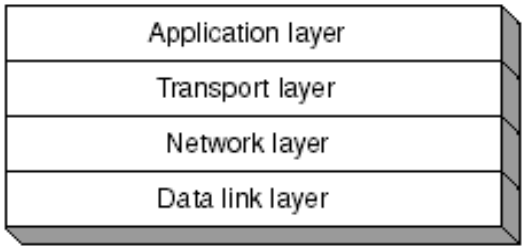
English Edition

6. Inter Process Communication (2)

6. IPC
- 6.2 Sockets
  - 6.2.2 Excursion: TCP/IP, UDP
  - 6.2.3 Sockets with Python
- 6.3 Pipes

TCP/IP (1)

- Internet Protocol Suite
- combination of several protocols
- four layers (cf. OSI layer model)



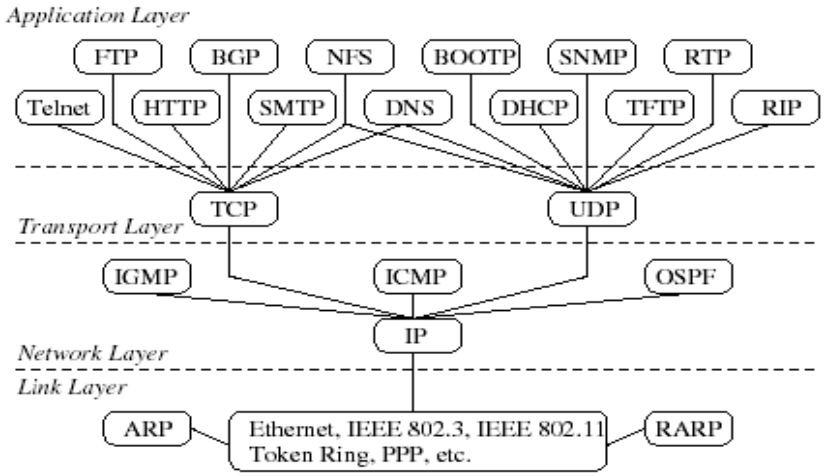
6.2 IPC: Brief excursion: TCP/IP, UDP

TCP/IP (2)

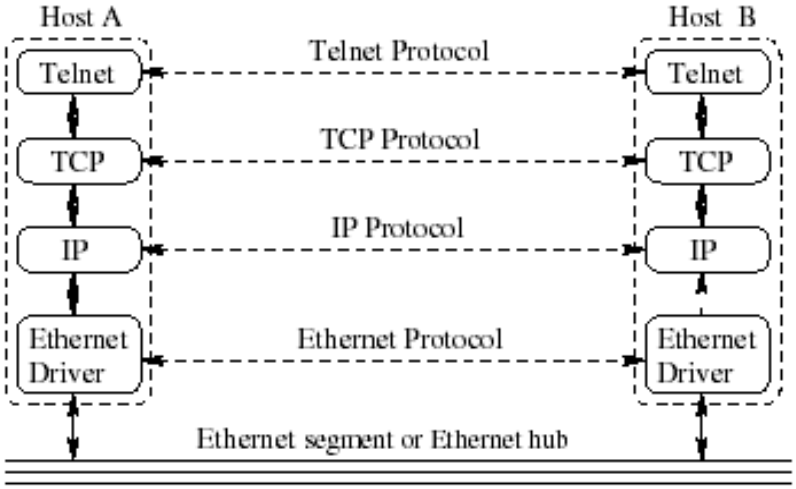
The four layers

- **Data Link Layer**
  - Service: transmit frames reliably over a connection
  - Functions: synchronization, error control, flow control
- **Network Layer**
  - Service: routes packages through the network
  - Functions: routing, addressing, switching, congestion control
- **Transport Layer**
  - Service: control delivery of data between machines
  - Functions: opening/closing a connection, error and flow control
- **Application Layer**
  - Service: deals with details of the user application
  - Functions: all application-specific

TCP/IP (3)

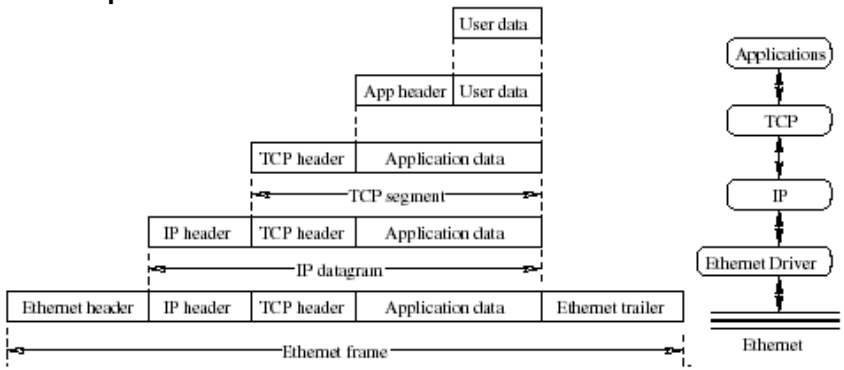


TCP/IP (4)



TCP/IP (5)

- encapsulation: on each layer „wrap“ the package (i. e. add a protocol-specific header) and put it on the route



TCP/IP (6)

Addressing

- Servers run several services, clients use different applications which issue simultaneous requests
- create order:
  - port number
  - host name

  } `imapsrv.fhm.edu:143`
  - IP address
  - MAC address (NIC, network adapter)

TCP/IP (7)

Host names

- uniquely identify a machine (on the internet or in the local network)
- user-friendly („speaking“ names)
- hierarchically organized
- Domain Name System (DNS): find the IP address that corresponds to a host name

TCP/IP (8)

Port numbers

- differentiate several services on one machine
- allow several parallel connections (possibly for the same service)
- **Port Number** field in TCP or UDP header
- „Well-known port numbers“: 0-1023
  - 1 - 255: internet-wide services
  - 256 - 1023: reserved for Unix-specific services
- registered ports: 1024-49151
- dynamically assigned ports: 49152-65535

TCP/IP (9)

Well-known port numbers: /etc/services (TCP & UDP)

```
#               0/tcp   Reserved
tcpmux          1/tcp   # TCP Port Service Multiplexer
compressnet     2/tcp   # Management Utility
compressnet     3/tcp   # Compression Process
#               4/tcp   # Unassigned
rje             5/tcp   # Remote Job Entry
#               6/tcp   # Unassigned
echo            7/tcp   Echo
#               8/tcp   # Unassigned
discard         9/tcp   # Discard
#              10/tcp   # Unassigned
systat         11/tcp   users    # Active Users
#              12/tcp   # Unassigned
daytime        13/tcp   # Daytime (RFC 867)
#              14/tcp   # Unassigned
netstat        15/tcp   # Unassigned [was netstat]
#              16/tcp   # Unassigned
qotd           17/tcp   quote    # Quote of the Day
msp            18/tcp   # Message Send Protocol
chargen        19/tcp   # Character Generator
ftp-data       20/tcp   # File Transfer [Default Data]
ftp            21/tcp   # File Transfer [Control]
ssh            22/tcp   # SSH Remote Login Protocol
telnet         23/tcp   # Telnet
#              24/tcp   any private mail system
smtp           25/tcp   mail     # Simple Mail Transfer
#              26/tcp   # Unassigned
nsw-fe         27/tcp   # NSW User System FE
#              28/tcp   # Unassigned
msg-icp        29/tcp   # MSG ICP
#              30/tcp   # Unassigned
```

```
#               0/udp   Reserved
tcpmux          1/udp   # TCP Port Service Multiplexer
compressnet     2/udp   # Management Utility
compressnet     3/udp   # Compression Process
#               4/udp   # Unassigned
rje             5/udp   # Remote Job Entry
#               6/udp   # Unassigned
echo            7/udp   Echo
#               8/udp   # Unassigned
discard         9/udp   # Discard
#              10/udp   # Unassigned
systat         11/udp   users    # Active Users
#              12/udp   # Unassigned
daytime        13/udp   # Daytime (RFC 867)
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#              15/udp   # Unassigned
#              16/udp   # Unassigned
qotd           17/udp   quote    # Quote of the Day
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fsp            21/udp   # File Transfer [Control]
ssh            22/udp   # SSH Remote Login Protocol
telnet         23/udp   # Telnet
#              24/udp   any private mail system
smtp           25/udp   mail     # Simple Mail Transfer
#              26/udp   # Unassigned
nsw-fe         27/udp   # NSW User System FE
#              28/udp   # Unassigned
msg-icp        29/udp   # MSG ICP
#              30/udp   # Unassigned
```


TCP/IP (10)

IP addresses

- every computer on the internet has a unique IP address (some machines have more than one)
- IPv4, 32 bits, decimal notation with dots

128.238.42.112 means

10000000	in 1st Byte
11101110	in 2nd Byte
00101010	in 3rd Byte
01110000	in 4th Byte

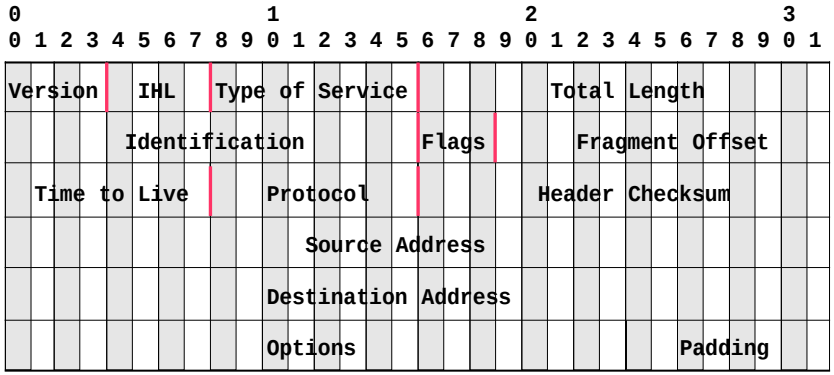
TCP/IP (11)

Internet Protocol (IP)

- Datagram (packet) protocol
- “Best-effort service”, yet the following can happen:
  - loss
  - reordering
  - package duplication
  - delay
- IP transports data **between machines,** not **between applications**

TCP/IP (12)

IP packet header:



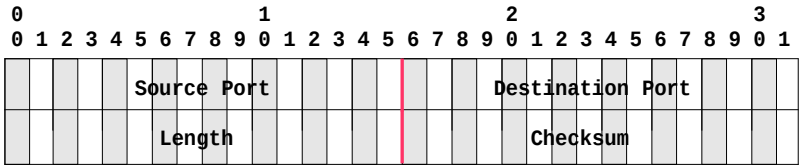
TCP/IP (13)

IP services are not sufficient, thus: extra services which are based on IP

- **User Datagram Protocol (UDP)**
  - checksums
  - application-specific (with port numbers)
- **Transmission Control Protocol (TCP)**
  - in addition to UDP (checksums, ports):
  - reliable bytestream transport
  - flow and congestion control

TCP/IP (14)

UDP packet header



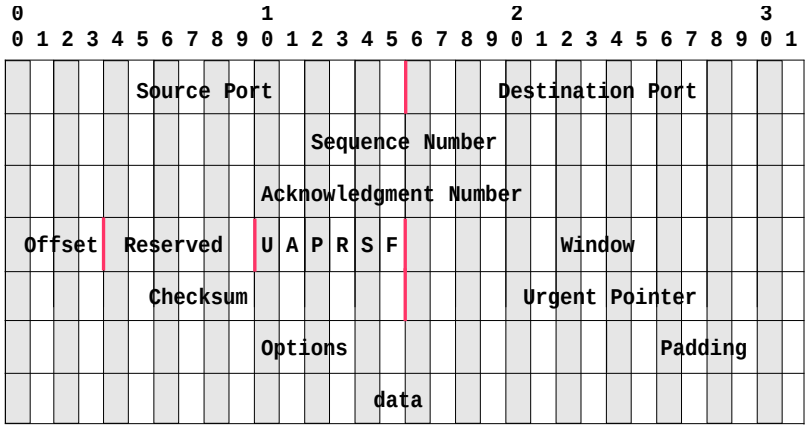
- checksum: is calculated from UDP header, UDP data and the following pseudo header

32-bit Source IP Address		
32-bit Destination IP Address		
0x00	8-bit Protocol (0x17)	16-bit UDP Length

- UDP packet has no address field since it will be put into an IP packet

TCP/IP (15)

TCP packet header



TCP/IP (16)

- transmitting data via sockets defined by:
  - sender (IP address and port)
  - receiver (IP address and port)
- typical example: web server request (HTTP) with server: www.fhm.edu (129.187.244.212)

TCP/IP (17)

- look up HTTP Port:

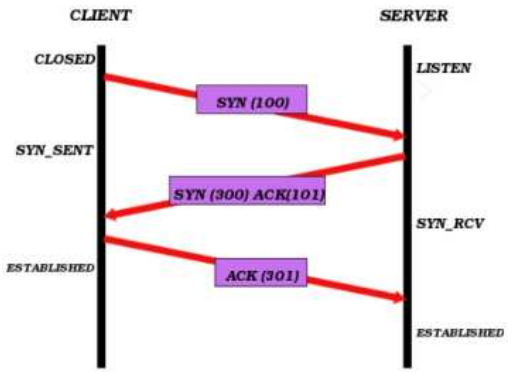
```
$ grep http /etc/services | grep tcp
http            80/tcp    # World Wide Web HTTP
```

- so it's Port 80
- sender (of the request) picks an arbitrary free port, e.g. 50001
- thus:
  sender = 192.168. 1. 2:50001
  receiver = 129.187.244.212:80

TCP/IP (18)

3-Way-Handshake for establishing connection

- client sends SYN
- server replies SYN/ACK
- client replies ACK
- after that the connection is up



picture: http://www.cs.pub.ro/~rc/Laborator/lab5.html

TCP/IP (19)

(1) 3-Way-Handshake

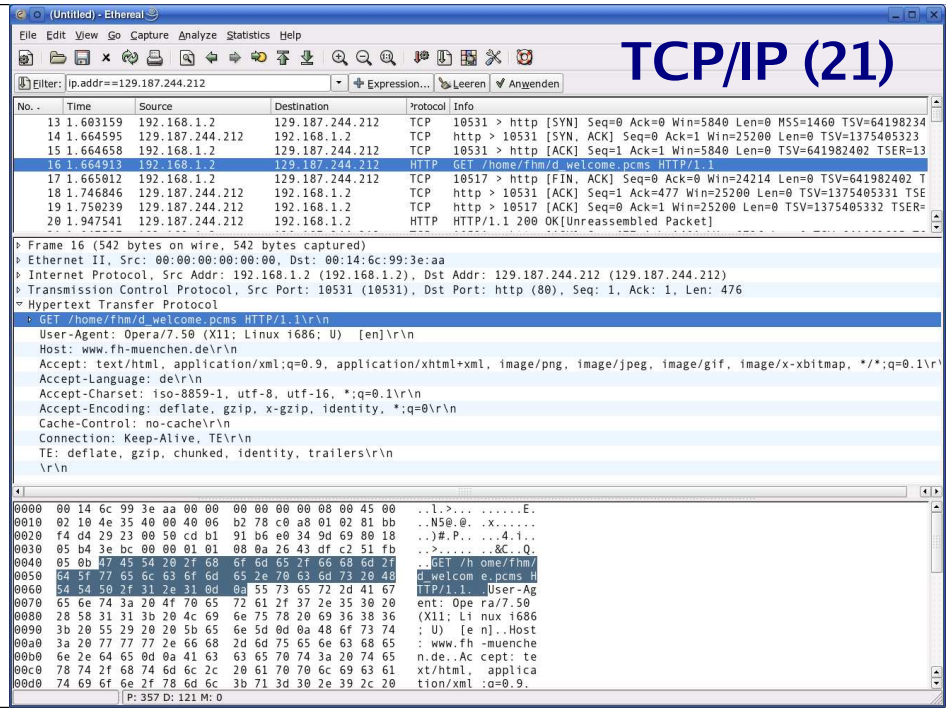
```
Frame 13 (74 bytes on wire, 74 bytes captured)
IP, Src Addr: 192.168.1.2 (192.168.1.2), Dst Addr: 129.187.244.212 (129.187.244.212)
TCP, Src Port: 10531 (10531), Dst Port: http (80), Seq: 0, Ack: 0, Len: 0
    Source port: 10531 (10531)
    Destination port: http (80)
    Sequence number: 0    (relative sequence number)
    Flags: 0x0002 (SYN)

Frame 14 (78 bytes on wire, 78 bytes captured)
IP, Src Addr: 129.187.244.212 (129.187.244.212), Dst Addr: 192.168.1.2 (192.168.1.2)
TCP, Src Port: http (80), Dst Port: 10531 (10531), Seq: 0, Ack: 1, Len: 0
    Source port: http (80)
    Destination port: 10531 (10531)
    Sequence number: 0    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Flags: 0x0012 (SYN, ACK)

Frame 15 (66 bytes on wire, 66 bytes captured)
IP, Src Addr: 192.168.1.2 (192.168.1.2), Dst Addr: 129.187.244.212 (129.187.244.212)
TCP, Src Port: 10531 (10531), Dst Port: http (80), Seq: 1, Ack: 1, Len: 0
    Source port: 10531 (10531)
    Destination port: http (80)
    Sequence number: 1    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Flags: 0x0010 (ACK)
```

(logged with Ethereal)

TCP/IP (21)



TCP/IP (20)

(2) HTTP request

```
Frame 16 (542 bytes on wire, 542 bytes captured)
Ethernet II, Src: 00:00:00:00:00:00, Dst: 00:14:6c:99:3e:aa
IP, Src Addr: 192.168.1.2 (192.168.1.2), Dst Addr: 129.187.244.212 (129.187.244.212)
TCP, Src Port: 10531 (10531), Dst Port: http (80), Seq: 1, Ack: 1, Len: 476
    Source port: 10531 (10531)
    Destination port: http (80)
    Sequence number: 1    (relative sequence number)
    Next sequence number: 477    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Flags: 0x0018 (PSH, ACK)
Hypertext Transfer Protocol
    GET /home/fhm/d_welcome.pcms HTTP/1.1\r\n
    User-Agent: Opera/7.50 (X11; Linux i686; U)  [en]\r\n
    Host: www.fh-muenchen.de\r\n
    Accept: text/html, application/xml;q=0.9, application/xhtml+xml, image/png, image/jpeg,
            image/gif, image/x-xbitmap, */*;q=0.1\r\n
    Accept-Language: de\r\n
    Accept-Charset: iso-8859-1, utf-8, utf-16, *;q=0.1\r\n
    Accept-Encoding: deflate, gzip, x-gzip, identity, *;q=0\r\n
    Cache-Control: no-cache\r\n
    Connection: Keep-Alive, TE\r\n
    TE: deflate, gzip, chunked, identity, trailers\r\n
    \r\n
```

(logged with Ethereal)

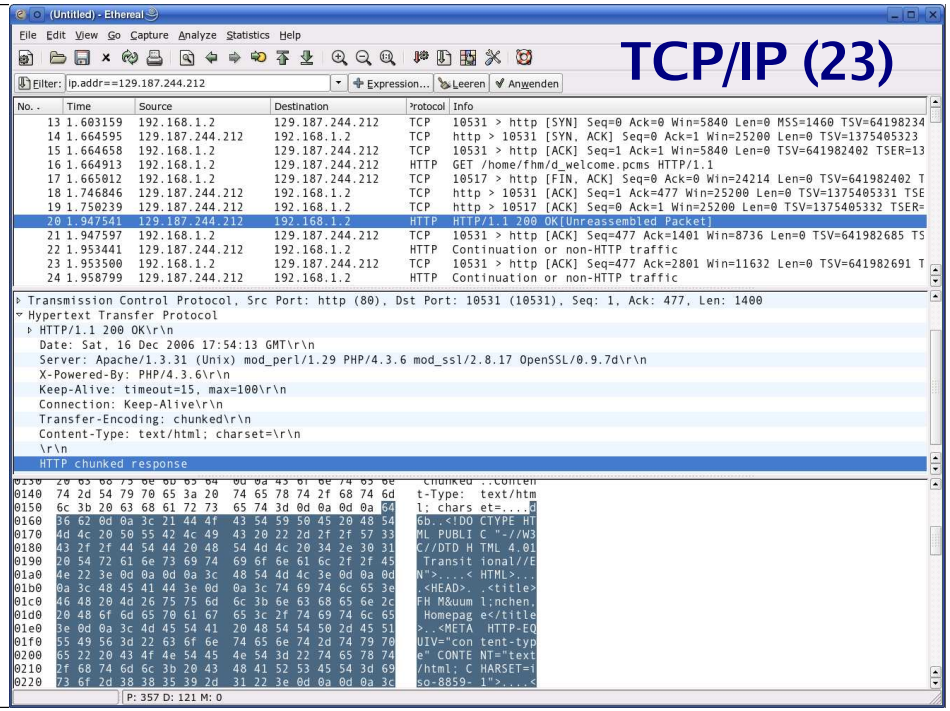
TCP/IP (22)

(3) HTTP reply

```
Frame 20 (1466 bytes on wire, 1466 bytes captured)
Ethernet II, Src: 00:14:6c:99:3e:aa, Dst: 00:00:00:00:00:00
IP, Src Addr: 129.187.244.212 (129.187.244.212), Dst Addr: 192.168.1.2 (192.168.1.2)
TCP, Src Port: http (80), Dst Port: 10531 (10531), Seq: 1, Ack: 477, Len: 1400
    Source port: http (80)
    Destination port: 10531 (10531)
    Sequence number: 1    (relative sequence number)
    Next sequence number: 1401    (relative sequence number)
    Acknowledgement number: 477    (relative ack number)
    Header length: 32 bytes
    Flags: 0x0010 (ACK)
Hypertext Transfer Protocol
    HTTP/1.1 200 OK\r\n
    Date: Sat, 16 Dec 2006 17:54:13 GMT\r\n
    Server: Apache/1.3.31 (Unix) mod_perl/1.29 PHP/4.3.6 mod_ssl/2.8.17 OpenSSL/0.9.7d\r\n
    X-Powered-By: PHP/4.3.6\r\n
    Keep-Alive: timeout=15, max=100\r\n
    Connection: Keep-Alive\r\n
    Transfer-Encoding: chunked\r\n
    Content-Type: text/html; charset=\r\n
    \r\n
    HTTP chunked response
```

(logged with Ethereal)

TCP/IP (23)



Sockets in Python (1)

Using sockets in Python is similar as in C:

C	Python
`sockfd = socket(AF_INET, SOCK_STREAM,0);`	`sock = socket(AF_INET,SOCK_STREAM)`

`serv_addr.sin_addr.s_addr = INADDR_ANY;`
`serv_addr.sin_family = AF_INET;`
`serv_addr.sin_port = htons (port);`	

`bind( sockfd, (sockaddr *)&serv_addr,` `  sizeof(serv_addr) );`	`sock.bind ("", port)`
`listen(sockfd, queuelen);`	`sock.listen (queuelen)`
`con = accept(sockfd, ..., ...);`	`client,addr = sock.accept()`
`n = read(con,buf,sizeof(buf));` `write(con,buf,sizeof(buf));`	`client.recv()` `client.send()`

Sockets in Python (2)

Create a socket

Client

```
# create INET / STREAM Socket
s = socket.socket(
    socket.AF_INET,
    socket.SOCK_STREAM)
# connect to Port 80
# (the standard HTTP port)
s.connect(("www.fhm.edu", 80))
```

Server

```
# create INET / STREAM Socket
serversocket = socket.socket(
    socket.AF_INET,
    socket.SOCK_STREAM)
# bind socket to hostname and HTTP
# standard port 80
serversocket.bind(
    (socket.gethostname(), 80) )
# become a server socket;
# max. 5 parallel connections
serversocket.listen(5)
```

source: http://www.amk.ca/python/howto/sockets/ ; modified

Sockets in Python (3)

transfer data and close connection

Client

```
# send request to server
request = "GET ..."
s.send (request)

# read server's reply
result = s.recv (MAXSIZE)

# disconnect
s.shutdown (SHUT_RDWR)
s.close ()
```

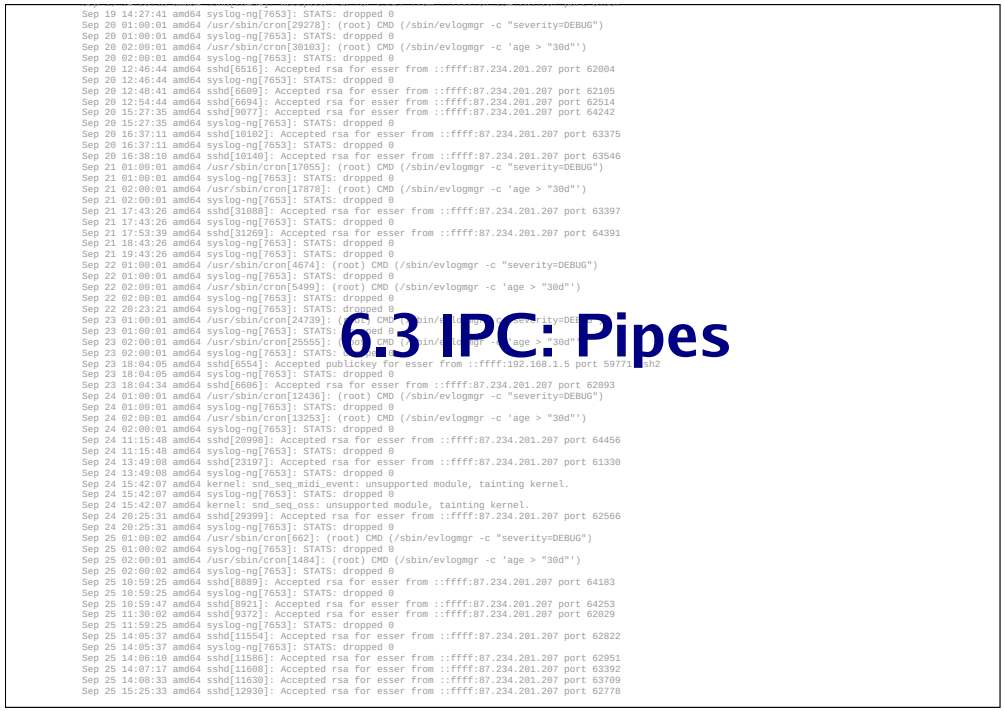
Server

```
while 1:
  # accept connections
  (clientsocket, address) = serversocket.accept()
  # deal with request in a new thread
  ct = client_thread(clientsocket)

def client_thread (sock):
  start_new_thread (client_handler,sock)

def client_handler (sock):
  request = sock.recv ()
  ... # deal with request
  sock.send (antwort)
  sock.shutdown(SHUT_RDWR); sock.close()
```

documentation: http://docs.python.org/lib/module-socket.html



Pipes (1)

- as introduction: pipes in the shell
- make the standard output of one program the standard input of the next program
- chaining several (filter) applications

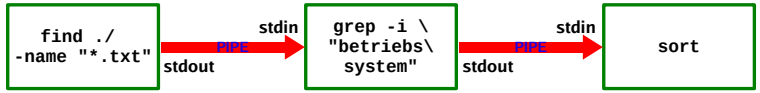
without pipe – temp. files instead	with pipe

`find ./ -name "*.txt" >/tmp/t1`
`grep -i "betriebssystem" </tmp/t1 >/tmp/t2`
`sort </tmp/t2`
`rm /tmp/t1 /tmp/t2`
	`find ./ -name "*.txt" | grep -i \`
	`  "betriebssystem" | sort`

Pipes (2)

- analysis:

```
find ./ -name "*.txt" | grep -i "betriebssystem" | sort
```



- the pipe is a **uni-directional** communication mechanism
- there are both named and unnamed pipes

Unnamed Pipes (1)

- Usage of unnamed pipes goes like this:
  - process creates pipe (read and write parts)
  - process clones itself with **fork()**
  - parent and child use the two ends of the pipe for (one way) communication
- Pipe stays open until one of the two processes explicitly closes it with **close()**
- Processes which are not „related“ (fork) need named pipes

Unnamed Pipes (2)

- writing to and reading from pipe as with files:

```
int pipe_fds[2];   // File descriptors for the two
                   // ends of the pipe

pipe(pipe_fds);    // create a pipe;
                   // pipe_fds[0]: for reading
                   // pipe_fds[1]: for writing

if (fork() != 0) { // parent process:
  // create data and send them through the pipe
  write(pipe_fds[1], data, ...);
} else             // child process:
  // read data from the pipe
  read(pipe_fds[0], data, ...);
  }
```


Named Pipes (1)

- named pipes allow communication between „unrelated“ processes:
- processes choose a common name (cf. named semaphores etc.)

  `int mkfifo(const char *pathname, mode_t mode);`

  this creates a new FIFO special file in the filesystem
- processes open pipe like a regular file

Named Pipes (2)

- afterwards the two processes also read and write as with files:

Server (reads)

```
#define PIPENAME "/tmp/mypipe"
int main() {
    int fd, ret_val, count, numread;
    char buf[MAX_BUF_SIZE];

    /* create named pipe */
    ret_val = mkfifo(PIPENAME, 0666);

    if ((ret_val == -1) && (errno != EEXIST)) {
        perror("Error creating the pipe");
        exit (1);
    }
    /* open pipe for READING */
    fd = open(PIPENAME, O_RDONLY);

    /* read from pipe */
    numread = read(fd, buf, MAX_BUF_SIZE);

    printf("Half Duplex Server: read from pipe: %sn", buf);
}
```

Client (writes)

```
#define PIPENAME "/tmp/mypipe"
int main(int argc, char *argv[]) {
    int fd;

    /* read arguments */
    if (argc != 2) {
        printf("Usage : %s <string>\n",
               argv[0]);
        exit (1);
    }

    /* open pipe for WRITING */
    fd = open(PIPENAME, O_WRONLY);

    /* write to the pipe */
    write(fd, argv[1], strlen(argv[1]));
}
```


Pipes (7)

- communication in both ways: use two pipes

```
#define PIPE_A "/tmp/mypipe-a"
#define PIPE_B "/tmp/mypipe-b"

int main() {
    int fd, ret_val, count, numread;
    char buf[MAX_BUF_SIZE];

    /* create named pipes */
    ret_val = mkfifo(PIPE_A, 0666);
    if ((ret_val == -1) && (errno != EEXIST)) { ... }
    ret_val = mkfifo(PIPE_B, 0666);
    if ((ret_val == -1) && (errno != EEXIST)) { ... }

    /* open pipes for READING and WRITING, respectively */
    fd_a = open(PIPE_A, O_RDONLY);
    fd_b = open(PIPE_B, O_WRONLY);

    /* work with pipes */
    numread = read(fd_a, buf, MAX_BUF_SIZE);
    write(fd_b, buf, ...);
}
```

Windows Pipes (1)

named pipes: two possibilities

- for Unix compatibility:

  `_pipe()`

  with the same syntax as Unix **pipe()** (**open**, **read**, **write**)

- standard pipes:

  ```
  #define FIFO_NAME "\\\\.\\pipe\\namedpipe"
  hPipe = CreateNamedPipe(FIFO_NAME, ...)
  ```

  Windows objects

Windows Pipes (2)

```
#include <stdio.h>
#include <stdlib.h>
#include <windows.h>
#include <io.h>
#include <fcntl.h>
#include <process.h>
#include <string.h>
#define FIFO_NAME
          "\\\\.\\pipe\\mynamedpipe"
#define BUFSIZE 1024
#define PIPE_TIMEOUT 5000 // 5 sec.
#define F_OK 0
```

Source: http://msdn2.microsoft.com/en-gb/library/ms811896.aspx#ucmgch09_topic13h

```
void main() {
  int fd;
  HANDLE hPipe;
  // Check if the FIFO exists and create it if necessary.
  if (_access(FIFO_NAME, F_OK) == -1) {
    hPipe = CreateNamedPipe(
      FIFO_NAME,                // pipe name
      PIPE_ACCESS_DUPLEX,       // read/write access
      PIPE_TYPE_MESSAGE |       // message type pipe
      PIPE_READMODE_MESSAGE |   // message-read mode
      PIPE_WAIT,                // blocking mode
      PIPE_UNLIMITED_INSTANCES, // max. instances
      BUFSIZE,                  // output buffer size
      BUFSIZE,                  // input buffer size
      PIPE_TIMEOUT,             // client time-out
      NULL);                    // no security attribute
    if (hPipe == INVALID_HANDLE_VALUE) {
      fprintf(stderr, "Could not create fifo %s\n", FIFO_NAME);
      exit(EXIT_FAILURE);
    }
  }
  printf("Process %d opening FIFO\n", getpid());
  // Open FIFO and output status result
  fd = open(FIFO_NAME, O_RDONLY);
  printf("Process %d file descriptor: %d\n", getpid(), fd);
  Sleep(PIPE_TIMEOUT);
  // Close FIFO
  if (fd != -1)
    (void)close(fd);
  printf("Process %d finished\n", getpid());
  exit(EXIT_SUCCESS);
}
```


Windows Pipes (3)

```
fConnected = ConnectNamedPipe(hPipe, NULL) ?
       TRUE : (GetLastError() == ERROR_PIPE_CONNECTED);

printf("Process %d opening FIFO O_WRONLY\n", getpid());

if (fConnected) {
  while(bytes_sent < TEN_MEG) {
    if (!WriteFile(
      hPipe,                  // handle to file
      buffer,                 // data buffer
      BUFFER_SIZE,            // number of bytes to write
      &NumberOfBytesWritten, // number of bytes written
      NULL)                   // overlapped buffer
      ) {
    fprintf(stderr, "Write error on pipe\n");
    exit(EXIT_FAILURE);
      }

              bytes_sent += NumberOfBytesWritten;
  }

  printf("Process %d finished\n", getpid());
}
else {
  // The client could not connect, so close the pipe.
  CloseHandle(hPipe);
}
```

```
hPipe1 = CreateFile(
  FIFO_NAME,                // Open the FIFO
  GENERIC_READ,             // open for reading
  0,                        // share for writing
  NULL,                     // no security
  OPEN_EXISTING,            // existing file only
  FILE_ATTRIBUTE_NORMAL,    // normal file
  NULL);                    // no attr. template
if (hPipe1 == INVALID_HANDLE_VALUE) {
  printf("Could not create file %s\n", FIFO_NAME);
  exit(EXIT_FAILURE);
}
printf("Process %d result %X\n", getpid(), hPipe1);
do {
  ReadFile(
    hPipe1,             // handle to file
    buffer,             // data buffer
    BUFFER_SIZE,        // number of bytes to read
    &NumberOfBytesRead, // number of bytes read
    NULL                // overlapped buffer
  );
  bytes_read += NumberOfBytesRead;
} while (NumberOfBytesRead > 0);
CloseHandle(hPipe1);
```