.168.10.50`
 - `route print`
- `netstat` – a command to display current network connections (see `netstat help`)
 - `netstat` – default to display current TCP connections
 - `netstat -a` – display all connections, including listening
- `tracert` – this command will display the path to the target host
 - `tracert www.ae.gatech.edu`
- `ping` – send a ping packet to the remote host (some hosts do not respond)
 - `ping www.ae.gatech.edu`
- `nbtstat` – display MS specific network info (see `nbtstat help`)
 - `nbtstat -A asdlserver.asdl.ae.gatech.edu`

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Windows - ipconfig

```
c:\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
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c:\>ipconfig

Windows IP Configuration

Ethernet adapter Local Area Connection 3:

    Connection-specific DNS Suffix  . : 
    IP Address. . . . . : 10.16.1.1
    Subnet Mask . . . . . : 255.255.0.0
    IP Address. . . . . : 10.61.184.1
    Subnet Mask . . . . . : 255.255.248.0
    Default Gateway . . . . . : 

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . : 
    IP Address. . . . . : 172.16.1.200
    Subnet Mask . . . . . : 255.255.0.0
    Default Gateway . . . . . : 172.16.0.1

Ethernet adapter Local Area Connection 4:

    Media State . . . . . : Media disconnected

c:\>
```

The ipconfig command will display the current IP configuration of a windows computer.

```
c:\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
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c:\>ipconfig /all

Windows IP Configuration

    Host Name . . . . . : zaphod
    Primary Dns Suffix . . . . . : 
    Node Type . . . . . : Hybrid
    IP Routing Enabled. . . . . : No
    WINS Proxy Enabled. . . . . : No
    DNS Suffix Search List. . . . . : asdl.ae.gatech.edu
                                         ae.gatech.edu

Ethernet adapter Local Area Connection 3:

    Connection-specific DNS Suffix  . : 
    Description . . . . . : Microsoft Loopback Adapter
    Physical Address. . . . . : 02-00-4C-4F-4F-50
    Dhcp Enabled. . . . . : No
    IP Address. . . . . : 10.16.1.1
    Subnet Mask . . . . . : 255.255.0.0
    IP Address. . . . . : 10.61.184.1
    Subnet Mask . . . . . : 255.255.248.0
    Default Gateway . . . . . : 
    NetBIOS over Tcpip. . . . . : Disabled

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . : 
    Description . . . . . : Intel(R) PRO/100+ Management Adapter

    Physical Address. . . . . : 00-02-B3-8C-2B-F9
    Dhcp Enabled. . . . . : No
    IP Address. . . . . : 172.16.1.200
    Subnet Mask . . . . . : 255.255.0.0
    Default Gateway . . . . . : 172.16.0.1
    DNS Servers . . . . . : 172.16.0.1

Ethernet adapter Local Area Connection 4:

    Media State . . . . . : Media disconnected
    Description . . . . . : TAP-Win32 Adapter V8
    Physical Address. . . . . : 00-FF-6D-06-00-39

c:\>
```

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Windows - nbtstat

```
cmd.exe
Microsoft Windows XP [Version 5.1.2600]
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c:\>nbtstat -A 172.16.0.100

Local Area Connection 3:
Node IpAddress: [10.61.184.1] Scope Id: []

Host not found.

Local Area Connection:
Node IpAddress: [172.16.1.200] Scope Id: []

NetBIOS Remote Machine Name Table

  Name                Type             Status
  ----                -
ASDLSERVER            <00>             UNIQUE          Registered
ASDLSERVER            <03>             UNIQUE          Registered
ASDLSERVER            <20>             UNIQUE          Registered
ASDL                  <00>             UNIQUE          Registered
ASDL                  <03>             UNIQUE          Registered
ASDL                  <20>             UNIQUE          Registered
ASDLNT                <00>             GROUP           Registered
ASDLNT                <1E>             GROUP           Registered
FILES                 <00>             UNIQUE          Registered
FILES                 <03>             UNIQUE          Registered
FILES                 <20>             UNIQUE          Registered

MAC Address = 00-00-00-00-00-00

Local Area Connection 4:
Node IpAddress: [0.0.0.0] Scope Id: []

Host not found.

c:\>
```

```
cmd.exe
Microsoft Windows XP [Version 5.1.2600]
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c:\>nbtstat -a asdlsrver

Local Area Connection 3:
Node IpAddress: [10.61.184.1] Scope Id: []

Host not found.

Local Area Connection:
Node IpAddress: [172.16.1.200] Scope Id: []

NetBIOS Remote Machine Name Table

  Name                Type             Status
  ----                -
ASDLSERVER            <00>             UNIQUE          Registered
ASDLSERVER            <03>             UNIQUE          Registered
ASDLSERVER            <20>             UNIQUE          Registered
ASDL                  <00>             UNIQUE          Registered
ASDL                  <03>             UNIQUE          Registered
ASDL                  <20>             UNIQUE          Registered
ASDLNT                <00>             GROUP           Registered
ASDLNT                <1E>             GROUP           Registered
FILES                 <00>             UNIQUE          Registered
FILES                 <03>             UNIQUE          Registered
FILES                 <20>             UNIQUE          Registered

MAC Address = 00-00-00-00-00-00

Local Area Connection 4:
Node IpAddress: [0.0.0.0] Scope Id: []

Host not found.

c:\>
```

The nbtstat command displays information about other Windows systems on the network. It accepts either DNS name or NetBIOS name.

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Windows - netstat

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

c:\>netstat

Active Connections

Proto Local Address           Foreign Address         State
TCP    zaphod:1037             zebra.asdl.ae.gatech.edu:http ESTABLISHED
TCP    zaphod:1041             143.215.203.14:http    CLOSE_WAIT
TCP    zaphod:3389             trillian.asdl.ae.gatech.edu:47219 ESTABLISHED

c:\>_
```

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

c:\>netstat -n

Active Connections

Proto Local Address           Foreign Address         State
TCP    172.16.1.200:1037       172.16.2.38:80         ESTABLISHED
TCP    172.16.1.200:1041       143.215.203.14:80      CLOSE_WAIT
TCP    172.16.1.200:3389       172.16.1.201:47219     ESTABLISHED

c:\>_
```

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

c:\>netstat -a -n

Active Connections

Proto Local Address           Foreign Address         State
TCP    0.0.0.0:135             0.0.0.0:0              LISTENING
TCP    0.0.0.0:445             0.0.0.0:0              LISTENING
TCP    0.0.0.0:2401            0.0.0.0:0              LISTENING
TCP    0.0.0.0:3389            0.0.0.0:0              LISTENING
TCP    0.0.0.0:6000            0.0.0.0:0              LISTENING
TCP    127.0.0.1:1027          0.0.0.0:0              LISTENING
TCP    127.0.0.1:2402          0.0.0.0:0              LISTENING
TCP    172.16.1.200:139        0.0.0.0:0              LISTENING
TCP    172.16.1.200:1037       172.16.2.38:80         ESTABLISHED
TCP    172.16.1.200:1041       143.215.203.14:80      CLOSE_WAIT
TCP    172.16.1.200:1245       130.207.242.247:80     ESTABLISHED
TCP    172.16.1.200:3389       172.16.1.201:47219     ESTABLISHED
UDP    0.0.0.0:445             **:*
UDP    0.0.0.0:500             **:*
UDP    0.0.0.0:1025            **:*
UDP    0.0.0.0:1026            **:*
UDP    0.0.0.0:4500            **:*
UDP    10.16.1.1:123           **:*
UDP    10.16.1.1:1900          **:*
UDP    10.61.184.1:123         **:*
UDP    127.0.0.1:123           **:*
UDP    127.0.0.1:1053          **:*
UDP    127.0.0.1:1900          **:*
UDP    172.16.1.200:123        **:*
UDP    172.16.1.200:137        **:*
UDP    172.16.1.200:138        **:*
UDP    172.16.1.200:1900       **:*

c:\>_
```

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

c:\>netstat -a -n -p tcp

Active Connections

Proto Local Address           Foreign Address         State
TCP    0.0.0.0:135             0.0.0.0:0              LISTENING
TCP    0.0.0.0:445             0.0.0.0:0              LISTENING
TCP    0.0.0.0:2401            0.0.0.0:0              LISTENING
TCP    0.0.0.0:3389            0.0.0.0:0              LISTENING
TCP    0.0.0.0:6000            0.0.0.0:0              LISTENING
TCP    127.0.0.1:1027          0.0.0.0:0              LISTENING
TCP    127.0.0.1:2402          0.0.0.0:0              LISTENING
TCP    172.16.1.200:139        0.0.0.0:0              LISTENING
TCP    172.16.1.200:1037       172.16.2.38:80         ESTABLISHED
TCP    172.16.1.200:1041       143.215.203.14:80      CLOSE_WAIT
TCP    172.16.1.200:1245       130.207.242.247:80     ESTABLISHED
TCP    172.16.1.200:3389       172.16.1.201:47219     ESTABLISHED

c:\>_
```

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Windows - netstat

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

c:\>netstat -e
Interface Statistics

              Received              Sent
Bytes          11703336          14893646
Unicast packets    51741          36904
Non-unicast packets 63063           82
Discards           0             0
Errors             0             0
Unknown protocols  245             0

c:\>_
```

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

c:\>netstat -s
IPv4 Statistics

Packets Received          = 65561
Received Header Errors    = 0
Received Address Errors   = 22
Datagrams Forwarded       = 0
Unknown Protocols Received = 0
Received Packets Discarded = 11
Received Packets Delivered = 65550
Output Requests           = 0
Routing Discards          = 0
Discarded Output Packets  = 0
Output Packet No Route    = 0
Reassembly Required       = 0
Reassembly Successful     = 0
Reassembly Failures       = 0
Datagrams Successfully Fragmented = 0
Datagrams Failing Fragmentation = 0
Fragments Created         = 0

ICMPv4 Statistics

              Received              Sent
Messages          67              47
Errors             0              0
Destination Unreachable  4              3
Time Exceeded      63              0
Parameter Problems  0              0
Source Quenches    0              0
Redirects           0              0
Echoes              0              44
Echo Replies        0              0
Timestamps          0              0
Timestamp Replies   0              0
Address Masks       0              0
Address Mask Replies 0              0

TCP Statistics for IPv4

Active Opens          = 216
Passive Opens         = 1
Failed Connection Attempts = 1
Reset Connections     = 5
Current Connections   = 4
Segments Received     = 52071
Segments Sent         = 36572
Segments Retransmitted = 9

UDP Statistics for IPv4

Datagrams Received    = 11638
No Ports              = 3598
Receive Errors        = 13
Datagrams Sent        = 924

c:\>_
```

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Windows - netstat

```
c:\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

c:\>netstat -b -n

Active Connections

  Proto Local Address          Foreign Address         State       PID
  TCP    172.16.1.200:1037      172.16.2.38:80         ESTABLISHED 1664
  [spoolsv.exe]
  TCP    172.16.1.200:3389      172.16.1.201:47219     ESTABLISHED 1076
  -- unknown component(s) --
  [svchost.exe]
  TCP    172.16.1.200:1041      143.215.203.14:80      CLOSE_WAIT 1940
  [jucheck.exe]

c:\>_
```

```
c:\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

c:\>netstat -b -v -n

Active Connections

  Proto Local Address          Foreign Address         State       PID
  TCP    172.16.1.200:1037      172.16.2.38:80         ESTABLISHED 1664
  C:\WINDOWS\system32\WS2_32.dll
  C:\WINDOWS\system32\WININET.dll
  -- unknown component(s) --
  [spoolsv.exe]
  TCP    172.16.1.200:3389      172.16.1.201:47219     ESTABLISHED 1076
  -- unknown component(s) --
  [svchost.exe]
  TCP    172.16.1.200:1041      143.215.203.14:80      CLOSE_WAIT 1940
  C:\WINDOWS\system32\WS2_32.dll
  C:\WINDOWS\system32\WININET.dll
  [jucheck.exe]

c:\>_
```

```
c:\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

c:\>netstat -a -n -p tcp -o

Active Connections

  Proto Local Address          Foreign Address         State       PID
  TCP    0.0.0.0:135            0.0.0.0:0              LISTENING   1144
  TCP    0.0.0.0:445            0.0.0.0:0              LISTENING   4
  TCP    0.0.0.0:2401           0.0.0.0:0              LISTENING   1780
  TCP    0.0.0.0:3389           0.0.0.0:0              LISTENING   1076
  TCP    0.0.0.0:6000           0.0.0.0:0              LISTENING   2856
  TCP    127.0.0.1:1027         0.0.0.0:0              LISTENING   1456
  TCP    127.0.0.1:2402         0.0.0.0:0              LISTENING   1792
  TCP    172.16.1.200:139       0.0.0.0:0              LISTENING   4
  TCP    172.16.1.200:1037      172.16.2.38:80         ESTABLISHED 1664
  TCP    172.16.1.200:1041      143.215.203.14:80      CLOSE_WAIT 1940
  TCP    172.16.1.200:3389      172.16.1.201:47219     ESTABLISHED 1076

c:\>_
```

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Windows - arp

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

c:\>arp -a

Interface: 172.16.1.200 --- 0x3
Internet Address      Physical Address      Type
172.16.0.1            00-02-b3-41-57-7b    dynamic
172.16.1.201          00-13-72-11-73-b2    dynamic
172.16.2.11           00-01-e6-27-f0-b3    dynamic
172.16.2.12           00-11-0a-bb-91-71    dynamic
172.16.2.19           00-30-c1-56-fc-4d    dynamic
172.16.2.25           00-01-e6-42-ed-77    dynamic
172.16.2.38           00-11-0a-c5-2f-73    dynamic

c:\>_
```

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

c:\>arp -a

Interface: 172.16.1.200 --- 0x3
Internet Address      Physical Address      Type
172.16.0.1            00-02-b3-41-57-7b    dynamic
172.16.1.201          00-13-72-11-73-b2    dynamic
172.16.2.11           00-01-e6-27-f0-b3    dynamic
172.16.2.12           00-11-0a-bb-91-71    dynamic
172.16.2.19           00-30-c1-56-fc-4d    dynamic
172.16.2.25           00-01-e6-42-ed-77    dynamic
172.16.2.38           00-11-0a-c5-2f-73    dynamic

c:\>arp -d 172.16.2.11

c:\>arp -a

Interface: 172.16.1.200 --- 0x3
Internet Address      Physical Address      Type
172.16.0.1            00-02-b3-41-57-7b    dynamic
172.16.1.201          00-13-72-11-73-b2    dynamic
172.16.2.12           00-11-0a-bb-91-71    dynamic
172.16.2.19           00-30-c1-56-fc-4d    dynamic
172.16.2.25           00-01-e6-42-ed-77    dynamic
172.16.2.38           00-11-0a-c5-2f-73    dynamic

c:\>_
```

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Windows - tracert

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

c:\>tracert acme.gatech.edu

Tracing route to acme.gatech.edu [130.207.165.22]
over a maximum of 30 hops:

  1      1 ms      <1 ms      1 ms      gw-asdl00.asdl.ae.gatech.edu [172.16.0.1]
  2      <1 ms     <1 ms     <1 ms     128.61.184.1
  3      1 ms      1 ms      1 ms      campus2-rtr.gatech.edu [130.207.254.13]
  4      1 ms      1 ms      1 ms      rich-rtr.gatech.edu [130.207.254.38]
  5      1 ms      1 ms      1 ms      acmex.gatech.edu [130.207.165.22]

Trace complete.

c:\>tracert -d acme.gatech.edu

Tracing route to acme.gatech.edu [130.207.165.22]
over a maximum of 30 hops:

  1      1 ms      <1 ms      1 ms      172.16.0.1
  2      <1 ms     <1 ms     <1 ms     128.61.184.1
  3      1 ms      1 ms      1 ms      130.207.254.13
  4      1 ms      1 ms      1 ms      130.207.254.38
  5      1 ms      1 ms      1 ms      130.207.165.22

Trace complete.

c:\>
```

Fundamentals of Computer Networking

Linux/Unix network commands

- ifconfig – configure and display network devices
 - ifconfig eth0 – display configuration of eth0
- route – configure and display the hosts route tables
 - route – display route table
- ip – multi-purpose network command
 - ip addr – display network configurations
 - ip route – display route table
- netstat – display current network connections
 - netstat – display all current tcp and udp connections
 - netstat -at – display all current tcp connections including listening ports

Fundamentals of Computer Networking

Linux/Unix network commands

- traceroute – display the path to remote host
 - traceroute www.ae.gatech.edu
- ping – send a ping to the remote host
 - ping www.ae.gatech.edu