Daytime Client/Server

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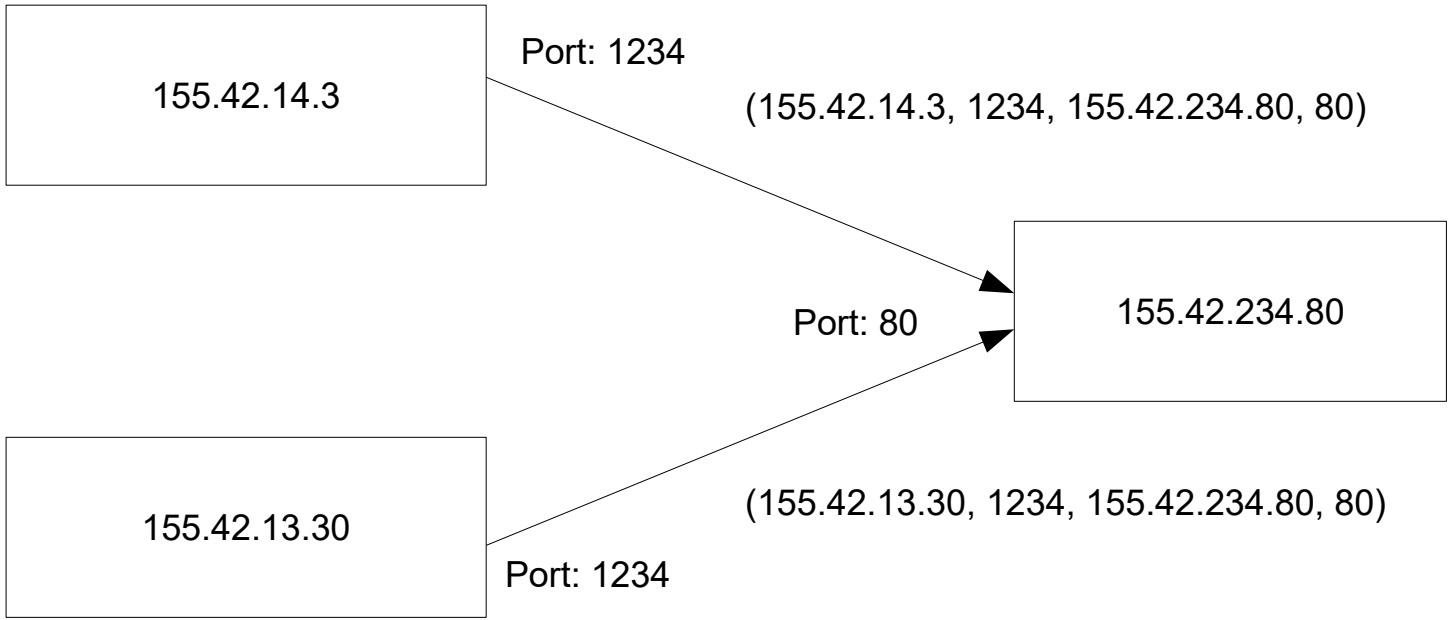
Addresses

- IP Addresses are assigned to interfaces
  - *A machine with multiple interfaces gets multiple addresses*.
    - Interfaces can be physical or virtual.
- “Machine's IP address” is technically incorrect.
  - Machines don't have addresses, interfaces do.
  - However, many machines have only one (relevant) interface.
    - Thus talk of a “machine's IP address” is common.

Connections

- TCP connections are described by a 4-tuple
  - (*src address*, *src port*, *dest address*, *dest port*)



Connections (Continued)

- TCP connections are bi-directional
  - Words like “source” and “destination” don't apply!
  - IP packets have sources and destinations, but on a connection both endpoints can send or receive data.
- However: creating a connection is asymmetric
  - Client **active**: initiates connection (dials the phone)
  - Server **passive**: accepts the connection (picks up the phone when it rings)

Connections (Continued)

- *Once connection is established, the peers are equal*.
- Either side can initiate a shutdown.
  - The first side that closes the connection does an active close.
  - The other side responds with a passive close.
- Which side does the active close is an application level decision.
  - Either side must be prepared for the other to close unexpectedly.
    - You have no idea what your peer will do.

Sockets is Protocol Independent

- *Important!*
  - The sockets API is *not specific to TCP/IP*
  - On machines supporting multiple protocols (OSI, IPX/SPX, etc) sockets could potentially work with all of them.
    - We will care about this when we look at IPv6.
- Design of Sockets is object oriented!
  - But... since C is not an OOP language, the interface is somewhat awkward.
  - Knowing this helps explain the awkwardness
    - And helps make it more acceptable!

Unix Style Error Handling

- Unix system calls follow a simple tradition:
  - Call returns integer -1 when error occurs
  - Sets a global integer `errno` with an error code.
    - Consult man page for specific error code possibilities.
      - Usually shown with symbolic name #defined in `<errno.h>`. For example: `EPERM` (meaning permission denied).
  - Check each system call for -1 return.
    - If found, consult `errno` for more specific information.
  - NOTE: Not all system calls follow this approach. Check the man page to be sure.

Quick Error Messages

- Checking `errno` all the time is a pain.
- Library function `perror` simplifies the process of producing useful error messages.
  - Looks up a generic message in an internal table using `errno` value as a table index.
  - EXAMPLE: Suppose `errno` set to `EPERM`
    - `perror("Unable to do operation");`
    - Displays: "Unable to do operation: Permission denied"
  - Sends message to standard error file.
- [Demonstrate `connect` man page]

Daytime Protocol

- A simple protocol good for testing.
  - Can focus on network issues because the protocol is trivial.
  - Stevens uses it as a first example in his book. We will also.
- Described by RFC-867
  - *Read it!*
    - It's very short... unlike some of the RFCs we'll look at later!
- [Demonstrate the RFC index]

Protocol Overview

- Daytime protocol steps:
  - Client connects to server port 13 (default)
  - Server sends ASCII string containing the date and time.
    - One line recommended
    - No particular format is required
  - Server closes the connection (does the active close)
- NOTE:
  - Client need not send any data (anything sent is ignored)

Daytime Client Using Sockets

- Client steps:
  - Create a socket object (inside the kernel) to represent the connection's endpoint.
  - Prepare a `sockaddr_in` structure to hold the server address and port.
  - Connect to the server.
  - Read the connection (like a file) until an end-of-file indication appears (that is, loop).
    - Sockets will indicate end-of-file when the server closes the connection.
  - Close the connection.

Create a Socket

- Creating a kernel socket object
  - ```
    if ((socket_handle = socket(PF_INET, SOCK_STREAM, 0))
            == -1 ) {
      perror("Unable to create socket");
      return error_code;
    }
    ```
  - Include headers as necessary (see man pages)
  - `socket_handle` is an integer file handle
  - `PF_INET` specifies the "INET" protocol family (TCP/IPv4)
  - `SOCK_STREAM` specifies a stream protocol (TCP)
  - `perror` is a library function that simplifies error handling.
    ```

Prepare Address Structure

- Fill in a `sockaddr_in` structure.
  - ```
    memset(&server_address, 0, sizeof(server_address));
    server_address.sin_family = AF_INET;
    server_address.sin_port   = htons(port);
    if (inet_pton(AF_INET, argv[1],
                  &server_address.sin_addr) <= 0) {
      fprintf(stderr, "Unable to convert address.\n");
      close(socket_handle);
      return error_code;
    }
    ```
  - Zero structure first to put unused fields into a default state
  - Use `htons` to convert host to network byte order
  - Use `inet_pton` to convert address from “presentation” to “network”
    ```

Connect To Server

- Call the connect function.
  - ```
    if (connect(socket_handle,
            (struct sockaddr *) &server_address,
            sizeof(server_address)) == -1) {
      perror("Unable to connect to server");
      close(socket_handle);
      return error_code;
    }
    ```
  - You must pass a pointer to the server address structure.
    - But you must cast it into a generic `sockaddr` pointer first!
    - This is like converting to a base class in C++
    - `connect` examines the structure and the socket to figure out what protocol you are trying to use.
    ```

Read Server's Data

- Read the data from the server like a file.
  - ```
    while ((count = read(
        socket_handle, buffer, BUFFER_SIZE - 1)) > 0) {
      buffer[count] = '\0';
      fputs(buffer, stdout);
    }
    ```
  - Repeatedly try to read `BUFFER_SIZE - 1` bytes.
  - Data may arrive in pieces (one byte at a time even)
  - Just read and print (in this case) each piece as it arrives.
  - `read` will block (wait) if no data has arrived.
  - `read` returns zero when connection closed.
    ```

Don't Forget Error Handling

- If read fails (due to network failure) the user will want to know.
  - ```
    if (count < 0) {
      perror("Problem reading socket");
      close(socket_handle);
      return 1;
    }
    ```
  - Errors on the network are common
    - Network is orders of magnitude less reliable than memory or disks.
  - You must write code to consider these errors.
    ```

Code Review

[Demonstrate complete client]

Daytime Server Using Sockets

- Server steps:
  - Create a socket object to represent the listening endpoint.
  - Prepare a `sockaddr_in` structure to specify the server port.
  - Bind the socket to the desired address.
  - Listen on the socket.
  - Accept a connection.
  - Write to the connection (like a file).
  - Close the connection.
  - Loop back and accept the next connection.

Create a Socket

- Exactly the same as with the client.
  - ```
    if ((listen_handle = socket(PF_INET, SOCK_STREAM, 0))
          == -1) {
      perror("Unable to create socket");
      return error_code;
    }
    ```
    ```

Prepare Address Structure

- Similar to the client
  - ```
    memset(&server_address, 0, sizeof(server_address));
    server_address.sin_family      = AF_INET;
    server_address.sin_addr.s_addr = htonl(INADDR_ANY);
    server_address.sin_port        = htons(port);
    ```
  - Zero out the address structure to give unspecified fields appropriate default values.
  - Use `INADDR_ANY` to specify listening on any IP address (any interface).
  - Use `htonl` and `htons` to deal with endianness issues in a portable way.
    ```

Bind Socket to Address

- Associate the socket with the desired address. This is called “binding.”
  - ```
    if (bind(listen_handle,
             (struct sockaddr *) &server_address,
             sizeof(server_address)) == -1) {
      perror("Unable to bind socket");
      close(listen_handle);
      return error_code;
    ```
  - Binding fails if, for example:
    - The process does not have permission to use the address/port
    - The address/port is already in use by another server.
  - Binding does not entail any network activity.
    ```

Listen on Socket

- This allows connections to be accepted.
  - ```
    if (listen(listen_handle, 32) == -1) {
      perror("Unable to listen");
      close(listen_handle);
      return error_code;
    }
    ```
  - After `listen`, connections will no longer be “refused.”
  - Second parameter controls size of “backlog” queue.
    - Number of pending connections that can be created without being accepted.
    - Often ignored. Each OS has its own idea about how to manage this value internally.
    ```

Accept Connection

- This is how to actually accept a connection.
  - ```
    client_length = sizeof(client_address);
    connection_handle = accept(listen_handle,
              (struct sockaddr *) &client_address,
              &client_length);
    ```
  - The `accept` function returns a handle to a new socket representing the connection endpoint.
    - ... different from the listening socket!
  - The `accept` function's third parameter is “in/out.”
    - `client_length` must be initialized with size of space.
    - `accept` modifies `client_length` to return used space.
    ```

Other Details

- Server reads/writes the connection like a file.
  - … just like the client.
  - If client closes first, server will get end-of-file indication.
- Server closes the connection with `close`.
  - … just like the client.
- Listening socket remains open.
  - Server loops back and calls `accept` again to get the next connection.

Code Review

[Demonstrate complete server]

Iterative Server

- The server described is *iterative*.
  - Only accepts one connection at a time.
  - If a connection arrives while one is being serviced, the new connection is added to the backlog queue.
    - Client making that connection must wait.
    - If current connection takes a “long time” the waiting client won't be happy. Example:
      - Servicing current client is time consuming.
      - Current client is unresponsive.
      - Current client is malicious.
  - Inefficient use of resources.

Iterative Daytime Server

- BUT... *iterative servers are easy to implement*.
- Iterative servers are appropriate for some protocols:
  - When service provided is trivial, AND
  - When server does not have to wait for client commands, AND
  - When server does the active close.
- *Daytime protocol meets these requirements!*

Windows Sockets

- Windows uses “WinSock”, not POSIX sockets.
  - Function names all begin with “WSA”
    - `WSAConnect`, `WSAAccept`, etc.
  - Functions have similar purpose to their POSIX counterparts, but very different parameter lists, etc.
  - More complicated to use.
- WinSock needs explicit initialization.
  - ... since it is in a DLL that needs to be loaded.
  - Use `WSAStartup` and `WSACleanup`.
- Retrieve error codes with `WSAGetLastError`

Compatibility Library

- Compatibility library eases porting of Unix programs.
  - Provides functions like `connect`, `accept`, etc with POSIX semantics.
  - Implemented on top of the WSA equivalents.
- Not 100% compatible!
  - Still need to use WSA functions to initialize WinSock, get error codes, etc.
  - Some of the data types are different.
- *Consult the MSDN library for the details.*