UNIVERSITY OF

Waterloo

Department of Electrical and Computer Engineering

ECE 358: Computer Networks

Project 2: Socket Programming using Python

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1 Objective

In this lab, you will learn the basics of socket programming in Python: how to create a socket, bind it to a specific address and port, as well as send and receive a packet.

2 Programming Language

You must use Python for this lab.

3 Task 1: Develop a web server that handles HTTP request.

3.1 Problem Description:

You will develop a code in Python for a web server that handles one HTTP request at a time.

3.2 Instructions:

- You will develop a server program in Python.
- Your web server should accept and parse the HTTP request, get the requested file from the server's file system. Your server should be able to handle GET and HEAD requests (other methods won't be tested). Use Postman to test GET and HEAD requests.
- Create an HTTP response message consisting of the requested file preceded by header lines, and then send the response directly to the client. The minimum header lines is six. It contains header fields of Connection, Date, Server, Last-Modified, Content-Length and Content-Type. For more information on header fields, please see RFC 2616 at https://datatracker.ietf.org/doc/html/rfc2616.
- If the requested file is not present in the server, the server should send an HTTP "404 Not Found" message back to the client.
- Put an HTML file (e.g., HelloWorld.html) in the same directory that the server is in. Run the server program. The content of the html file is a free choice. The HelloWorld.html is just an example.
- In this lab, we will be using the host's loop back address which is 127.0.0.1.
- From the same host, open a browser and provide the corresponding URL using the format http://Server_IP_Address:Port_Numbr/"requested_file_name". For example: http://127.0.0.1:6789/HelloWorld.html, where 'HelloWorld.html' is the name of the file you placed in the server directory. The port number is a number bigger than 1023. We recommend the number in the range of [10,000, 11,000].
- Note also the use of the port number after the colon. You need to replace this port number with whatever port number you have used in the server code. In the above example, we have used the port number 6789. The browser should then display the contents of HelloWorld.html.
- If you omit ":6789", the browser will assume port 80 and you will get the web page from the server only if your server is listening at port 80.
- Then try to get a file that is not present at the server. You should get a "404 Not Found" message.
- Your server is required to handle html files that are nested in the subdirectories of the directory where the server is in. You will be given a path to the HTML file you want to serve in the request.
- We implement persistent http in this lab. By persistent, we mean the server socket stays open but the client one closes after each sendall(). To avoid complication of implementing Timeout we have slightly modified this part. Every thing else should work as persistent http.
- You must use socket library to implement webserver. Any library that bypasses that requirement is not allowed. Otherwise, you are allowed to use any library you want.
- We only ask for server code in Task-1, not the client code, client will be a WebBrowser in this case.
- Learn may modify the html file. Don't worry about that.

3.3 Deliverables in report format:

- Explain your code. (Snippets of some portions of the code explaining the logic in the report)
- You will hand in the complete server code along with the screenshots of your client browser, verifying that you have received the contents of the HTML file from the server.
- Screenshot of Postman for both GET and HEAD requests.

3.4 Other deliverables:

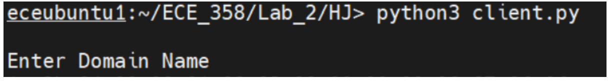
- Python code for the webserver program. The file name should be “webserver.py”.
- Readme file regarding how someone can execute your code.

4 Task 2: Design and implement an Authoritative DNS server using a Client-Server system that uses UDP socket.

4.1 Problem Description:

The client program sends a request containing domain-name to the server, and the server replies with IP Address/es that corresponds to the domain name. A DNS query will be sent from the client to the server, and the server will send a DNS response to the client.

4.2 Instructions:

- You will develop a client program, “client.py” and a server program, “server.py” in Python. Open two separate terminal windows, one for the client and the other one for the server. After executing the codes in the respective terminals, communication between the server and the client will be established.
  <u>Example (client terminal):</u>
  

```
eceubuntu1:~/ECE_358/Lab_2/HJ> python3 client.py

Enter Domain Name
```

- The client initiates communication with a server. The server remembers the client for the entire duration of the communication session. The client then runs in an infinite loop where it accepts a domain-name from the user through the command line.
- A DNS query message is created on the client side. Follow the guidelines provided in the “DNS Message Format” section in this manual to create the DNS query. The query message (in Hex/byte array or any other format) is then forwarded to the DNS server.
- Once the DNS server receives the message, it will parse the message and accordingly generate a response message following the guidelines provided in the “DNS Message Format” section in this manual. The response message (in Hex) is then forwarded to the client.
- The server-side terminal should display both request and response messages (in Hex) in the following format.
  <u>The server terminal should display:</u>
  <u>Request:</u>

```
1a 2b 04 00 00 01 00 00 00 00 00 00 06 67 6f 6f
67 6c 65 03 63 6f 6d 00 00 01 00 01
```

  <u>Response:</u>

```
1a 2b 84 00 00 01 00 02 00 00 00 00 06 67 6f 6f
67 6c 65 03 63 6f 6d 00 00 01 00 01 c0 0c 00 01
00 01 00 00 01 04 00 04 c0 a5 01 01 c0 0c 00 01
00 01 00 00 01 04 00 04 c0 a5 01 0a
```

- The client will parse the message and display the results. The client terminal should display output in the following format once a DNS request is made.
  <u>Client terminal should display:</u>
  <u>Input from the user:</u>

```
> Enter Domain Name: google.com
```

  <u>Output:</u>

```
> google.com: type A,  class IN,  TTL 260,  addr  (4) 192.165.1.1
> google.com: type A,  class IN,  TTL 260,  addr  (4) 192.165.1.10
```

  *Note: (4) represents the length of the records in bytes.
- The server holds an array with at least five domain names and the corresponding IP addresses (see table 1). The server runs an infinite loop where it keeps waiting for requests from the client.
  *You may use other data structures.

- If the user enters “end,” the communication session ends (it does not need to send the message to the server, just close the client connection). Upon ending the session, it prints “Session ended” on the client terminal.
- We assume that the input will only be provided from Table 1.
  Example format:
  > Enter Domain Name: end
  Session ended
- You will use the loop back address 127.0.0.1 for your server, and the client will start on the same host where the server runs. The port number can be any number bigger than 1023. Recommended port number range is [10,000, 11,000].
- You code should handle upper case and lower-case input scenarios. The client only input domains that do exist in the DNS server (Table-1).

4.3 Deliverables in report format:

- Explain your code. (snippets of some portions of the code explaining the logic in the report)
- Give a screenshot of the output (for both client and server terminal) in your report when the client enters “google.com” in the client terminal. (Terminal output does not need to be color coded)
- Give a screenshot of the output (for both client and server terminal) in your report when the client enters “wikipedia.org” in the client terminal. (Terminal output does not need to be color coded)
- Colour code the DNS query messages (in Hex), identify different fields. (See Table. 2 for submission format).
- Colour code the DNS response messages (in Hex), identify different fields. (See Table. 2 for submission format).

4.4 Other deliverables:

- Python code for the server program. The file name should be “server.py”.
- Python code for the client program. The file name should be “client.py”.
- Readme file regarding how someone can execute your code.

Table 1: The list of domain names and corresponding IP addresses.

Sl no.	Domain name	Type	Class	TTL	IP address
1	google.com	A	IN	260	192.165.1.1 192.165.1.10
2	youtube.com	A	IN	160	192.165.1.2
3	uwaterloo.ca	A	IN	160	192.165.1.3
4	wikipedia.org	A	IN	160	192.165.1.4
5	amazon.ca	A	IN	160	192.165.1.5

4.5 DNS Message Format:

DNS allows you to interact with devices on the Internet without having to remember long strings of numbers. Changing of information between client and server is carried out by two types of DNS messages:

- Query message
- Response message.

The format is similar for both types of messages.

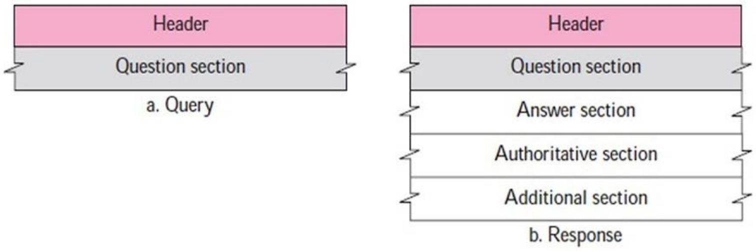
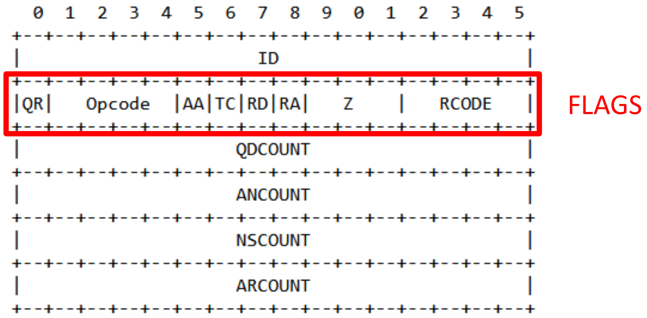


Fig 1: DNS Query and Response Message.

4.5.1 DNS Header:



```
  0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                      ID                       |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|QR|   Opcode  |AA|TC|RD|RA|   Z    |   RCODE   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    QDCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ANCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    NSCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ARCOUNT                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

Fig 2: DNS Header Format

ID: A 16-bit identifier assigned by the program that generates any kind of query.

*Generate randomly. The response header id need to match the request header id

QR: A one bit field that specifies whether this message is a query (0), or a response (1).

*Select based on the type of message.

OPCODE: A four bit field that specifies kind of query in this message. This value is set by the originator of a query and copied into the response. The values are:

0 a standard query (QUERY).

1 an inverse query (IQUERY)

2 a server status request (STATUS)

3-15 reserved for future use.

*For this lab set OPCODE as 0.

AA: Authoritative Answer - this bit is valid in responses, and specifies that the responding name server is an authority for the domain name in question section.

* For this lab set AA as 1.

TC: TrunCation - specifies that this message was truncated due to length greater than that permitted on the transmission channel.

* For this lab set TC as 0.

RD: Recursion Desired - this bit may be set in a query and is copied into the response. If RD is set, it directs the name server to pursue the query recursively. Recursive query support is optional.

* For this lab set RD as 0.

RA: Recursion Available - this be is set or cleared in a response, and denotes whether recursive query support is available in the name server.

* For this lab set RA as 0.

Z: Reserved for future use. Must be zero in all queries and responses.

* For this lab set Z as 000.

RCODE: Response code - this 4-bit field is set as part of responses. The values have the following interpretation:

0 No error condition

1 Format error - The name server was unable to interpret the query.

2 Server failure - The name server was unable to process this query due to a problem with the name server.

3 Name Error - Meaningful only for responses from an authoritative name server, this code signifies that the domain name referenced in the query does not exist.

4 Not Implemented - The name server does not support the requested kind of query.

5 Refused - The name server refuses to perform the specified operation for policy reasons. For example, a name server may not wish to provide the information to the particular requester, or a name server may not wish to perform a particular operation.

* For this lab set RCODE as 0.

QDCOUNT: an unsigned 16-bit integer specifying the number of entries in the question section.

* For this lab set QDCOUNT as 1.

ANCOUNT: an unsigned 16-bit integer specifying the number of resource records in the answer section.

* Set ANCOUNT based on message type.

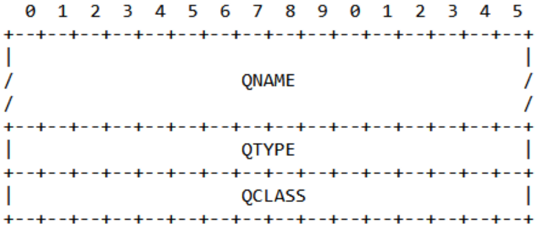
NSCOUNT: an unsigned 16-bit integer specifying the number of name server resource records in the authority records section.

* For this lab set NSCOUNT as 0.

ARCOUNT: an unsigned 16 bit integer specifying the number of resource records in the additional records section.

* For this lab set ARCOUNT as 0.

4.5.2 Question section format:



```
  0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                                               |
/                     QNAME                     /
/                                               /
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                     QTYPE                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                     QCLASS                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

Fig 3: DNS Question Format

QNAME: a domain name represented as a sequence of labels, where each label consists of a length octet followed by that number of octets. The domain name terminates with the zero length octet for the null label of the root. Note that this field may be an odd number of octets; no padding is used.

*See the example below to set this field.

QTYPE: a two octet code which specifies the type of the query. The values for this field include all codes valid for a TYPE field, together with some more general codes which can match more than one type of RR.

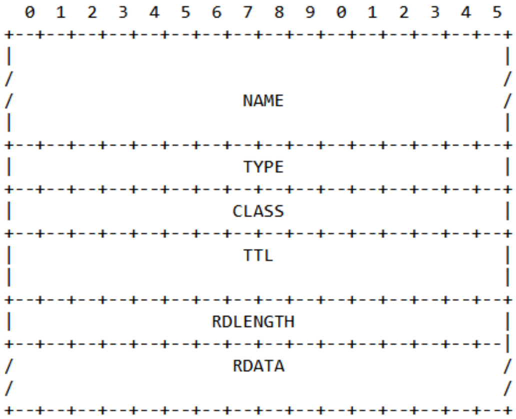
TYPE	**value and meaning**
A	1 a host address
NS	2 an authoritative name server
MD	3 a mail destination (Obsolete - use MX)
MF	4 a mail forwarder (Obsolete - use MX)

* For this lab use TYPE A. Set this field according.

QCLASS: a two octet code that specifies the class of the query.

*Set QCLASS field as IN (00 01) (hex value) for the Internet.

4.5.3 Answer section format:



```
  0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                                               |
/                                               /
/                      NAME                     /
|                                               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                      TYPE                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                     CLASS                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                      TTL                      |
|                                               |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                   RDLENGTH                    |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
/                     RDATA                     /
/                                               /
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

Fig 4: Resource Record (RR) format

NAME: an owner name, i.e., the name of the node to which this resource record pertains.

*set this field as (c0 0c) (hex value).

TYPE: two octets containing one of the RR TYPE codes.

*set this field accordingly. We only deal with TYPE A message.

CLASS: two octets containing one of the RR CLASS codes.

*set this field accordingly. We only deal with IN message.

TTL: a 32 bit unsigned integer that specifies the time interval that the resource record may be cached before the source of the information should again be consulted. Zero values are interpreted to mean that the RR can only be used for the transaction in progress, and should not be cached. For example, SOA records are always distributed with a zero TTL to prohibit caching. Zero values can also be used for extremely volatile data.

*set this field accordingly. The info is provided in Table 1.

RDLENGTH: an unsigned 16 bit integer that specifies the length in octets of the RDATA field.

*set this field accordingly. The info is provided in Table 1.

RDATA: a variable length string of octets that describes the resource. The format of this information varies according to the TYPE and CLASS of the resource record.

*set this field accordingly. The info is provided in Table 1.

4.5.4 Authoritative section & Additional Section:

*Do not include these fields in the DNS response message.

4.5.5 Example:

The example shows a DNS Query. From the colors you can identify different fields in the message.

1a 2b 04 00 00 01 00 00 00 00 00 00 06 67 6f 6f
67 6c 65 03 63 6f 6d 00 00 01 00 01

Table 2: DNS Query.

Type	Key	Value
DNS HEADER	ID	1a 2b
	FLAGS	04 00
	QDCOUNT	00 01
	ANCOUNT	00 00
	NSCOUNT	00 00
	ARCOUNT	00 00
QUERY	QNAME	06 67 6f 6f 67 6c 65 03 63 6f 6d 00
	QTYPE	00 01
	QCLASS	00 01

5 Task 3: Answer the following questions

1. What is Socket?
2. How sockets work? Why is socket required?
3. What are the types of Internet Sockets? Briefly explain the characteristics of each type. (Lesser known sockets are not required.)
4. Mention at least one application of each type of socket?
5. Briefly explain the following function.

Function	Description
socket()	
bind()	
connect()	
listen()	
accept()	
close()	

6. Draw the flow diagram of TCP Socket Programming that you used in this lab.
7. On which layer socket will execute in the Internet protocol stack?
8. Complete the following table:

Protocol	Port #	Common Function
HTTP		
FTP		
IMAP4		
SMTP		
Telnet		
POP3		

9. What is DNS and how does it work?

Instruction: Try to give your answer in your own words. Copy and paste with reference may be allowed for particular answers. TAs are expecting to the point answer.

6 Final Report Guidelines

Submit the following to the dropbox on LEARN:

1. A complete report with
   a. Table of contents
   b. Answer all the questions and provide explanations as asked for.
2. Source code with proper documentation/comments. Insufficient documentation will result in losing marks. Include a readme file with clear instructions on how to run your code.
3. You must submit files individually (zipped files are not allowed). If you have multiple submissions, most recent one will be marked.
4. Screenshots in the IDE on your own laptop (Mac/Windows) is acceptable.
5. You may be asked to give a demo of your simulator.

7 References

[1] J. F. Kurose and K. W. Ross: Computer Networking, A Top-Down Approach. 8th Edition.

[2] P. Mockapetris, Domain Names – Implementation and Specification, document RFC 1035, 1987.