**Assignment:** Project#03
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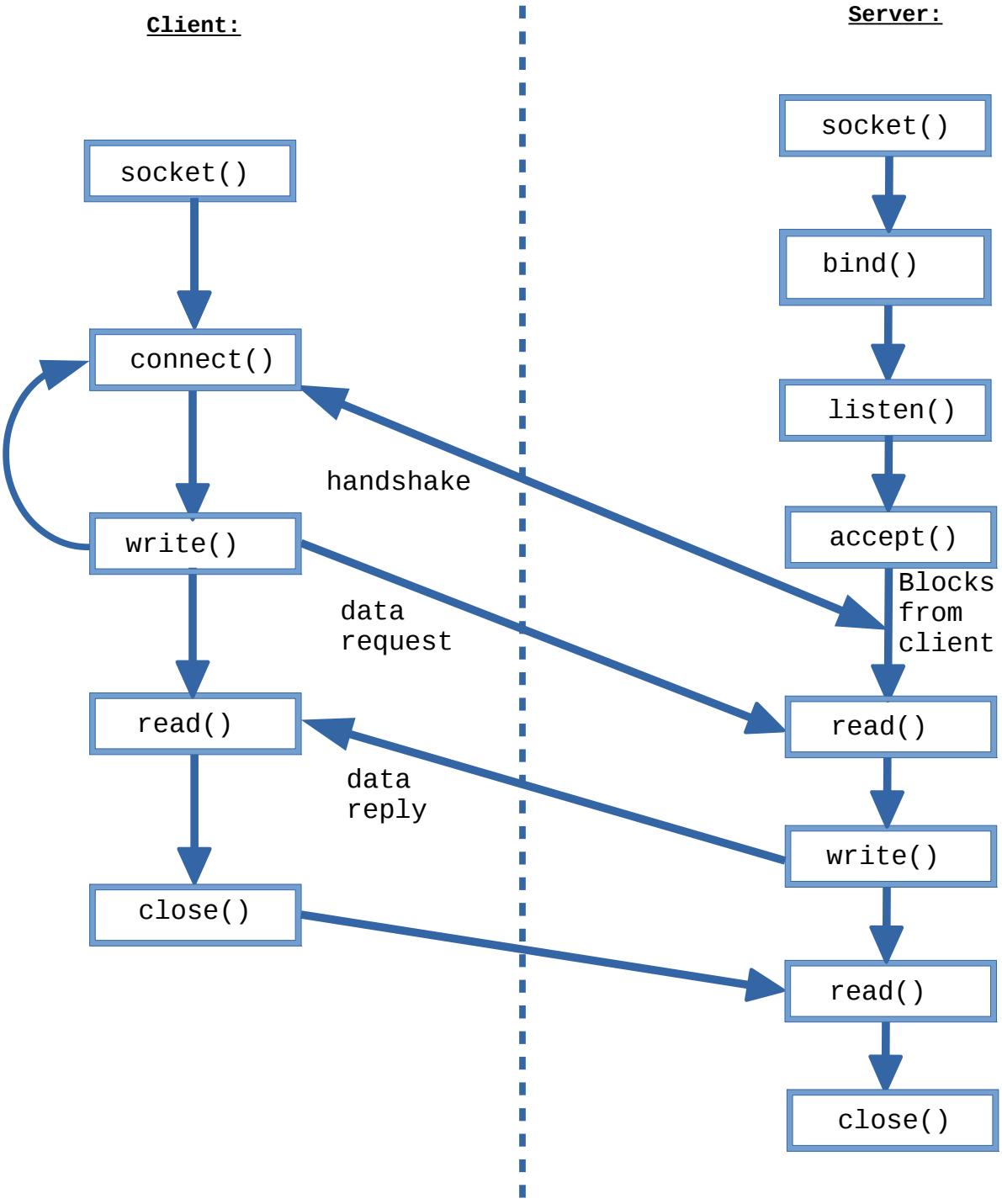
1. **Summary:**
   1. The purpose of this project is to design a client-server network system that can query a database. It will exercise functions like TCP/UDP sockets, lseek(), and lockf(). The program is broken down into 3 files, the (1) servicemap.c, (2)server.c, and (3)client.c files. Each of them are described in more detail in this report.

2. **Flow:**
   1. **Diagram:**



2. **Description:**
   1. This project uses a client-server connection model using a TCP/UDP socket. Transmission-Control-Protocol(TCP) is a connection-oriented protocol designed for applications that require high reliability but at the cost of transmission speed. It receives data in the same order it was sent, handles congestion, and provides error checking. On the other hand, User-datagram-protocol(UDP) is a connection-less protocol that works like TCP but doesn't require as much error-checking and recovery services.
   2. A main component of this client-server model is socket programming. Socket programming is a way of connecting two nodes in a network by having one node listen to a port at a specific ip# address, while the other socket reaches out to the other to form a connection.
   3. The key elements of the TCP network process is described below, as described during the 02/02/20 lecture.
3. **Socket:**
   1. **Prototype:**
      1. int socket(int domain, int type, int protocol);
   2. **Description:**
      1. Creates a socket, to initialize an endpoint referenced by the file descriptor returned.
4. **Connect:**
   1. **Prototype:**
      1. int connect(int sockfd, const struct sockaddr *addr, socklen_t addrlen);
   2. **Description:**
      1. Initiates a connection with the socket that is referenced by the file descriptor to the addr address.
5. **Bind:**
   1. **Prototype:**
      1. int bind(int sockfd, const struct sockaddr *addr, socklen_t addrlen);
   2. **Description:**
      1. Assigns the address from addr to the socket referenced by the file descriptor.
6. **Listen:**
   1. **Prototype:**
      1. int listen(int sockfd, int backlog);
   2. **Description:**
      1. sets the sockfd socket as passive, so it can accept incoming connection requests using the accept() function.
7. **Accept:**
   1. **Prototype:**
      1. int accept(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
   2. **Description:**
      1. It accepts and processes the 1st request from the queue of connections. It returns a file descriptor of the newly connected socket.
8. **Read:**
   1. **Prototype:**
      1. ssize_t read(int fd, void *buf, size_t count);
   2. **Description:**
      1. Reads a message from the file descriptor, up to the count byte size.
9. **Write:**
   1. **Prototype:**
      1. ssize_t write(int fd, const void *buf, size_t count);
   2. **Description:**
      1. Writes a message to the buffer, starting at the buf pointer, and up to the count byte size.
10. **Close:**

1. **Prototype:**
   1. int close(int fd);
2. **Description:**
   1. Used to close a file descriptor.

3. **File servicemap.c:**
   1. **Summary:**
      1. This file is used for initializing the server-client database program. After the server requests a local TCP port, and broadcast a registration message in UDP, this program will accept the message, determine the command, and return socket addresses to the client.
   2. **Code Description:**
      1. The program begins with a series of networking and socket libraries for connectivity reasons. This includes <sys/socket.h>, <netinet/ip.h>, and <arpa/inet.h>.
      2. Next, the main() function starts by creating a socket and binding. The program will exception handle if either of those functions return less than 0. To convert the port#, the htons() function was used, because the unsigned short integer from the host needs to be converted to network byte order.
      3. Next, the program listens for the incoming string from the UDP socket, and parses it into tokens. The 1st token is the command i.e. 'PUT' or 'GET', the 2nd token is the service name, and the 3rd token is the ip#/port# string. Once the command is received, a "received" confirmation is printed.
      4. If the mapper receives a 'PUT', it will insert the service name, ip# address, and port# into an address table, and confirm success to the server.
      5. If the mapper receives a 'GET', it will fetch the ip# and port# from the address table(provided a service name argument) and return this to the client.

4. **File server.c:**
   1. **Summary:**
      1. This file is used to run client commands against a database. To achieve this, it needs to make a connection with the client and fork a child process to handle the request. The child process will use lseek() to locate the position to rewrite, and lockf() to protect a critical region from updating simultaneously. The parent process will use a signal-catching routine to clean up child processes that have terminated.
      2. The server will follow a similar sequence of events described on the flow diagram of this report i.e. socket() → bind() → listen() → accept() → read() → write() → read() → close() and is structured similarly to the class Server_TCP.c example.
   2. **Code Description:**
      1. The program begins with a series of networking and socket libraries for network connectivity reasons.
      2. Next, a series of global variables that are re-used throughout the program are defined here. This includes port#s and addresses. The client/port#s are well-known, whereas the service map port# is custom defined as 2 + 4#s of the turnin csuId# as described on the 03/05/20 lecture.
      3. Next, a series of structs are defined for the command messages and socket.
      4. Next, it broadcasts the service to the mapper using a broadcast_service() function. In this function, it first creates a socket using socket() and enables broadcasting by using setsockopt(). The port# is converted between host and network byte order using htons(), for the same reason described in the mapper section. Next, the socket is bound to the address

using the bind() function, as described by the sequence in the flow diagram. The program will then run through a series of internet address manipulation routines such as inet_addr() and inet_ntoa(), because different address types have different formats. For example, linux lab broadcast address is 137.148.254.255, local in-home address is 192.168.0/1.255, and generic broadcast address is 255.255.255.255. It then sends the message to the socket using sendto(), and waits to receive the message using recvfrom(). Finally, the socket is closed using close().

5. Once the broadcast is done, the server is ready to read messages from the client, through a process of binding, listening, and accepting. The program will run through an infinite while loop, to continuously listen for signals from the client. If a message is accepted, it creates a new process using fork(). If the process is a child, it will read the message, process the command with the database, return the results to the client using the send() command, and exit with a success mode of 0. If the process is the parent, the remote_tcp_sk socket will close. If the process is anything else, an error is handled and the program exits with a failure mode of 1.
6. When the program is running the commands from the client, it will either run the query_db() or the update_db() function.
    1. The query_db() function is similar to SELECT in SQL. It begins by calling open(), to bind the db20 binary database to a file descriptor. The descriptor is then read through, one byte at a time, to search for a match with the account# provided in the acctnum argument. If no match is found, query_db() returns -1.
    2. The update_db() function is a data manipulation command similar to UPDATE in SQL. It begins by calling open(), to bind the db20 binary database to a file descriptor. If the account# is found, it will use lseek() to update the location of the pointer in the database data, and update the proper record. The lockf() function is used to protect the critical region from being updated by another concurrent query.
7. The print_db() function is used for printing the database results clearly to the user. It opens and reads the proper records, and uses the printf() command to display properties of the account.
8. Finally, there are a series of other helper functions for string manipulation, token extraction, and byte format conversion. Since the port# is represented in 2 byte format, the quotient(using the / operator) and remainder(using the % operator) can be extracted by dividing by 256.
9. The reason some of these helper functions are not included in their own file is to maintain the syntax of the provided turnin command. In a real application, these functions would live inside their own utility files to avoid code redundancy.

**5. File client.c:**

**1. Summary:**

1. This file takes input from the user and communicates with the server to execute database commands(in this case, the ‘query’ and ‘update’ command).
2. The ‘query’ command will return the record for the account# and has the following message structure: 1001(4-byte int)+acct num(4-byte int) in big-endian order.
3. The ‘update’ command will change a person’s record in the database and has the following message structure: 1002(4-byte int)+a ct num(4-byte int) +amount(4-byte float) in big-endian order.
4. This client will follow a similar sequence to the Client_TCP.c example described on 02/02/20, with the following socket() → connect() → write() → read() → close().

2. **Code Description:**
   1. The program begins with a series of networking and socket libraries for network connectivity reasons.
   2. Next, a series of global variables are defined here. This includes port#s and addresses similar to server.c.
   3. Next, the program begins by creating a socket() to initialize an end point.
   4. Next, a request is made to get the address string by using the get_service_address() function. This function starts by enabling the socket to broadcast, by updating the socket using setsockopt(). A series of conversions are done after that, using htons() and inet_address() similar to what was done and described in the boradcast_service() function of server.c. Once the socket is updated, it assigns the address to the socket using the bind() function and is ready to send and receive messages using the the sendto() and recvfrom() functions. It then uses memcpy() and memset() to store the s_addr_info it received from the database. Finally, it closes the socket with close().
   5. Once the address is received, it is parsed for its ip#/port# using the from_addr_string() function. These numbers are then printed to the user.
   6. Next, the program is ready to take input commands from the user. To start, it needs to initialize a local TCP socket to communicate commands.
   7. The prompt begins with a while loop set to 1, to continuously search for input. It then prints a prompt initiator, in this case the char “>”, and waits for user input. If the string is empty, it will skip the remaining code and run the next iteration to prevent a segmentation error. If the string is not empty, it will parse the string for its tokens using the same parse_string() function used in the server.c file. In this case, the delimiter is the comma instead of the period.
      1. The 1st token is the command type, if it reads “query”, the command will build a query request using init_query() and memcpy() and send it to the database using the connect_and_send() function. The connect_and_send() function is used for both query and update commands, and contains a series of arguments to properly connect from the socket and send a message. The arguments include the local socket to send from, the peer to send a message to, the size of the peer, the buffer containing the message to send, the length of the send buffer, the buffer to write the response back to, and the length of the received buffer. The function will return 0 on success, and -1 on error. The function will first clone the socket because it is not good to connect directly to an original client socket. Next, a connection is made with the clone socket using connect(). It will then send the message using send(), receive using recv(), and finally close().
      2. If the command reads “update”, the command will run a similar routine for the update command.
      3. If the user types “help”, a help menu will show the user the proper syntax for running database commands in this program.
      4. If the user types “quit”, the while loop will break, and the program will exit out naturally.
      5. If the user types neither of those 4 conditions, the user will be asked to try again, because the provided input was not valid.
   8. The code finishes by closing the socket using the close() function.

6. **File db20 description:**
   1. **Summary:**
      1. this file is the provided database which contains data in binary format.
   2. **Code Description:**
      1. The data contains records of accounts in the form of the following struct

record{int acctnum; char name[20]; float value; int age;};

7. **File makefile description:**
   1. **Summary:**
      1. This file is used to run complex commands by using a single term.
   2. **Code Description:**
      1. The file starts with a series of header macros and $() variables to maintain one source of truth.
      2. The file then includes a series of commands for cleaning files, linking, compiling, and submitting. It contains 3 main commands: (1)make, (2)clean, (3)submit.
         1. The ‘make’ command will build the object and executable files.
         2. The ‘clean’ command will remove the object and executable files.
         3. The ‘submit’ command will run turnin to compress and send the project to the cis620 archive for grading.

8. **Results:**
   1. **Run instructions:**
      1. To run the program, open 3 terminals and ssh connect to 3 linux computers i.e. spirit, strauss, and rodin.
      2. Browse to the location of the program and type ‘make’.
      3. On the 1st terminal, type: ./servicemap.
      4. On the 2nd terminal, type: ./server.
      5. On the 3rd terminal, type ./client.
      6. Still on the 3rd terminal, type the database command.

   2. **Run output:**
      1. run servicemap on spirit:

```
daizadne@spirit:~/Desktop/cis620/hw04$ ./servicemap
Received from 137.148.204.16: PUT CISBANK 137,148,204,16,178,110
Received from 137.148.204.10: GET CISBANK
```

      2. run server on strauss:

```
daizadne@strauss:~/Desktop/cis620/hw04$ ./server
Registration OK from 137.148.204.15
Service Requested from 137.148.204.10
Service Requested from 137.148.204.10
```

      3. run client query and update on rodin:

```
daizadne@rodin:~/Desktop/cis620/hw04$ ./client
Service provided by 137.148.204.16 at port 45678
> query 11111
MULAN HUA 11111 99.9
> update 34567 8.2
BILL SUN 34567 74.2
> quit
```

3. **Description:**
   1. The outputs are displayed in sequence of how the program is suppose to be run servicemap→server→client. The servicemap output confirms that it was able to initiate our system and runs 2 simple commands against the database. The server output confirms that it was able to register and accept requests from the provided address, and can now accept requests from the client. The client output shows that the user can now enter queries, and that the output from the queries is consistent with the data in the database.

9. **Experiences in testing/debugging:**
   1. **Error#01:**
      1. **File:**
         1. server.c
      2. **Description:**
         1. host addresses in struct h_addr_list is not accepting provided input.
      3. **Solution:**
         1. The h_addr_list struct requires in_addr pointers instead, per the IBM documentation.
   2. **Error#02:**
      1. **File:**
         1. client.c
      2. **Description:**
         1. Segmentation error is displayed when there is no input provided from the command prompt.
      3. **Solution:**
         1. The bug is caused from setting the end of the input to the null terminator \0. To address this, a script was added to continue to next iteration of while loop if the input string length is 0.