Virtual Private Networks

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Outline

- What is VPN?
- Overview of TLS VPN
- TLS VPN Details
- Building a VPN

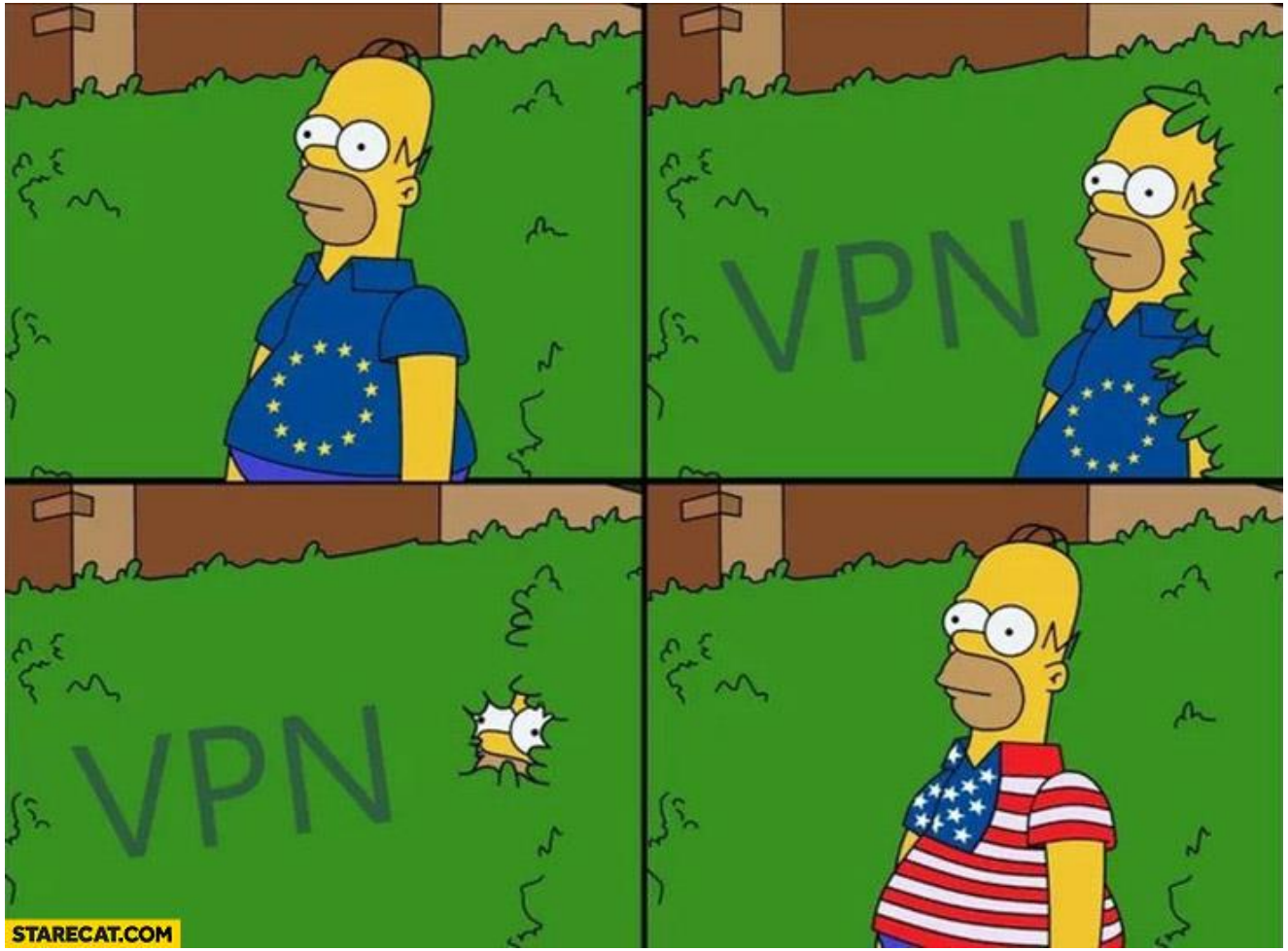
What is VPN?

VPN: Use Cases

Protect yourself from hackers in untrustworthy Wi-Fi hotspots

VPN: Use Cases

Bypass geographic restrictions

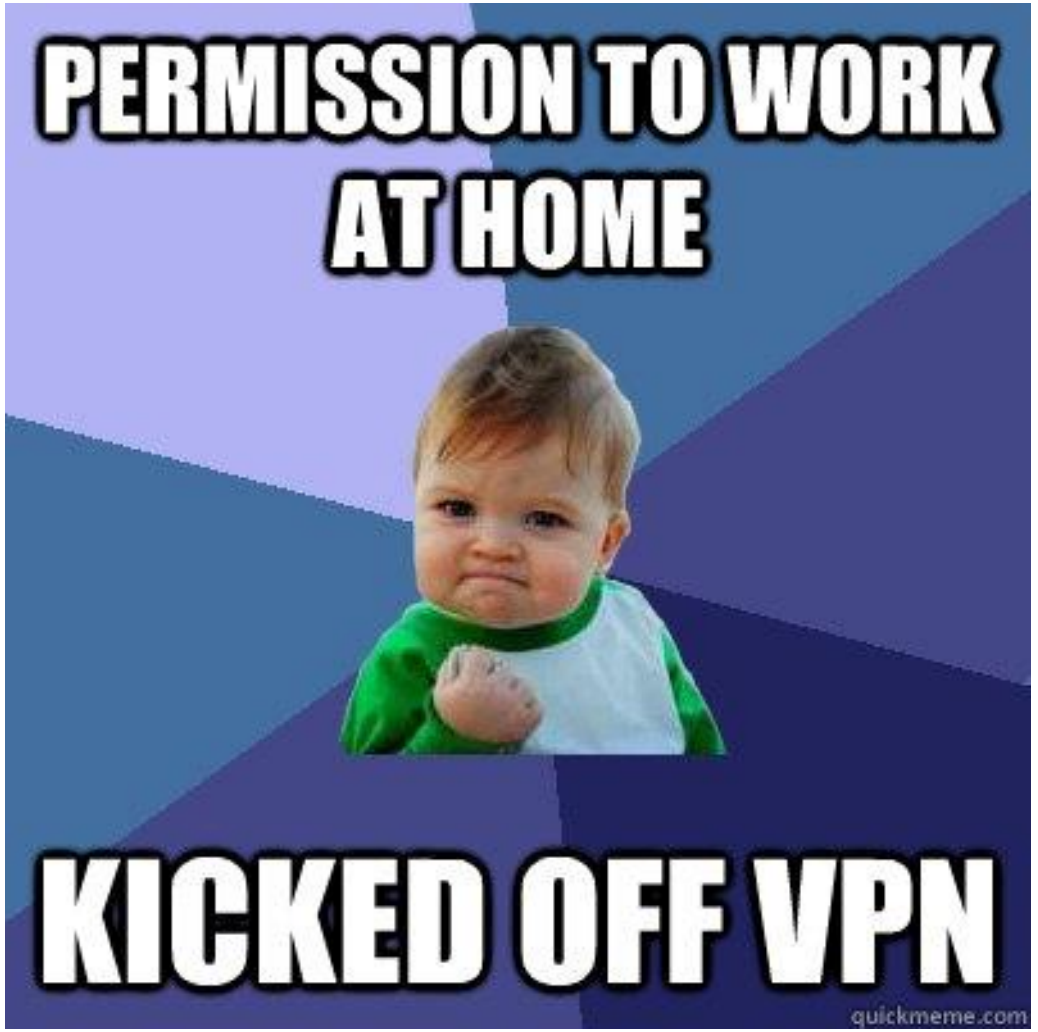


VPN: Use Cases

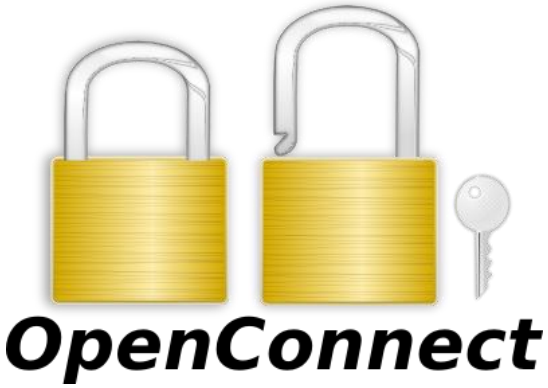
Bypassing egress filtering at firewalls

VPN: Use Cases

Extend private network (e.g., enterprise, home, etc.)



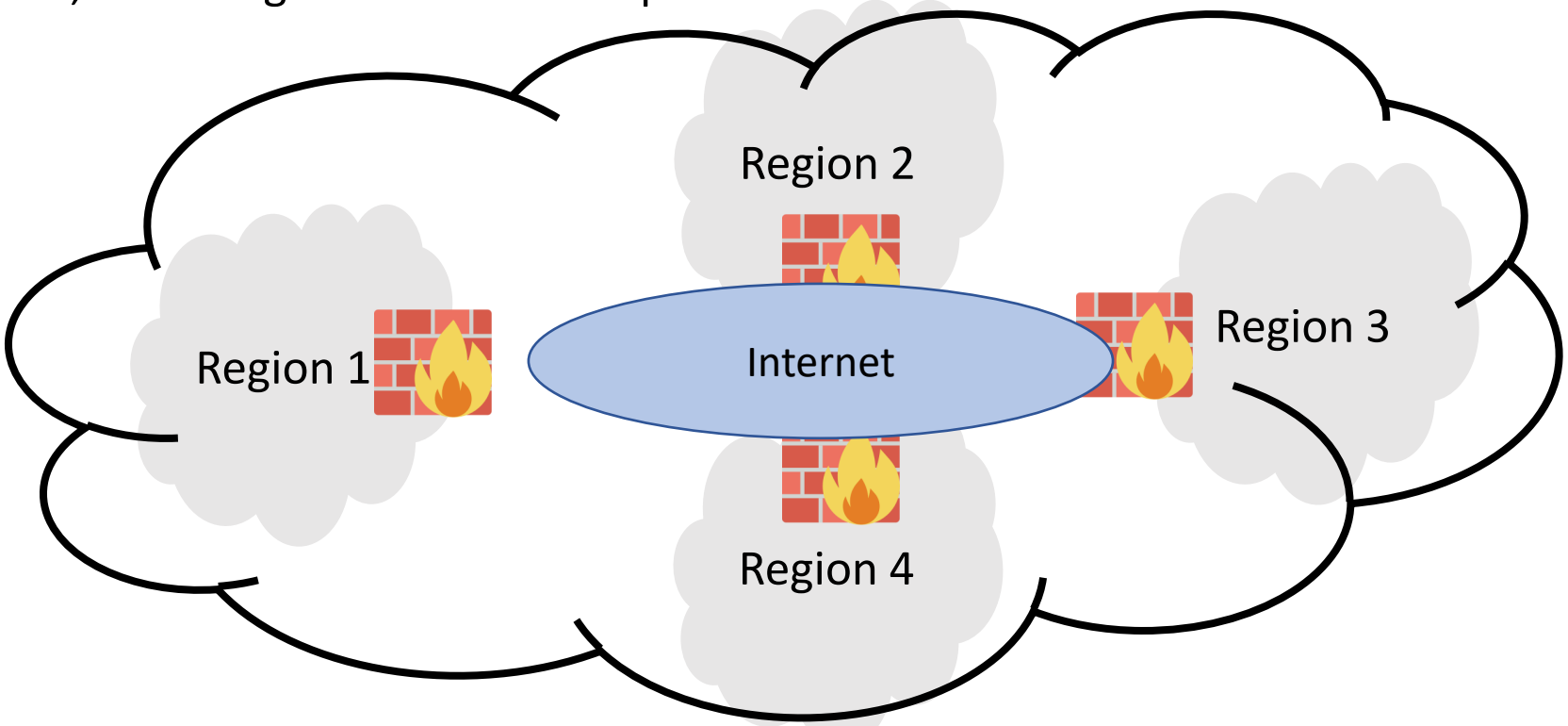
Many VPN Options



And other commercial VPN software

Motivation

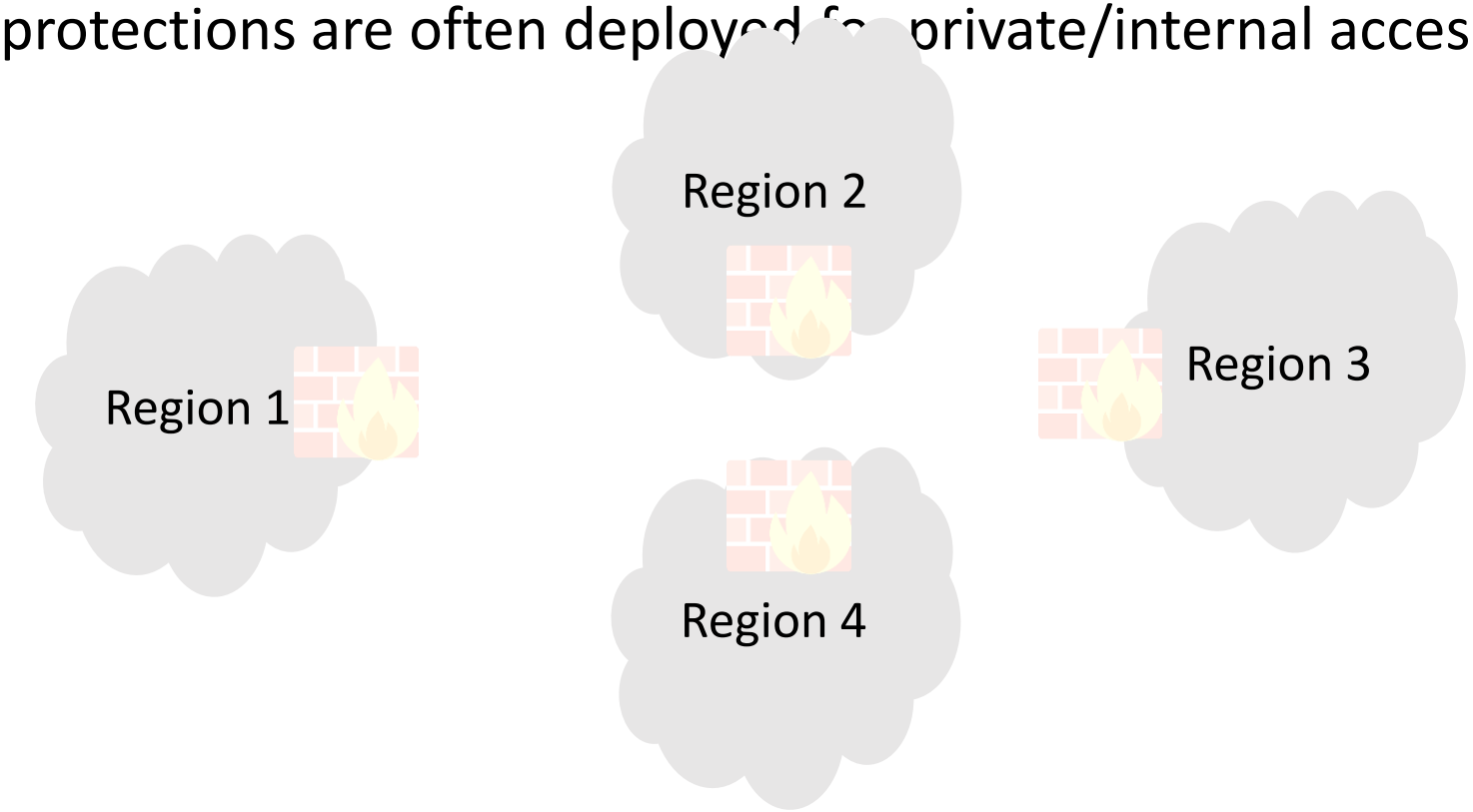
- As enterprises grow:
  - Their private networks deployed to different geographical regions
  - Employees need while travelling or at home
    - i.e., accessing resources inside private networks



Should act as a single **private** network

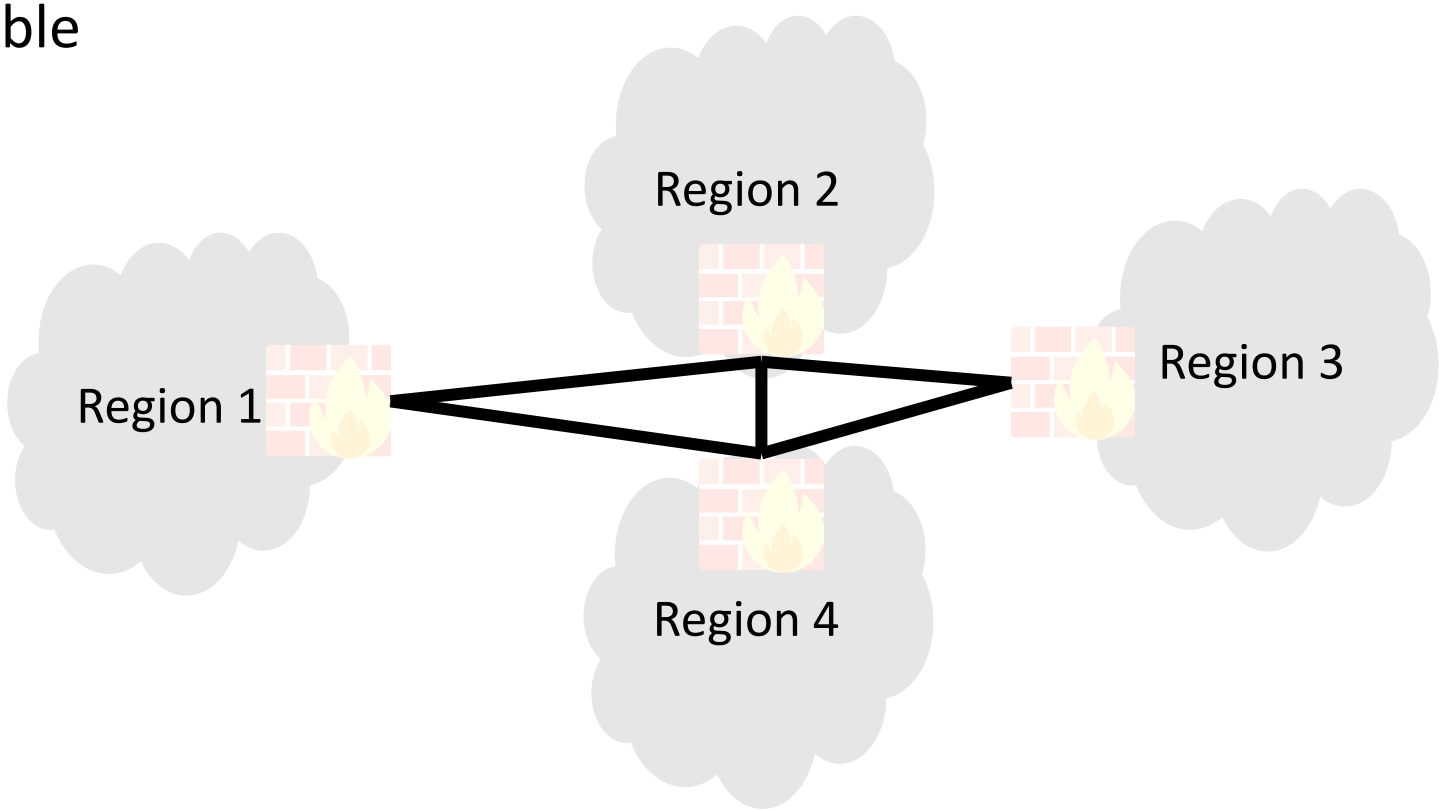
Option #1

- Relax firewall policies to allow external networks/users
- Drawbacks:
  - Increasing the attack surface and risks
  - Simple protections are often deployed for private/internal accesses



Option #2

- Lease/own dedicated links between sites
- Drawbacks:
  - Expensive
  - Not flexible



Other Options?

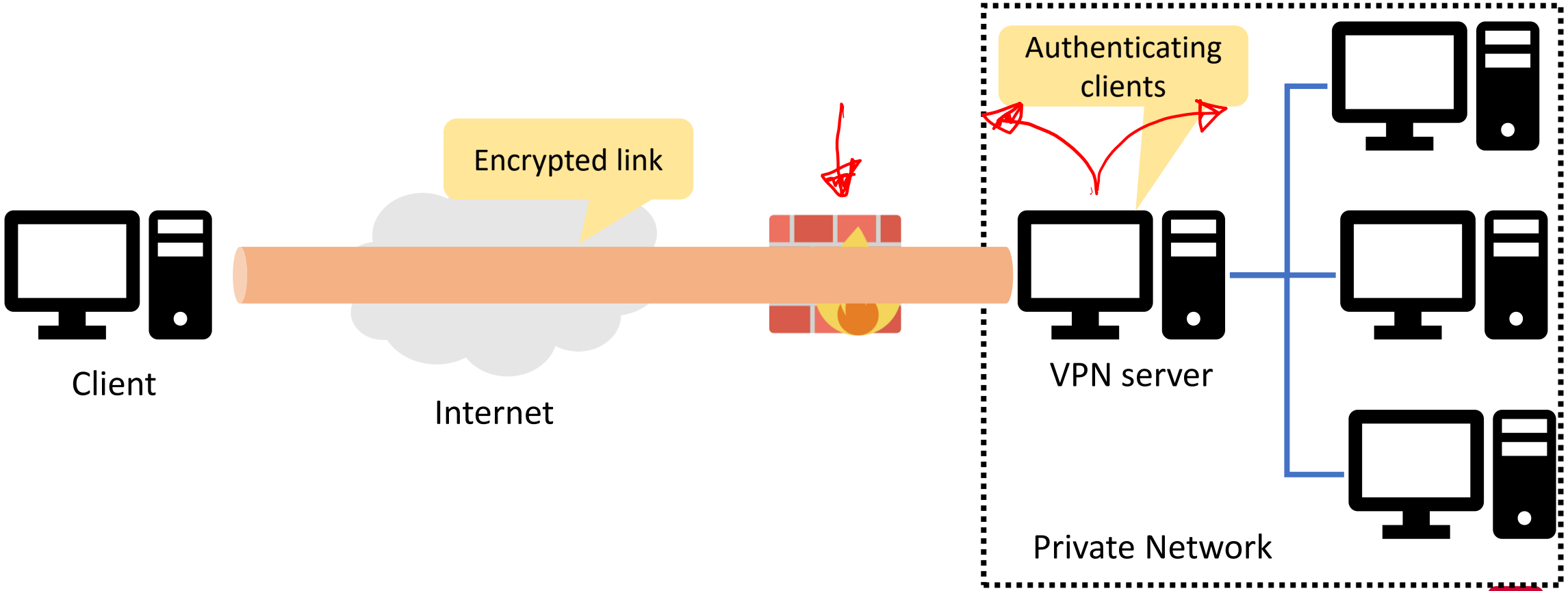
- Instead, we need to think:
  - of what protection guarantees are made by private networks
  - whether these guarantees are achieved if a host is outside the private network

Guarantees of a Private Network

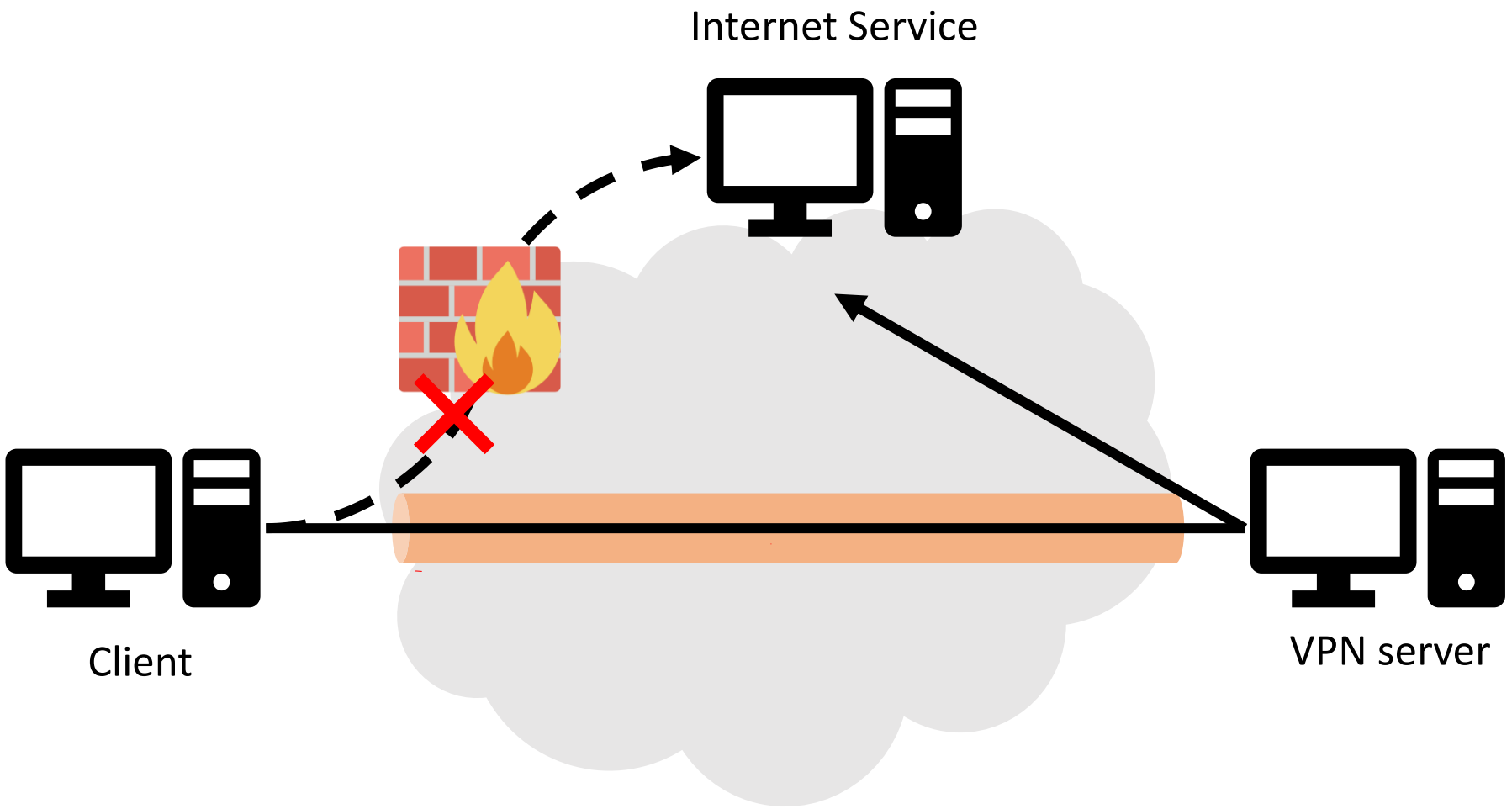
- User authenticated
  - Verified identity
- Content protected
  - Content of communication cannot be seen from the outside
- Integrity preserved
  - Outsiders cannot inject fake data

What is a VPN?

- A private network consisting of hosts from both inside and outside
  - Virtual → because this network isn't **physically** private



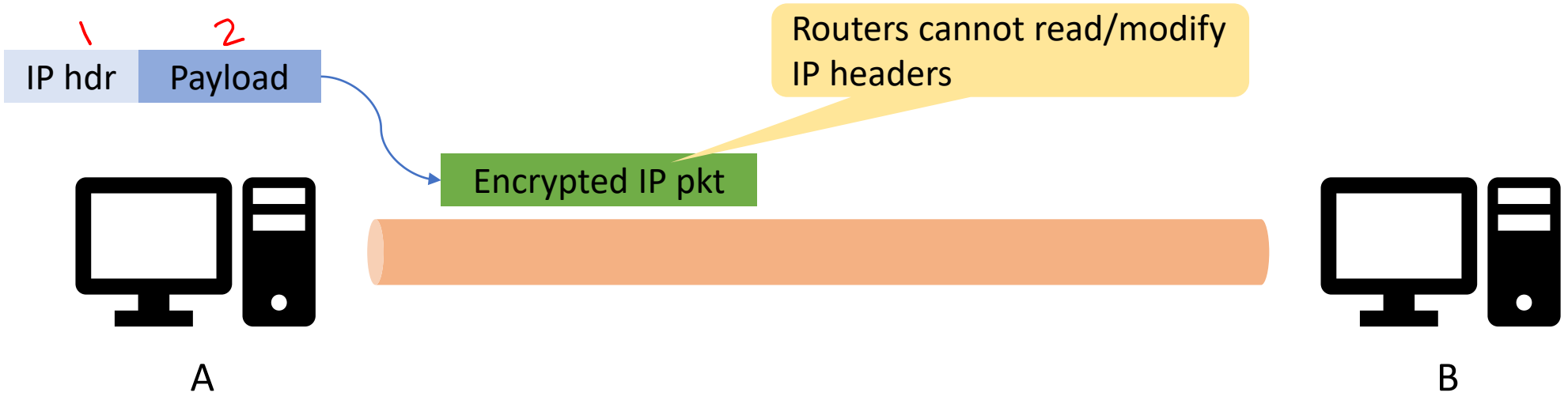
What is a VPN?



What is a VPN?

- Regardless of whether an application encrypts its data

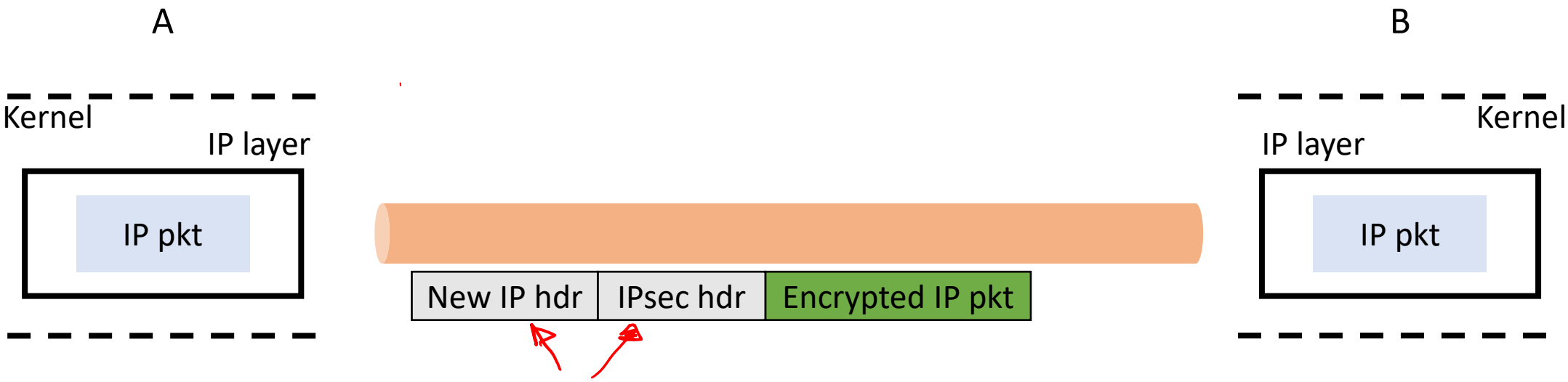
→ IP packets need to be encrypted (including headers)



- Two techniques to implement IP tunneling:
  - TIPsec Tunneling (using IPsec Tunnel Mode)
  - LS Tunneling

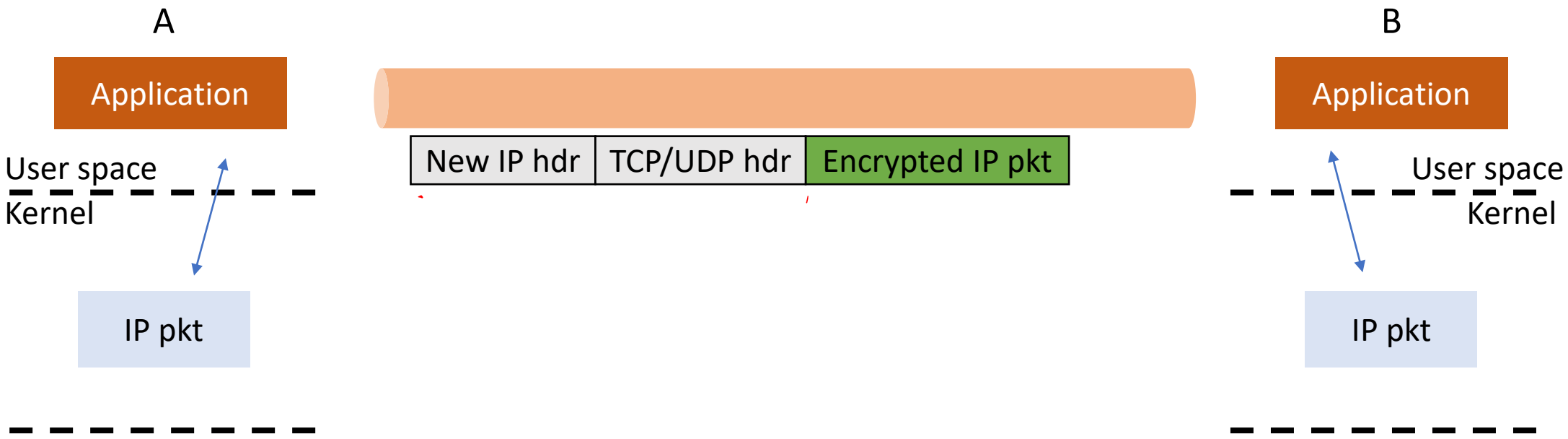
IPsec Tunneling: Tunnel Mode

- Encrypts the whole IP packet
- Encapsulates the encrypted IP packet with a new IP packet
- Operates at the kernel space



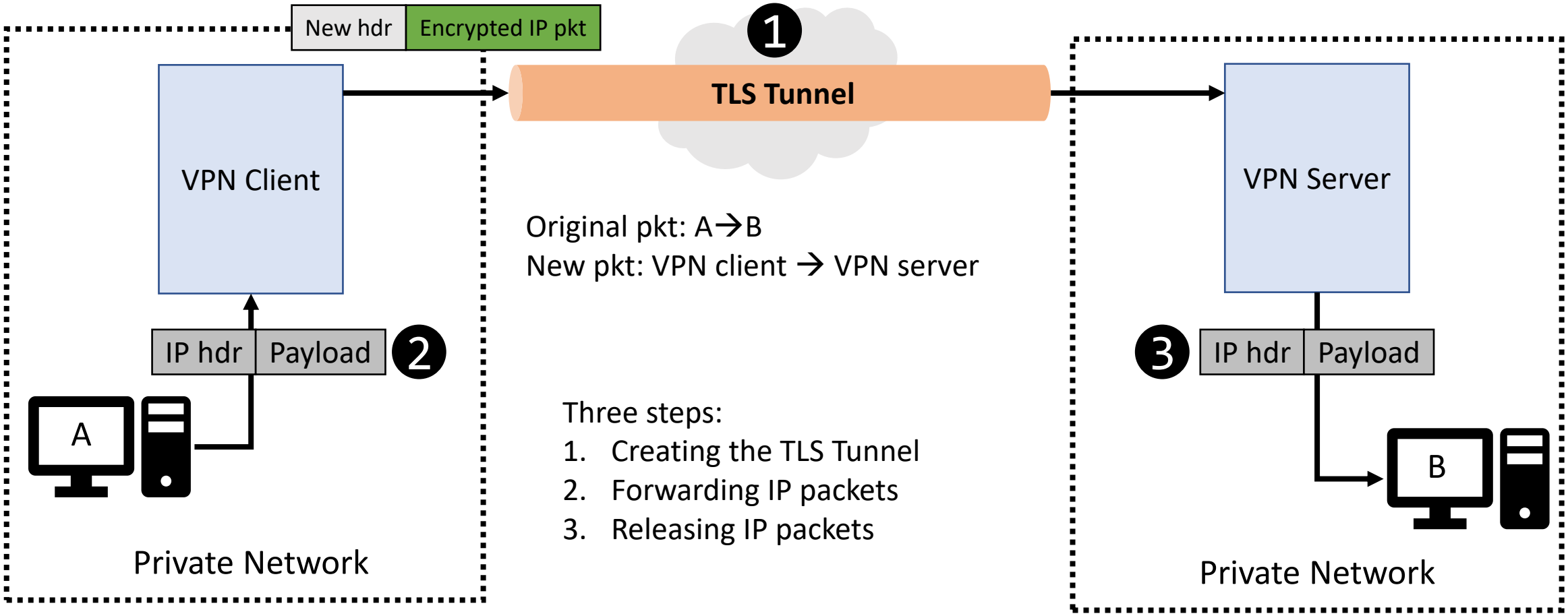
TLS Tunneling

- VPN-bound IP packets are handled by an application
- Encrypted using TLS protocol
- Operates at the application layer



Overview of TLS VPN

TLS-based VPN



Creating a Tunnel

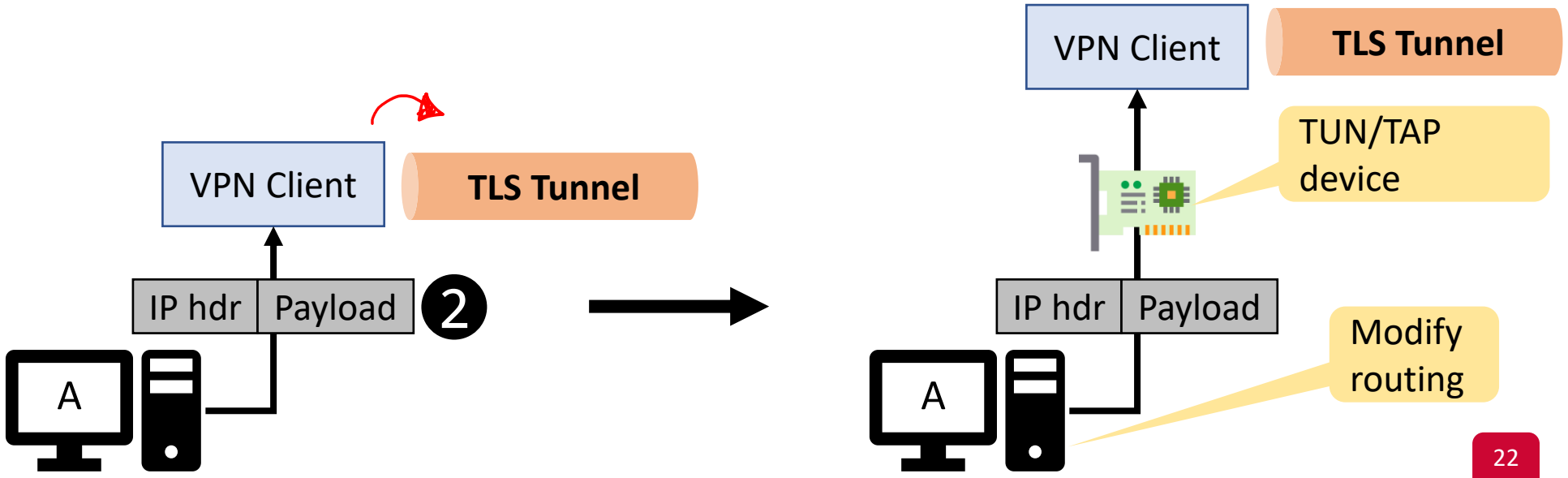
- This is a TLS channel
- It is built on top of a transport-layer protocol

- Before creating a channel, mutual authentication is needed:
  - Server authenticates client: e.g., using passwords
  - Client authenticates server: e.g., using certificates

Forwarding IP Packets

- VPN Client needs to receive the whole IP pkt to encrypt it
  - The kernel removes these headers

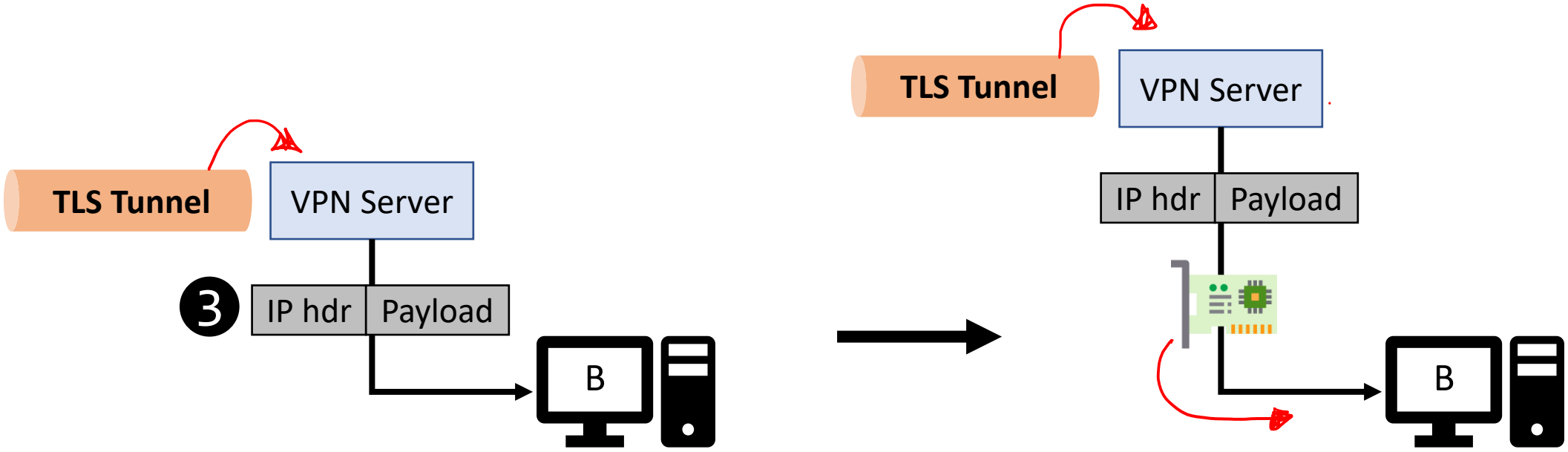
- How can an application receive the whole pkt?
  - Create a TUN/TAP device
  - Modify routing table: All VPN-bound traffic goes to the new device



Releasing IP Packets

- VPN Server needs to release the original IP pkt after decrypting it

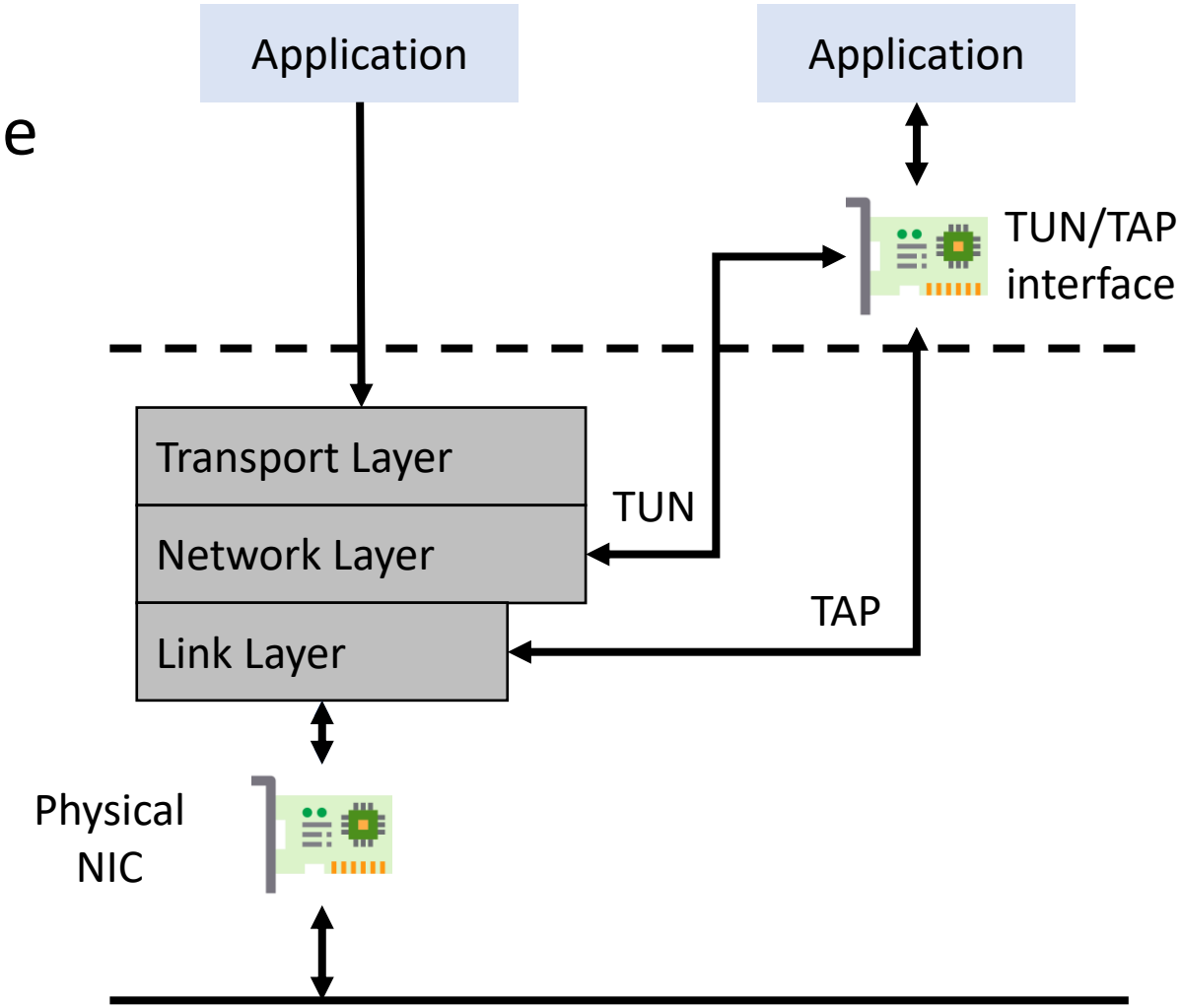
- How can an application send the whole pkt to the kernel?
  - Same idea as before



TLS VPN Details

Virtual Network Interfaces

- A virtual interface is a virtualized representation of a network interface
- TUN interface:
  - Works at the IP layer
  - Point-to-point is the default
  - Sending a pkt to a TUN interface will result in the pkt being delivered to the user-space program
- TAP interface:
  - Works at the Ethernet layer



Creating a TUN Interface

```
int createTunDevice()
{
   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);

   return tunfd;
}
```

No additional info sent by the driver

Create a TUN device

Register the device with the kernel

Configuring the TUN Interface

- We need to:
  - Specify what network the interface is connected to
  - Assign an IP address to the interface
  - Activate the interface

$ ifconfig -a
tun0

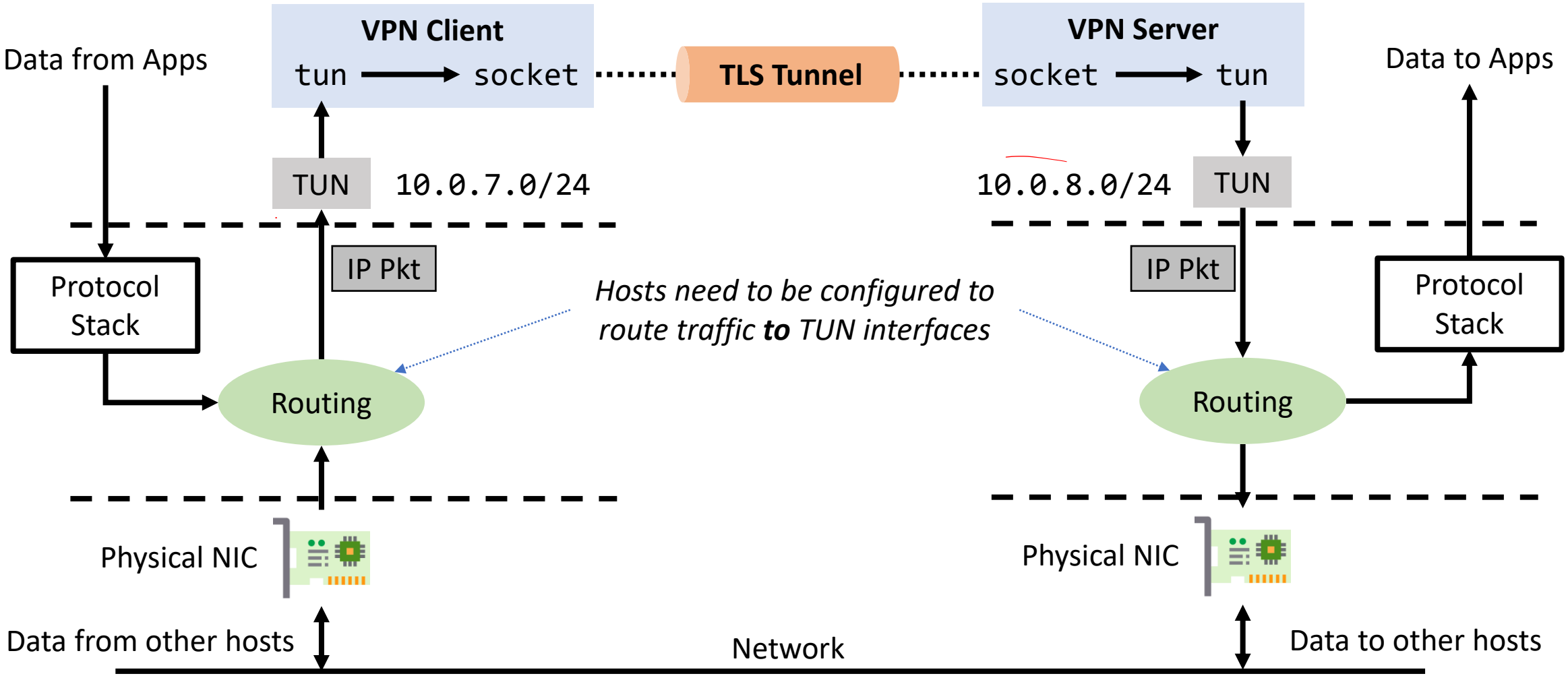
IP

up

```
$ sudo ifconfig tun0 10.0.7.99/24 up
```

net- 10.0.7.0/24

What is missing?



Routing Packets

- Routing is modified by configuring routing tables
  - Traffic to `10.0.8.0/24` goes through `tun0`

```
$ sudo route add -net 10.0.8.0/24 tun0
```

- Packets written to `tun0` are received by our VPN application
  - Should be forwarded to the TLS tunnel
- Packets written to socket are received on the other side

Building a VPN

Overview of Our VPN Program

Overview of Our VPN Program

Establishing the IP Tunnel

- We build a simple UDP-based tunnel with no encryption.

- The server:
  - Creates a socket
  - Binds to a specific port
  - Receives data from the client

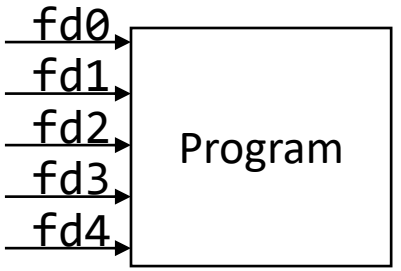
Decrypt

- The client:
  - Creates a socket
  - Sends data to the server

Encrypt

Monitoring File Descriptors

- Option #1: create a thread for each fd → inefficient



- Option #2: IO multiplexing allows:
  - Examining and blocking on multiple I/O streams
  - Notifying the program whenever any one of the streams is active so that it can process data on that stream

select poll epoll

- We will use `select` system call for our VPN

Monitoring File Descriptors

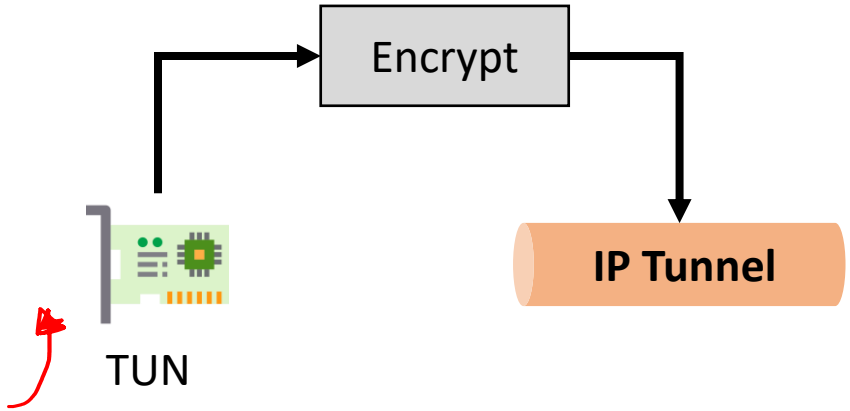
```
while (1) {
      fd_set readFDSet;
      FD_ZERO(&readFDSet);
      FD_SET(sockfd, &readFDSet);
      FD_SET(tunfd, &readFDSet);
      select(FD_SETSIZE, &readFDSet, NULL, NULL, NULL);

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

Register the fds

IO multiplexing

From TUN to Socket

- When the kernel sends an IP pkt to our VPN program

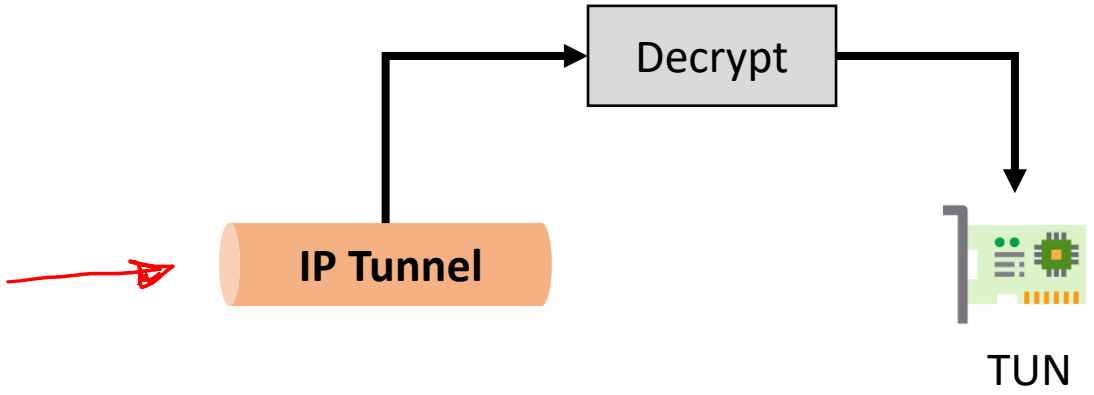



```
void tunSelected(int tunfd, int sockfd){
    int  len;
    char buff[BUFF_SIZE];
    bzero(buff, BUFF_SIZE);
    len = read(tunfd, buff, BUFF_SIZE);
    sendto(sockfd, buff, len, 0, (struct sockaddr *) &peerAddr,
                        sizeof(peerAddr));
}
```

Pkt should be encrypted

From Socket to TUN

- When our VPN program sends an IP pkt to the kernel




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

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

Pkt should be decrypted

Summary

- VPNs extend private networks to include hosts from the outside

- VPNs are implemented using IP tunneling
  - IPsec Tunnel Mode
  - TLS Tunneling