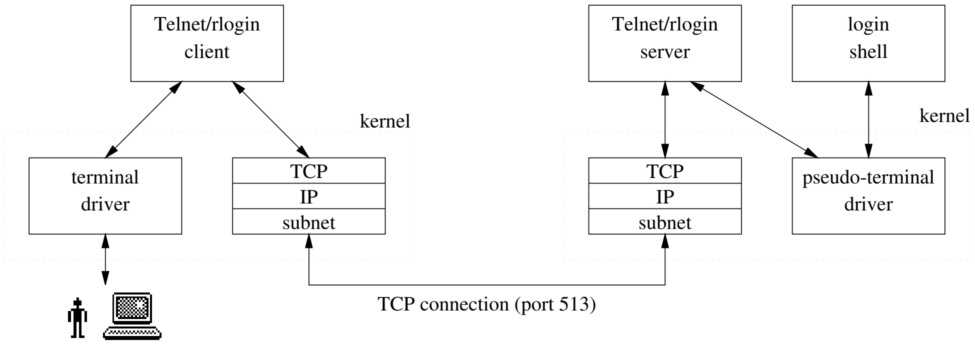
Applications: Telnet, rlogin, ftp, Sun RPC, nfs, finger, whois, X

Remote login

- remote login to host from host to host ➠ telnet, rlogin
- rlogin: mostly Unix systems
- rlogin: simpler (no option negotiation)
- both use client/server (rlogind, telnetd)
- one TCP connection
- low volume, short packets, asymmetric

Remote login: components



Telnet/rlogin client

kernel

terminal driver

TCP
IP
subnet

Telnet/rlogin server

login shell

kernel

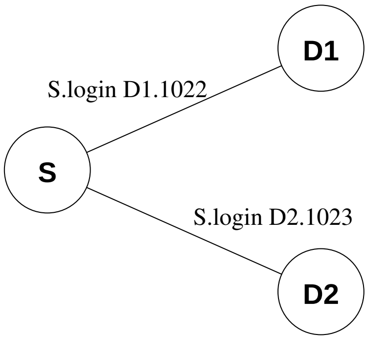
TCP
IP
subnet

pseudo-terminal driver

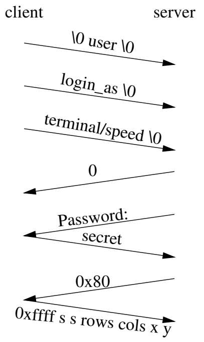
TCP connection (port 513)

Multiple connections

How two clients connect to the login server:



rlogin protocol



- password sent as cleartext (snooping!) ➠ Kerberos
- `.rhosts` file (host list) bypasses login check ➠ security risk!
- echoing done by server
- everything typed sent to server, everything received displayed

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rlogin server-client interaction

- flow control must be done by client (pipe!) ➠ XON/XOFF ASCII (control-s/q)
- client interrupt (control-c): stop display locally
- server → client commands via *TCP urgent mode*
  - flush output (server sends after interrupt)
  - client stops performing flow control
  - client resumes performing flow control
  - please send window size
- client → server commands: window size changes *in-band* via escape sequence 0xffff

telnet: remote login

- one of the oldest Internet applications (1969)
- *network virtual terminal*: dumb terminal, 7-bit ASCII
- common to FTP, SMTP, finger, whois: CRLF for end-of-line
- *in-band* signaling via IAC (0xff): “interpret as command”
- can do *line mode* (good for slow connections) or character-by-character mode

telnet: option negotiation

- start with NVT, then either side can propose changes
- Negotiation:

WILL	sender wants to enable option itself
DO	sender wants receiver to enable option
WONT	sender wants to disable option itself
DONT	sender wants receiver to disable option

- always needs to honor request to disable option
- Typical exchanges:

WILL	DO	sender wants own option, receiver agrees
WILL	DONT	sender wants own option, receives refuses
DO	WILL	sender wants receiver option, receiver agrees
DO	WONT	sender wants receiver option, receiver refuses
WONT	DONT	sender wants to disable, receiver agrees
DONT	WONT	sender wants to disable, receiver agrees

telnet options codes

1	echo
2	suppress go ahead
6	timing mark
24	terminal type
31	window size
32	terminal speed
33	remote flow control
34	linemode
36	environment variables

telnet example

```
telnet> toggle options
Will show option processing.
telnet> open tao
Trying 192.35.149.93 ...
Connected to tao.
Escape character is ’^]’.
SENT do SUPPRESS GO AHEAD
SENT will TERMINAL TYPE (don’t reply)
RCVD do TERMINAL TYPE (don’t reply)
RCVD will SUPPRESS GO AHEAD (don’t reply)

UNIX(r) System V Release 4.0 (tao)

RCVD will ECHO (reply)
SENT do ECHO (don’t reply)
RCVD do ECHO (reply)
SENT wont ECHO (don’t reply)
RCVD dont ECHO (don’t reply)
```

ftp: file transfer protocol

- file transfer ↔ file access (NFS)
- copies complete files
- file management (directory, renaming, deleting, …)
- *two* TCP connections: control (port 21) + data
- ➠ no need for escape characters
- control stays open through ftp session ➠ low throughput, delay
- data connection opened for each file ➠ high throughput

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ftp: data representation

File type: ASCII (NVT ASCII), EBCDIC, image (=binary), $\neq 8$ bits/byte

Format control (text): nonprint, telnet format, Fortran carriage control

Structure: file, record, page

Transmission mode: stream, block, run-length compressed

ftp: commands

Commands sent as NVT ASCII (4 characters - why?).

ABOR	abort previous FTP command, transfer
LIST *filelist*	list files or directories
PASS *password*	password
PORT $a_1, a_2, a_3, a_4, p_1, p_2$	client IP address
QUIT	logoff from server
RETR *file*	retrieve (get) a file
STOR *file*	store (put) a file
SYST	return system type
TYPE *type*	specify file type: A=ASCII, I=Image
USER *username*	username on server

ftp replies

Reply codes: 3-digit number, optional message
Same idea found in a number of protocols: SMTP, HTTP, ….

$1yz$	positive preliminary reply
$2yz$	positive completion
$3yz$	Positive intermediate reply
$4yz$	Transient negative reply - retry later
$5yz$	Permanent negative reply - don't retry

$x0z$	syntax errors
$x1z$	information
$x2z$	connection
$x3z$	authentication
$x4z$	unspecified
$x5z$	filesystem status

ftp: sample error codes

125	data connection already open; transfer starting.
150	pending BINARY mode data connection for *file* (N bytes)
200	Command OK
226	Transfer complete.
331	Username OK, password required.
425	Can’t open data connection.
452	Error writing file.
500	Syntax error.

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ftp: opening data connection

1. initiated by ftp client
2. choose ephemeral port option for client; *passive* open (listen/accept)
3. client sends own address and port to server
4. server does *active* open
5. new port avoids TIME-WAIT between connections

Anonymous ftp

- pre-web "browsing"
- commonly used for downloading free software, papers
- same as ftp, but user is *ftp* or *anonymous*
- use email address as password (or just `user@`)
- some servers require valid address-to-host mapping for logging

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ftp: example

```
ftp> debug 255
Debugging on (debug=255).
ftp> open gaia.cs.umass.edu
Connected to gaia.cs.umass.edu.
220 gaia.cs.umass.edu FTP server (Version wu-2.4(8) Tue Jul 26
14:49:31 EDT 1994) ready.
Name (gaia.cs.umass.edu:hgs): hgschulz
---> USER hgschulz
331 Password required for hgschulz.
Password:
---> PASS xxxxxxx
230 User hgschulz logged in.
---> SYST
215 UNIX Type: L8
Remote system type is UNIX.
---> TYPE I
200 Type set to I.
Using binary mode to transfer files.
ftp> ls
---> PORT 192,35,149,52,175,88
200 PORT command successful.
```

```
---> TYPE A
200 Type set to A.
---> LIST
150 Opening ASCII mode data connection for /bin/ls.
total 1012
-rw-------  1 hgschulz dcc           275 Apr 17  1995 .Xauthority
...
226 Transfer complete.
---> TYPE I
200 Type set to I.
ftp> get outgoing
---> PORT 192,35,149,52,175,107
200 PORT command successful.
---> RETR outgoing
ftp> quit
---> QUIT
221 Goodbye.
```

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nfs: network file system

- *transparent* file access ➠ part of file system tree ➠ application doesn’t know whether file is local or remote
- mostly used in LANs
- client (workstation) ↔ server (disk storage)
- uses Sun RPC with UDP (mostly) or TCP (rarely; for WAN)

Sun RPC

Look like function calls to programmer, but…

1. function invokes *client stub* procedure
2. client stub packages arguments into packets
3. *server stub* receives message and calls function
4. on function return, server stub sends result
5. client stub returns results to program

Advantages:

- no network programming
- retransmission handled by RPC package
- data translation (no `htonl()`, …) ➠ XDR: (un)signed integers, booleans, floating point, fixed/variable-length arrays, structures

RPC request

field	length
(length field for TCP)	4
transaction ID (XID)	4
call (0)	4
RPC version (2)	4
program number	4
version number	4
procedure number	4
credentials	< 400
verifier	< 400
parameters	

RPC reply

field	length
transaction ID (XID) of request	4
reply (1)	4
status (0=accepted)	4
verifier	< 400
accept status (0=success)	4
procedure results	

Portmapper

- RPC servers use ephemeral ports
- *portmapper* server registers RPC programs via RPC
- always resides at port 111
- client obtains port numbers of desired program via RPC

Portmapper: example

```
rpcinfo -p
   program vers proto   port  service
    100000    4   tcp    111  rpcbind
    100000    3   tcp    111  rpcbind
    100000    2   tcp    111  rpcbind
    100000    4   udp    111  rpcbind
    100000    3   udp    111  rpcbind
    100000    2   udp    111  rpcbind
    100007    3   udp  32773  ypbind
    100003    2   udp   2049  nfs  [fixed port!]
    100005    1   udp  32828  mountd
    100005    2   udp  32828  mountd
    100005    1   tcp  32793  mountd
    100005    2   tcp  32793  mountd
```

NFS

- usually multithreaded (why?)
- stateless
- *opaque* file handle: created by server; contains local file system info
- mounts server file system at some local location:

  ```
  mount -t nfs host:/usr /nfs/host/usr
  ```

- UDP: retransmit with exponential backoff, potentially forever
- application not aware of server crashes

NFS Commands

GETATTR	file attributes (directory listing)
SETATTR	set attributes
STATFS	status of filesystem (`df`)
LOOKUP	given name, return handle
READ	read from file at offset
WRITE	write to a file at offset
CREATE	create a file
REMOVE	remove a file
RENAME	rename a file
LINK	make a hard link to file
SYMLINK	create a symbolic link
READLINK	reads symbolic link
MKDIR	make a directory
RMDIR	remove a directory
READDIR	read a directory (`ls`)

Most commands are *idempotent* (can be repeated) ➠ needed for server crash, UDP packet loss.

Finger

- one-line query (user), returns result (.plan, .project, /etc/passwd name, …), server closes
- potential security risk (reveals personal info)
- empty line: get all users
- `/W user` ➠ verbose
- can be recursive: user@host
- used for vending machines

```
finger @gaia.cs.umass.edu
Login       Name             TTY  Idle    When            Office
yajnik   Maya Yajnik      p0     4 Tue 09:39
casetti  Claudio Casetti  p1       Tue 10:16
zhzhang  Zhi-Li Zhang     p2    30 Tue 10:32  GRC A203  413 545-3179
yamamoto Miki yamamoto    p3    52 Tue 10:37
```

whois

- “protocol” like finger, but information returned differs

```
whois -h rs.internic.net .gmd-fokus
GMD-FOKUS (NET-GMD-FOKUS-B)
   Hardenbergplatz 2
   D-1000 Berlin 12
   GERMANY

   Netname: GMD-FOKUS-B
   Netnumber: 192.35.152.0

   Coordinator:
      Wasserroth, Stephan  (SW111)  stephan.wasserroth@GMD.DE
      +49 30 25499 253

   Record last updated on 17-Apr-91.
```

The X window system

- allows remote display/execution
- client: program that wants to draw
- server: screen, keyboard, mouse; serves several local or remote clients
- uses TCP or local Unix IPC
- draw ops, mouse, keyboard events ➠ network packets
- several layers (Xlib, Motif, …)