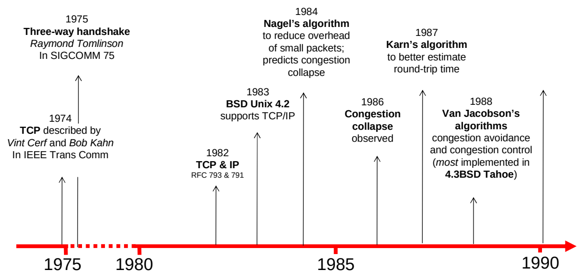
TCP Evolution



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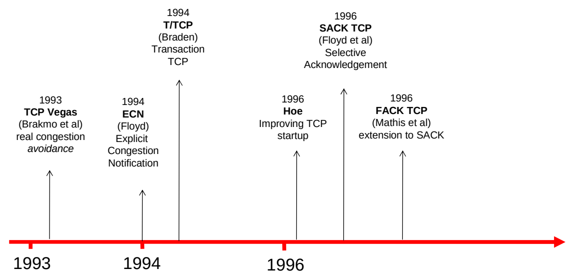
TCP Through the 90s



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TCP / UDP Comparison

- TCP:
  - Connection-oriented protocol
  - Full-duplex
  - Messages received in order, no loss or duplication
  - Error, flow and congestion control
  - $\Rightarrow$ *Reliable but with overhead*

- UDP:
  - Messages called ``datagrams''
  - Messages may be lost or duplicated
  - Messages may be received out of order
  - $\Rightarrow$ *Unreliable but potentially faster*

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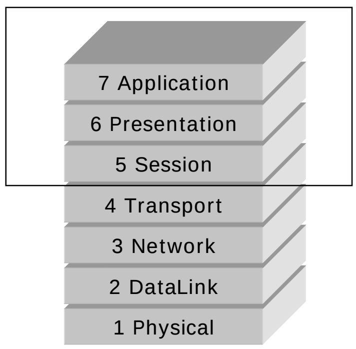
Where Are We?



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Separation of Duties

- Network
  - – Transfer bits/bytes
  - – Operates at the application's request
- Applications
  - – What data to transmit
  - – When to transmit data
  - – Where to transmit data to
  - – Meaning of bits/bytes

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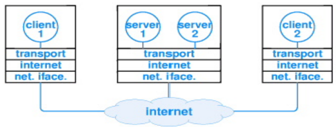
Client-Server Paradigm

- Network applications use a form of communication known as the client-server paradigm
- A server application waits passively for contact, while a client application initiates communication actively



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Characteristics

- Client
  - – Actively initiates contact with server(s)
  - – Invoked directly by a user
  - – Uses different source port for each connection
- Server
  - – Passively awaits connections from clients
  - – Accepts contact from arbitrary clients, but offers a single service
  - – Uses the same source port for all clients

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Use of Ports

- Each service given unique port number, *P*
- Server
  - – Informs operating system it is using port *P*
  - – Waits for requests to arrive
- Client
  - – Forms request
  - – Sends request to port *P* on server computer

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Interacting with Protocol Software

- Client or server uses transport protocols
- Protocol software resides in OS (kernel)
- Applications outside the OS (userland)
- Mechanism to bridge the two
  - *Application Programming Interface (API)*

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Application Programming Interface

- Part of the operating system
- Permits applications to use protocols
- Defines
  - Operations allowed
  - Arguments for each operation

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Example API: Sockets

- Originally designed
  - On and for BSD UNIX
  - To use with TCP/IP protocols
- Now
  - Industry standard
  - Available on many operating systems and languages
    - E.g. Winsock
    - Java, Python, etc. sockets

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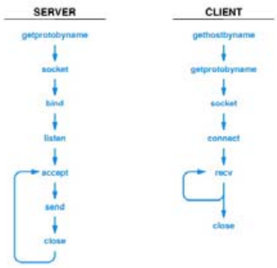
Sample Socket Procedure



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Automated Protocol Configuration

- In a layered protocol stack, like TCP/IP, layers are configured from lowest to highest
- Higher-layer protocols use lower layer protocols to obtain configuration information
- Broadcasting main mechanism

- Must be supported by the networking technology, e.g. Ethernet

- Applications that use broadcasting to obtain configuration information must be prepared to receive multiple responses

  * One approach: Accept first, ignore others

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Bootstrapping: Sequence of Protocols Used

- Step 1: Broadcast *RARP request* to obtain IP address
- Step 2: Wait for *RARP response*; if none arrives within T1 seconds go to Step 1
- Step 3: Broadcast *ICMP address mask request*
- Step 4: Wait for *ICMP address mask response*; if none arrives within T2 seconds go to Step 3
- Step 5: Use *ICMP gateway discovery* to find IP address of default router and add default route to the routing table

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RARP Limitations

- Provides a mechanism for a host to determine its IP address when it is only aware of its MAC address
- RARP can determine and configure a diskless workstation with an IP address
- No method for determining and delivering other configuration data
- RARP server can service only a single subnet because of its complete reliance on Ethernet broadcasts

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Bootstrap Protocol (BOOTP)

- BOOTP allows hosts to be dynamically configured to use the TCP/IP protocol suite
- BOOTP delivers configuration information automatically instead of each TCP/IP host on a network being manually configured
- BOOTP is based on UDP so it uses IP for transport and is routeable
- RFC 951

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BOOTP Operation

- BOOTP is a client/server process where the BOOTP client, during the boot phase, requests configuration information from a BOOTP server
- After receiving a request from a BOOTP client, the server looks up the clients MAC address in its BOOTP configuration database and sends a reply containing IP configuration information
- Client receives the reply and configures its TCP/IP stack
- BOOTP client will also load a boot file if the BOOTP server supplies a path using the fully qualified filename.
- The magic cookie, a mechanism for a BOOTP server to supply vendor-specific operating system options to a BOOTP client

  - Options include DNS servers, WINS or NetBIOS name server, time servers, etc.

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BOOTP Messages

- BOOTREQUEST

  - Includes information that allows the BOOTP server to determine what configuration data it must supply to the requesting host
- BOOTREPLY

  - Includes the information that the client requested from the server
- Have the same packet structure

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BOOTREQUEST (1/2)

- Contains following information:

1. Source's MAC address
2. Destination's MAC address
3. Destination's IP address
4. Source's IP address
5. Destination server hostname
6. Boot filename
7. Vendor-specific data (e.g. boot image via TFTP)

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BOOTREQUEST (2/2)

- Appears to use IP that has not been configured
- IP uses the all-1's broadcast address as a destination address, and all-0's as a source address
- If a computer uses the all-0's address to send a request a BOOTP server either uses broadcast to respond or uses the MAC address of the incoming frame to respond via a unicast
- Server must avoid ARP requests since the client does not know its IP address and cannot answer them

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BOOTP Limitations

- BOOTP database is a static text file
  - File has to be maintained by hand as changes are made to the network
- Unable to dynamically allocate and distribute IP addresses
  - Dynamic IP addressing critical for many application scenarios

Dynamic Host Configuration Protocol

- DHCP: Dynamic Host Configuration Protocol (RFC 1531)
- Superset of BOOTP, provides the same service with more options
- Does not require an administrator to add an entry for each computer to the database that a server uses
- *Plug-and-play networking*

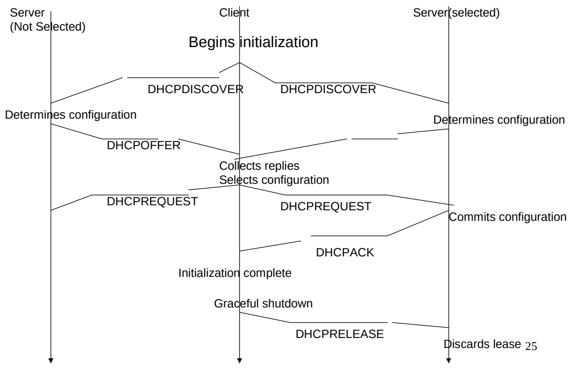
DHCP Operation (1/2)

- IP addresses bound to workstations dynamically
  - Workstation broadcasts DHCPDISCOVER message on boot
  - Several DHCP servers may respond with DHCPOFFER messages containing:
    - * IP address, subnet mask
    - * Default router IP address
    - * Renewal time

DHCP Operation (2/2)

- Workstation responds to one offer with DHCPREQUEST
  - * Request may include items like: DNS servers, time servers, boot files, etc.
- DHCP server now binds IP address and replies with DHCPACK message with requested options

DHCP New Address Allocation



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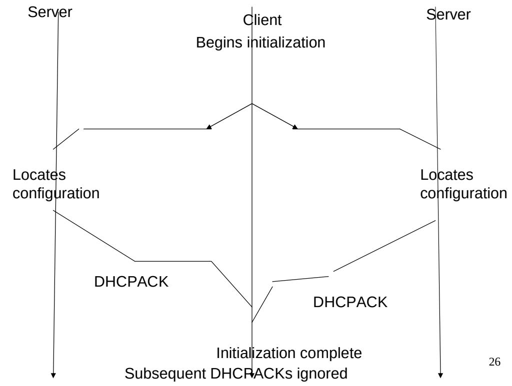
DHCP Previously Allocated Address



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DHCP Server Configuration

- System administrator assigns multiple ranges of IP addresses to each DHCP server and server manages distribution to clients
- Client must renew IP address at regular intervals indicated by *Renewal time*

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DHCP Message Format (1/2)

op (1)	htype (1)	hlen (1)	hops (1)
xid (4)			
secs (2)		flags (2)	
ciaddr (4)			
yiaddr (4)			
siaddr (4)			
giaddr (4)			
chaddr (16)			
sname (64)			
file (128)			
options (312)			

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DHCP Message Format (2/2)

Fields	Bytes	Descriptions
op	1	op code/message type
htype	1	Hardware address type
hlen	1	hardware address length
hops	1	Client sets to zero, optionally used by relay agents when booting via relay agent
xid	4	Transaction ID
secs	2	Filled in by client, seconds elapsed since client began address acquisition or renewal process.
flags	2	Flags
ciaddr	4	Client IP address
yiaddr	4	``your'' (client) IP address
siaddr	4	IP address of next server to use in bootstrap; returned in DHCPOFFER, DHCPACK by server.
giaddr	4	Relay agent IP address
chaddr	16	Client hardware address
sname	64	Optional server host name, null terminated string.
file	128	Boot file name
options	var	Optional parameters field.

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IPv6 Autoconfiguration

- IPv6 has a stateless autoconfiguration capability
- Stateless autoconfiguration does not require manual host configuration, minimal router configuration, and no additional servers
- A host is able generate its own addresses using a combination of locally available information and information advertised by routers

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DHCPv6 (DHCP for IPv6)

- DHCPv6 complements IPv6 by providing a stateful autoconfiguration option to facilitate the automatic configuration of DHCP clients (RFC 3315)
- Hosts obtain interface addresses and/or configuration information and parameters from a server
- The server maintains a database of the addresses that have been assigned to hosts
- DHCPv6 uses a combination of unicast and multicast messages instead of broadcast messages for the majority of its conversation

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