Network Programming with Python

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IPv4 and IPv6

IPv4 Names

```
from socket import *

print(gethostname())

print(getfqdn())

print(gethostbyname('lip6.fr'))

print(gethostbyaddr('132.227.104.15'))

print(gethostbyname(getfqdn()))
```

IPv4 Names

```
from socket import *

print(gethostname())

print(getfqdn())

print(gethostbyname('lip6.fr'))

print(gethostbyaddr('132.227.104.15'))

print(gethostbyname(getfqdn()))
```

```
postetixeuil4.rsr.lip6.fr

postetixeuil4.rsr.lip6.fr

132.227.104.15

('ww.lip6.fr', ['15.104.227.132.in-addr.arpa'], ['132.227.104.15'])

132.227.84.244
```

IPv4-IPv6 Names

```
infolist = getaddrinfo('lip6.fr','www')

print(infolist)

info = infolist[1]

print(info)

s = socket(*info[0:3])

s.connect(info[4])
```

IPv4-IPv6 Names

```
infolist = getaddrinfo('lip6.fr','www')

print(infolist)

info = infolist[1]

print(info)

s = socket(*info[0:3])

s.connect(info[4])
```

```
[(<AddressFamily.AF_INET: 2>,
<SocketKind.SOCK_DGRAM: 2>, 17,
'', ('132.227.104.15', 80)),
(<AddressFamily.AF_INET: 2>,
<SocketKind.SOCK_STREAM: 1>, 6,
'', ('132.227.104.15', 80))]
```

```
(<AddressFamily.AF_INET: 2>,
<SocketKind.SOCK_STREAM: 1>, 6,
'', ('132.227.104.15', 80))
```

Strings and Bytes

Strings vs. Bytes

- **Strings** are meant for general Unicode support
- **Bytes** are what is sent/received through the network
- **Encoding** of Strings into Bytes before sending

```
toSend = str.encode('utf-8')
```

- **Decoding** Bytes into Strings when receiving

```
str = received.decode('utf-8')
```

UDP Python Client

```
from socket import *

serverName = 'A.B.C.D'

serverPort = 1234

clientSocket = socket(AF_INET,SOCK_DGRAM)

message = input('lowercase sentence:').encode('utf-8')

clientSocket.sendto(message,(serverName,serverPort))

modifiedMessage, serverAddress = clientSocket.recvfrom(2048)

print(modifiedMessage.decode('utf-8'))

clientSocket.close()
```

UDP Python Server

```
from socket import *

serverPort = 1234

serverSocket = socket(AF_INET,SOCK_DGRAM)

serverSocket.bind(('',serverPort))

print('server ready')

while True:

 message, clientAddress = serverSocket.recvfrom(2048)

 modifiedMessage = message.decode('utf-8').upper()

 serverSocket.sendto(modifiedMessage.encode('utf-8'),
clientAddress)
```

Numbers and Byte Order

Byte Order over the Network

```
from struct import *


print(hex(1234))


print(pack('<i',1234))

print(pack('>i',1234))

print(pack('!i',1234))


print(unpack('>i',b'\x00\x00\x04\xd2'))


print(unpack('!i',b'\x00\x00\x04\xd2'))
```

Byte Order over the Network

```
from struct import *

print(hex(1234))                                  0x4d2

print(pack('<i',1234))                            b'\xd2\x04\x00\x00'
print(pack('>i',1234))                            b'\x00\x00\x04\xd2'
print(pack('!i',1234))                            b'\x00\x00\x04\xd2'

print(unpack('>i',b'\x00\x00\x04\xd2'))           (1234,)

print(unpack('!i',b'\x00\x00\x04\xd2'))           (1234,)
```

Network Exceptions

Network Exceptions

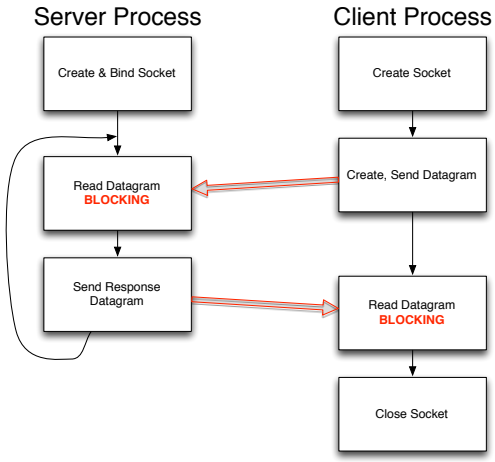
- `OSError`: almost every failure that can happen during a network connection
- `socket.gaierror`: address-related error
- `socket.timeout`: timeout expired

Network Exceptions

```
from socket import *


try:
    infolist = getaddrinfo('nonexistent.com','www')
except gaierror:
    print("This host does not seem to exist")
```

UPD Packet Drops

UDP Packet Drops



UDP Packet Drops

```
…
delay = 0.1 # sec
while True:
  clientSocket.sendto(message,(serverName,serverPort))
  clientSocket.settimeout(delay)
  try:
    modifiedMessage, serverAddress = clientSocket.recvfrom(2048)
  except socket.timeout:
    delay *= 2
  else:
    break
print(modifiedMessage.decode('utf-8'))
clientSocket.close()
```

UDP Packet Drops

```
…
delay = 0.1 # sec
while True:
  clientSocket.sendto(message,(serverName,serverPort))
  clientSocket.settimeout(delay)
  try:
    modifiedMessage, serverAddress = clientSocket.recvfrom(2048)
  except socket.timeout:
    delay *= 2
    if delay > 2.0:
      raise RuntimeError('server seems down')
  else:
    break
print(modifiedMessage.decode('utf-8'))
```

UDP Broadcast

UDP Broadcast Client

```
from socket import *
broadcastAddr = 'W.X.Y.255' # assuming 255.255.255.0 netmask
serverPort = 1234
clientSocket = socket(AF_INET,SOCK_DGRAM)
clientSocket.setsockopt(SOL_SOCKET,SO_BROADCAST,1)
message = input('lowercase sentence:').encode('utf-8')
clientSocket.sendto(message,(serverName,serverPort))
modifiedMessage, serverAddress = clientSocket.recvfrom(2048)
print(modifiedMessage.decode('utf-8'))
clientSocket.close()
```

UDP Broadcast Server

```
from socket import *
serverPort = 1234
serverSocket = socket(AF_INET,SOCK_DGRAM)
serverSocket.bind(('',serverPort))
print('server ready')
while True:
 message, clientAddress = serverSocket.recvfrom(2048)
 modifiedMessage = message.decode('utf-8').upper()
 serverSocket.sendto(modifiedMessage.encode('utf-8'),
 clientAddress)
```

TCP Sending

TCP `send`

- If TCP/IP stack has enough room, `send` returns immediately, and the **complete** message will be handled
- If TCP/IP stack is full, `send` is **blocking**
- If TCP/IP stack is **almost** full, `send` returns immediately, but only a **part** of the message will be handled

TCP `send` Loop

```
…

message=input('lowercase sentence:').encode('utf-8')

bytes_sent = 0

while bytes_sent < len(message):

  message_remaining = message[bytes_sent:]

  bytes_sent +=
  clientSocket.send(message_remaining)

…
```

TCP `sendall`

```
…

message = input('lowercase
sentence:').encode('utf-8')

clientSocket.sendall(message)

…
```

TCP Receiving

TCP `recv`

- If TCP/IP stack is full enough, `recv` returns immediately, and the **specified size** message will be delivered
- If TCP/IP stack is empty, `recv` is **blocking**
- If TCP/IP stack is not empty, `recv` returns immediately, but only a **fraction** of the specified size will be delivered

TCP `recvall` ?

- Deciding when **all** data is received is **application specific**
  - Fixed size messages
  - Message size is announced before data is sent
  - Special delimiters announce end of data

Framing and Quoting

TCP `recvall`

```
def recvall(sock, length):
    blocks = []
    while length:
        block = sock.recv(length)
        if not block:
            raise EOFError('socket closed with %d bytes left'
                           ' in this block'.format(length))
        length -= len(block)
        blocks.append(block)
    return b''.join(blocks)
```

Sending a Block

```
from struct import *
from socket import *

header_struct = Struct('!I')

def put_block(sock, message):

    block_length = len(message)

    sock.sendall(header_struct.pack(
        block_length))

    sock.sendall(message)
```

Receiving a Block

```
from struct import *
from socket import *

header_struct = Struct('!I')

def get_block(sock):

    data = recvall(sock, header_struct.size)

    (block_length,) = header_struct.unpack(data)

    return recvall(sock, block_length)
```

XML and JSON

JSON

```
from json import *
from socket import *


print(dumps(['aéçèà',1234,[2,3,4,5,6]]))
print(loads('["a\u00e9\u00e7\u00e8\u00e0", 1234, [2, 3, 4, 5, 6]]'))


s = socket(AF_INET,SOCK_STREAM)
try:
    print(dumps(s))
except TypeError:
    print("this data does not seem serializable with JSON")
```

JSON

```
from json import *
from socket import *
print(dumps(['aéçèà',1234,[2,3,4,5,6]]))
print(loads('["a\u00e9\u00e7\u00e8\u00e0", 1234, [2, 3, 4, 5, 6]]'))
s = socket(AF_INET,SOCK_STREAM)
try:
    print(dumps(s))
except TypeError:
    print("this data does not seem serializable with JSON")
```

```
["a\u00e9\u00e7\u00e8\u00e0", 1234, [2, 3, 4, 5, 6]]
['aéçèà', 1234, [2, 3, 4, 5, 6]]
```

Compression

Python Data Compression

```
from zlib import *
str = b'A very long test string to evaluate compression and how much it improves
bandwidth usage'
print(len(str))

data = compress(str)
print(data)
print(len(data))

d = decompressobj()
newdata = d.decompress(data)
print(newdata)
```

Python Data Compression

```
from zlib import *
str = b'A very long test string to evaluate compression and how much it improves
bandwidth usage'
print(len(str))
```

```
88
```

```
data = compress(str)
print(data)
print(len(data))
```

```
b'x\x9c\x15\xc9\xd1\t\xc0 \x0c\x05\xc0U\xde*
\x1d%\xd5\xa0\x015%\x89J\xb7\xaf\xfd;\xb8\x0b
\x8b\xedE\xd3Q\x10\xec\x01\x0f\x93\xdf\n^\xd4&
\x05#i\x7f\x8c\xddE\x07hdT\xdd\xe83UH@N\xe9b
\xc7}fK\x8e\x8a\xe9T\xf8\x03\xad\\!\x05'
```

```
78
```

```
d = decompressobj()
newdata = d.decompress(data)
print(newdata)
```

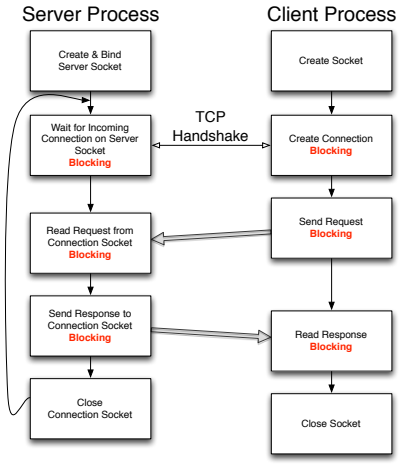
```
b'A very long test string to evaluate
compression and how much it improves bandwidth
usage'
```

Server-side Programming

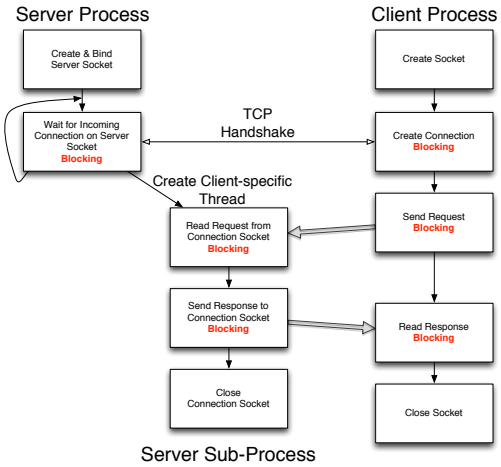
Sequential TCP Server

```
…
def handle_client(clientSocket):

    while True:

        received = clientSocket.recv(4096)

        if not received:

            clientSocket.close()

        else:

            to_send = received.decode('utf-8').upper().encode('utf-8')

            clientSocket.sendall(to_send)


while True:

        connectionSocket, address = serverSocket.accept()

        handle_client(connectionSocket)
```

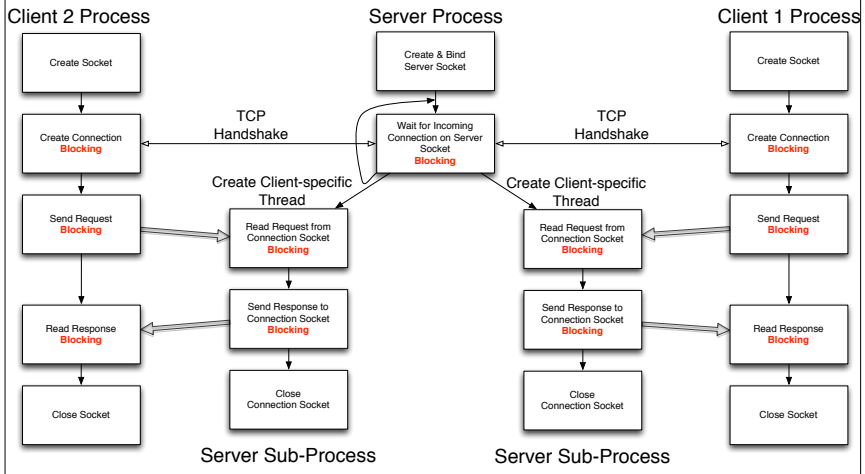
Sequential TCP Server



Multi-thread TCP Server



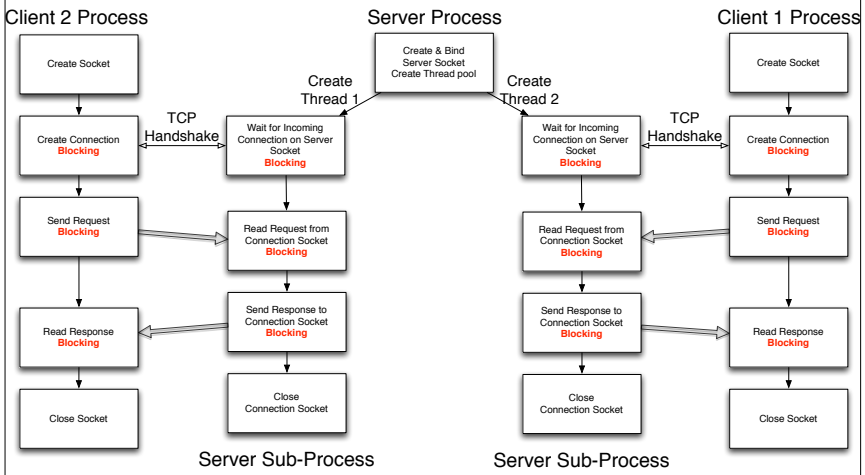
Multi-thread TCP Server



Multi-Thread TCP Server

```
from threading import *
…
def handle_client(clientSocket):
    while True:
        received = clientSocket.recv(4096)
        if not received:
            clientSocket.close()
        else:
            to_send = received.decode('utf-8').upper().encode('utf-8')
            clientSocket.sendall(to_send)
while True:
        connectionSocket, address = serverSocket.accept()
        Thread(target=handle_client,args=(connectionSocket,)).start()
```

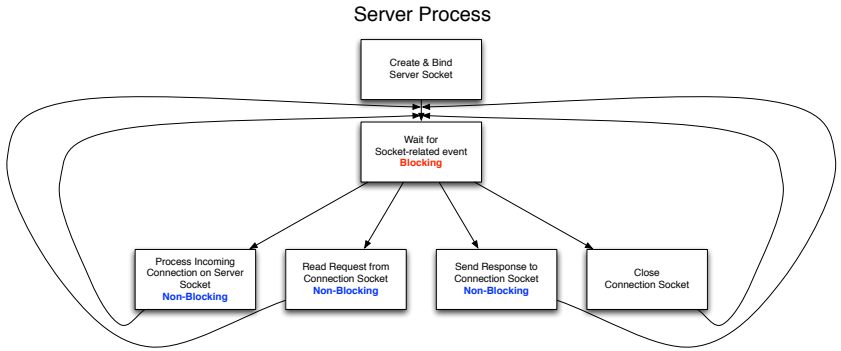
Thread Pool TCP Server



Thread Pool TCP Server

```
…
def handle_client(listeningSocket):
    while True:
        clientSocket, address = listeningSocket.accept()
        while True:
            received = clientSocket.recv(4096)
            if not received:
                clientSocket.close()
            else:
                to_send = received.decode('utf-8').upper().encode('utf-8')
                clientSocket.sendall(to_send)
for i in range(4):
        Thread(target=handle_client,args=(serverSocket,)).start()
```

Multiplexing TCP Server



Multiplexing TCP Server

```
from select import *
…
my_poll = poll()
my_poll.register(serverSocket,POLLIN)

sockets = {serverSocket.fileno(): serverSocket}
 # retrieve socket object from fileno
received = dict()
 # bytes received from fileno, that are not yet processed
to_send = dict()
 # bytes to be sent from fileno, that have been processed
```

Multiplexing TCP Server

```
while True:
    for fd, event in my_poll.poll():
        if event & (POLLHUP|POLLERR|POLLNVAL):
            received.pop(fd)
            to_send.pop(fd)
            my_poll.unregister(fd)
            del sockets[fd]
            sockets.pop(fd)
```

Multiplexing TCP Server

```
elif sockets[fd] is serverSocket:
    connectionSocket, address =
    serverSocket.accept()
    sockets[connectionSocket.fileno()] =
    connectionSocket
    my_poll.register(connectionSocket,
    POLLIN)
```

Multiplexing TCP Server

```
else:
            if event & POLLIN:
                data = sockets[fd].recv(4096)
                if not data:
                    sockets[fd].close()
                    continue
                if fd in received:
                    received[fd] += data
                else:
                    received[fd] = data
                my_poll.modify(fd,POLLIN|POLLOUT)
```

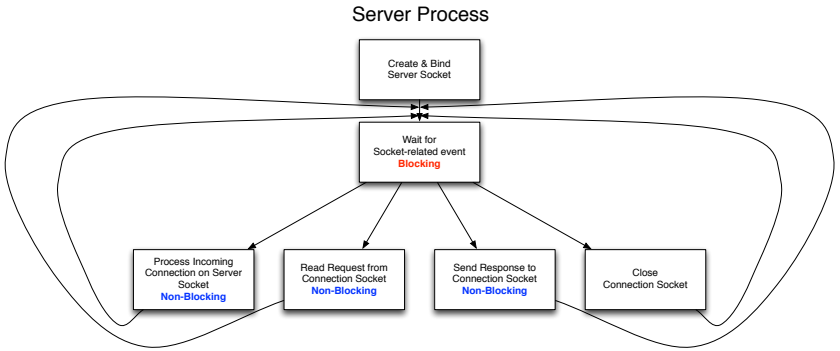
Multiplexing TCP Server

```
if event & POLLOUT:
                data = received.pop(fd).decode('utf-8')
                data = data.upper().encode('utf-8')
                if fd in to_send:
                    data = to_send.pop(fd) + data
                n = sockets[fd].send(data)
                if n < len(data):
                    to_send[fd] = data[n:]
                else:
                    my_poll.modify(fd,POLLIN)
```

Multiplexing TCP Server

```
from select import *
…
while True:
   for fd, event in my_poll.poll():
     if event & (POLLHUP|POLLERR|POLLNVAL):
      …
     elif sockets[fd] is serverSocket:
       …
     else:
          if event & POLLIN:
           …
          if event & POLLOUT:
           …
```

Multiplexing TCP Server



XML-RPC

Remote Procedure Call

- The main objective is to make client-server calls (almost) transparent to the programmer
- The server **defines a set of functions** and makes them available through the network
- The client **calls the function** (almost) as if they were local
- No need to define a protocol, a data format, etc.

Python XML-RPC Server

```
from operator import *

from math import *

from xmlrpc.server import *

from functools import *

def addtogether(*things):

    return reduce(add,things)

def quadratic(a,b,c):

    b24ac = sqrt(b*b - 4.0*a*c)

    return list((set([(-b-b24ac)/2.0*a,(-b+b24ac)/2.0*a])))
```

Python XML-RPC Server

```
…

server = SimpleXMLRPCServer(('127.0.0.1', 7001))

server.register_introspection_functions()

server.register_multicall_functions()

server.register_function(addtogether)

server.register_function(quadratic)

print("Server ready")

server.serve_forever()
```

Python XML-RPC Client

```
from xmlrpc.client import *

proxy = ServerProxy('http://
127.0.0.1:7001')

print(proxy.addtogether('x','y','z'))

print(proxy.addtogether(1,2,3,4,5))

print(proxy.quadratic(2,-4,0))

print(proxy.quadratic(1,2,1))
```

Python XML-RPC Client

```
from xmlrpc.client import *

proxy = ServerProxy('http://
127.0.0.1:7001')

print(proxy.addtogether('x','y','z'))→xyz

print(proxy.addtogether(1,2,3,4,5))→15

print(proxy.quadratic(2,-4,0))→[0.0, 8.0]

print(proxy.quadratic(1,2,1))→[-1.0]
```

Wireshark

```
POST /RPC2 HTTP/1.1
Host: 127.0.0.1:7001
Accept-Encoding: gzip
Content-Type: text/xml
User-Agent: Python-xmlrpc/3.4
Content-Length: 258

<?xml version='1.0'?>
<methodCall>
<methodName>addtogether</methodName>
<params>
<param>
<value><string>x</string></value>
</param>
<param>
<value><string>y</string></value>
</param>
<param>
<value><string>z</string></value>
</param>
</params>
</methodCall>
```

```
HTTP/1.0 200 OK
Server: BaseHTTP/0.6 Python/3.4.3
Date: Mon, 18 Jan 2016 13:41:45 GMT
Content-type: text/xml
Content-length: 129

<?xml version='1.0'?>
<methodResponse>
<params>
<param>
<value><string>xyz</string></value>
</param>
</params>
</methodResponse>
```

Wireshark

```
POST /RPC2 HTTP/1.1
Host: 127.0.0.1:7001
Accept-Encoding: gzip
Content-Type: text/xml
User-Agent: Python-xmlrpc/3.4
Content-Length: 330

<?xml version='1.0'?>
<methodCall>
<methodName>addtogether</methodName>
<params>
<param>
<value><int>1</int></value>
</param>
<param>
<value><int>2</int></value>
</param>
<param>
<value><int>3</int></value>
</param>
<param>
<value><int>4</int></value>
</param>
<param>
<value><int>5</int></value>
</param>
</params>
</methodCall>
```

```
HTTP/1.0 200 OK
Server: BaseHTTP/0.6 Python/3.4.3
Date: Mon, 18 Jan 2016 13:41:45 GMT
Content-type: text/xml
Content-length: 122

<?xml version='1.0'?>
<methodResponse>
<params>
<param>
<value><int>15</int></value>
</param>
</params>
</methodResponse>
```

Conclusion

- Python makes network programming really easy
- A number of Python modules have been developed for popular Internet-based protocols
- The socket API remains important for developing new protocols, and accessing lower layers