

TCP/IP
Transmission Control Protocol / Internet Protocol

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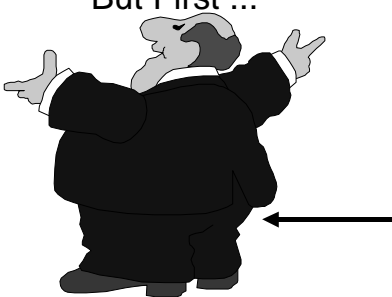
TCP/IP & OSI

- ◆ In OSI reference model terminology -the TCP/IP protocol suite covers the network and transport layers.
- ◆ TCP/IP can be used on many data-link layers (can support many network hardware implementations).

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But First ...



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Ethernet - A Real Data-Link Layer

- ◆ It will be useful to discuss a real data-link layer.
- ◆ Ethernet (really IEEE 802.3) is widely used.
- ◆ Supported by a variety of physical layer implementations.

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Ethernet

- ◆ Multi-access (shared medium).
- ◆ Every Ethernet interface has a unique 48 bit address (a.k.a. *hardware address*).
- ◆ Example: `c0:b3:44:17:21:17`
- ◆ The broadcast address is all 1's.
- ◆ Addresses are assigned to vendors by a central authority.

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CSMA/CD

*Carrier Sense Multiple Access
with
Collision Detection*

- ◆ *Carrier Sense*: can tell when another host is transmitting
- ◆ *Multiple Access*: many hosts on 1 wire
- ◆ *Collision Detection*: can tell when another host transmits at the same time.

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An Ethernet Frame

Preamble	Destination Address	Source Address	Len	DATA	CRC
8 bytes	6	6	2	0-1500	4

- ◆ The preamble is a sequence of alternating 1s and 0s used for synchronization.
- ◆ CRC is Cyclic Redundancy Check

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Ethernet Addressing

- ◆ Each interface looks at every *frame* and inspects the destination address. If the address does not match the hardware address of the interface or the broadcast address, the frame is discarded.
- ◆ Some interfaces can also be programmed to recognize multicast addresses.

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Back to TCP/IP



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Internet Protocol The IP in TCP/IP

- ◆ IP is the network layer
 - ◆ packet delivery service (host-to-host).
 - ◆ translation between different data-link protocols.

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IP Datagrams

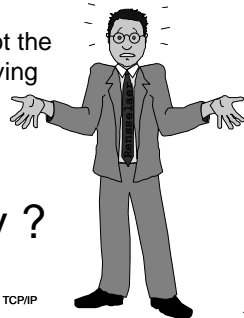
- ◆ IP provides connectionless, unreliable delivery of *IP datagrams*.
- ◆ *Connectionless*: each datagram is independent of all others.
- ◆ *Unreliable*: there is no guarantee that datagrams are delivered correctly or at all.

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IP Addresses

- ◆ IP addresses are not the same as the underlying data-link (MAC) addresses.



Why ?

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IP Addresses

- ◆ IP is a network layer - it must be capable of providing communication between hosts on different kinds of networks (different data-link implementations).
- ◆ The address must include information about what *network* the receiving host is on. This makes routing feasible.

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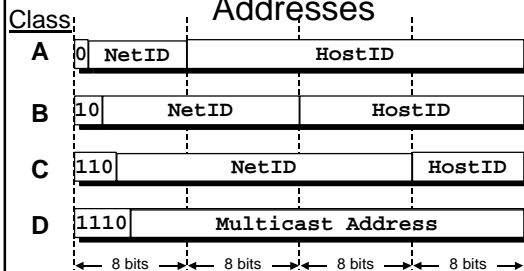
IP Addresses

- ◆ IP addresses are *logical* addresses (not physical)
- ◆ 32 bits.
- ◆ Includes a network ID and a host ID.
- ◆ Every host must have a unique IP address.
- ◆ IP addresses are assigned by a central authority (the NIC at SRI International).

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The four formats of IP Addresses



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Class A

- 128 possible network IDs
- over 4 million host IDs per network ID

Class B

- 16K possible network IDs
- 64K host IDs per network ID

Class C

- over 2 million possible network IDs
- about 256 host IDs per network ID

Network and Host IDs

- ◆ A Network ID is assigned to an organization by a global authority.
- ◆ Host IDs are assigned locally by a system administrator.
- ◆ Both the Network ID and the Host ID are used for routing.

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IP Addresses

- ◆ IP Addresses are usually shown in *dotted decimal* notation:

1.2.3.4 → 00000001 00000010 00000011 00000100

- ◆ cs.rpi.edu is 128.213.1.1

10000000 11010101 00000001 00000001

↑
CS has a class B network

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Host and Network Addresses

- ◆ A single network interface is assigned a single IP address called the *host* address.
- ◆ A host may have multiple interfaces, and therefore multiple *host* addresses.
- ◆ Hosts that share a network all have the same IP *network* address (the network ID).

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IP Broadcast and Network Addresses

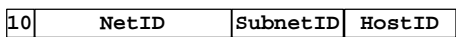
- ◆ An IP broadcast addresses has a host ID of all 1s.
- ◆ IP broadcasting is not necessarily a true broadcast, it relies on the underlying hardware technology.
- ◆ An IP address that has a host ID of all 0s is called a *network address* and refers to an entire network.

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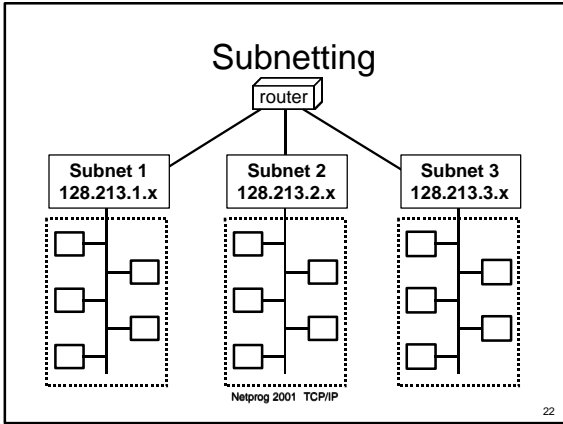
Subnet Addresses

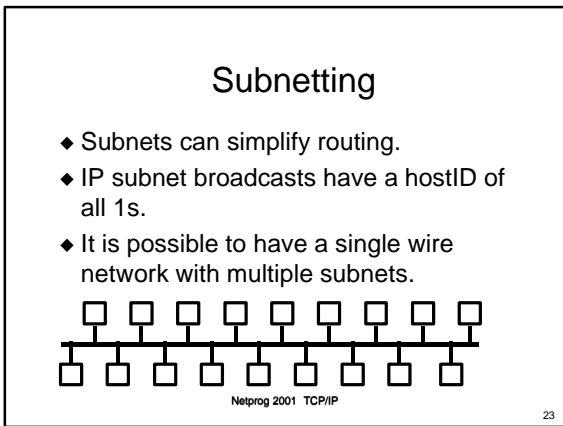
- ◆ An organization can subdivide it's host address space into groups called subnets.
- ◆ The subnet ID is generally used to group hosts based on the physical network topology.

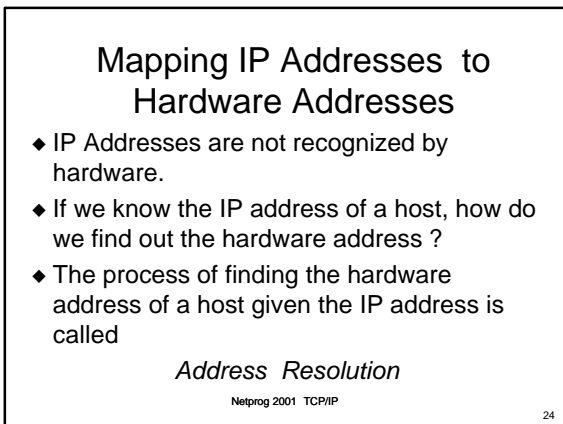


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Reverse Address Resolution

- ◆ The process of finding out the IP address of a host given a hardware address is called
Reverse Address Resolution
- ◆ Reverse address resolution is needed by diskless workstations when booting.

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ARP



- ◆ The *Address Resolution Protocol* is used by a sending host when it knows the IP address of the destination but needs the Ethernet address.
- ◆ ARP is a broadcast protocol - every host on the network receives the request.
- ◆ Each host checks the request against its IP address - the right one responds.

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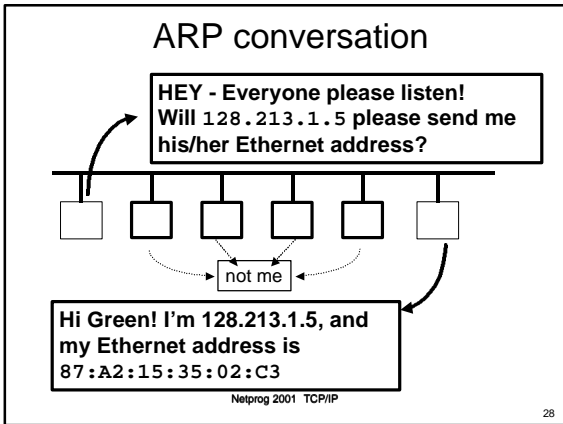
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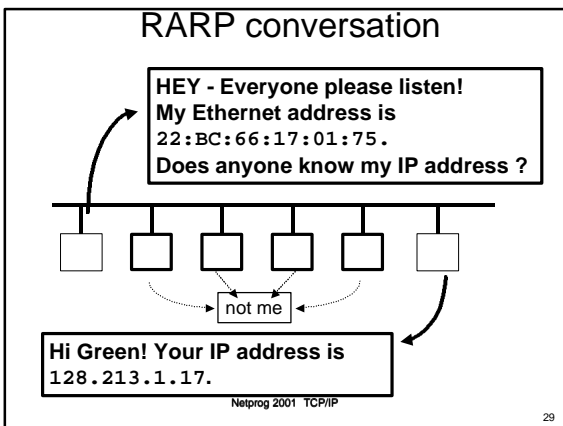
ARP (cont.)

- ◆ ARP does not need to be done every time an IP datagram is sent - hosts *remember* the hardware addresses of each other.
- ◆ Part of the ARP protocol specifies that the receiving host should also remember the IP and hardware addresses of the sending host.

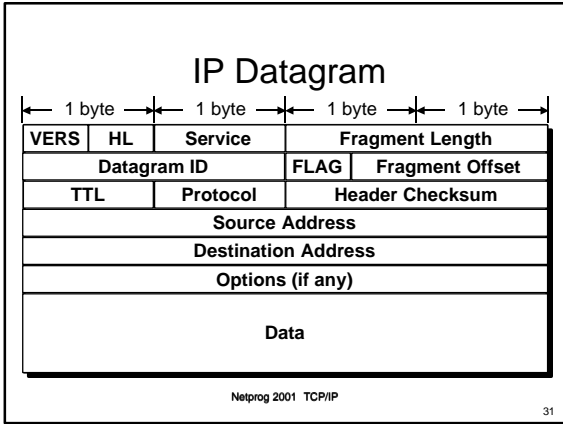
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- ### Services provided by IP
- ◆ Connectionless Delivery (each datagram is treated individually).
 - ◆ Unreliable (delivery is not guaranteed).
 - ◆ Fragmentation / Reassembly (based on hardware MTU).
 - ◆ Routing.
 - ◆ Error detection.
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IP Datagram Fragmentation

- ◆ Each fragment (packet) has the same structure as the IP datagram.
- ◆ IP specifies that datagram reassembly is done only at the destination (not on a hop-by-hop basis).
- ◆ If any of the fragments are lost - the entire datagram is discarded (and an ICMP message is sent to the sender).

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IP Flow Control & Error Detection

- ◆ If packets arrive too fast - the receiver discards excessive packets and sends an ICMP message to the sender (SOURCE QUENCH).
- ◆ If an error is found (header checksum problem) the packet is discarded and an ICMP message is sent to the sender.

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ICMP
Internet Control Message Protocol

- ◆ ICMP is a protocol used for exchanging control messages.
- ◆ ICMP uses IP to deliver messages.
- ◆ ICMP messages are usually generated and processed by the IP software, not the user process.

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ICMP Message Types

- ◆ Echo Request
- ◆ Echo Response
- ◆ Destination Unreachable
- ◆ Redirect
- ◆ Time Exceeded
- ◆ Redirect (route change)
- ◆ there are more ...

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IP/BYE-BYE

- ◆ IP/BYE-BYE is a lecture protocol used to signal the class that we have just finished our discussion of IP - the network layer of TCP/IP.
- ◆ The appropriate response to an IP/BYE-BYE request is immediate applause, although simply opening your eyes is enough (known as a WAKEUP response).

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Transport Layer & TCP/IP

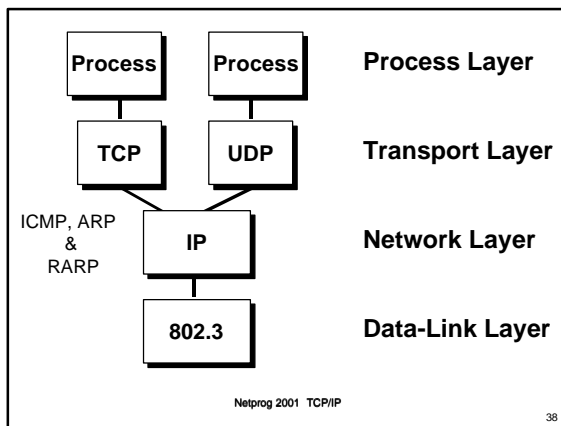
Q: We know that IP is the network layer - so TCP must be the transport layer, right ?

A: No... well, almost.

TCP is only part of the TCP/IP transport layer - the other part is UDP (User Datagram Protocol).

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UDP User Datagram Protocol

- ◆ UDP is a transport protocol
 - ◆ communication between processes
- ◆ UDP uses IP to deliver datagrams to the right host.
- ◆ UDP uses *ports* to provide communication services to individual processes.

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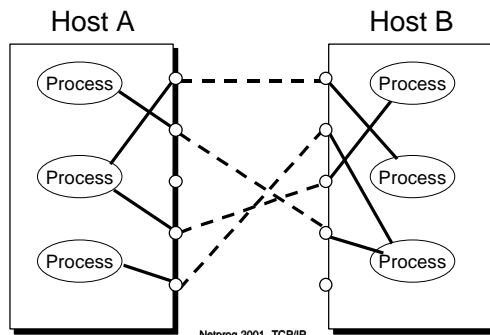
Ports

- ◆ TCP/IP uses an abstract destination point called a protocol port.
- ◆ Ports are identified by a positive integer.
- ◆ Operating systems provide some mechanism that processes use to specify a port.

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Ports



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UDP

- ◆ Datagram Delivery
- ◆ Connectionless
- ◆ Unreliable
- ◆ Minimal

UDP Datagram Format

Source Port	Destination Port
Length	Checksum
Data	


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TCP

Transmission Control Protocol

- ◆ TCP is an alternative transport layer protocol supported by TCP/IP.
- ◆ TCP provides:
 - Connection-oriented
 - Reliable
 - Full-duplex
 - Byte-Stream



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Connection-Oriented

- ◆ *Connection oriented* means that a virtual connection is established before any user data is transferred.
- ◆ If the connection cannot be established - the user program is notified.
- ◆ If the connection is ever interrupted - the user program(s) is notified.

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Reliable

- ◆ *Reliable* means that every transmission of data is acknowledged by the receiver.
- ◆ If the sender does not receive acknowledgement within a specified amount of time, the sender retransmits the data.

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Byte Stream

- ◆ *Stream* means that the connection is treated as a stream of bytes.
- ◆ The user application does not need to package data in individual datagrams (as with UDP).

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Buffering

- ◆ TCP is responsible for buffering data and determining when it is time to send a datagram.
- ◆ It is possible for an application to tell TCP to send the data it has buffered without waiting for a buffer to fill up.

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Full Duplex

- ◆ TCP provides transfer in both directions.
- ◆ To the application program these appear as 2 unrelated data streams, although TCP can piggyback control and data communication by providing control information (such as an ACK) along with user data.

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TCP Ports

- ◆ Interprocess communication via TCP is achieved with the use of ports (just like UDP).
- ◆ UDP ports have no relation to TCP ports (different name spaces).

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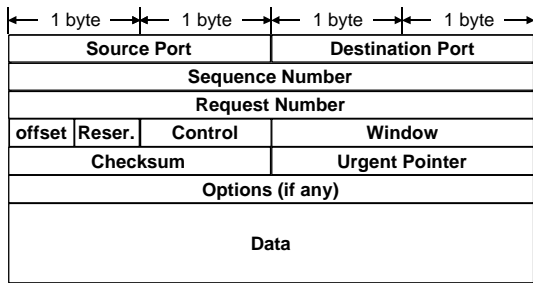
TCP Segments

- ◆ The chunk of data that TCP asks IP to deliver is called a *TCP segment*.
- ◆ Each segment contains:
 - data bytes from the byte stream
 - control information that identifies the data bytes

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TCP Segment Format



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Addressing in TCP/IP

◆ Each TCP/IP address includes:

- Internet Address
- Protocol (UDP or TCP)
- Port Number

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TCP vs. UDP

Q: Which protocol is better ?
A: It depends on the application.

TCP provides a connection-oriented, reliable byte stream service (lots of overhead).

UDP offers minimal datagram delivery service (as little overhead as possible).

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TCP/IP Summary

◆ IP: network layer protocol

- unreliable datagram delivery between hosts.

◆ UDP: transport layer protocol

- unreliable datagram delivery between processes.

◆ TCP: transport layer protocol

- reliable, byte-stream delivery between processes.

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Hmmmmm.
TCP or UDP ?

- ◆ Internet commerce ?
- ◆ Video server?
- ◆ File transfer?
- ◆ Email ?
- ◆ Chat groups?
- ◆ Robotic surgery controlled remotely over a network?

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