DNS: Domain Name System

People: many identifiers:

  - SSN, name, Passport #

Internet hosts, routers:

  - IP address (32 bit) - used for addressing datagrams
  - "name", e.g., gaia.cs.umass.edu - used by humans

Q: map between IP addresses and name ?

Domain Name System:

- *distributed database* implemented in hierarchy of many *name servers*
- *application-layer protocol* host, routers, name servers to communicate to *resolve* names (address/name translation)
  - note: core Internet function implemented as application-layer protocol
  - complexity at network's "edge"

DNS name servers

Why not centralize DNS?

- single point of failure
- traffic volume
- distant centralized database
- maintenance

doesn't *scale!*

- no server has all name-to-IP address mappings

local name servers:

  - each ISP, company has *local (default) name server*
  - host DNS query first goes to local name server

authoritative name server:

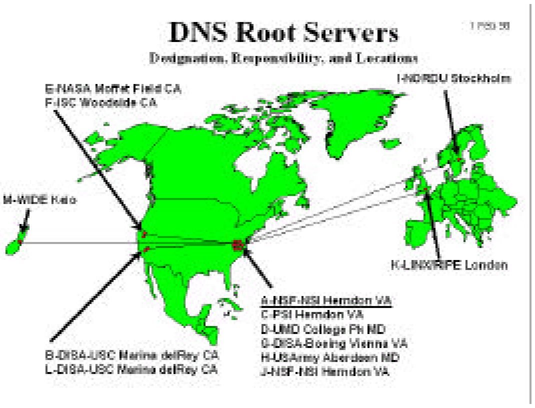
  - for a host: stores that host's IP address, name
  - can perform name/address translation for that host's name

DNS Query Example:

```
Bayou.UH.EDU> nslookup
Default Server:  Masala.CC.UH.EDU
Address:  129.7.1.1

> www.yahoo.com
Server:  Masala.CC.UH.EDU
Address:  129.7.1.1

Non-authoritative answer:
Name:    www.yahoo.akadns.net
Addresses:  216.32.74.53, 216.32.74.55, 216.32.74.50, 216.32.74.51
          216.32.74.52
Aliases:  www.yahoo.com

> set querytype=ANY
> www.yahoo.com
Server:  Masala.CC.UH.EDU
Address:  129.7.1.1

Non-authoritative answer:
www.yahoo.com   canonical name = www.yahoo.akadns.net

Authoritative answers can be found from:
YAHOO.com       nameserver = ns1.YAHOO.com
YAHOO.com       nameserver = ns3.europe.YAHOO.com
YAHOO.com       nameserver = ns5.dcx.YAHOO.com
ns1.YAHOO.com   internet address = 204.71.200.33
ns3.europe.YAHOO.com    internet address = 194.237.108.51
ns5.dcx.YAHOO.com       internet address = 216.32.74.10
```

DNS: Root name servers

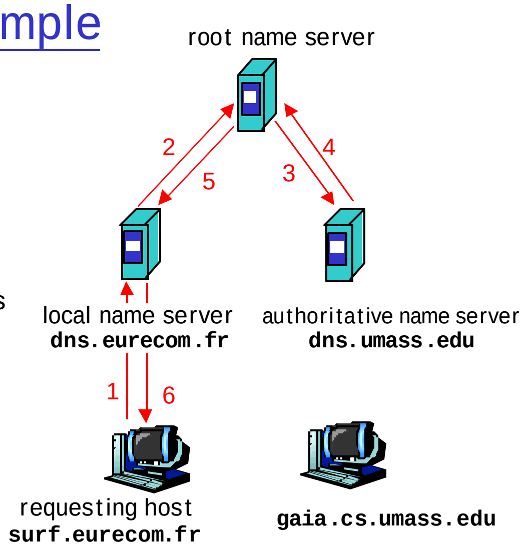
- contacted by local name server that can not resolve name
- root name server:
  - contacts authoritative name server if name mapping not known
  - gets mapping
  - returns mapping to local name server
- ~ dozen root name servers worldwide



Simple DNS example

host **surf.eurecom.fr** wants IP address of **gaia.cs.umass.edu**

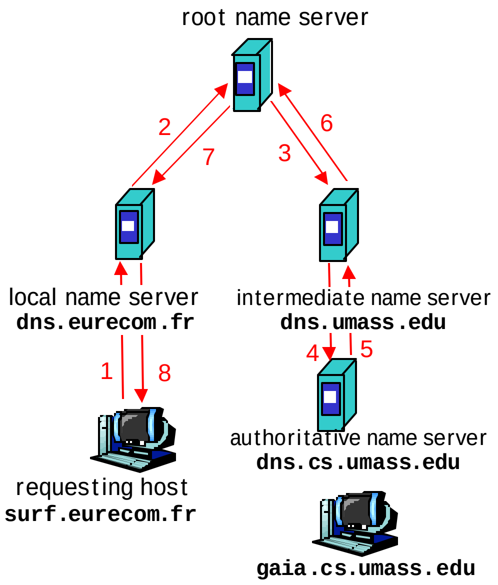
1. Contacts its local DNS server, **dns.eurecom.fr**
2. **dns.eurecom.fr** contacts root name server, if necessary
3. root name server contacts authoritative name server, **dns.umass.edu,** if necessary



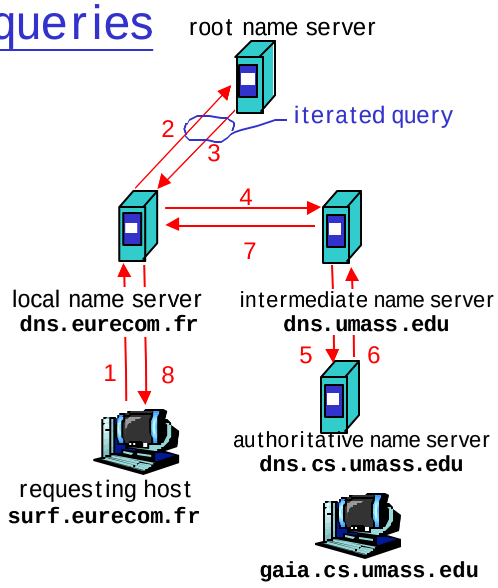
DNS example

Root name server:

- may not know authoritative name server
- may know *intermediate name server:* who to contact to find authoritative name server



DNS: iterated queries



recursive query:

- puts burden of name resolution on contacted name server
- heavy load?

iterated query:

- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"

DNS: caching and updating records

- once (any) name server learns mapping, it *caches* mapping
  - cache entries timeout (disappear) after some time
- update/notify mechanisms under design by IETF
  - RFC 2136
  - http://www.ietf.org/html.charters/dnsind-charter.html

DNS records

DNS: distributed db storing resource records (RR)

RR format: **`(name, value, type,ttl)`**

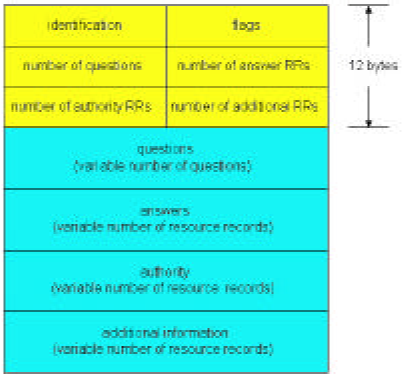
- Type=A
  - **`name`** is hostname
  - **`value`** is IP address
- Type=NS
  - **`name`** is domain (e.g. foo.com)
  - **`value`** is IP address of authoritative name server for this domain
- Type=CNAME
  - **`name`** is an alias name for some “cannonical” (the real) name
  - **`value`** is cannonical name
- Type=MX
  - **`value`** is hostname of mailserver associated with **`name`**

DNS protocol, messages

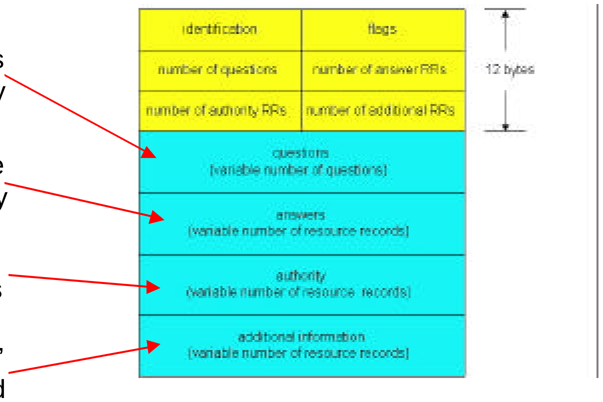
DNS protocol : *query* and *repy* messages, both with same *message format*

msg header

- identification: 16 bit # for query, reply to query uses same #
- flags:
  - query or reply
  - recursion desired
  - recursion available
  - reply is authoritative



DNS protocol, messages



Name, type fields for a query

RRs in response to query

records for authoritative servers

additional "helpful" info that may be used

Socket programming

Goal: learn how to build client/server application that communicate using sockets

Socket API

r introduced in BSD4.1 UNIX, 1981

r explicitly created, used, released by apps

r client/server paradigm

r two types of transport service via socket API:

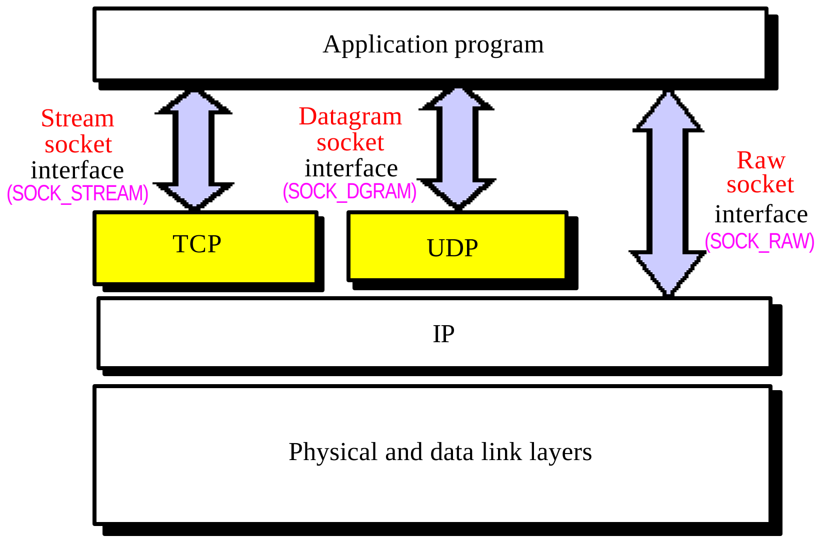
m unreliable datagram

m reliable, byte stream-oriented

socket

a *host-local*, *application-created/owned*, *OS-controlled* interface (a "door") into which application process can both send and receive messages to/from another (remote or local) application process

Socket types



Socket Functions

Server:	create endpoint	`socket()`
	bind address	`bind()`
	specify queue	`listen()`
	wait for connection	`accept()`
Client:	create endpoint	`socket()`
	bind address	`bind()`
	connect to server	`connect()`

	transfer data	`read()`
		`write()`
		`recv()`
		`send()`

	datagrams	`recvfrom()` `sendto()`
	terminate	`close()` `shutdown()`

socket() System Call

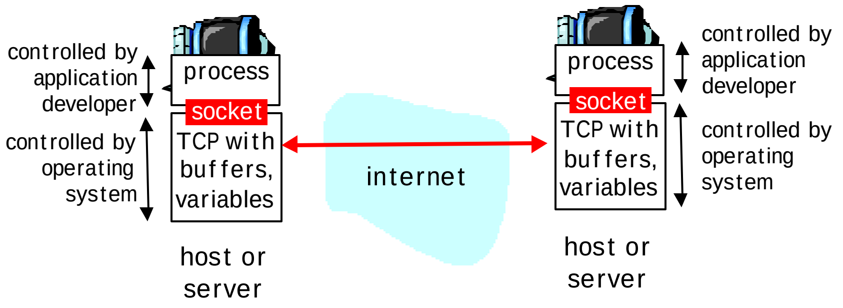
```
int socket (int family, int type,       int protocol);
                AF_UNIX    SOCK_STREAM
                AF_INET    SOCK_DGRAM
                           SOCK_RAW
```

family	*type*	*protocol*	Actual protocol
AF_INET	SOCK_DGRAM	IPPROTO_UDP	UDP
AF_INET	SOCK_STREAM	IPPROTO_TCP	TCP
AF_INET	SOCK_RAW	IPPROTO_ICMP	ICMP
AF_INET	SOCK_RAW	IPPROTO_RAW	(raw)

Socket-programming using TCP

Socket: a door between application process and end-end-transport protocol (UCP or TCP)

TCP service: reliable transfer of bytes from one process to another



Socket programming with TCP

Client must contact server

- server process must first be running
- server must have created socket (door) that welcomes client's contact

Client contacts server by:

- creating client-local TCP socket
- specifying IP address, port number of server process

- When client creates socket: client TCP establishes connection to server TCP
- When contacted by client, server TCP creates new socket for server process to communicate with client
    - allows server to talk with multiple clients

application viewpoint

TCP provides reliable, in-order transfer of bytes (“pipe”) between client and server

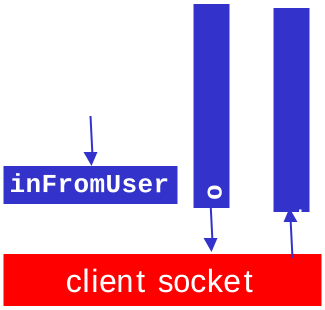
Socket programming with TCP

Example client-server app:

- client reads line from standard input (**inFromUser** stream) , sends to server via socket (**outToServer** stream)
- server reads line from socket
- server converts line to uppercase, sends back to client
- client reads, prints modified line from socket (**inFromServer** stream)

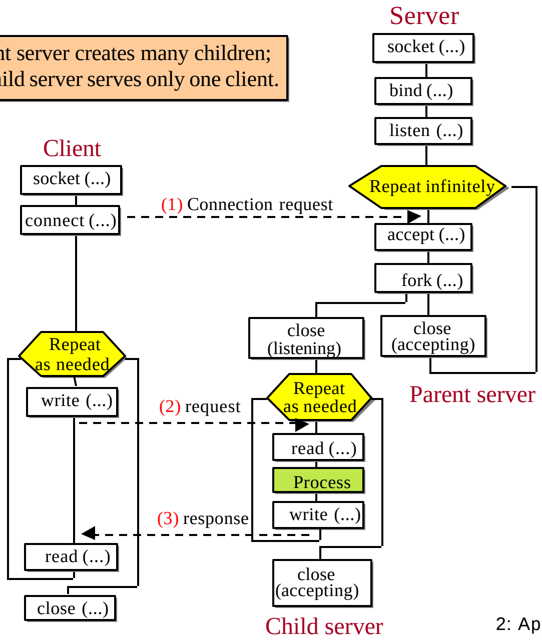
Input stream: sequence of bytes into process

Output stream: sequence of bytes out of process

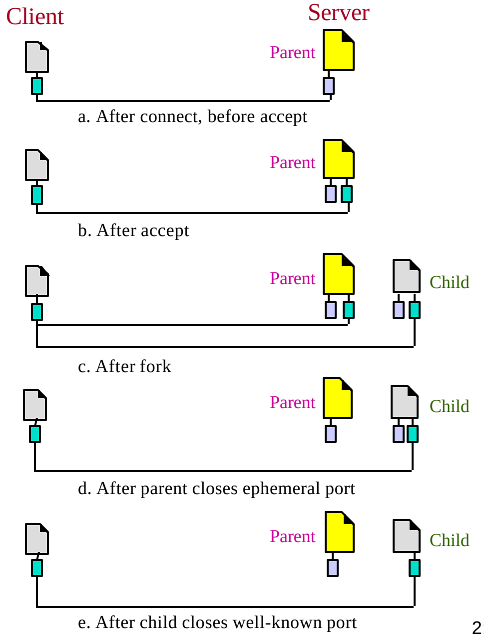


Socket interface for connection-oriented concurrent server

A parent server creates many children;
each child server serves only one client.



Relationship between the client and the server



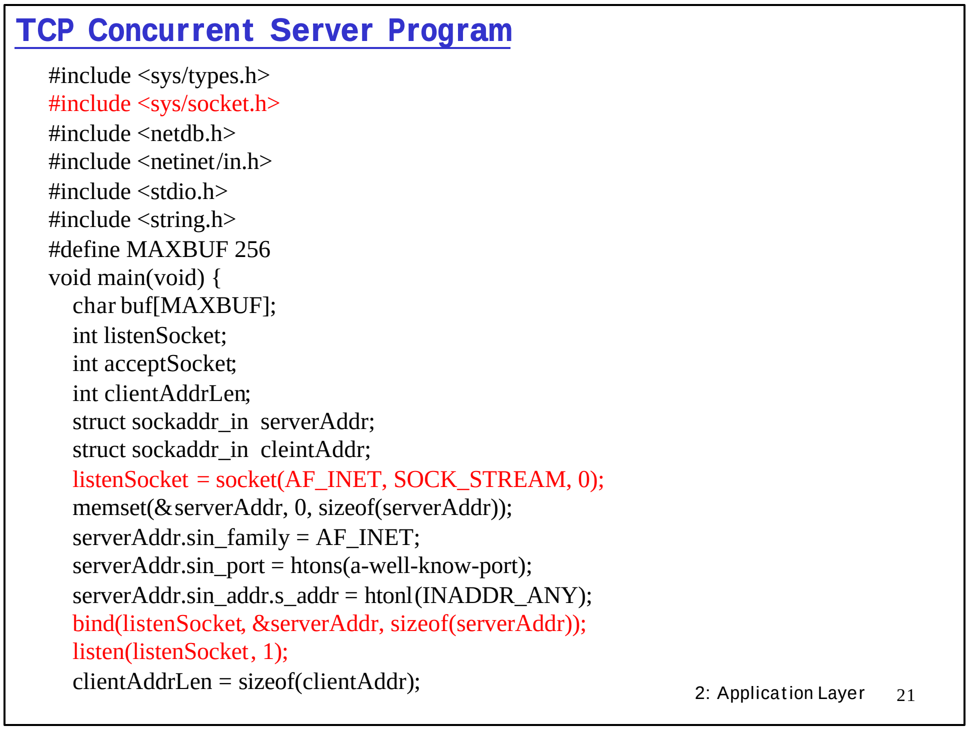
a. After connect, before accept

b. After accept

c. After fork

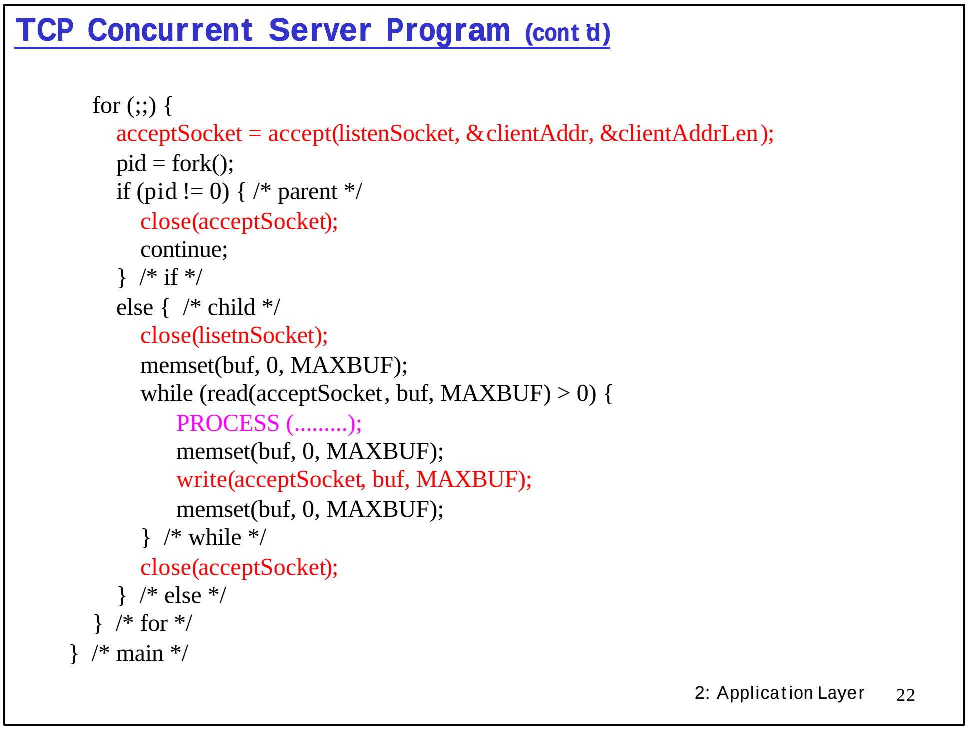
d. After parent closes ephemeral port

e. After child closes well-known port



TCP Concurrent Server Program

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <netinet/in.h>
#include <stdio.h>
#include <string.h>
#define MAXBUF 256
void main(void) {
   char buf[MAXBUF];
   int listenSocket;
   int acceptSocket;
   int clientAddrLen;
   struct sockaddr_in  serverAddr;
   struct sockaddr_in  cleintAddr;
   listenSocket = socket(AF_INET, SOCK_STREAM, 0);
   memset(&serverAddr, 0, sizeof(serverAddr));
   serverAddr.sin_family = AF_INET;
   serverAddr.sin_port = htons(a-well-know-port);
   serverAddr.sin_addr.s_addr = htonl(INADDR_ANY);
   bind(listenSocket, &serverAddr, sizeof(serverAddr));
   listen(listenSocket, 1);
   clientAddrLen = sizeof(clientAddr);
```



TCP Concurrent Server Program (cont'd)

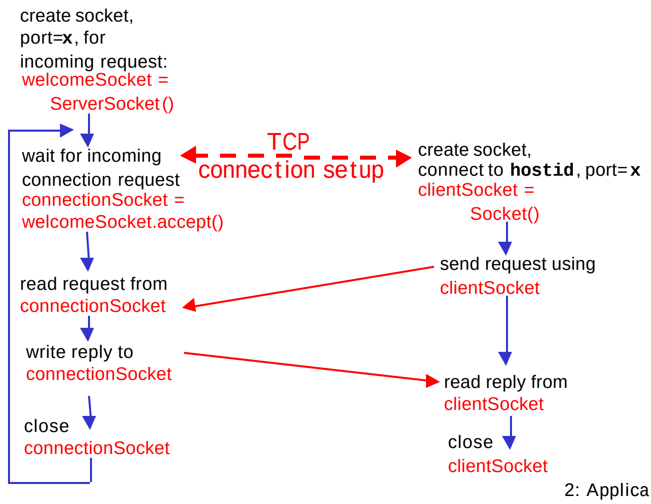
```
      for (;;) {
         acceptSocket = accept(listenSocket, &clientAddr, &clientAddrLen);
         pid = fork();
         if (pid != 0) { /* parent */
            close(acceptSocket);
            continue;
         }  /* if */
         else {  /* child */
            close(lisetnSocket);
            memset(buf, 0, MAXBUF);
            while (read(acceptSocket, buf, MAXBUF) > 0) {
                 PROCESS (.........);
                 memset(buf, 0, MAXBUF);
                 write(acceptSocket, buf, MAXBUF);
                 memset(buf, 0, MAXBUF);
            }  /* while */
            close(acceptSocket);
         }  /* else */
      }  /* for */
   }  /* main */
```

TCP Concurrent Client Program

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <netinet/in.h>
#include <stdio.h>
#include <string.h>
#define MAXBUF 256
void main(void) {
   char buf[MAXBUF];
   int activeSocket;
   struct sockaddr_in  remoteAddr;
   struct sockaddr_in  localAddr;
   struct hostent  *hptr;
   activeSocket = socket(AF_INET, SOCK_STREAM, 0);
   memset(&remoteAddr, 0, sizeof(remoteAddr));
   remoteAddr.sin_family = AF_INET;
   remoteAddr.sin_port = htons(a-well-know-port);
   hptr = gethostbyname("a-domain-name");
   memcpy((char*)&remoteAddr.sin_addr.s_addr,
               hptr->h_addr_list[0], hptr->h_length);
   memset(&buf, 0, MAXBUF);
while (gets(buf)) {
      write(activeSocket, buf, MAXBUF);
      memset(&buf, 0, MAXBUF);
      read(sockds, buf, MAXBUF);
      printf(%s\n, buf);
      memset(&buf, 0, MAXBUF);
   }  /* while */
   close(activeSocket);
}  /* main */
```

Client/server socket interaction: TCP

Server (running on **hostid**) Client



create socket, port=**x**, for incoming request: welcomeSocket = ServerSocket()

wait for incoming connection request connectionSocket = welcomeSocket.accept()

TCP connection setup

create socket, connect to **hostid**, port=**x** clientSocket = Socket()

send request using clientSocket

read request from connectionSocket

write reply to connectionSocket

read reply from clientSocket

close connectionSocket

close clientSocket

Example: Java client (TCP)

```
import java.io.*;
import java.net.*;
class TCPClient {

    public static void main(String argv[]) throws Exception
    {
        String sentence;
        String modifiedSentence;
```

Create input stream

```
        BufferedReader inFromUser =
          new BufferedReader(new InputStreamReader(System.in));
```

Create client socket, connect to server

```
        Socket clientSocket = new Socket("hostname", 6789);
```

Create output stream attached to socket

```
        DataOutputStream outToServer =
          new DataOutputStream(clientSocket.getOutputStream());
```

Example: Java client (TCP), cont.

Create input stream attached to socket

```
        BufferedReader inFromServer =
          new BufferedReader(new
          InputStreamReader(clientSocket.getInputStream()));

        sentence = inFromUser.readLine();
```

Send line to server

```
        outToServer.writeBytes(sentence + '\n');
```

Read line from server

```
        modifiedSentence = inFromServer.readLine();

        System.out.println("FROM SERVER: " + modifiedSentence);

        clientSocket.close();

    }
}
```

Example: Java server (TCP)

```
import java.io.*;
import java.net.*;

class TCPServer {

 public static void main(String argv[]) throws Exception
  {
   String clientSentence;
   String capitalizedSentence;
```

Create welcoming socket at port 6789

```
   ServerSocket welcomeSocket = new ServerSocket(6789);

   while(true) {
```

Wait, on welcoming socket for contact by client

```
      Socket connectionSocket = welcomeSocket.accept();
```

Create input stream, attached to socket

```
     BufferedReader inFromClient =
       new BufferedReader(new
       InputStreamReader(connectionSocket.getInputStream()));
```

Example: Java server (TCP), cont

Create output stream, attached to socket

```
     DataOutputStream  outToClient =
       new DataOutputStream(connectionSocket.getOutputStream());
```

Read in line from socket

```
     clientSentence = inFromClient.readLine();

     capitalizedSentence = clientSentence.toUpperCase() + '\n';
```

Write out line to socket

```
     outToClient.writeBytes(capitalizedSentence);
    }
   }
  }
```

End of while loop, loop back and wait for another client connection

Socket programming with UDP

UDP: no "connection" between client and server

- no handshaking
- sender explicitly attaches IP address and port of destination
- server must extract IP address, port of sender from received datagram

UDP: transmitted data may be received out of order, or lost

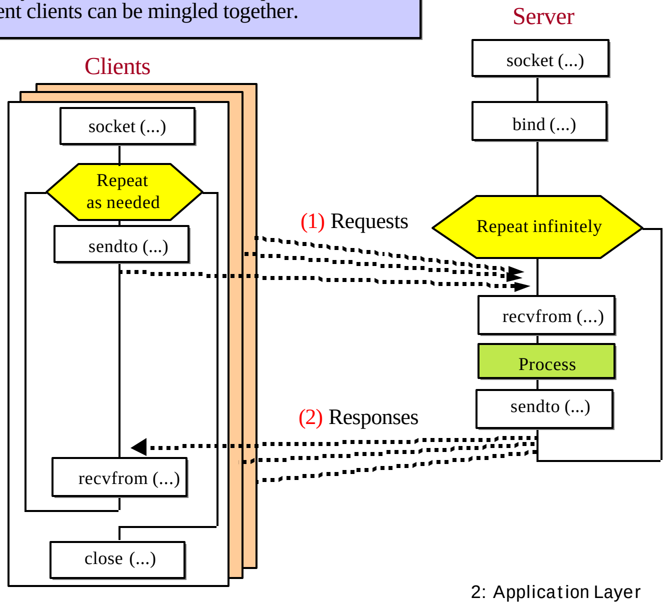
application viewpoint

UDP provides unreliable transfer of groups of bytes ("datagrams") between client and server

---

Socket interface for connectionless iterative server

Each server serves many clients but handles one request at a time. Requests from different clients can be mingled together.



UDP Iterative Server Program

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <netinet/in.h>
#include <stdio.h>
#include <string.h>
#define MAXBUF 256
void main(void)  {
   char buf[MAXBUF];
   int passiveSocket;
   int clientAddrLen;
   struct sockaddr_in  serverAddr;
   struct sockaddr_in  cleintAddr;
   passiveSocket = socket(AF_INET, SOCK_DGRAM, 0);
   memset(&serverAddr, 0, sizeof(serverAddr));
   serverAddr.sin_family = AF_INET;
   serverAddr.sin_port = htons(a-well-know-port);
   serverAddr.sin_addr.s_addr = htonl(INADDR_ANY);
   bind(passiveSocket, &serverAddr, sizeof(serverAddr));
   clientAddrLen = sizeof(clientAddr);
```

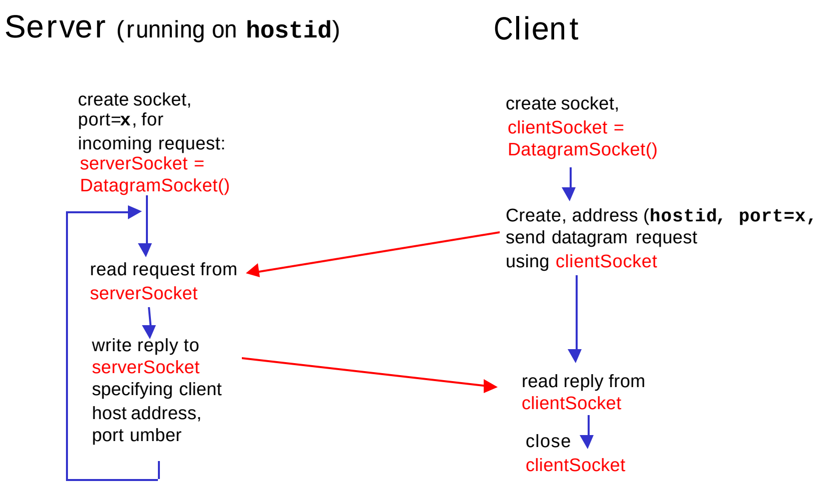
```
   for (;;) {
      while (recvfrom(passiveSocket, buf, MAXBUF,
              0, &clientAddr, &clientAddrLen) > 0)  {
         PROCESS (.........);
         memset(buf, 0, MAXBUF);
         sendto(passiveSocket, buf, MAXBUF, 0,
                  &clientAddr, clientAddrLen);
         memset(buf, 0, MAXBUF);
      }  /* while */
   }  /* for */
}  /* main */
```

UDP Iterative Client Program

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <netinet/in.h>
#include <stdio.h>
#include <string.h>
#define MAXBUF 256
void main(void)  {
   char buf[MAXBUF];
   int activeSocket;
   struct sockaddr_in  remoteAddr;
   struct sockaddr_in  localAddr;
   struct hostent  *hptr;
   activeSocket = socket(AF_INET, SOCK_DGRAM, 0);
   memset(&remoteAddr, 0, sizeof(remoteAddr));
   remoteAddr.sin_family = AF_INET;
   remoteAddr.sin_port = htons(a-well-know-port);
   hptr = gethostbyname("a-domain-name");
   memcpy((char*)&remoteAddr.sin_addr.s_addr,
               hptr->h_addr_list[0], hptr->h_length);
   connect(activeSocket, &remoteAddr, sizeof(remoteAddr));
   memset(&buf, 0, MAXBUF);
   remoteAddLen = sizeof(remoteAddr);
```

```
   while (gets(buf)) {
      sendto(activeSocket, buf, size(buf), 0,
               &remoteAddr, sizeof(remoteAddr));
      memset(&buf, 0, MAXBUF);
      recvfrom(activeSocket, buf, MAXBUF, 0,
                &remoteAddr, &remoteAddrLen);
      printf(%s\n, buf);
      memset(&buf, 0, sizeof(buf));
   }  /* while */
   close(activeSocket);
}  /* main */
```

Client/server socket interaction: UDP



Server (running on **`hostid`**)

create socket,
port=**x**, for
incoming request:
serverSocket =
DatagramSocket()

read request from
serverSocket

write reply to
serverSocket
specifying client
host address,
port umber

Client

create socket,
clientSocket =
DatagramSocket()

Create, address (**`hostid, port=x,`**
send datagram request
using clientSocket

read reply from
clientSocket

close
clientSocket

Example: Java client (UDP)

```
import java.io.*;
import java.net.*;

class UDPClient {
    public static void main(String args[]) throws Exception
    {
```

Create input stream

```
      BufferedReader inFromUser =
        new BufferedReader(new InputStreamReader(System.in));
```

Create client socket

```
      DatagramSocket clientSocket = new DatagramSocket();
```

Translate hostname to IP address using DNS

```
      InetAddress IPAddress = InetAddress.getByName("hostname");

      byte[] sendData = new byte[1024];
      byte[] receiveData = new byte[1024];

      String sentence = inFromUser.readLine();
      sendData = sentence.getBytes();
```

Example: Java client (UDP), cont.

Create datagram with data-to-send, length, IP addr, port

```
DatagramPacket sendPacket =
  new DatagramPacket(sendData, sendData.length, IPAddress, 9876);
```

Send datagram to server

```
clientSocket.send(sendPacket);

DatagramPacket receivePacket =
  new DatagramPacket(receiveData, receiveData.length);
```

Read datagram from server

```
  clientSocket.receive(receivePacket);

  String modifiedSentence =
     new String(receivePacket.getData());

  System.out.println("FROM SERVER:" + modifiedSentence);
  clientSocket.close();
  }
}
```

Example: Java server (UDP)

```
import java.io.*;
import java.net.*;

class UDPServer {
  public static void main(String args[]) throws Exception
    {
```

Create datagram socket at port 9876

```
      DatagramSocket serverSocket = new DatagramSocket(9876);

      byte[] receiveData = new byte[1024];
      byte[] sendData  = new byte[1024];

      while(true)
        {
```

Create space for received datagram

```
          DatagramPacket receivePacket =
             new DatagramPacket(receiveData, receiveData.length);
```

Receive datagram

```
           serverSocket.receive(receivePacket);
```

Example: Java server (UDP), cont

```
String sentence = new String(receivePacket.getData());

InetAddress IPAddress = receivePacket.getAddress();

int port = receivePacket.getPort();

        String capitalizedSentence = sentence.toUpperCase();

sendData = capitalizedSentence.getBytes();

DatagramPacket sendPacket =
  new DatagramPacket(sendData, sendData.length, IPAddress,
               port);

serverSocket.send(sendPacket);
  }
 }
}
```

Get IP addr port #, of sender

Create datagram to send to client

Write out datagram to socket

End of while loop, loop back and wait for another datagram

Chapter 2: Summary

Our study of network apps now complete!

- application service requirements:
  - reliability, bandwidth, delay
- client-server paradigm
- Internet transport service model
  - connection-oriented, reliable: TCP
  - unreliable, datagrams: UDP
- specific protocols:
  - http
  - ftp
  - smtp, pop3
  - dns
- socket programming
  - client/server implementation
  - using tcp, udp sockets

Chapter 2: Summary

Most importantly: learned about *protocols*

- typical request/reply message exchange:
  - client requests info or service
  - server responds with data, status code
- message formats:
  - headers: fields giving info about data
  - data: info being communicated

- control vs. data msgs
  - in-based, out-of-band
- centralized vs. decentralized
- stateless vs. stateful
- reliable vs. unreliable msg transfer
- “complexity at network edge”
- security: authentication