TCP/IP Overview

CYBR371: System and Network Security, (2024/T1)

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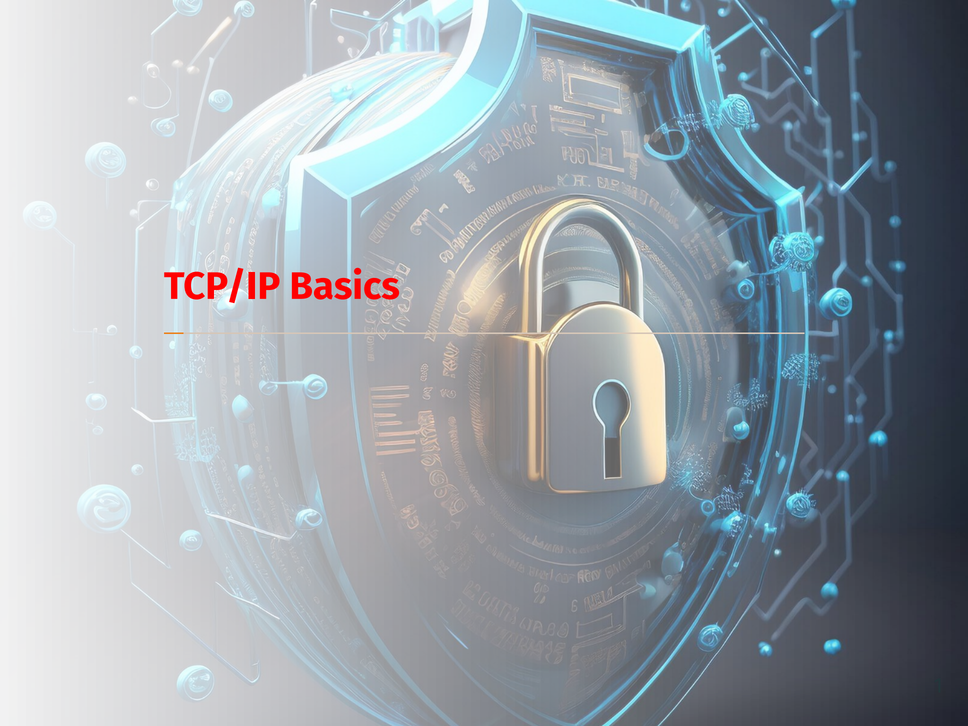
TCP/IP Basics



How Internet works

Protocol: Agreement on how to communicate.

Internet is based on the TCP/IP protocol.

Transmission Control Protocol / Internet Protocol (TCP/IP) is a suite of many protocols for transmitting information on a network.

- Often referred to as a “protocol stack”.

OSI and TCP/IP Models

OSI reference model: divides the communication functions used by two hosts into seven separate layers.

TCP/IP has its own stack of protocols.

OSI Layers	TCP/IP Layers
Application	Application
Presentation	
Session	
Transport	Transport
Network	Internet
Data Link	Network Interface
Physical	

Note: Direct or strict comparisons of the OSI and TCP/IP models should be avoided, because the layering in TCP/IP is not a principal design criterion.

TCP/IP Protocols

	TCP/IP layers	TCP/IP Protocols
Application Specific Semantics	Application	HTTP, DNS, BGP, NTP, SMTP, IMAP, FTP, NFS, SNMP
E2E communication between processes; Adds ports/reliability	Transport	TCP, UDP
Adds global addresses; Requires routing	Network	IP, ICMP
Adds framing & destination; Still assumes shared link. Broadcasts on shared link	Network Interface	Ethernet, 802.11 (wifi), High-Level Data Link Control (HDLC), Asynchronous Transfer Mode (ATM), PPP

TCP / IP Network

- THE NETWORK IS DUMB.
- **End-hosts** are the periphery (users, devices).
- **Routers** and **switches** are Intermediary devices that:
  - Route (figure out where to forward).
  - Forward (actually send).

Principles of IP:

- The routers have no knowledge of ongoing connections through them.
- They do "destination-based" routing and forwarding.
  - Given the destination IP address in the packet, send it to the "next hop" that is best suited to help ultimately get the packet there.

Types of Addresses in Internet

- Media Access Control (MAC) addresses in the network access layer.
  - Associated with network interface card (NIC).
  - 48 bits or 64 bits.
- IP addresses for the network layer.
  - 32 bits for IPv4, and 128 bits for IPv6.
  - e.g., **`128.3.23.3`**
- IP addresses + ports for the transport layer.
  - e.g., **`128.3.23.3:80`**
- Domain names for the application/human layer.
  - e.g., **`ecs.wgtn.ac.nz`**

Routing and Translation of Addresses

Translation between IP addresses and MAC addresses.

- Address Resolution Protocol (**ARP**) for IPv4.
- Neighbour Discovery Protocol (**NDP**) for IPv6.

Routing with IP addresses

- TCP, UDP, IP for routing packets, connections.
- Border Gateway Protocol (**BGP**) for routing table updates.

Translation between IP addresses and domain names

- Domain Name System (**DNS**).

Types of Addresses in Internet

Private IP address

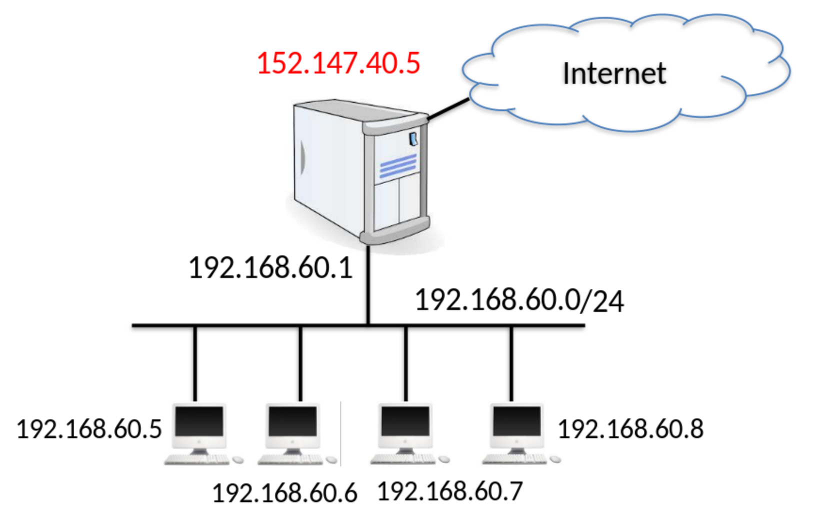
- Private addresses are not routable over the internet
  - **`10.0.0.0/8`** (**`10.x.x.x`**)
  - **`172.16.0.0/12`** (**`172.16.x.x`**)
  - **`192.168.0.0/16`** (**`192.168.x.x`**)

▶ **NAT** (Network Address Translation): the process of replacing a private IP address to a public IP address and vice-versa.

Loopback Address

- **`localhost`**, **`Interface lo`**
  - **`127.0.0.0/8`** (**`127.x.x.x`**)
  - Commonly used **`127.0.0.1`**

Network Address Translation (NAT)

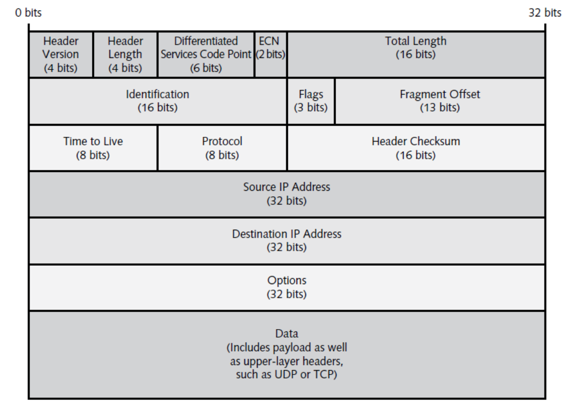


Networking

Data is transmitted in *small chunks*.

- At Level 3 these chunks are called packets.
- At Level 2 these chunks are called dataframe.

A packet/frame has 2 primary subdivisions: Header and Data.



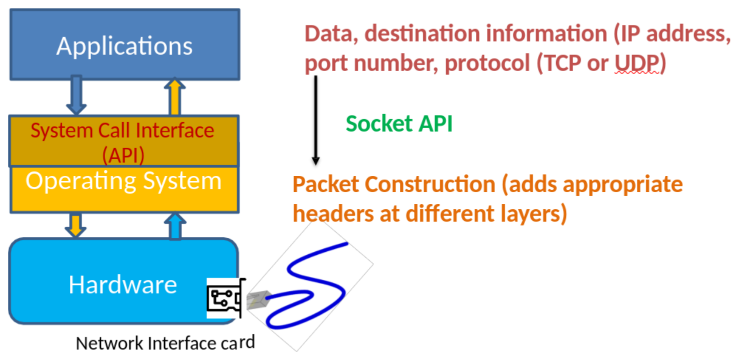
TCP / IP Security Issues

- Anyone can send to any port on any host.
- No check on authenticity of IP address.
- Network packets are not private (Intermediate networks cannot be trusted).
- TCP state is easy to guess.

Sending Packets

Creation of packets is handled by the OS.

In our programs, we specify the data that needs to be sent; the packets are then created by the OS and sent over the network to the destination.



Example Program to Send a Packet

SendPkt.py

```
import socket
IP = "127.0.0.1"
PORT = 9090
data = b'Hello World!'

sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
sock.sendto(data, (IP, PORT))
```

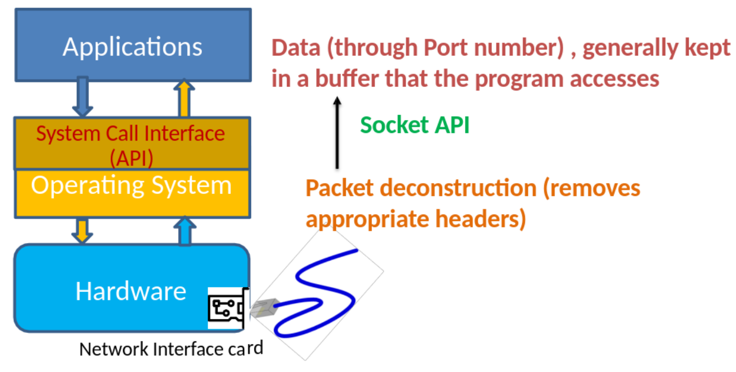
```
$ python SendPkt.py
```

```
$ nc -luvp 9090
```

Receiving Packets

Packets go through the network routers and eventually reach the destination IP address.

Packet at the destination goes through different layers, Data link, IP, Network layer; and finally data is handed over to the application (thorough the socket).



e.g. Program to receive a packet

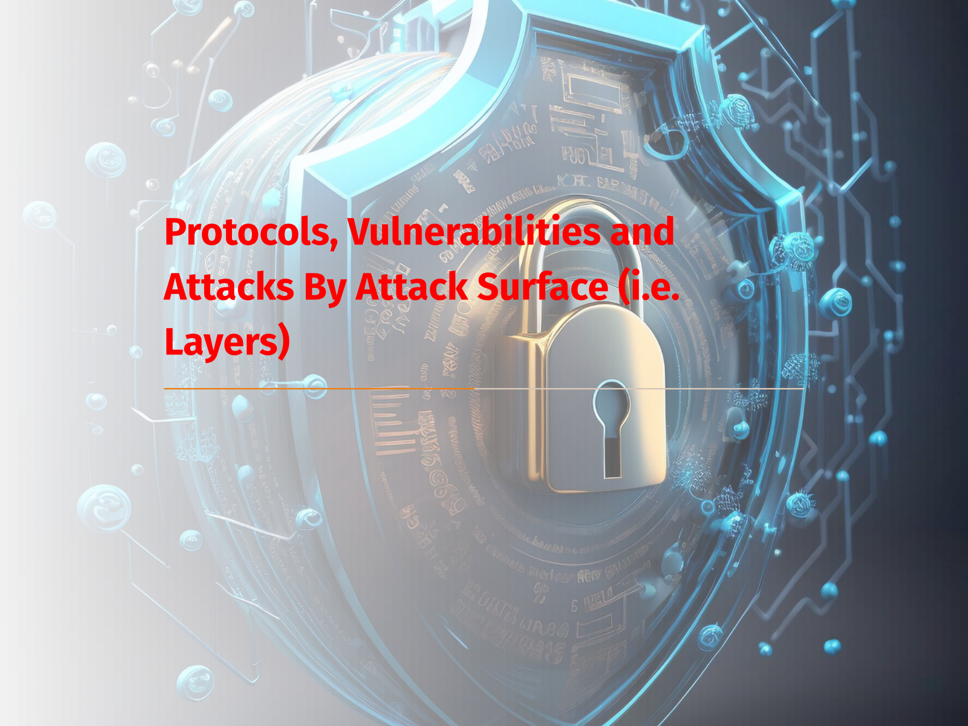
ReceivePkt.py

```
import socket

IP = "0.0.0.0"
PORT = 9090
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
sock.bind(IP, PORT)

While True:
    data, (ip, port) = sock.recvfrom(1024)
    print("Sender: {} and Port: {}".format(ip, port))
    print("Received Message: {}".format(data))
```

```
$ nc -u <IP address> -p 9090
```

Why did we not bind the client with a port number?

Protocols, Vulnerabilities and Attacks By Attack Surface (i.e. Layers)



Attack Types

“Most” attacks on the Network Interface and the Network layer are DoS and Spoofing attacks.

DoS: Resource exhaustion which leads to lack of availability.

- Categorisation by Volume (exhausting bandwidth):
  - Volumetric, e.g., `ICMP Flood`, `UDP Flood`
  - Protocol/Application (misusing a protocol or an application to disrupt or exhaust the target’s resources)
    - e.g. protocol: `SYN Flood`, `Ping of Death`, `Smurf Attack`, `Fragmentation Attacks`
    - e.g. application: `HTTP Flood`, `Slowloris`
- Categorisation by resource disparity (attack v defence):
  - Symmetric
  - Asymmetric (substantial damage with minimal resources)
- Categorisation by Direction:
  - Direct
  - Reflected

Sniffing and Spoofing

Fundamental skills that lots of network attacks depend on.

- **Sniffing:** (a.k.a snooping) *tapping* each packet as it flows across the network; i.e., it is a technique in which a user sniffs data belonging to other users of the network.
- **Spoofing:** *forging* a packet, to put some fake information in a packet and send it out.

Packet Sniffing

Many LAN networks work with a broadcast medium.

- Packets on the wire are *heard* by all machines in that network.
- If the destination address matches with the machine's address, it accepts it; otherwise, it rejects it.

Addresses:

- Layer 2: MAC address: identifies a machine on a network.
- Layer 3: IP address: identifies a network.

Packet Sniffing

Layer 2: How do we tell the NIC card to accept all the packets irrespective of what it is programmed to receive (specified by the destination MAC address)?

- Set NIC card in *promiscuous mode*.

Layer 3: Checks destination IP address: not for me → drops.

- However, many OS provide raw socket type:
  - in **normal socket**, packets get passed through the TCP/IP protocol stack: each layer strips the corresponding headers, the application gets the data.
  - in **raw sockets**, the packets are passed directly by the OS to the application, it *includes all the headers*.

Packet Sniffing: Programmes/Libraries

Although we can write our own sniffer programs,

- it will be time consuming (involves low level programming)
- not portable

Sniffing API:

- **PCAP** (Packet Capture API)
  - **`lipcap`** in linux, **`WinPcap`** and **`Npcap`** in Windows
  - Written in C. Other languages offer wrappers.
  - Widely used by many tools:
    - **`Wireshark`**
    - **`tcpdump`**
    - **`Scapy`**
    - **`McAfee`**
    - **`Nmap`**
    - **`Snort`**, ...

Packet Sniffing using Scapy

Scapy
(https://scapy.readthedocs.io/en/latest/introduction.html)

- is built on top of Pcap.
- is a packet manipulation tool for computer networks, originally written in Python

Installation:

```
$ sudo pip3 install scapy
```

Importing **Scapy** in a python program:

```python
from scapy.all import *
```

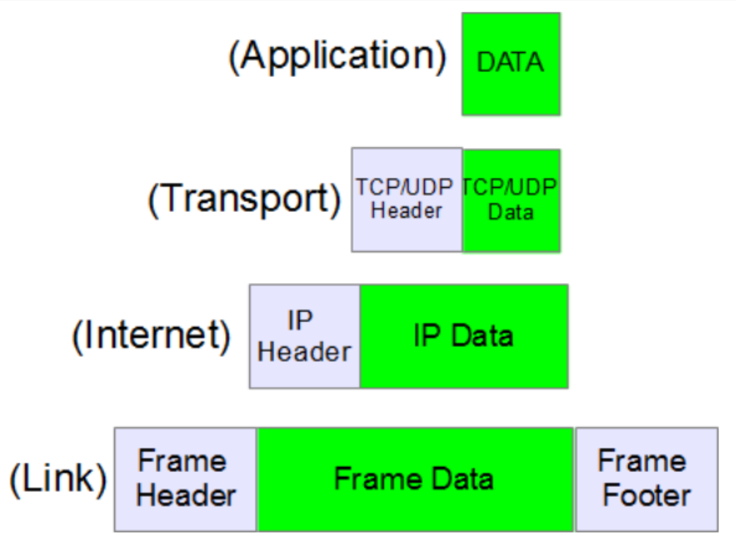
Scapy: Example

```python
from scapy.all import *
pkt = sniff(iface='enp0s3',
            filter='icmp or udp',
            count=10)
pkt.summary ()
```

Ways to display:

- **`hexdump()`**
- **`pkt.show()`**

Layers and Headers



What's in the packet

E.g.: the packet that we get through **Scapy** is an object of type Ethernet:

```
>>> pkt
<Ether type =IPv4 | <IP frag = 0 proto = udp | UDP | Raw
     load = 'hello' | >>>>
```

```
>>> pkt.payload
<IP frag = 0 proto = udp | UDP | Raw load = 'hello' |
    >>>
```

```
>>> pkt.payload.payload
UDP | Raw load = 'hello' | >>
```

```
>>> pkt.payload.payload.payload
Raw load = 'hello' | >
```

Accessing Layers

```
>>> pkt.haslayer(UDP)
True
>>> pkt.haslayer(TCP)
0
```

```
>>> pkt.getlayer(UDP)
UDP | Raw load = 'hello' | >>
```

```
>>> pkt[UDP]
UDP | Raw load = 'hello' | >>
```

```
>>> pkt[Raw].load
b'hello'
```

Get Information of Protocol Classes

Get attribute names:

```
>>> ls(IP)
```

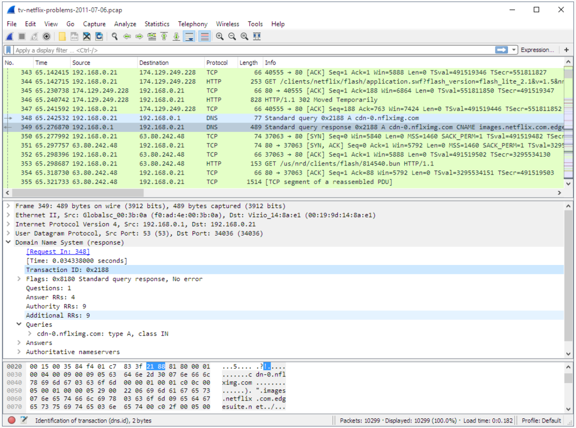
Get method names:

```
>>> help(IP)
```

Using Tools : Wireshark

Free and open source network protocol analyser.

Similar to **TCPDump** but has a graphical front-end:



Packet Spoofing

Recap: Sending a normal packet

```
import socket
IP = ”127.0.0.1”
PORT = ”9090”
data = b'Hello World !'
sock = socket(socket.AF_INET, socket.SOCK_DGRAM)
Sock.sendto(data, (IP, PORT))
```

Source IP? Source Port?

TCP/IP Protocol stack creates the packet by adding headers (by different layers). We generally set only a few attributes of headers (destination IP address, port number, some flags).

Packet Spoofing with Scapy

Constructing packets:

- We need to control the headers for packet snooping.
- raw socket sends the forged packets.

```
>>> a = IP(src='1.2.3.4', dst ='10.20.30.40')
>>> b = UDP(sport='1234', dport ='1020')
>>> c = ”Hello World”
>>> pkt = a/b/c
>>> pkt.show()
```

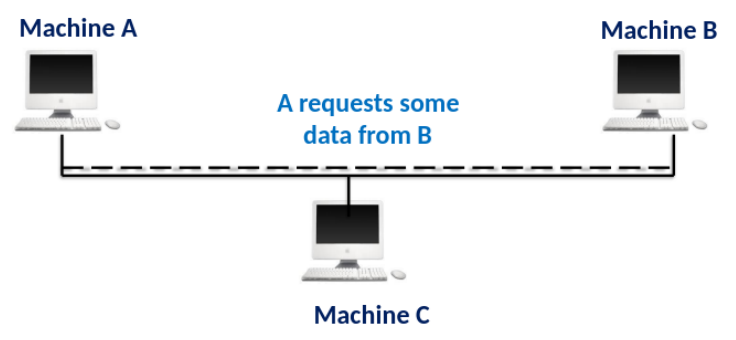
Spoofing ICMP Packet

```python
from scapy.all import *

ip = IP(src='1.2.3.4', dst='94.180.216.34')
icmp = ICMP()
pkt = ip/icmp
send(pkt, verbose=0)
```

Spoofing UDP Packet

```
from scapy.all import *

ip = IP(src='1.2.3.4', dst='94.180.216.34')
udp = UDP(sport=9090, dport=9100)
data = 'Hello! \n'
pkt = ip/udp/data
send(pkt)
```

Sniff Request and Spoof Reply



- Sniffing traffic, knows what is being requested by A.
- Sends data to A showing that the data has come from B.

Next: Physical Layer and Data Link Layer Attacks