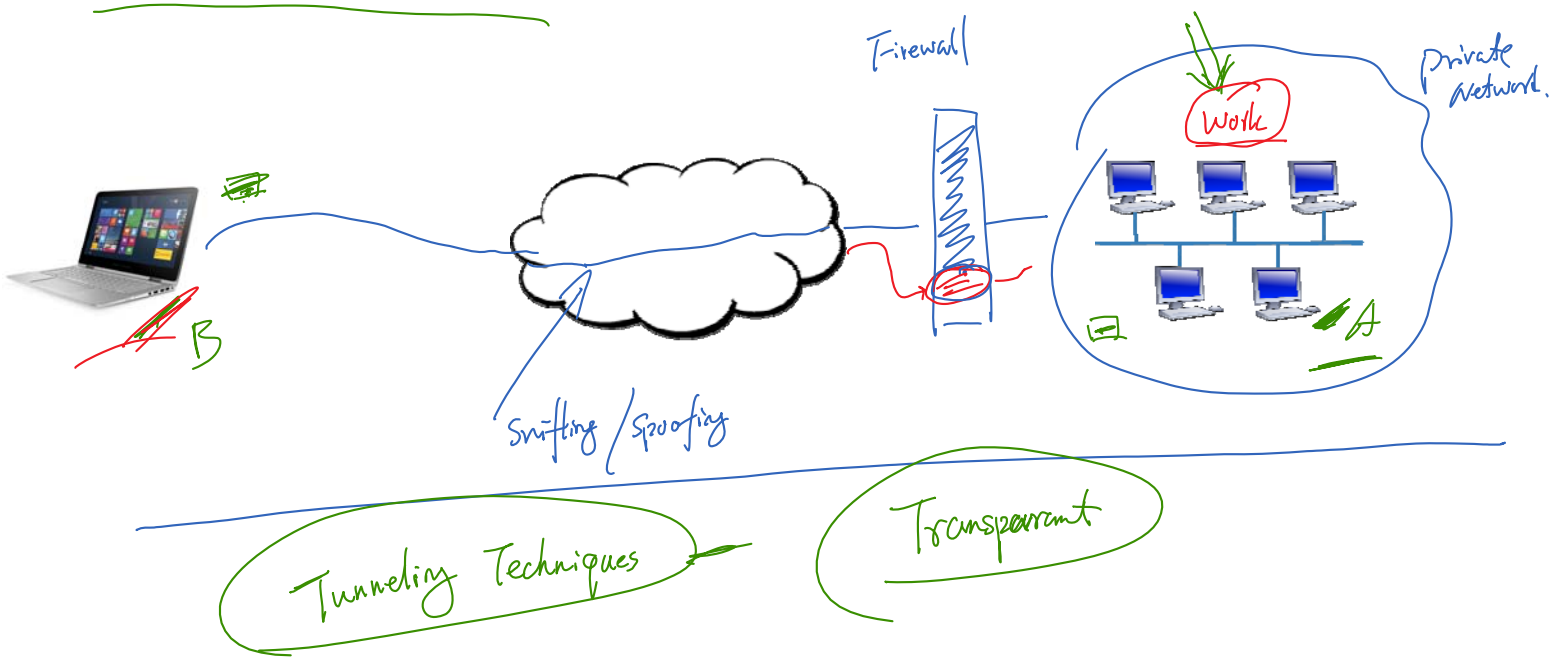
Virtual Private Network

Why Virtual Private Network (VPN)?



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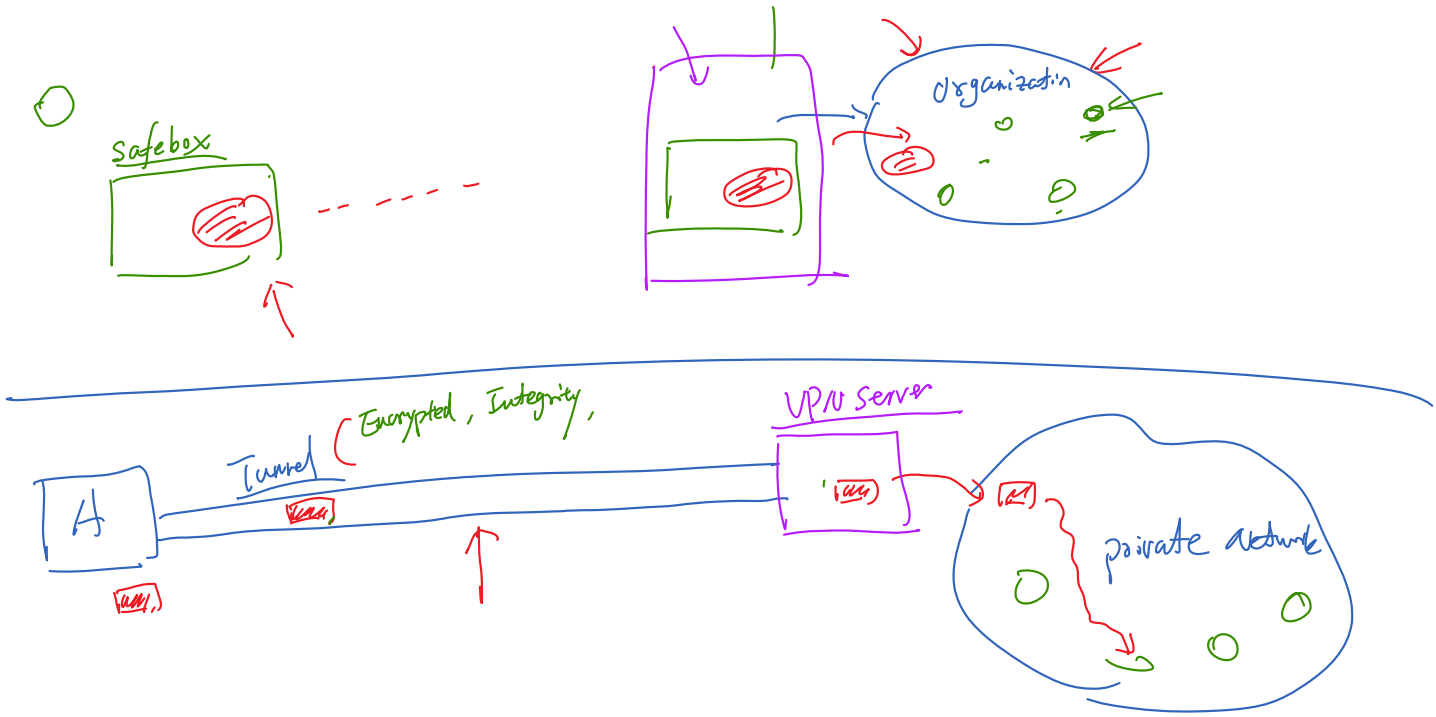
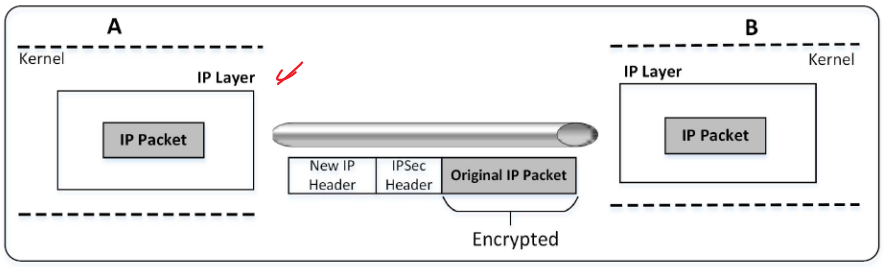
How VPN Works

Solutions


Safebox
Organization
Tunnel
Encrypted, Integrity,
VPN Server
A
private network

IP Tunneling

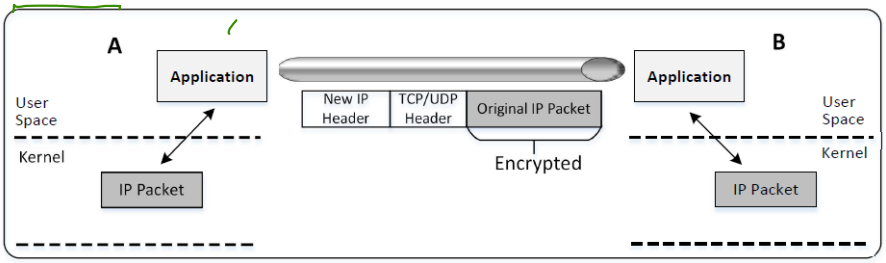
❖ IPSec Approach



IP packet

IPSec

❖ SSL/TLS Approach



User Space

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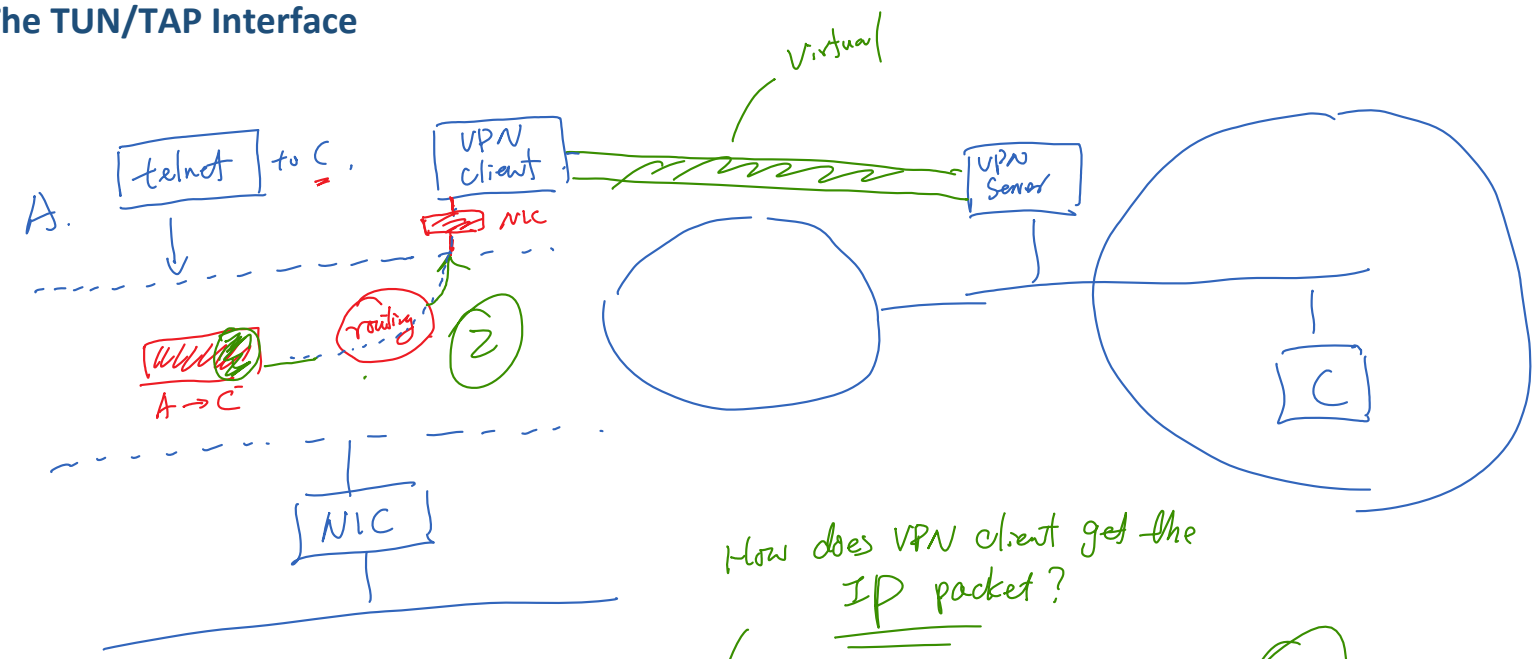
VPN Implementation I

The TUN/TAP Interface



How does VPN client get the IP packet?

TUN/TAP interface. 1

Create a TUN Interface (Virtual Network Interface)

❖ Code.

```
int tunfd;
struct ifreq ifr;
memset(&ifr, 0, sizeof(ifr));

ifr.ifr_flags = IFF_TUN | IFF_NO_PI;

tunfd = open("/dev/net/tun", O_RDWR);
ioctl(tunfd, TUNSETIFF, &ifr);
```

Virtual Interface

❖ Compile and run the code.

```
seed@ubuntu(10.0.2.18):~/vpn/TunDemo$ gcc -o tundemo tundemo.c
seed@ubuntu(10.0.2.18):~/vpn/TunDemo$ sudo ./tundemo
TUN file descriptor: 3
[07/01/16 15:57] root@ubuntu:.../TunDemo#
```

❖ Check the interface.

new NIC

```
seed@ubuntu(10.0.2.18):~/vpn$ ifconfig tun0
tun0      Link encap:UNSPEC  HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
          POINTOPOINT NOARP MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:500
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

❖ Assign an IP address to the tun0 interface.

assign IP.

```
seed@ubuntu(10.0.2.18):~/vpn$ sudo ifconfig tun0 10.0.4.99/24 up
seed@ubuntu(10.0.2.18):~/vpn$ ifconfig tun0
tun0      Link encap:UNSPEC  HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
          inet addr:10.0.4.99  P-t-P:10.0.4.99  Mask:255.255.255.0
          UP POINTOPOINT RUNNING NOARP MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:500
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

❖ Check the route for the 10.0.4.0/24 network (the route is automatically added).

```
seed@ubuntu(10.0.2.18):~/vpn$ route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         10.0.2.1        0.0.0.0         UG    0      0        0 eth18
```

```
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         10.0.2.1        0.0.0.0         UG    0      0        0 eth18
10.0.2.0        *               255.255.255.0   U     1      0        0 eth18
10.0.4.0        *               255.255.255.0   U     0      0        0 tun0
link-local      *               255.255.0.0     U     1000   0        0 eth18
192.168.56.0    *               255.255.255.0   U     1      0        0 eth16
```

If the route is not there, use the following command to add it:

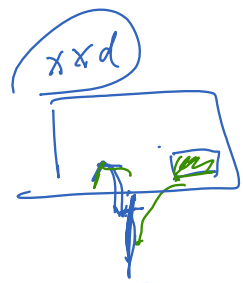
```
$ sudo route add -net 10.0.4.0/24 tun0
```

Read From and Write to the TUN Interface

❖ **Read from the TUN interface (`ping 10.0.4.32`).**

file descriptor 3

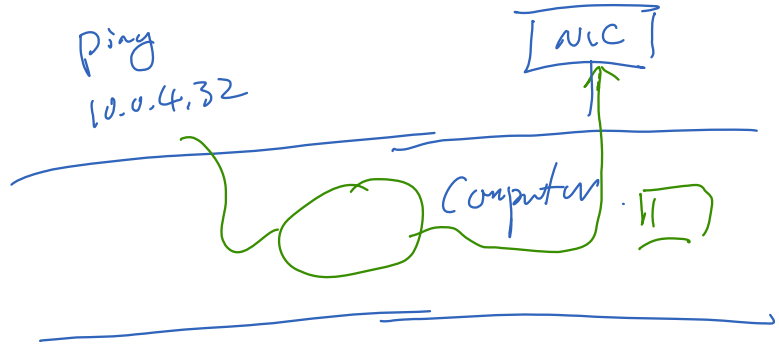
```
[07/01/16 15:58] root@ubuntu:.../TunDemo# xxd <& 3
0000000: 4500 0054 0000 4000 4001 1e27 0a00 0463  E..T..@.@..'...c
0000010: 0a00 0420 0800 fb1d 10f5 0001 fbcb 7657  ... ..........vW
0000020: 87c5 0700 0809 0a0b 0c0d 0e0f 1011 1213  ................
0000030: 1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
0000040: 2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
0000050: 3435 3637 4500 0054 0000 4000 4001 1e27  4567E..T..@.@..'
```



❖ **Write to the TUN interface.**

cat file >& 3

IP packet



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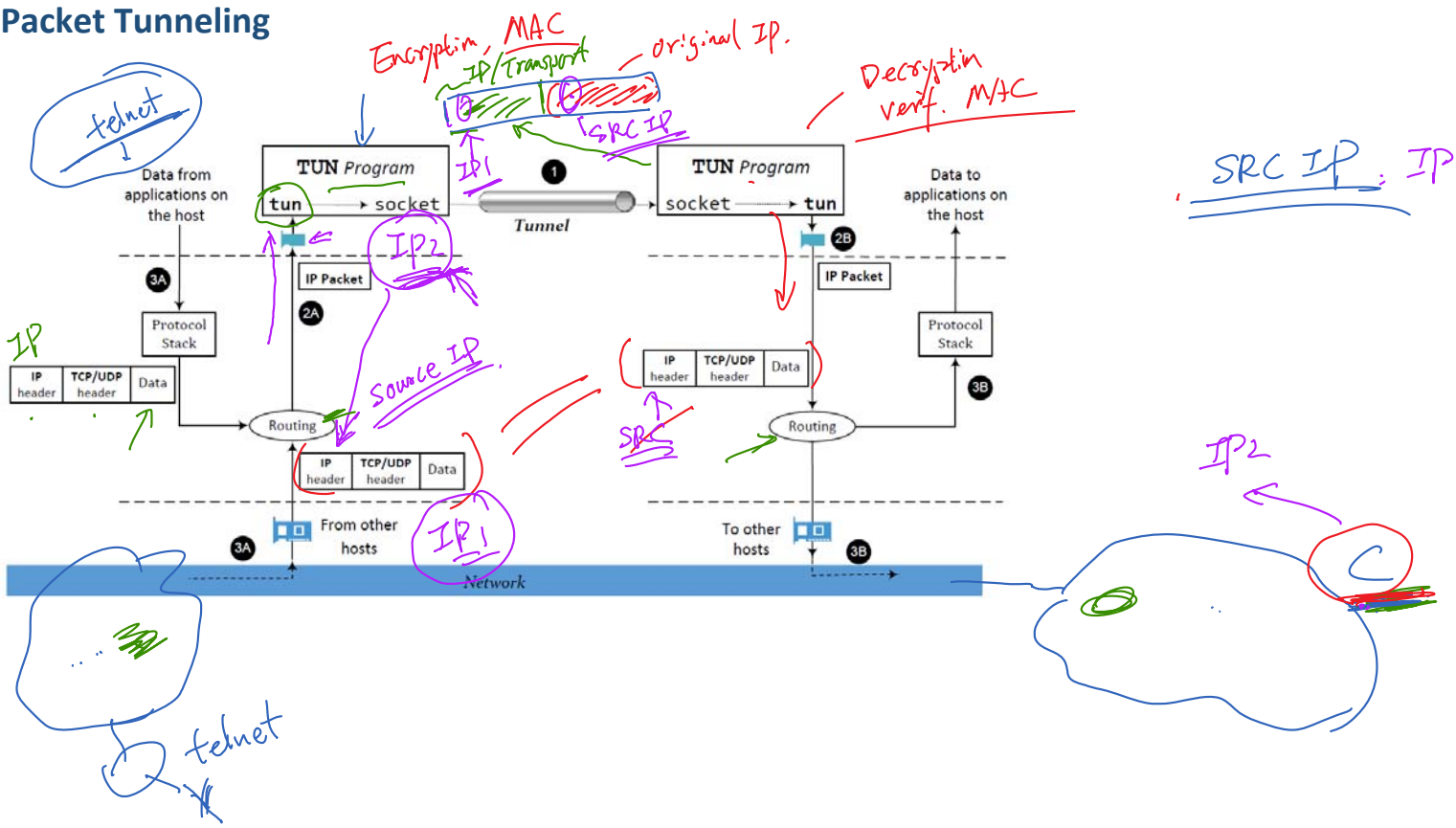
VPN Implementation II

Packet Tunneling



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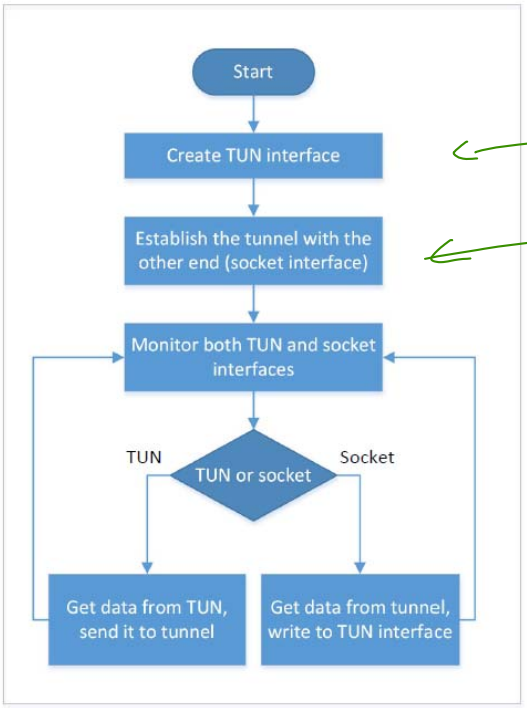
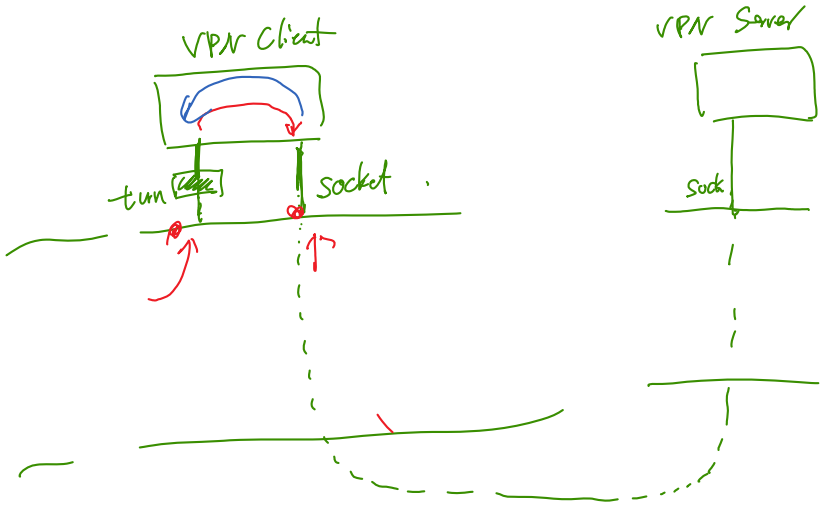
VPN Code Explanation I

VPN Implementation Code: The Overall Flow





Establish the Tunnel

VPN Client

```c
int connectToUDPServer(){
    int sockfd;
    char *hello="Hello";

    memset(&peerAddr, 0, sizeof(peerAddr));
    peerAddr.sin_family = AF_INET;
    peerAddr.sin_port = htons(PORT_NUMBER);
    peerAddr.sin_addr.s_addr = inet_addr(SERVER_IP);

    sockfd = socket(AF_INET, SOCK_DGRAM, 0);

    // Send a hello message to "connect" with the VPN server
    sendto(sockfd, hello, strlen(hello), 0,
                (struct sockaddr *) &peerAddr, sizeof(peerAddr));

    return sockfd;
}
```

VPN Server

```c
int initUDPServer() {
    int sockfd;
    struct sockaddr_in server;
    char buff[100];

    memset(&server, 0, sizeof(server));
    server.sin_family = AF_INET;
    server.sin_addr.s_addr = htonl(INADDR_ANY);
    server.sin_port = htons(PORT_NUMBER);

    sockfd = socket(AF_INET, SOCK_DGRAM, 0);
    bind(sockfd, (struct sockaddr*) &server, sizeof(server));

    // Wait for the VPN client to "connect".
    bzero(buff, 100);
    int peerAddrLen = sizeof(struct sockaddr_in);
    int len = recvfrom(sockfd, buff, 100, 0,
                (struct sockaddr *) &peerAddr, &peerAddrLen);

    printf("Connected with the client: %s\n", buff);
    return sockfd;
}
```

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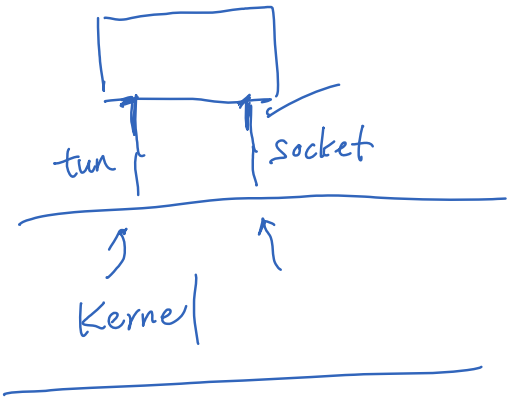
VPN Code Explanation II

Monitor the TUN and Socket Interfaces

```
// Enter the main loop
while (1) {
   int ret;
   fd_set readFDSet;

   FD_ZERO(&readFDSet);
   FD_SET(sockfd, &readFDSet);
   FD_SET(tunfd, &readFDSet);
   ret = select(FD_SETSIZE, &readFDSet, NULL, NULL, NULL);

   if (FD_ISSET(tunfd, &readFDSet))
       tunSelected(tunfd, sockfd);

   if (FD_ISSET(sockfd, &readFDSet))
       socketSelected(tunfd, sockfd);
}
```

set of interfaces

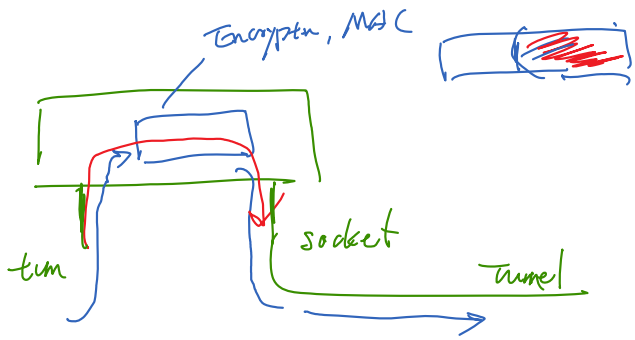
blocked on interface



Transfer Data Between TUN and Tunnel

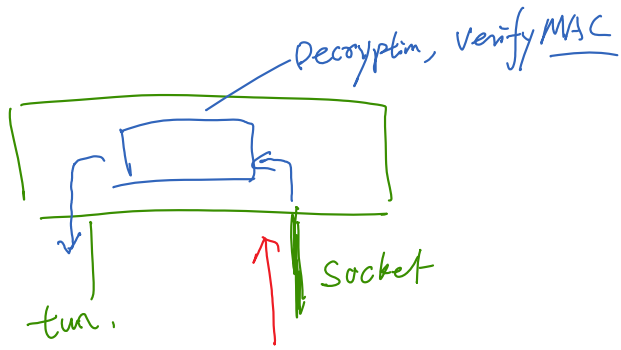
❖ From TUN to tunnel

```
void tunSelected(int tunfd, int sockfd){
    int  len;
    char buff[BUFF_SIZE];

    printf("Got a packet from TUN\n");

    bzero(buff, BUFF_SIZE);
    len = read(tunfd, buff, BUFF_SIZE);
    sendto(sockfd, buff, len, 0, (struct sockaddr *) &peerAddr,
                 sizeof(peerAddr));
}
```



❖ From tunnel to TUN

```
void socketSelected (int tunfd, int sockfd){
    int  len;
    char buff[BUFF_SIZE];

    printf("Got a packet from the tunnel\n");

    bzero(buff, BUFF_SIZE);
    len = recvfrom(sockfd, buff, BUFF_SIZE, 0, NULL, NULL);
    write(tunfd, buff, len);
}
```



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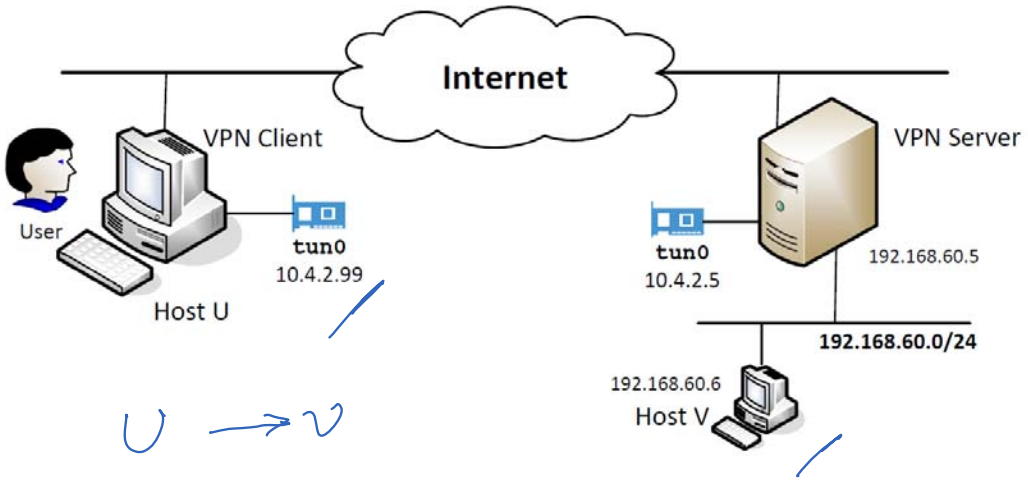
Set Up a VPN

Network Setup

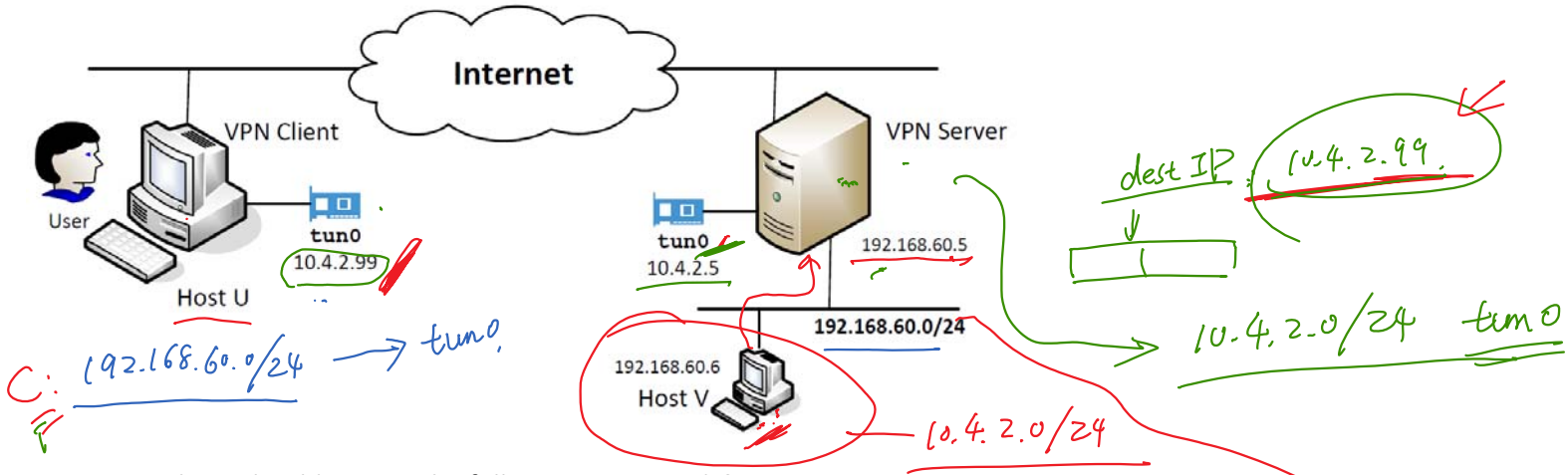


Set up routing

private

U → V

Question: Network Setup



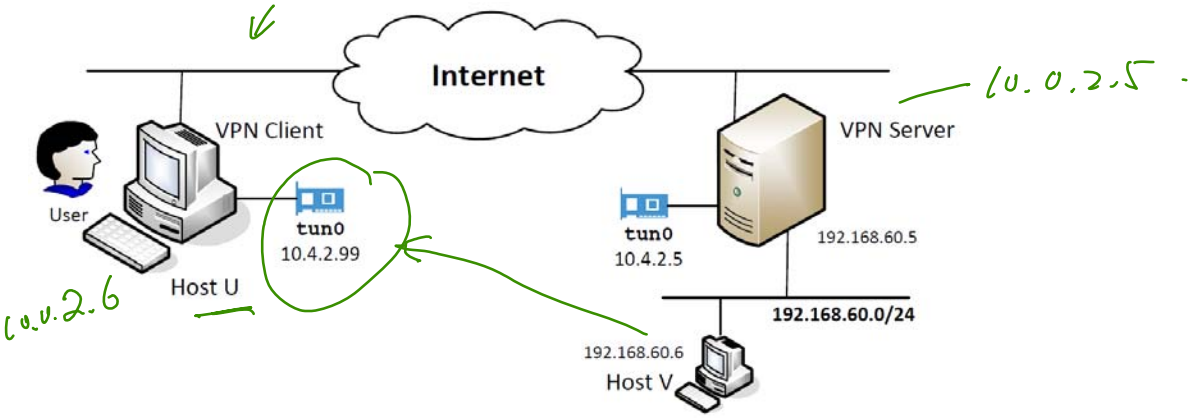
Question: Where should we run the following commands?

```
A: $ sudo route add -net 10.4.2.0/24 gw 192.168.60.5 eth19
B: $ sudo route add -net 10.4.2.0/24 tun0
C: $ sudo route add -net 192.168.60.0/24 tun0
```

U VPN Server

Host U.

Testing VPN



No.	Source	Destination	Protocol	Length	Info
1	10.4.2.99	192.168.60.6	ICMP	100	Echo (ping) request id=0x0e85, seq=1/256, ttl=64
2	10.0.2.6	10.0.2.5	UDP	128	Source port: 59793 Destination port: 55555
3	10.0.2.5	10.0.2.6	UDP	128	Source port: 55555 Destination port: 59793
4	192.168.60.6	10.4.2.99	ICMP	100	Echo (ping) reply id=0x0e85, seq=1/256, ttl=63
5	10.4.2.99	192.168.60.6	ICMP	100	Echo (ping) request id=0x0e85, seq=2/512, ttl=64
6	10.0.2.6	10.0.2.5	UDP	128	Source port: 59793 Destination port: 55555
7	10.0.2.5	10.0.2.6	UDP	128	Source port: 55555 Destination port: 59793
8	192.168.60.6	10.4.2.99	ICMP	100	Echo (ping) reply id=0x0e85, seq=2/512, ttl=63

not protected

tunnel

reply

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Find the IP Address

Answer: Find the IP Addresses

SU's VPN is called SURA. If you run SURA on your computer, once you have logged in, a VPN tunnel will be established between your host machine and SU's network (128.230.0.0/16). After I run SURA, the routing table on my computer appears as in the picture below. Please answer the following questions.

- What is my computer's real IP address (i.e., the IP address of my WiFi card)?
  - A. 10.1.63.255
  - B. **10.1.56.64**
  - C. 128.230.153.11
  - D. 128.230.153.98
  - E. 192.168.147.1

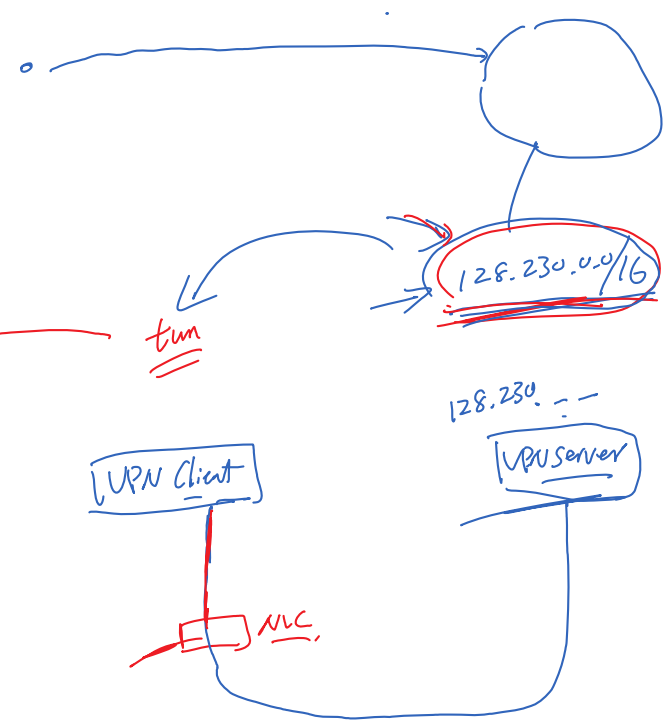
- What is the IP address of the VPN server?
  - A. 10.1.63.255
  - B. 10.1.56.64
  - C. **128.230.153.11**
  - D. 128.230.153.98
  - E. 192.168.147.1

- What is the IP address of my TUN interface?
  - A. 10.1.63.255
  - B. 10.1.56.64
  - C. 128.230.153.11
  - D. **128.230.153.98**
  - E. 192.168.147.1

IPv4 Route Table

Active Routes:

Network Destination	Netmask	Gateway	Interface	Metric
0.0.0.0	0.0.0.0	10.1.0.1	10.1.56.64	25
10.1.0.0	255.255.192.0	On-link	10.1.56.64	281
10.1.56.64	255.255.255.255	On-link	10.1.56.64	281
10.1.63.255	255.255.255.255	On-link	10.1.56.64	281
127.0.0.0	255.0.0.0	On-link	127.0.0.1	306
127.0.0.1	255.255.255.255	On-link	127.0.0.1	306
127.255.255.255	255.255.255.255	On-link	127.0.0.1	306
128.230.0.0	255.255.0.0	128.230.153.30	128.230.153.98	21
128.230.153.11	255.255.255.255	10.1.0.1	10.1.56.64	26
128.230.153.98	255.255.255.255	On-link	128.230.153.98	276
192.168.147.0	255.255.255.0	On-link	192.168.147.1	276
192.168.147.1	255.255.255.255	On-link	192.168.147.1	276
192.168.147.255	255.255.255.255	On-link	192.168.147.1	276
224.0.0.0	240.0.0.0	On-link	127.0.0.1	306
224.0.0.0	240.0.0.0	On-link	192.168.147.1	276
224.0.0.0	240.0.0.0	On-link	10.1.56.64	281
224.0.0.0	240.0.0.0	On-link	128.230.153.98	276
255.255.255.255	255.255.255.255	On-link	127.0.0.1	306
255.255.255.255	255.255.255.255	On-link	192.168.147.1	276
255.255.255.255	255.255.255.255	On-link	10.1.56.64	281
255.255.255.255	255.255.255.255	On-link	128.230.153.98	276



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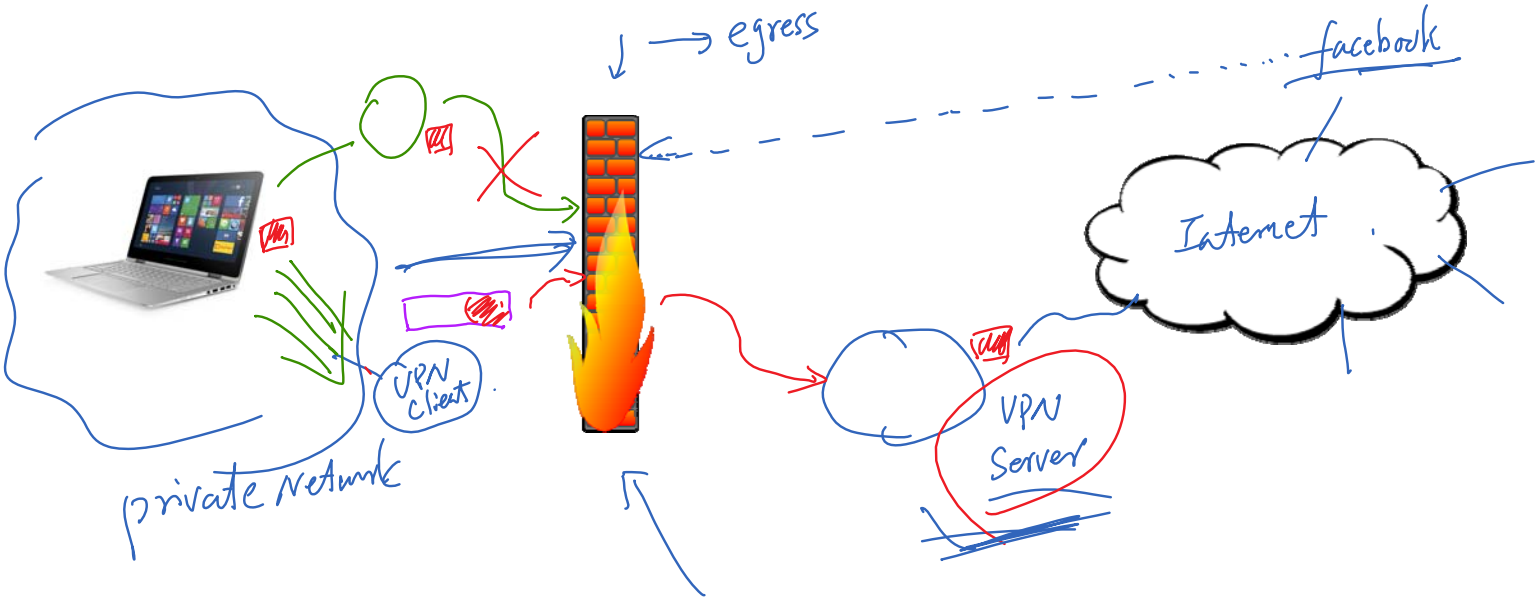
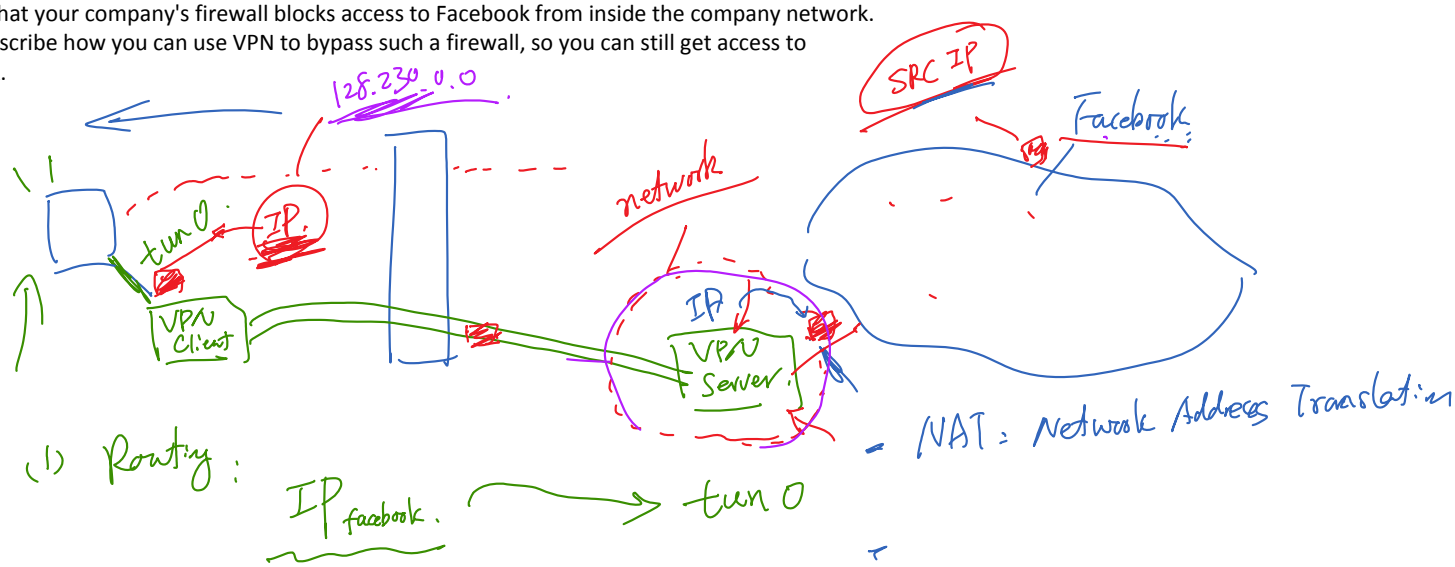
Bypassing Firewalls Using VPN

Bypassing Firewalls: Another Popular Use of VPN



Question: Bypassing Firewall

Assume that your company's firewall blocks access to Facebook from inside the company network. Please describe how you can use VPN to bypass such a firewall, so you can still get access to Facebook.



(1) Routing:

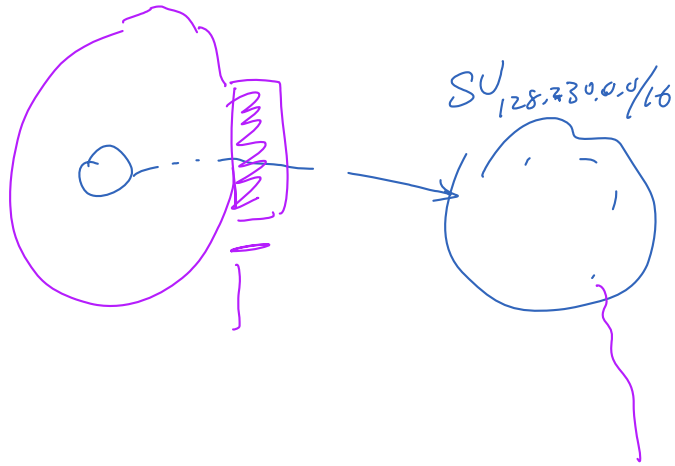
$IP_{facebook}$ → tun0

(2)

SURA: Before Running VPN

❖ Interfaces

```
PS C:\Users\kevin> ipconfig

Windows IP Configuration


Wireless LAN adapter Wireless Network Connection 2:

   Media State . . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wireless Network Connection:

   Connection-specific DNS Suffix  . : syr.edu
   Link-local IPv6 Address . . . . . : fe80::30c5:d02c:ed1d:2d2e%13
   IPv4 Address. . . . . . . . . . . : 10.1.56.64
   Subnet Mask . . . . . . . . . . . : 255.255.192.0
   Default Gateway . . . . . . . . . : 10.1.0.1
```



❖ Routing table (Windows: Route PRINT)

```
IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0         10.1.0.1       10.1.56.64     25
         10.1.0.0    255.255.192.0         On-link        10.1.56.64    281
       10.1.56.64  255.255.255.255         On-link        10.1.56.64    281
      10.1.63.255  255.255.255.255         On-link        10.1.56.64    281
        127.0.0.0        255.0.0.0         On-link         127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link         127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link         127.0.0.1    306
    192.168.147.0    255.255.255.0         On-link     192.168.147.1    276
    192.168.147.1  255.255.255.255         On-link     192.168.147.1    276
  192.168.147.255  255.255.255.255         On-link     192.168.147.1    276
        224.0.0.0        240.0.0.0         On-link         127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link     192.168.147.1    276
        224.0.0.0        240.0.0.0         On-link        10.1.56.64    281
  255.255.255.255  255.255.255.255         On-link         127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link     192.168.147.1    276
  255.255.255.255  255.255.255.255         On-link        10.1.56.64    281
===========================================================================
```

SURA: After Running VPN

❖ Interfaces

```
PS C:\Users\kevin> ipconfig

Windows IP Configuration


PPP adapter Syracuse University Remote Access VPN:

   Connection-specific DNS Suffix  . :
   IPv4 Address. . . . . . . . . . . : 128.230.153.98
   Subnet Mask . . . . . . . . . . . : 255.255.255.255
   Default Gateway . . . . . . . . . :

Wireless LAN adapter Wireless Network Connection 2:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wireless Network Connection:

   Connection-specific DNS Suffix  . : syr.edu
   Link-local IPv6 Address . . . . . : fe80::30c5:d02c:ed1d:2d2e%13
   IPv4 Address. . . . . . . . . . . : 10.1.56.64
   Subnet Mask . . . . . . . . . . . : 255.255.192.0
   Default Gateway . . . . . . . . . : 10.1.0.1
```

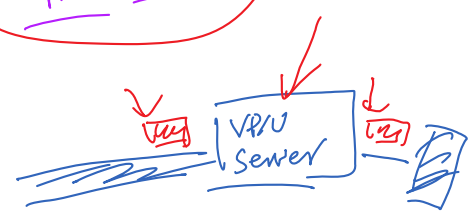
❖ Routing table

IP facebook → Interface 128.230.153.98

real NIC

```
IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0         10.1.0.1      10.1.56.64     25
         10.1.0.0    255.255.192.0         On-link       10.1.56.64    281
       10.1.56.64  255.255.255.255         On-link       10.1.56.64    281
      10.1.63.255  255.255.255.255         On-link       10.1.56.64    281
        127.0.0.0        255.0.0.0         On-link        127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link        127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link        127.0.0.1    306
      128.230.0.0      255.255.0.0   128.230.153.30  128.230.153.98     21
  128.230.153.11  255.255.255.255         10.1.0.1      10.1.56.64     26
  128.230.153.98  255.255.255.255         On-link    128.230.153.98    276
    192.168.147.0    255.255.255.0         On-link     192.168.147.1    276
    192.168.147.1  255.255.255.255         On-link     192.168.147.1    276
  192.168.147.255  255.255.255.255         On-link     192.168.147.1    276
        224.0.0.0        240.0.0.0         On-link        127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link     192.168.147.1    276
        224.0.0.0        240.0.0.0         On-link       10.1.56.64    281
        224.0.0.0        240.0.0.0         On-link    128.230.153.98    276
  255.255.255.255  255.255.255.255         On-link        127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link     192.168.147.1    276
  255.255.255.255  255.255.255.255         On-link       10.1.56.64    281
  255.255.255.255  255.255.255.255         On-link    128.230.153.98    276
===========================================================================
```

VPN NIC



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Summary

Summary

- The concept of VPN
- How VPN works
  - SSL/TLS VPN
  - Tun/Tap interface
  - Routing setup
- VPN implementation (code explanation)
- Bypassing firewalls using VPN

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