Mid-Term Quiz

- Please refer to the announcement released in LumiNUS!
- Time: **Friday, 4 October 2018, 10:20-11:30am** (please do come by 10:05am as usual if you can)
- Venue: **LT19** (the usual lecture venue)
- Weightage: **15%** of your final mark
- **Format**:
  - Part A: Multiple choice questions
  - Part B: Security terminology questions
  - Part C: Short-answer and scenario-based questions (similar to tutorial questions)

Mid-Term Quiz

- **Scope**:
  - Lectures 0-5, Tutorials 1-4
  - The details of techniques in your assignments *are not* examinable
- **Open book**:
  - Please be self-sufficient
  - ***No*** communication devices
  - NUS approved calculators are fine: but you *should be able* to answer the solutions even without a calculator
- Past-year mid-term quiz will be uploaded soon
- Consultation hours during the recess week will be open

Lecture 5: Network Security

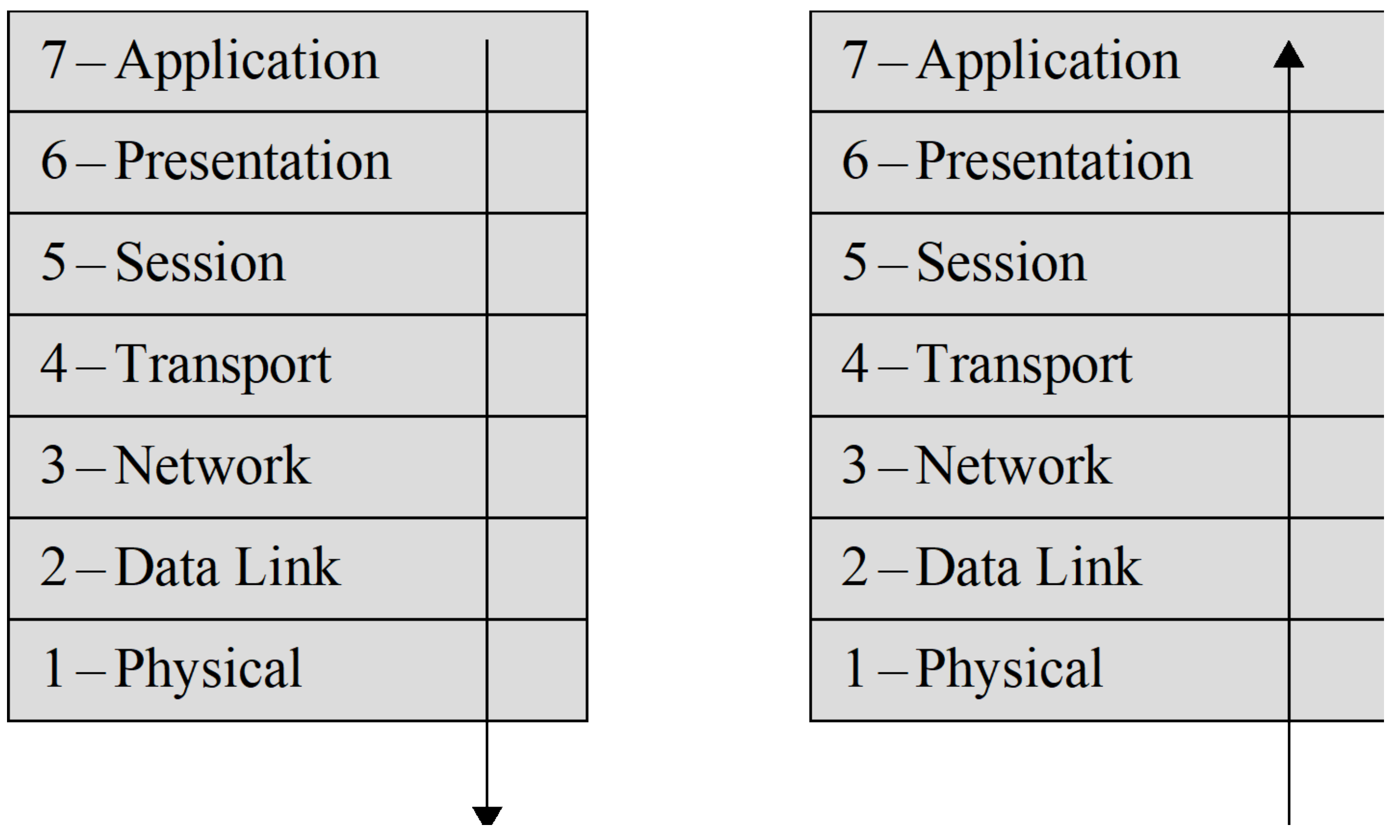
5.1 Background: Network layers
5.2 Name resolution and attacks
5.3 Denial of Service (Dos) attacks
5.4 Useful network security tools
5.5 Protection: Securing the communication channel using cryptography
5.6 Protection: Firewall
5.7 Protection: Network security management

See: [PF6.1], [PF6.2],[PF6.4],[PF6.6], [PF6.9]

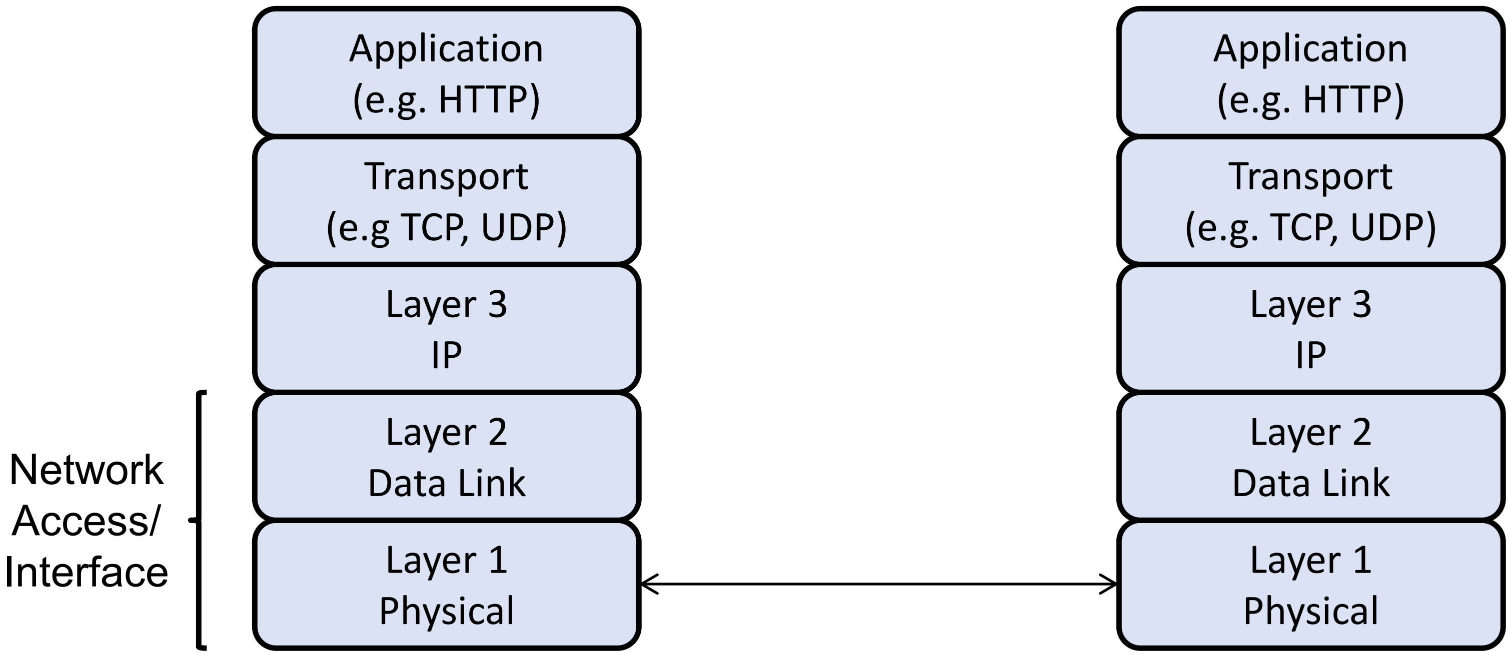
5.1 Background: Network Layers

The OSI Seven-Layer Network Model

The ***Open Systems Interconnection (OSI) model***:
a conceptual/reference model that standardizes the *communication functions* of a telecommunication/computing system

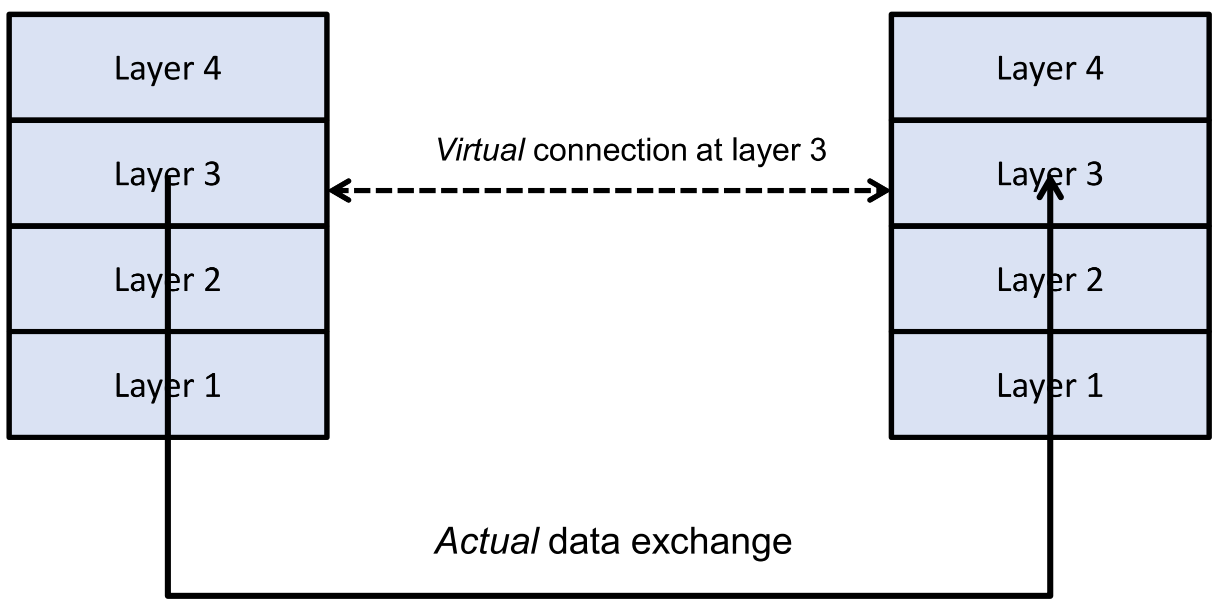


The Internet (TCP/IP) Reference Model



Why Network Layering?

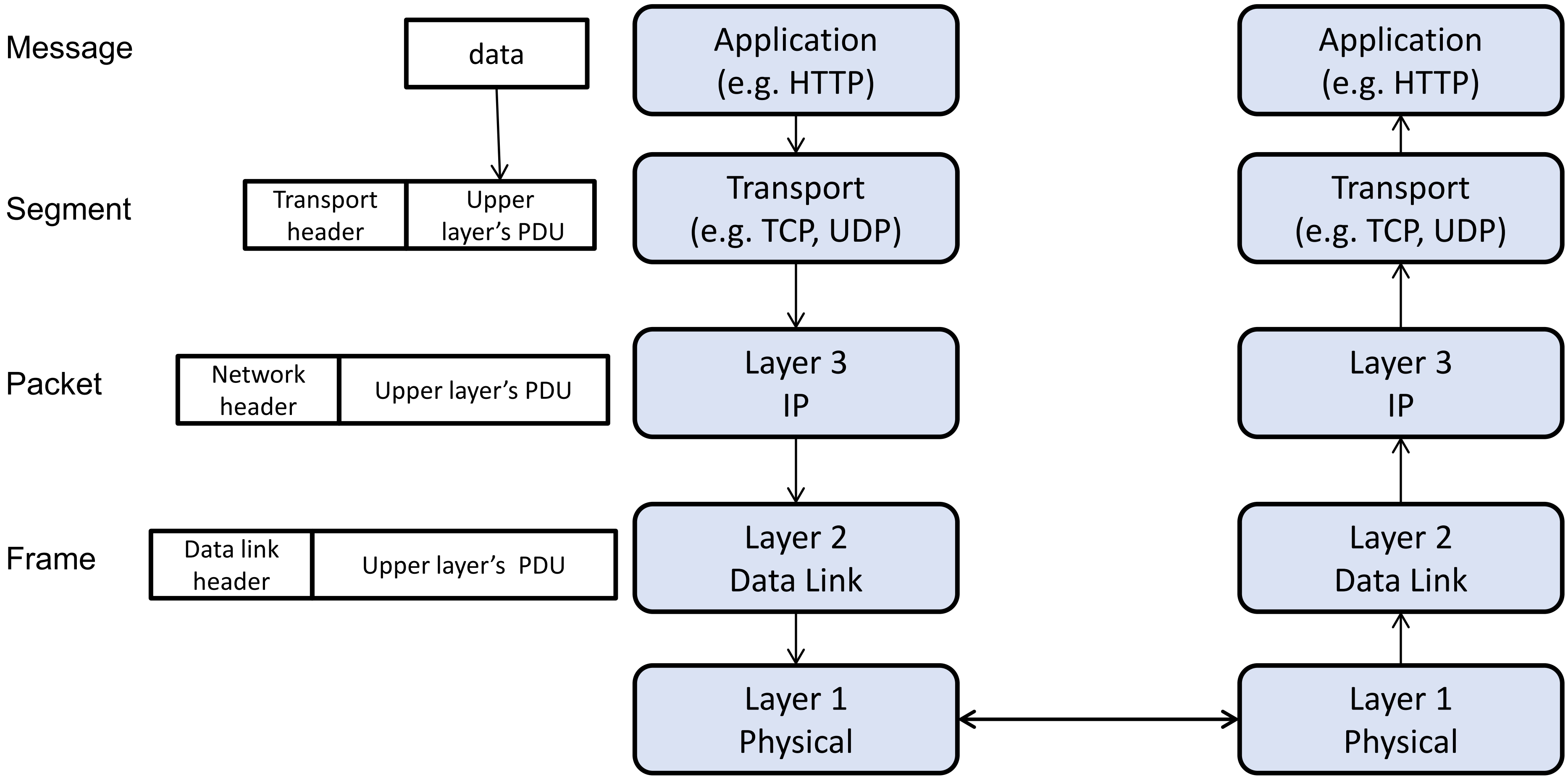
- It partitions a complex communication system into several **abstraction layers**
- The **peer entities** at the same layer *N* “conceptually” communicate with each other by executing a protocol *at that layer*



Why Network Layering?

- The layer-*N* protocol is built **on top of** a virtual connection at layer ***N*-1** below
- Example of a protocol at **layer 4** (end-to-end protocol):
  (1) $A \rightarrow B$: "hello"
  (2) $A \leftarrow B$: certificate of *B*
- The "virtual connection" at layer 3 sends the message "hello" from *A* to *B* in Step (1), and sends *B*'s certificate in Step (2)
- At layer *N*:
  - A message to be sent is called: layer-*N* ***protocol data unit*** (PDU)
  - **Encapsulation** of upper (i.e. *N*+1) layer's PDU

Network Layers and Message Encapsulation



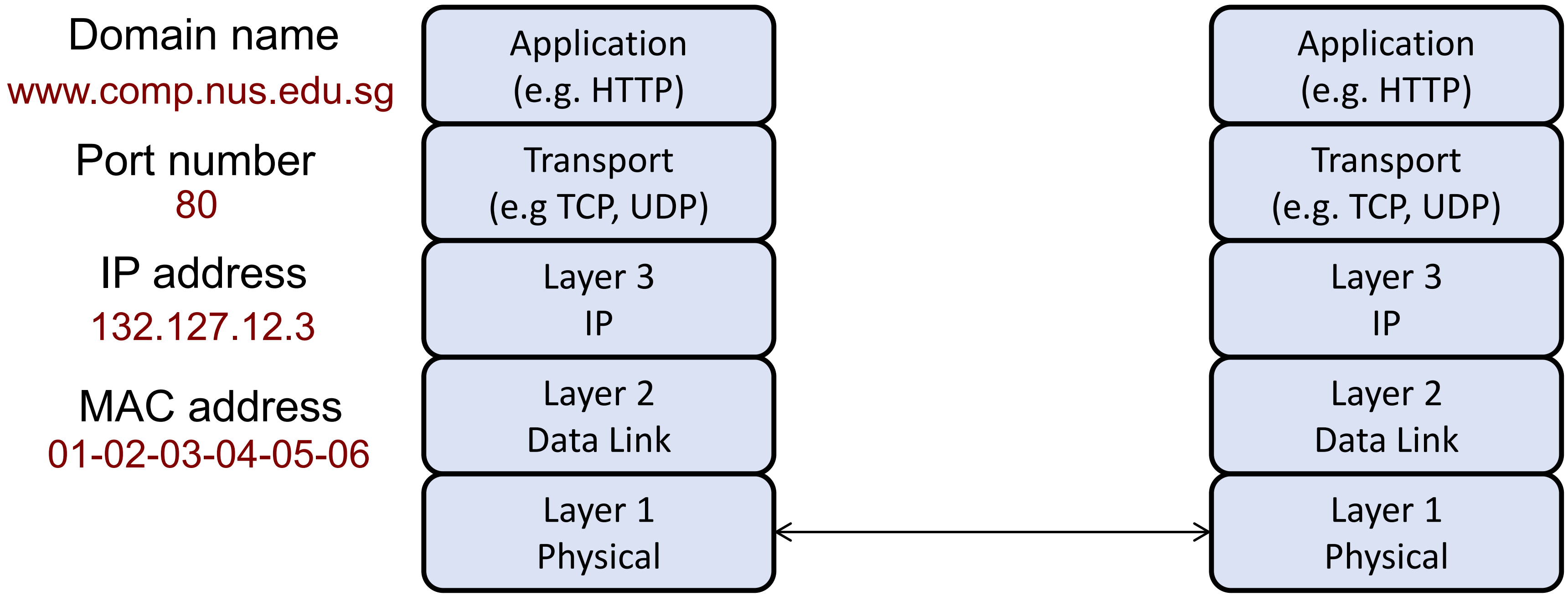
General PDU format:

Header	**Payload**

Header: meta data   Payload: the message/information intended to be sent

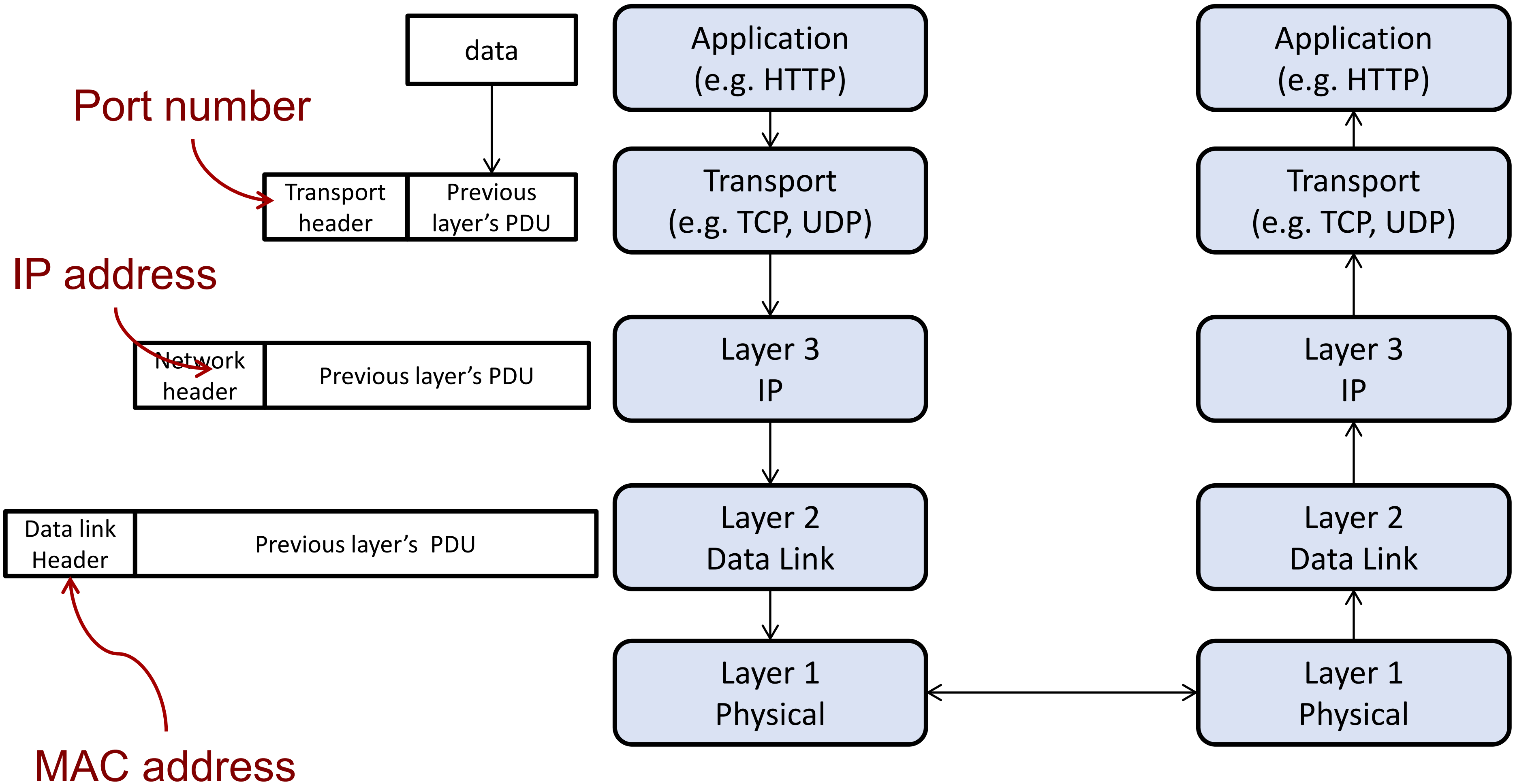
Internet Layers: Different Addressing Schemes

- Different **addressing schemes** at different layers



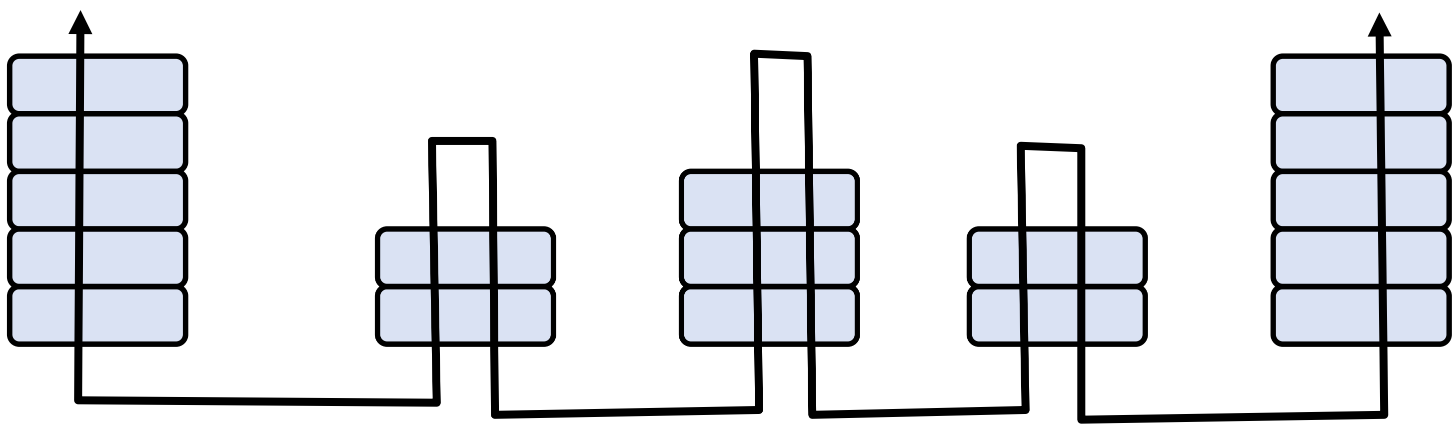
Note: MAC (medium access control) is *not* to be confused with crypto's MAC

Addressing at Various Layers



Multiple Hops from Sender to Destination

- Note that data may go through **multiple hops**
- Can you guess each device type in the diagram below?
- Some networking devices: *router*, *switch*, *hub*, *repeater*



Security Weakness

- The original Internet design **does *not*** take into account of *intentional* attacks
- Possible threats (from Lecture 1):
  - **Interception**: unauthorized viewing
  - **Modification**: unauthorized change
  - **Fabrication**: unauthorized creation
  - **Interruption**: preventing authorized access
- Attacker at any layer can modify the **data** *and* the **header**:
  - Consider the **source IP address** in the IP header, which indicates the sender address
  - Without any protection mechanisms, an attacker can easily send a packet with **spoofed** "source" IP address

5.2 Name Resolution and Attacks

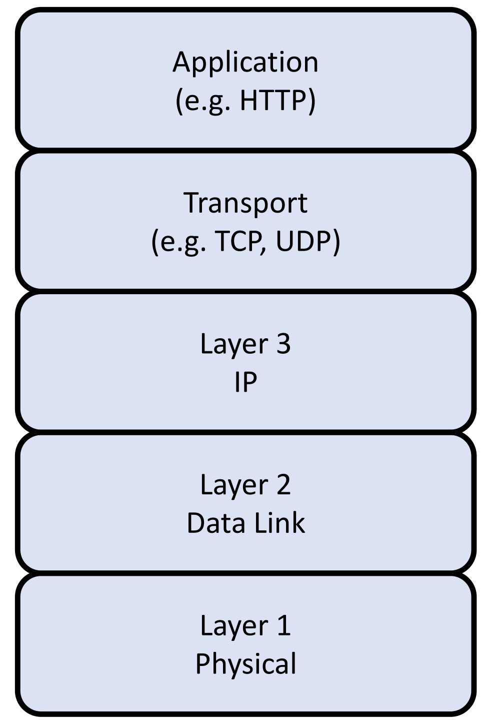
Naming Schemes and Resolution

- Each peer entity has a ***name***
- On a single node, at different layer, the name can be **different**

www.comp.nus.edu.sg — Domain name

132.127.12.3 — IP address

01-02-03-04-05-06 — MAC address



Naming Schemes and Resolution

- When a peer entity uses the virtual connection in the layer below, it needs to find out the corresponding ***name mapping***
- Example: finding the IP address of a domain name
- Protocols that perform name mappings are known as "***resolution***" protocols
- Many initial design of resolution protocols **didn't** take security into account, and thus *easy* for attackers to **manipulate the outcome**

Resolution Protocols

- Domain Name System (DNS):
  - Maps **domain name** to **IP address**
  - A hierarchical decentralized naming system
  - An attacker can target the association of domain name with IP address

In this module, we only consider a *basic* type of DNS attack

- Address Resolution Protocol (ARP):
  - Associate/map **IP address** (logical address) with/to **MAC address** (physical address)
  - Use a *broadcast mechanism* on a local network
  - An attacker **on the local network** can target the association

DNS (Domain Name System)

- Given a domain name (e.g. www.comp.nus.edu.sg), its IP address can be found by either looking up a locally stored **host table**, or by **querying a DNS server**. The process is known as ***name resolution***.
- The entity (a.k.a client) that initiates the query is called the ***resolver***
- If the address is found, we say that the domain name is ***resolved***

The domain name to look up

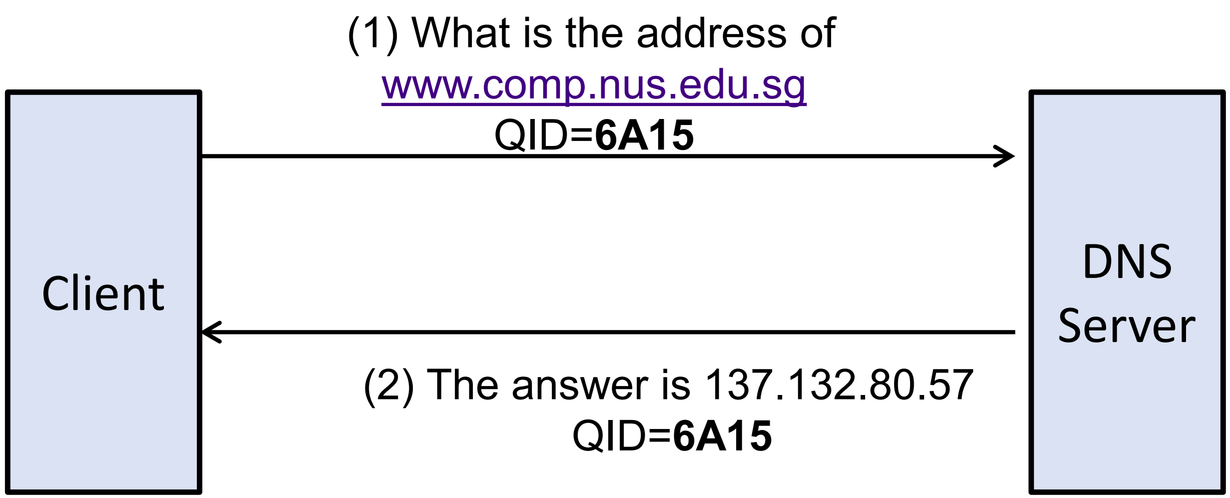
```
$ nslookup www.comp.nus.edu.sg
Server:         192.168.1.1
Address:        192.168.1.1#53

Non-authoritative answer:
www.comp.nus.edu.sg    canonical name =
www0.comp.nus.edu.sg.
Name:   www0.comp.nus.edu.sg
Address: 137.132.80.57

$
```

Address of the DNS server

Result of the query

(Lightweight) Authentication of DNS Query

- Each query contains a 16-bit number, known as **Query ID (QID)**
- The response from the name server must also contains a QID
- If the QID in the response doesn't match the QID in the query, the client rejects the answer
- Note that **no** encryption/MAC is involved



Remark: In the original design consideration, the QID is probably *not* meant for authentication, but as an efficient way to match multiple queries

Local DNS Attack Scenario

Alice:

- is using a café’s free/open (without protection) WiFi to surf the web
- wants to visit the webpage www.comp.nus.edu.sg
- types the domain name into the browser’s address bar

- **Alice’s browser:**
  - makes a query to a DNS server to determine the IP address
  - then connects to the IP address (after the browser obtains the IP address)

Local DNS Attack Scenario

Active Attacker (Mallory):

- We consider an attacker at the ***physical layer***:
  for example, he/she can be another person in the café
- Since the WiFi is not protected, the attacker can:
  - Sniff data from the communication channel
  - Spoof data into the communication channel
- Attacker, however, can't remove/modify data already sent by Alice
- Attacker also owns a Web server (e.g. with IP address 100.100.100.3), which is a spoofed SoC website

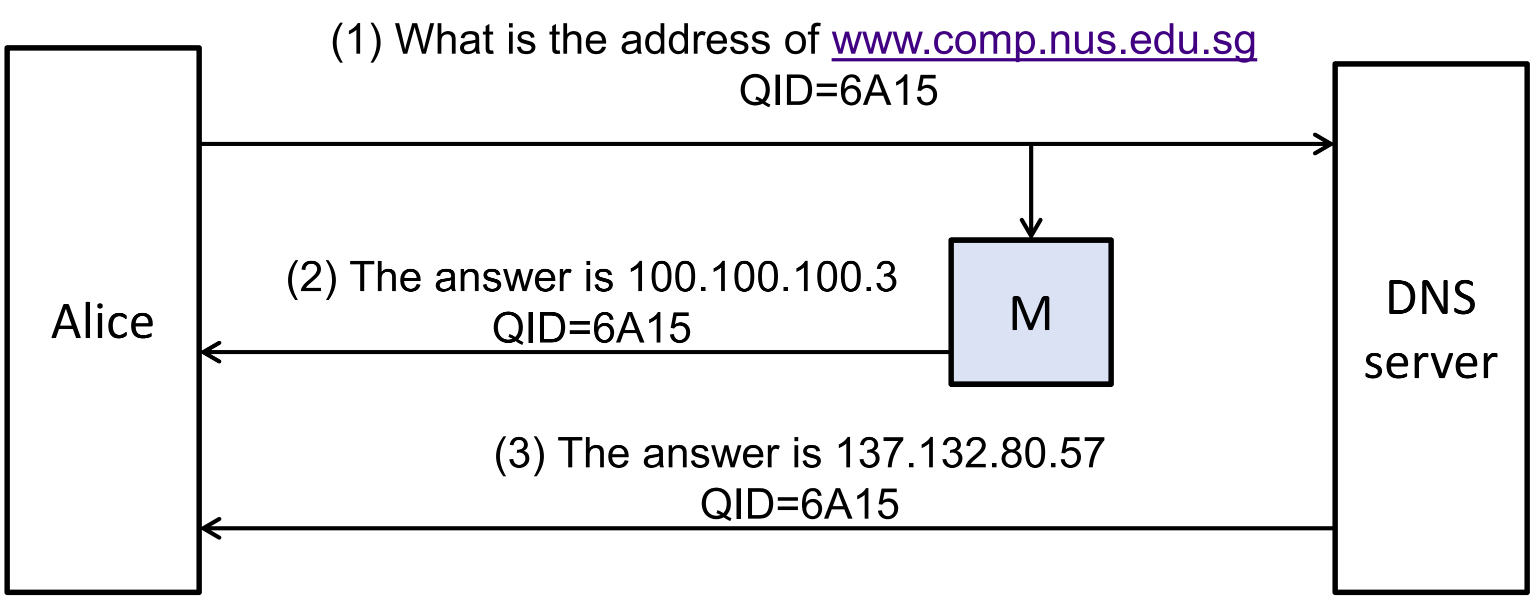
The Attack (See [PF] page 409)

(1) Alice asks for the address

(2) Mallory sniffs and knows about it.
She quickly spoofs a reply with the same QID.

(3) DNS server also sends a reply.
Since Mallory is closer to Alice,
Mallory's reply is likely to reach Alice first.

Alice takes the *first* reply as answer, and connects to 100.100.100.3.



Some Remarks

- DNS operates at the **application layer**.
- Although the attacker is at the physical layer, for ease of analysis, we can assume that the attacker is just below the application layer. That is, there exists some virtual connection that can send the message across.
  Hence, the previous slide doesn't mention about the MAC and IP addresses, etc., of the DNS server.
- The DNS is an important component as it resolves the domain name. Hence, an DNS server can be the "**single-point-of-failure**" for the network.
- A DoS attacks, instead of attacking a Web server, could attack the **DNS server** instead.
  E.g. see attack on WikiLeak (See [PF6.5] pg. 414, [PF] pg. 485),
  StarHub attack 2016 (next slide).

Recent DNS Attacks

www.channelnewsasia.com/news/singapore/broadband-service-outag

Menu

Broadband service outages due to DDoS attacks: StarHub

Posted 25 Oct 2016 15:36 **Updated** 25 Oct 2016 23:07

719 Email More

SINGAPORE: The two recent broadband service outages that hit StarHub were the result of "intentional and likely malicious attacks" on its servers, the telco confirmed on Tuesday (Oct 25), adding that the attacks were "unprecedented in scale, nature and complexity".

In a media statement, StarHub said: "We have completed inspecting and analysing network logs from the home broadband incidents on Oct 22 and Oct 24 and we are now able to confirm that we had experienced intentional and likely malicious distributed denial-of-service (DDoS) attacks on our domain name servers (DNS).

"These two recent attacks that we experienced were unprecedented in scale, nature and complexity," it said.

Starhub said that the DDoS attacks caused temporary web connection issue for some of its home broadband customers. "On both occasions, we mitigated the attacks by filtering unwanted traffic and increasing our DNS capacity, and restored service within two hours. No impact was observed

Channel News Asia, 25 Oct 2016

5.3 Denial of Service Attacks

DOS Attacks

- **Availability**: the property of being accessible and usable upon demand by an authorized entity
- **Denial of service (DoS)**:
  - The prevention of authorized access to resources or the delaying of time-critical operations
  - An attack on availability
- Types of **DoS attacks**:

	Stopping Service	Exhausting Resources
Local Attack	• Process killing • Process crashing • System reconfiguring	• Spawning processes • Filling up file system
Remote Attack	Sending malformed packet attacks	***Packet flooding***

DoS Attack Types

- **Local attacks** can be more easily tracked
- Sending **malformed attack** remotely does not usually work on updated OSes
- **Packet flooding** attacks:
  - Many effective DOS attacks simply remotely **flood** the victims with overwhelming requests/data
  - The attacker can ***amplify*** small traffic to obtain large traffic, typically by using available **public servers** (Internet infrastructure), such as DNS, NTP, CharGen

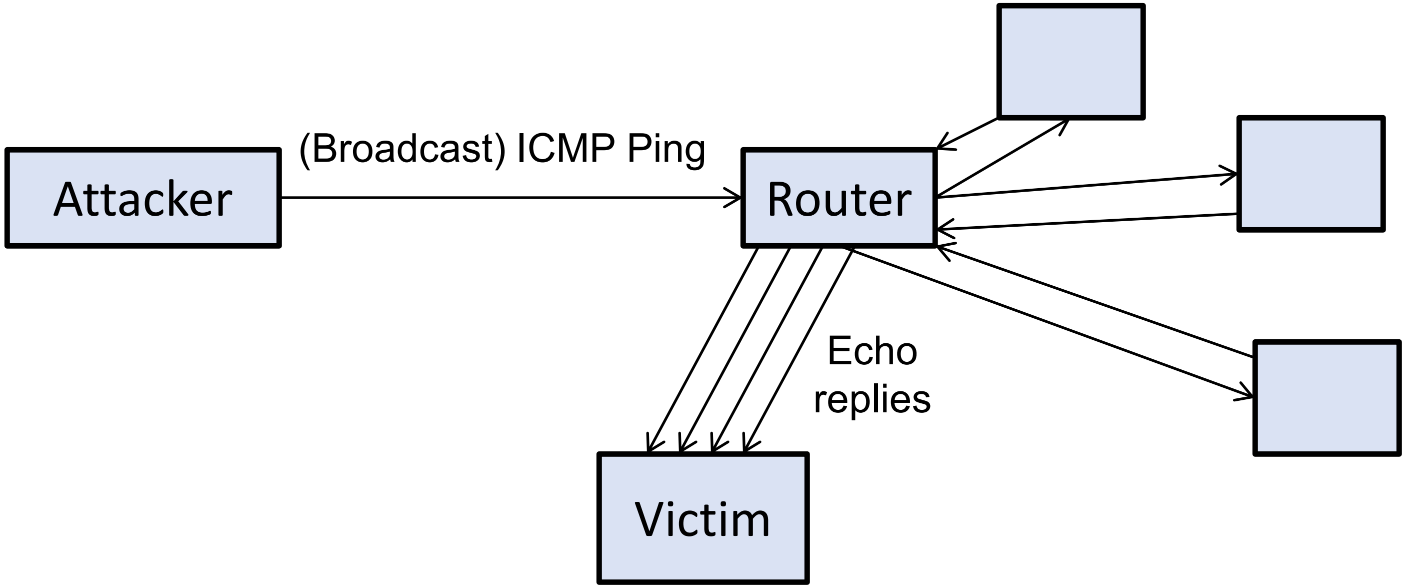
ICMP/Smurf Flood Attack [PF] page 404

(1) An attacker sends the “**ICMP PING**” request to a router, instructing the router to **broadcast** this request.
The request’ source IP address is spoofed with the victim IP address.

(2) The router broadcasts this request.

(3) Each entity who has received this request, replies to it by sending an “**Echo reply**” to the source, which is the victim

The victim is thus overwhelmed with “**Echo reply**” from the entire network.
The attacker takes advantage of the ***amplification*** effect.



ICMP/Smurf Flood Attack: Preventive Measures

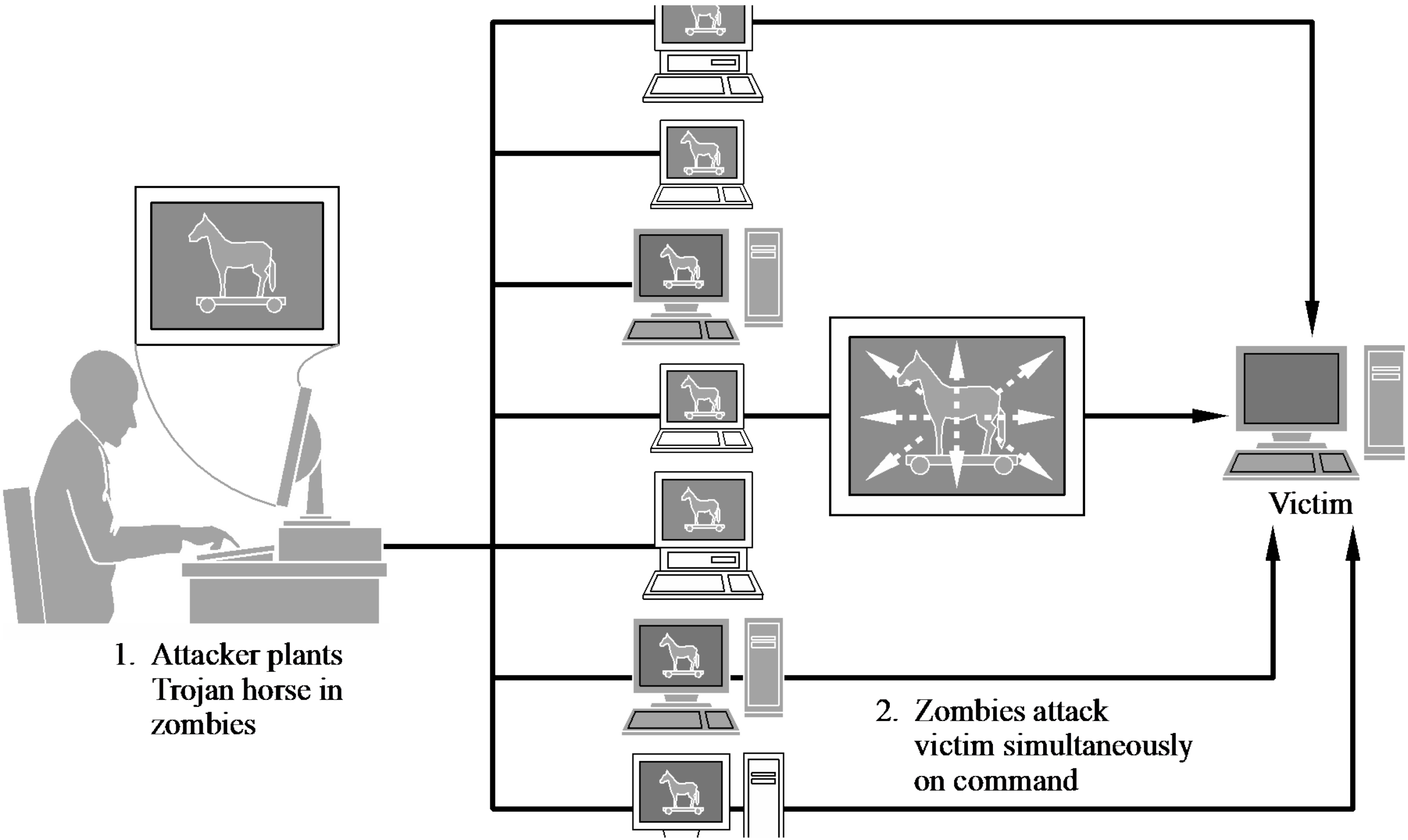
- Is this attack technique still effective?
- *No!*
- Why not?
- Most routers are now configured *not* to broadcast the requests
- To prevent the attack, this measure simply *disables* a feature that was previously thought to be useful

See: IP broadcasting, http://en.wikipedia.org/wiki/Broadcast_address

Example of Application-Layer DoS Attack (HTTP Get)

- Simply flood a Web server with **HTTP requests**
- Example: MyDoom worm, which targeted SCO's website. Attacks started on Feb 12, 2004.
  This is after the SCO's legal actions and public statements against Linux.
- For this attack to be effective, **a large number** of attackers are required.
  (Since each attacker can send requests at a low rate only).
- When DoS is carried out by large number of attackers, this is called **Distributed Denial of Service (DDoS)**.

Distributed Denial of Service (DDoS)

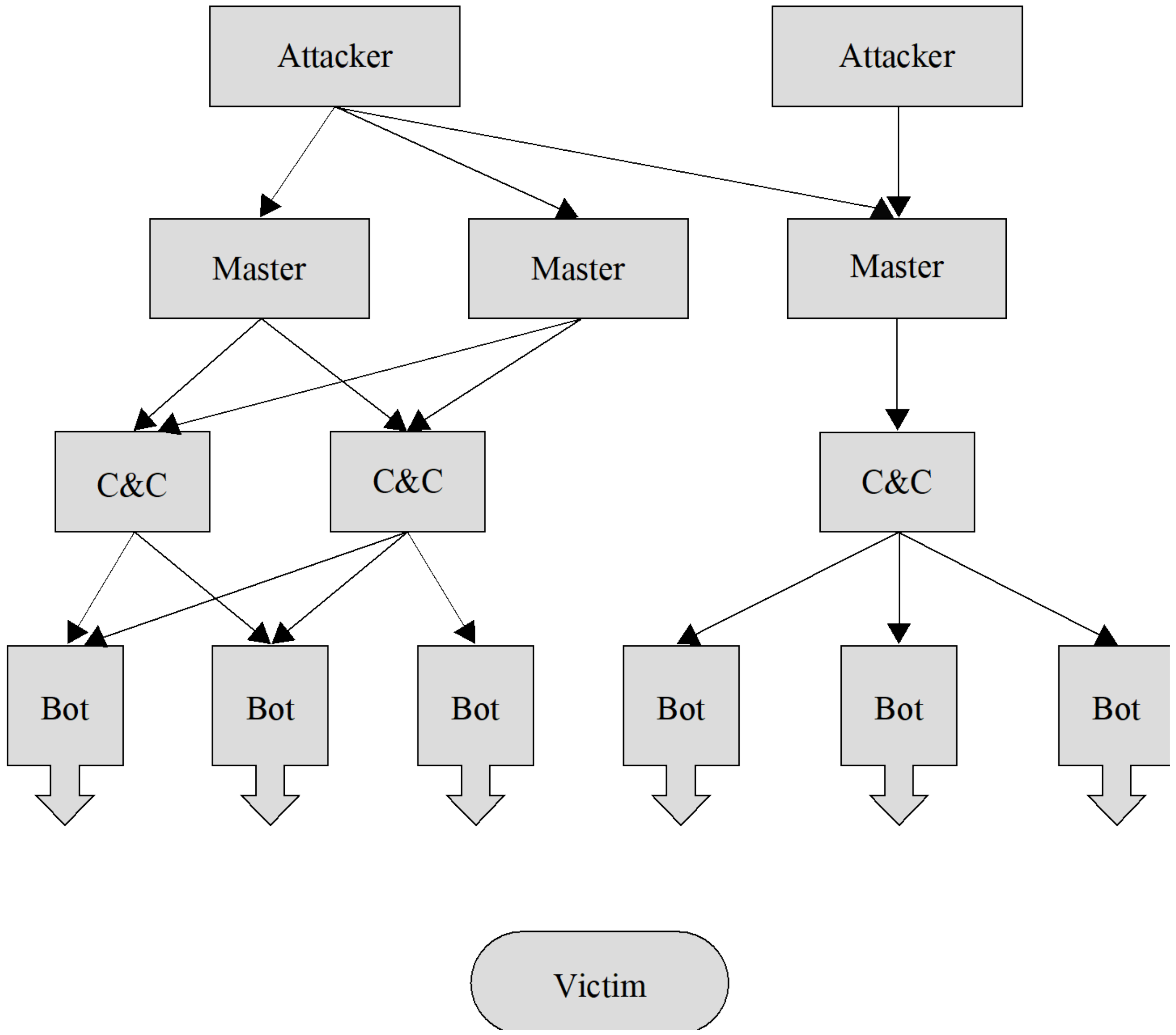


Botnet

- A ***bot*** (aka *zombie*) is a compromised machine
- A ***botnet*** (aka *zombie army*) is a large collection of connected bots, communicating via covert channels
- A botnet has a **command-and-control** mechanism, and thus can be control by an individual to carry out DDOS
- Possible usages of a botnet:
  - DDoS flooding, vulnerability scanning, anonymizing HTTP proxy, email address harvesting, cipher breaking!
- See Wiki for the size of known botnets: http://en.wikipedia.org/wiki/Botnet

Question: Why **covert** channels are used by a botnet?

Botnet


Attacker
Attacker
Master
Master
Master
C&C
C&C
C&C
Bot
Bot
Bot
Bot
Bot
Bot
Victim

IoT Devices: a New Trend

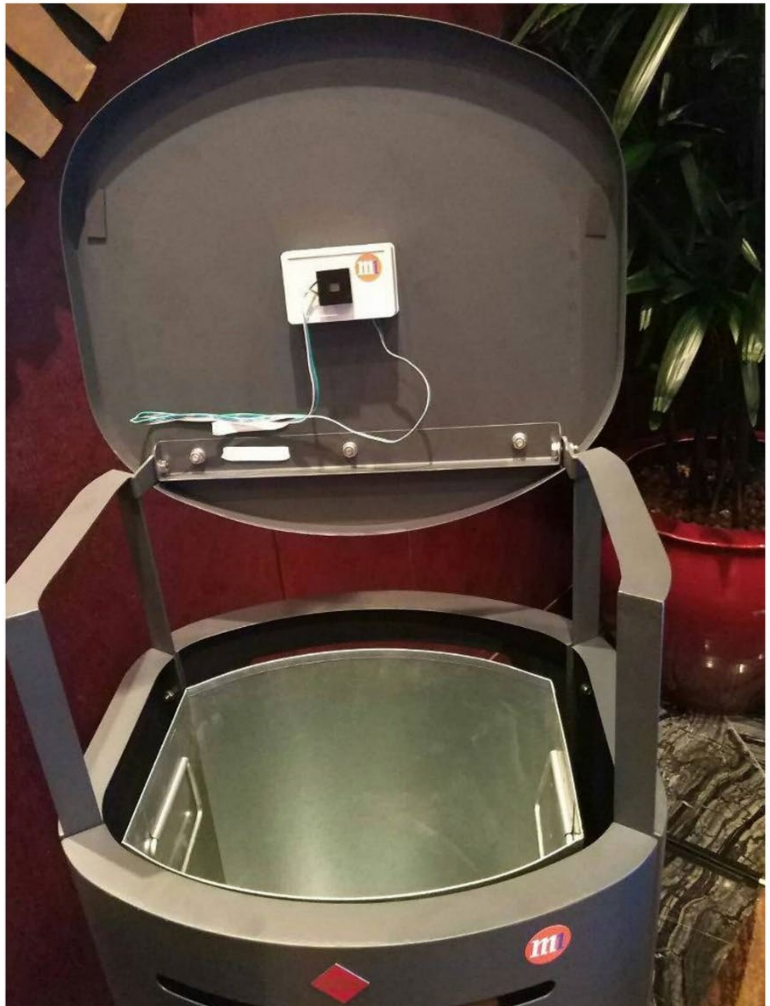
TECHNOLOGY

M1 launches commercial IoT network in boost to Singapore's Smart Nation drive

All Sections

By Kevin Kwang
@KevinKwangCNA

07 Aug 2017 06:20PM
(Updated: 07 Aug 2017 09:28PM)



Smart rubbish bins enabled with sensors will trigger an alert to cleaners to clear them after a certain level is met. (Photo: M1)

Channel News Asia,
7 Aug 2017

5.4 Useful Tools

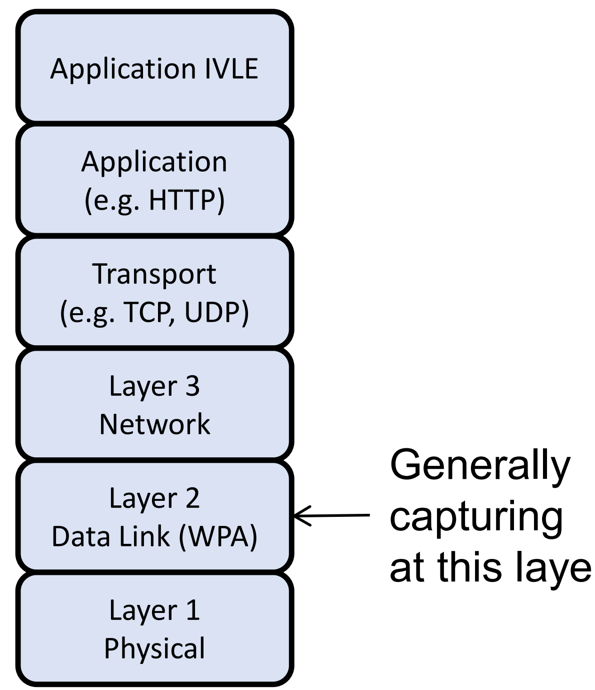
Wireshark (a Packets Analyzer)

- **Wireshark**: a popular free open-source network packet analyzer, https://www.wireshark.org/.
- What does Wireshark exactly capture?

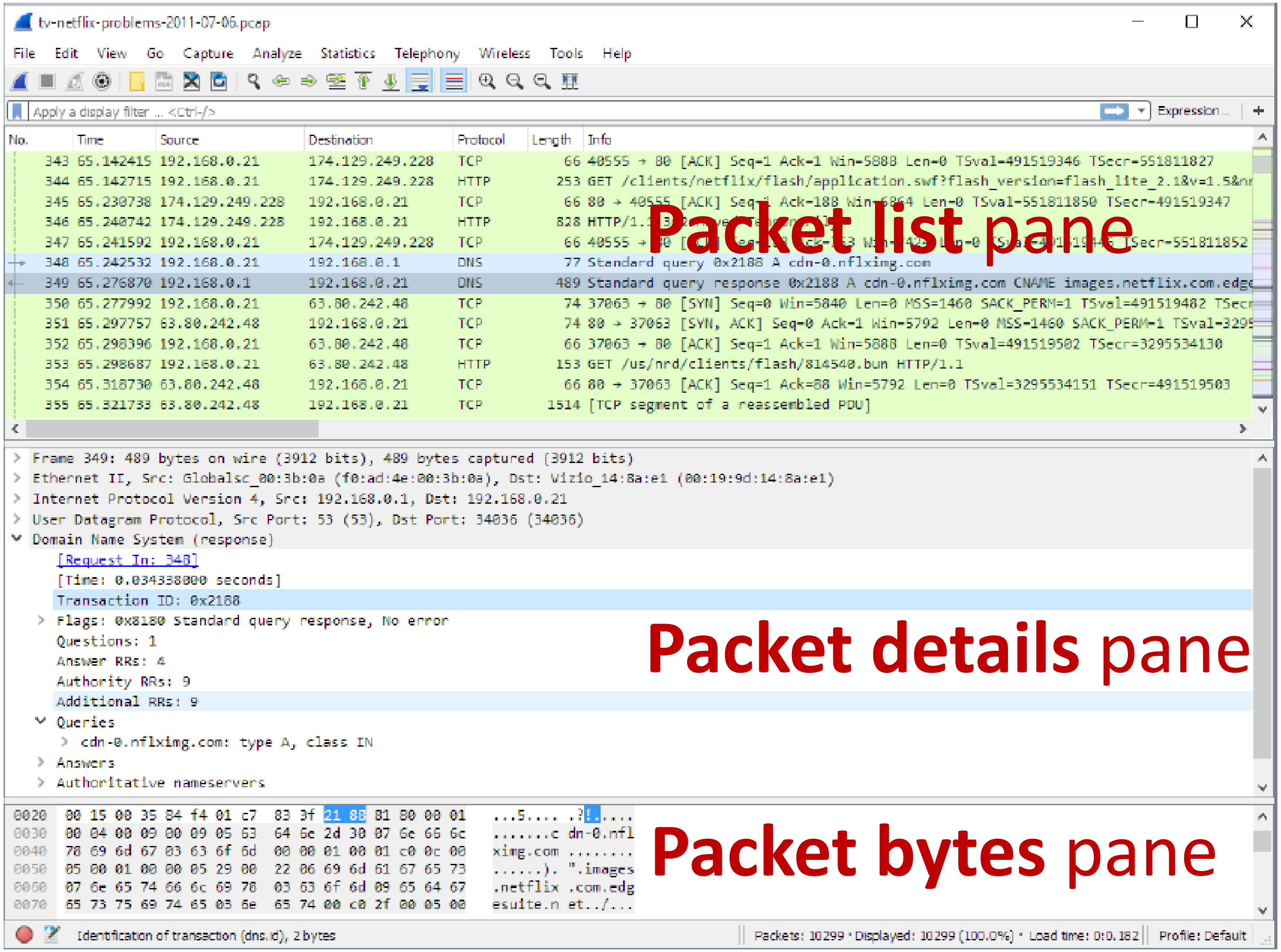
Generally performs capturing at the link layer.
This depends on OS and hardware.
Essentially captures "interactions" between the OS and the network card driver.

See the following FAQ for more info:
https://ask.wireshark.org/questions/22956/where-exactly-wireshark-does-captures-packets

(**Demo**: Wireshark)

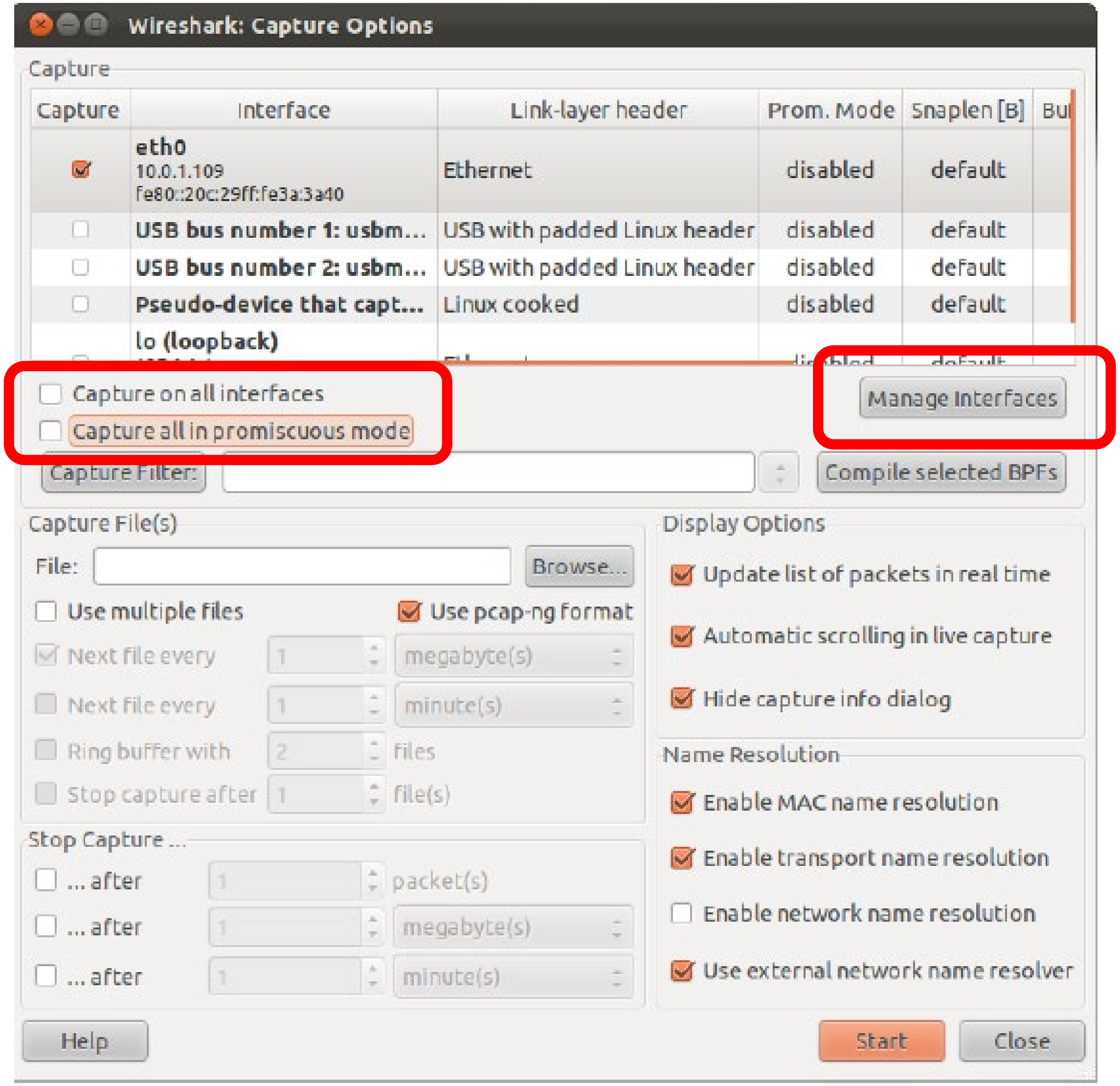


Wireshark (a Packets Analyzer)



For Wireshark usage, see: Wireshark User's Guide, https://www.wireshark.org/docs/wsug_html/

Sniffing using Wireshark: Capture Options



Source: Wireshark User's Guide

Sniffing using Wireshark: Popup Menu

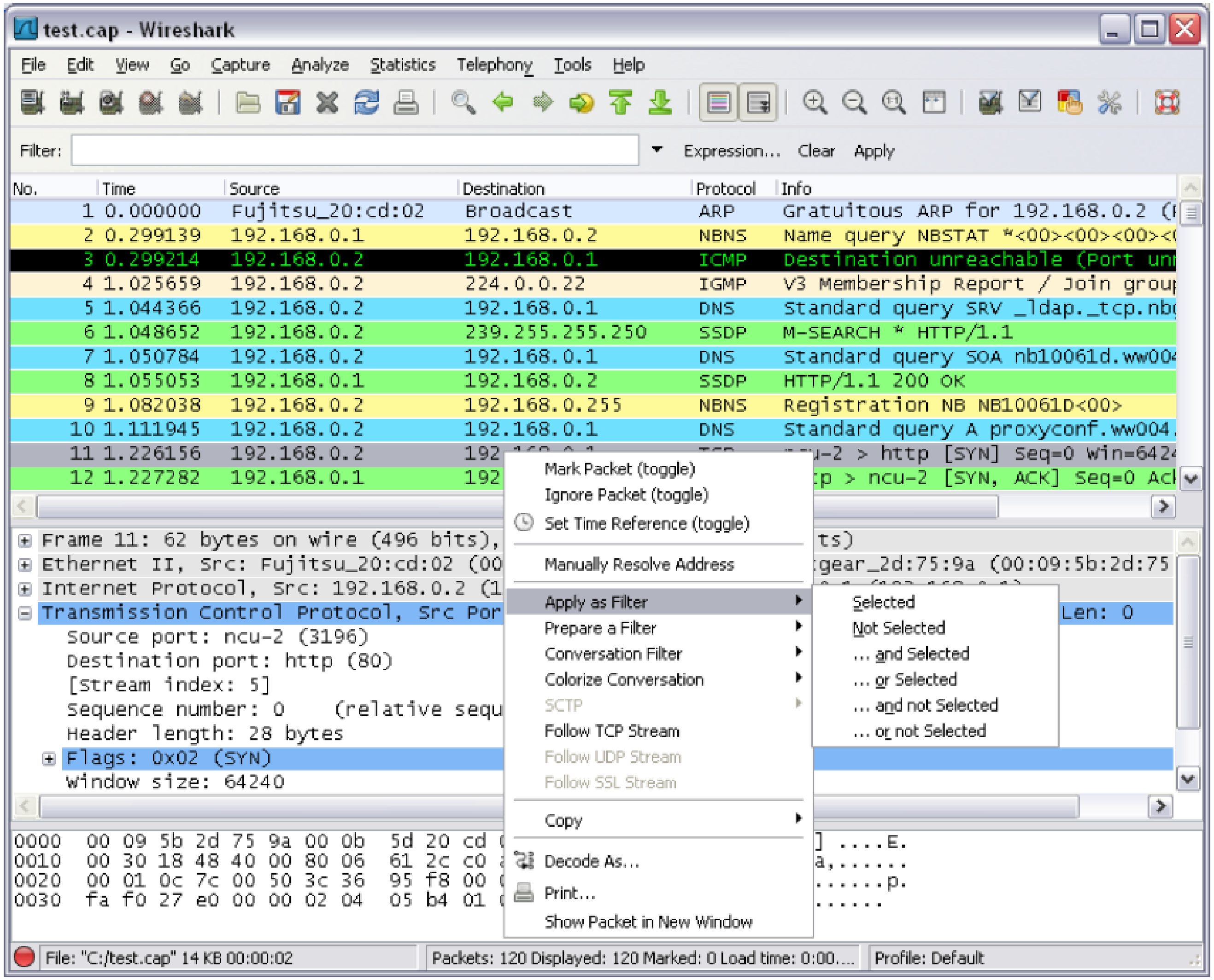


Figure 59. Pop-up menu of the "Packet List" pane

Source: Wireshark User's Guide

Sniffing using Wireshark: Filter

You need to specify a good (while-viewing) filter:

Filter comparison operators

Table 20. Display Filter comparison operators

English	C-like	Description and example
eq	==	Equal. `ip.src==10.0.0.5`
ne	!=	Not equal. `ip.src!=10.0.0.5`
gt	>	Greater than. `frame.len > 10`
lt	<	Less than. `frame.len < 128`
ge	>=	Greater than or equal to. `frame.len ge 0x100`
le	<=	Less than or equal to. `frame.len <= 0x20`
contains		Protocol, field or slice contains a value. `sip.To contains "a1762"`
matches	~	Protocol or text field match Perl regualar expression. `http.host matches "acme\.(org|com|net)"`
bitwise_and	&	Compare bit field value. `tcp.flags & 0x02`

Sniffing using Wireshark: Follow TCP Stream

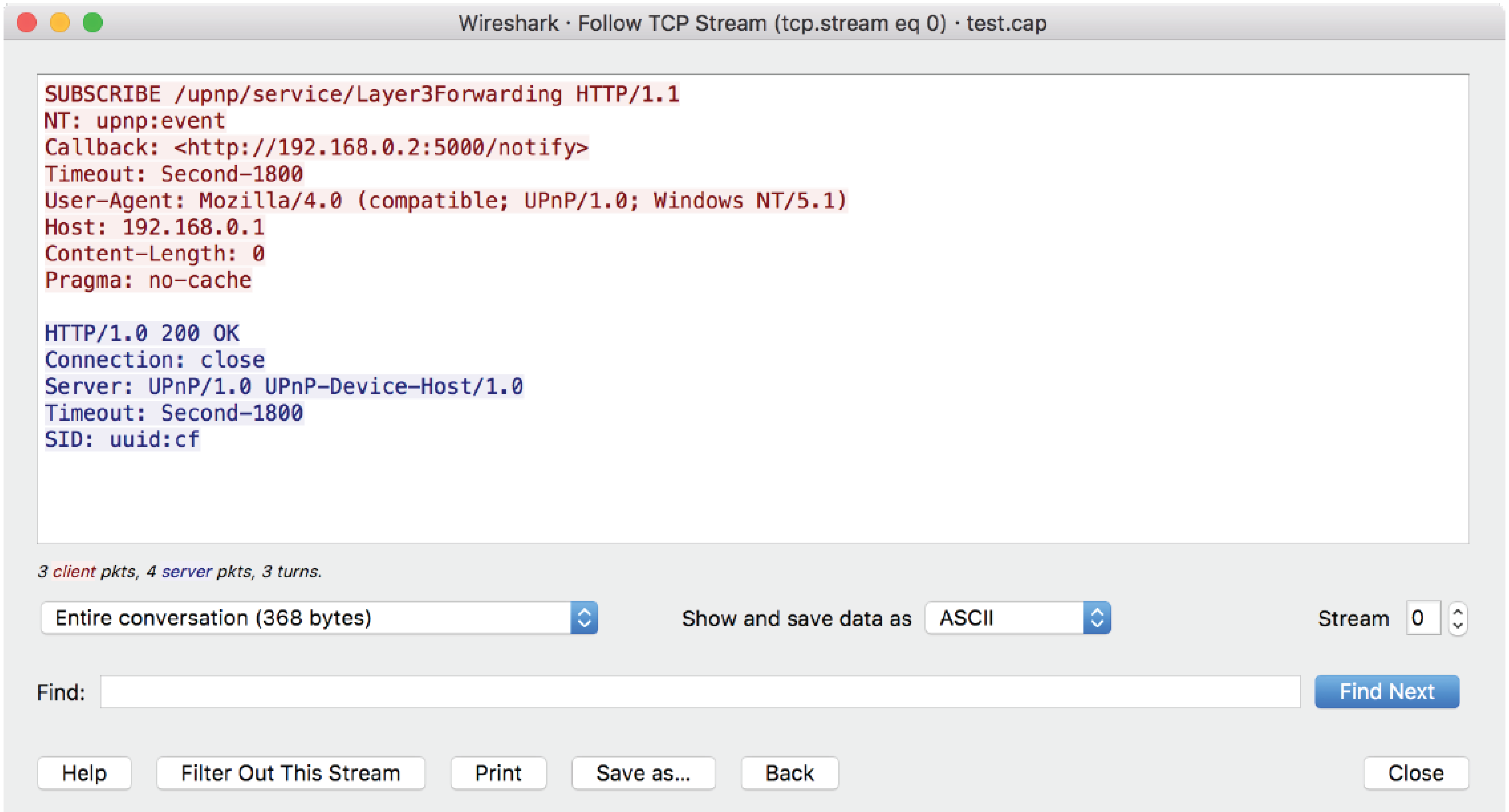
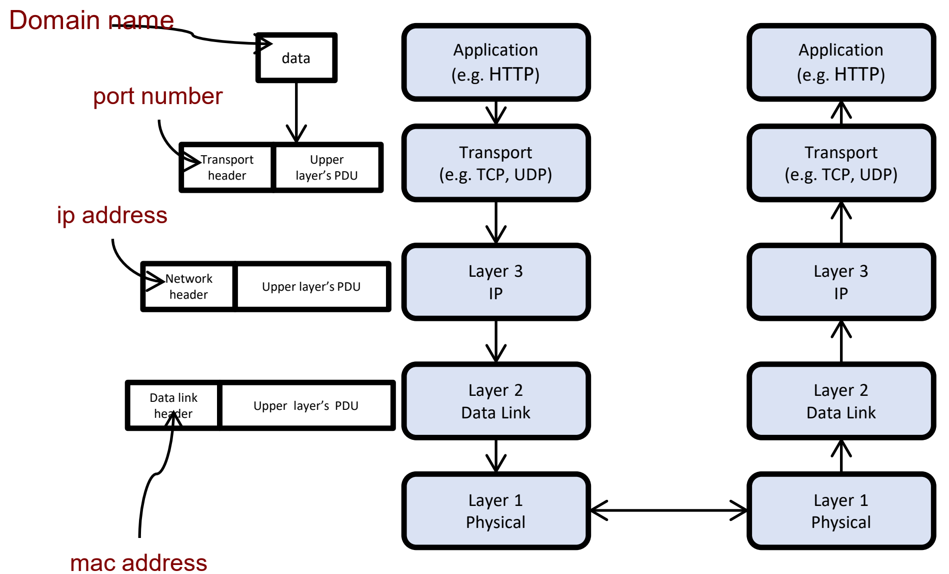


Figure 67. The "Follow TCP Stream" dialog box

Source: Wireshark User's Guide

Nmap (Port Scanner)

- What is a **port**?



- When a server receives an incoming packet, it will decide **which application process** to handle that packet based on the port no
- By saying that a process/service is "***listening***" to a particular port, we mean that the process **is running and ready to process** packets with that particular port no

Nmap (Port Scanner)

- When a port is "***open***", there exist such a process running in the server
- See well-known port numbers: https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers#Well-known_ports.
- ***Port scanning***: the process of determining which ports are open on hosts in a network
- Ports are "doors" into each machine, hence port scanning is like **knocking at the doors**
- ***Port scanner***:
  - A tool for performing port scanning
  - Is useful for both attacker and network administrator to scan for vulnerabilities
  - E.g. **Nmap** (very popular!)

Nmap (Port Scanner)

- Nmap is a full featured port-scanning tool:
  - Command-line tool, with GUI frontend
  - Installation:
    `sudo apt-get install nmap, zenmap`
  - Usage: `nmap` [Scan Type(s)] [Options] {target specification}
  - Examples:

    TCP ACK scan (a stealthier scan): `nmap -sA`

    OS fingerprinting: `nmap -O`

    Service/version detection: `nmap -sV`

(**Demo**: Nmap)

Nmap: Sample Output

```
Nmap scan report
192.168.1.1 / somehost.com (online) ping results
address: 192.168.1.1 (ipv4)
hostnames: somehost.com (user)
The 83 ports scanned but not shown below are in state: closed
Port       State     Service Reason       Product  Version  Extra info
21    tcp  open      ftp     syn-ack      ProFTPD  1.3.1
22    tcp  filtered  ssh     no-response
25    tcp  filtered  smtp    no-response
80    tcp  open      http    syn-ack      Apache   2.2.3    (CentOS)
106   tcp  open      pop3pw  syn-ack      poppassd
110   tcp  open      pop3    syn-ack      Courier pop3d
111   tcp  filtered  rpcbind no-response
113   tcp  filtered  auth    no-response
143   tcp  open       imap    syn-ack      Courier Imapd        released
2004
443   tcp  open      http    syn-ack      Apache  2.2.3         (CentOS)
465   tcp  open      unknown syn-ack
646   tcp  filtered  ldp     no-response
993   tcp  open      imap    syn-ack      Courier Imapd         released
2004
995   tcp  open              syn-ack
2049  tcp  filtered  nfs     no-response
3306  tcp  open      mysql   syn-ack      MySQL   5.0.45
8443  tcp  open      unknown syn-ack
34 sec. scanned
1 host(s) scanned
1 host(s) online
0 host(s) offline
```

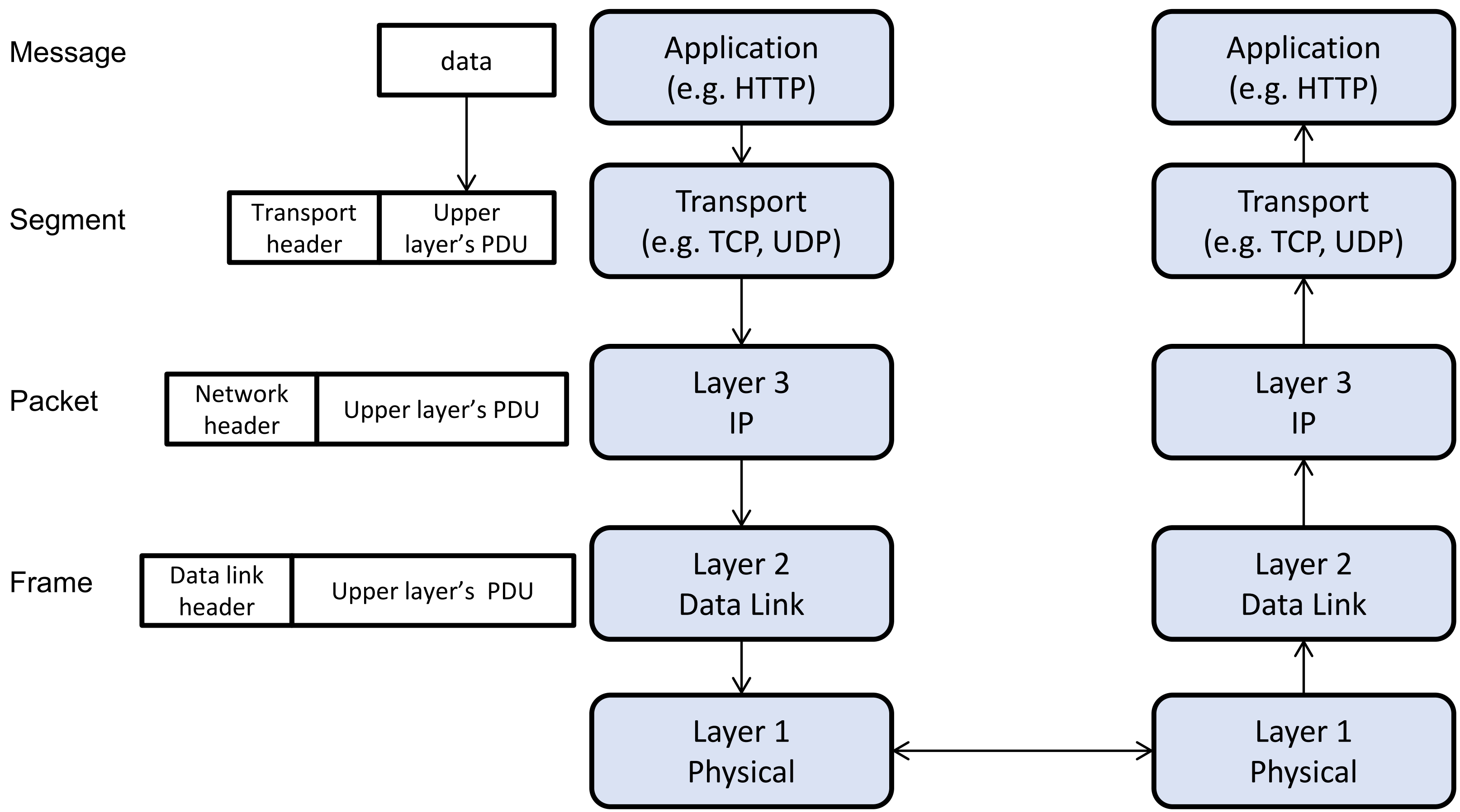
5.5 Protection: Securing the Communication Channel using Cryptography

Cryptography for Securing Network Communication

- Several cryptographic techniques to achieve **confidentiality** (encryption) and **authenticity** (MAC, PKI, strong authentication) over a public communication channel, even if the adversary can sniff & spoof data
- There are **many** security protocols that essentially achieve that, but operates at **different "layers"**
- Prominent **protocols**:
  - TLS/SSL
  - Wi-Fi Protected Access II (WPA2)
  - Internet Protocol Security (IPsec)

Security Protocols at Different Layers

- Recall the network layering shown previously
- TLS/SSL, WPA, IPSEC protect **different** layers



Remarks on Security Protocols and Network Layering

- Very often, when referring to a **security protocol**, we indicate the "**layer**" that the protocol **targets to protect**
- **Complication**: some protections *span across* multiple layers, or do *not* provide full protection of the targeted layer

- When analyzing an **attack**, it is also insightful to figure out at **what layer the attacker resides**
- **Complication**: likewise, some attacks *span across* multiple layers. In such situations, trying hard to pinpoint the layer could sometimes be very confusing

Remark on Security Protocols and Network Layering

- Below are the **general guideline** and example

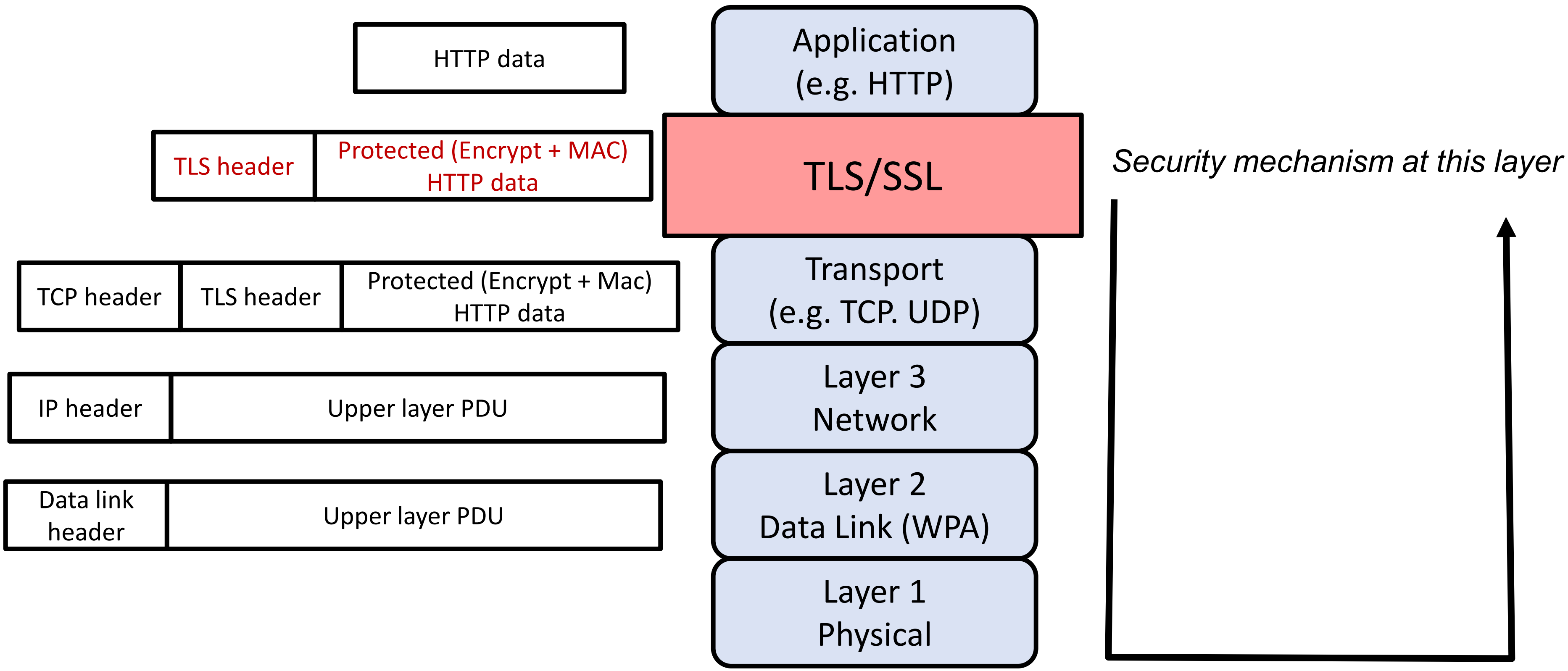
- A security protocol that **protects layer *k***
  would protect information from **that layer and above**
  against an attacker sitting at **layer *k*-1 and below**

- **Example**: what happens if an attacker resides at layer 1, and there is a security protocol that protects layer 3*?*
- What is protected by the security protocol:
  the information generated in layer 3 and above
- What is *not* protected:
  the information generated in layer 2

1. SSL/TLS

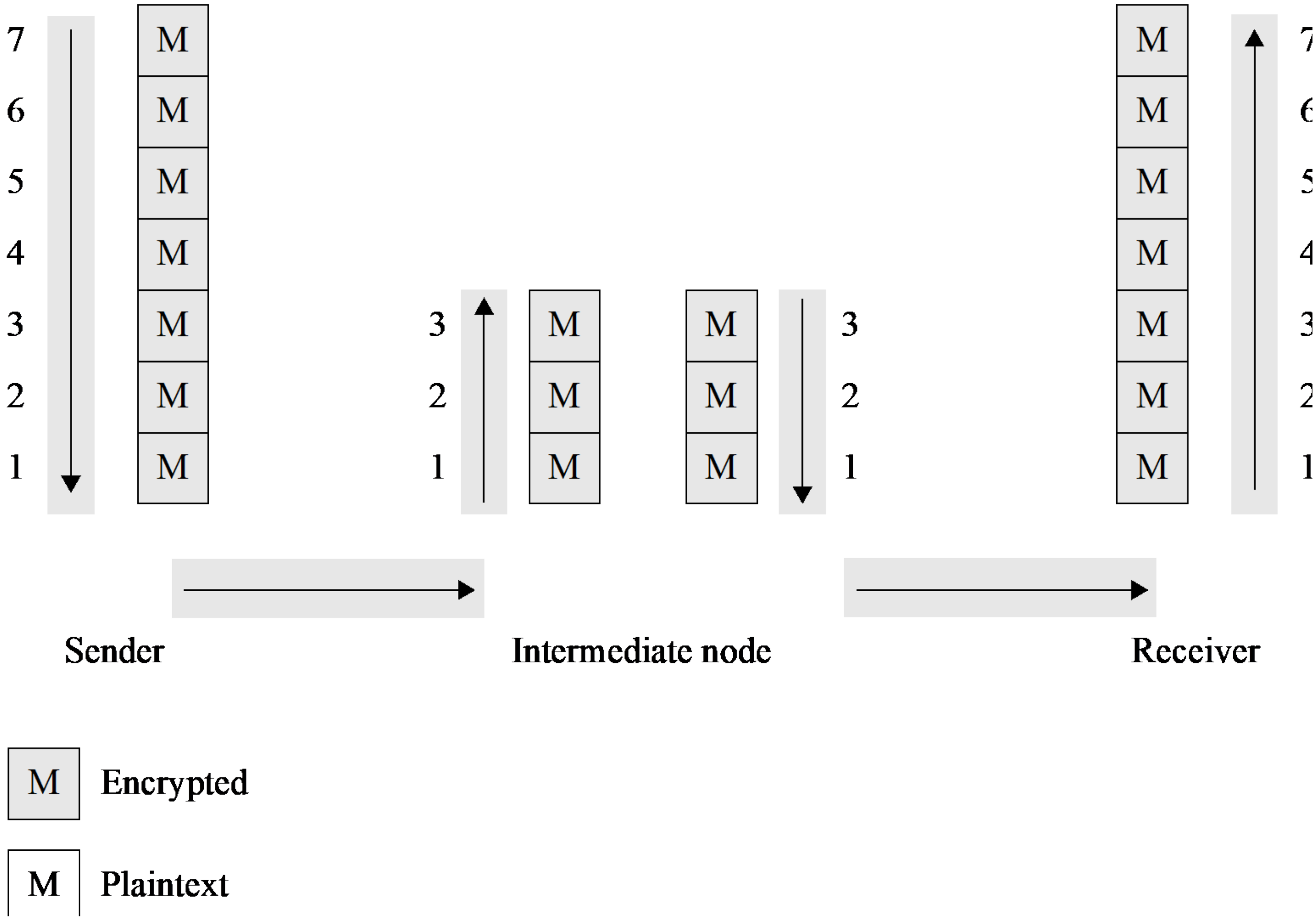
- The SSL/TLS sit on top of **transport layer**
- We can imagine that, when an application (e.g. browser or email agent) wants to send data to the other end point, it first pass the data and the destination IP address to SSL/TLS
- Next, SSL/TLS first "protects" the data using encryption (for confidentiality) and MAC (for authenticity), and then instructs the transport layer to send the protected data
- An **end-to-end encryption** is performed

SSL/TLS Location

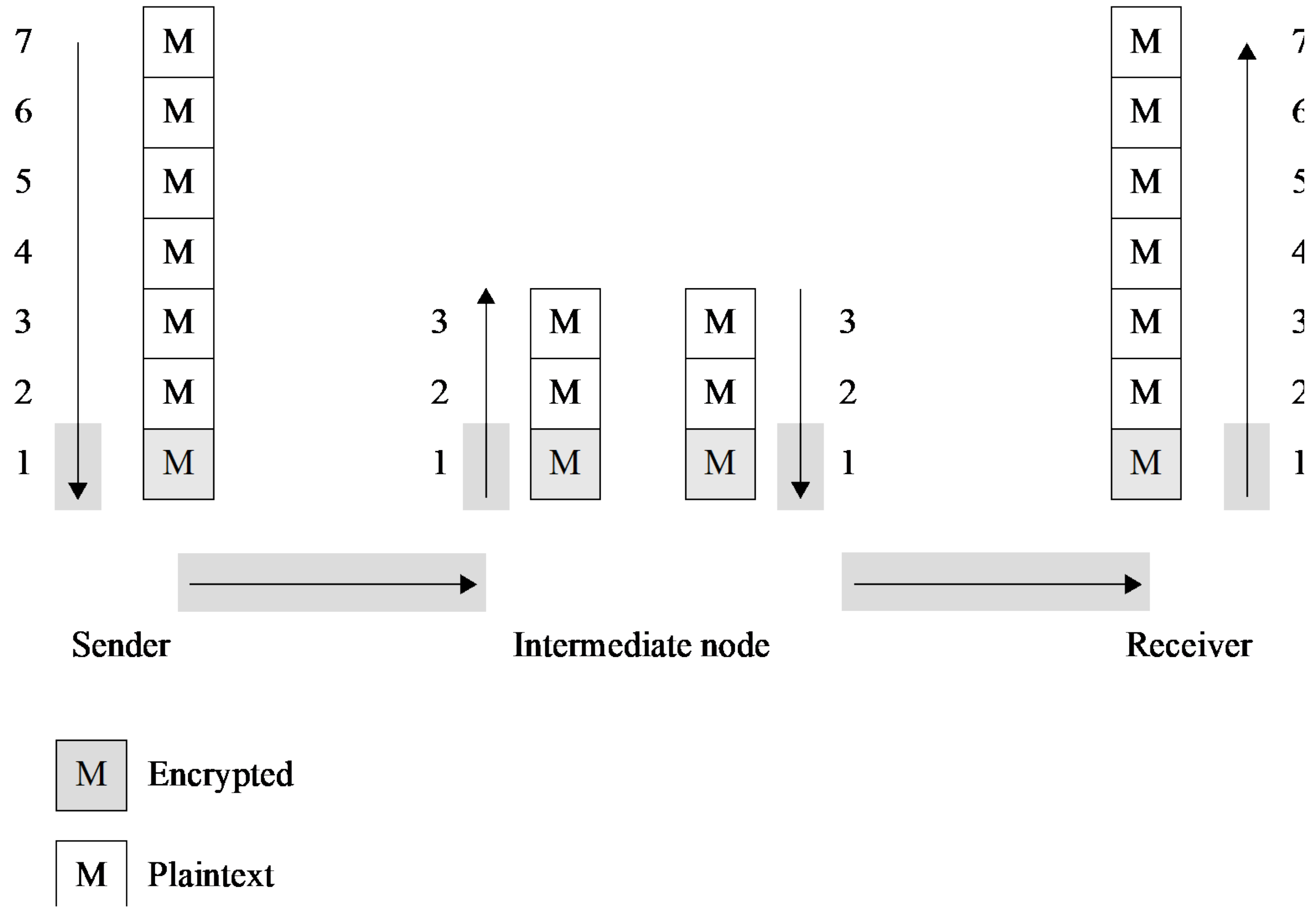


The receiver end-point **decrypts** the received data at the corresponding layer

Terminology: End-to-End Encryption



Terminology: Link (Hop-by-Hop) Encryption



Sample Usage Scenario

- Alice accesses LumiNUS web application to upload her report `a.pdf` to the LumiNUS server
- Note that LumiNUS uses HTTPS, which in turn employs SSL/TLS

Alice's machine carries the following:

1. The "LumiNUS client" passes the file `a.pdf` to HTTPS, and then to TLS
2. TLS protects the data by encryption and MAC
3. TLS passes the protected data to the transport layer

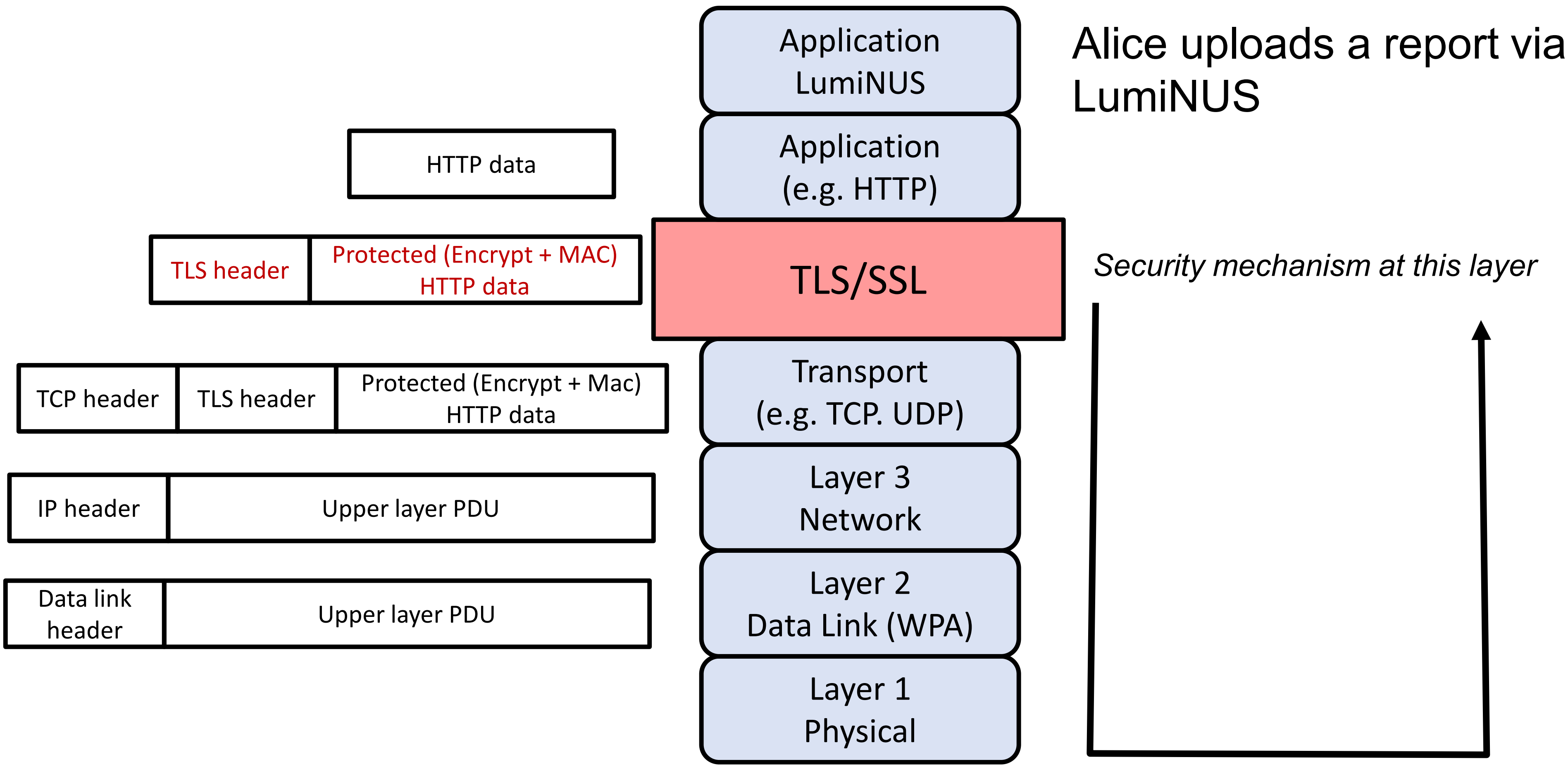
Sample Usage Scenario

The LumiNUS server carries out the following:

1. The transport layer passes the protected data to TLS
2. TLS decrypt the data and verify the MAC for integrity
3. TLS passes the decrypted data to LumiNUS application

- ***Remark***: Many details are omitted in the description. For instance, the "handshaking", whereby the two parties establishing the session keys.

Sample Usage Scenario



The receiver end-point **decrypts** the received data at the corresponding layer

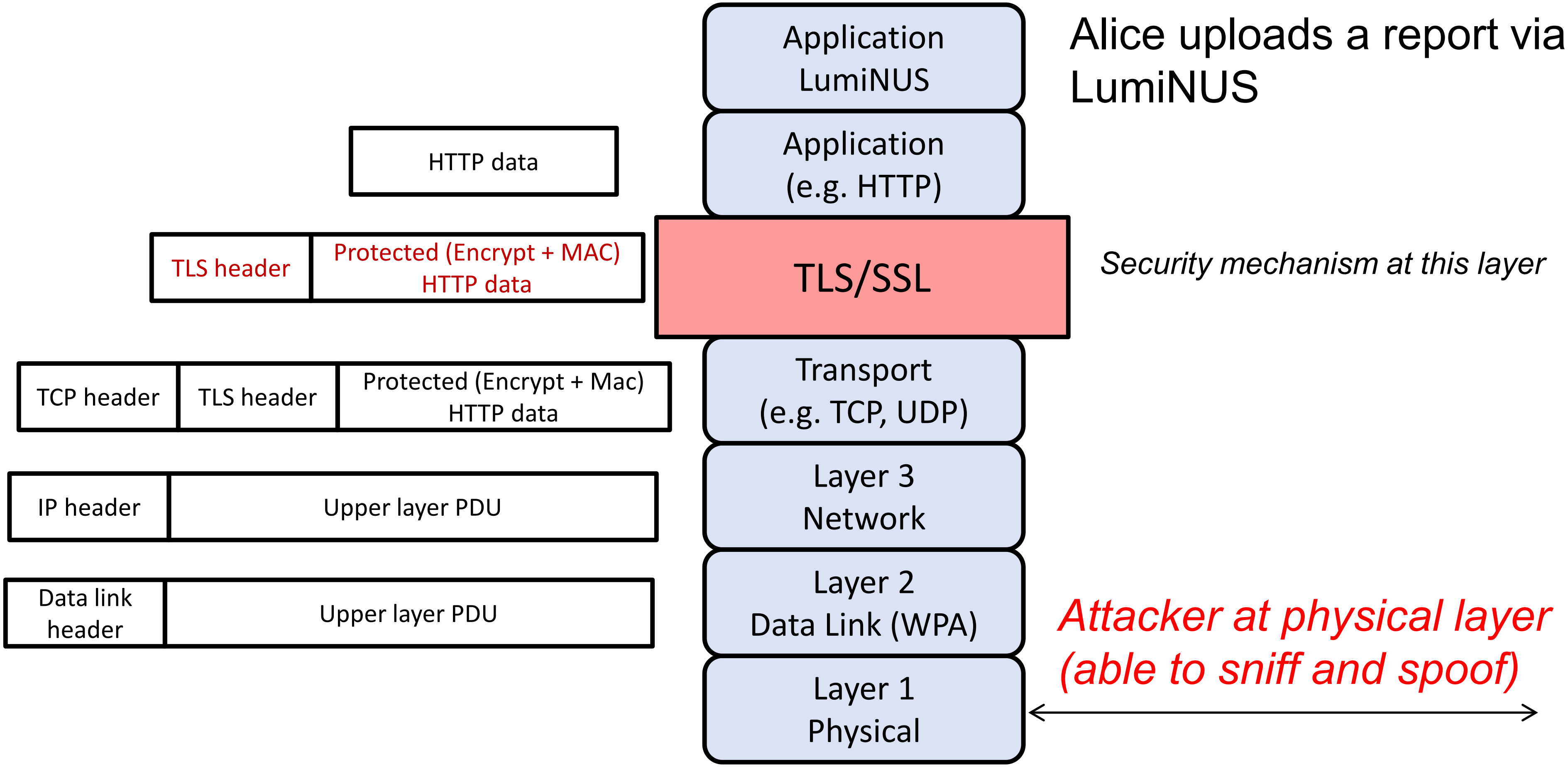
Attack Scenario 1: Attacker at Physical Layer

- Suppose that there is an attacker **at the physical layer**, who can sniff and spoof message at that layer
- **For example**, Alice uploads her report in a cafe using a free/open WiFi (without WPA protection).
  Hence, anyone in the café has access to the physical layer, and thus can sniff and spoof messages in that layer.

Question: Can the attacker learn:

1. Alice's uploaded report?
2. The fact that Alice is visiting LumiNUS website
   (i.e. can the attacker learn the website's IP address)?

Attack Scenario 1: Attacker at Physical Layer



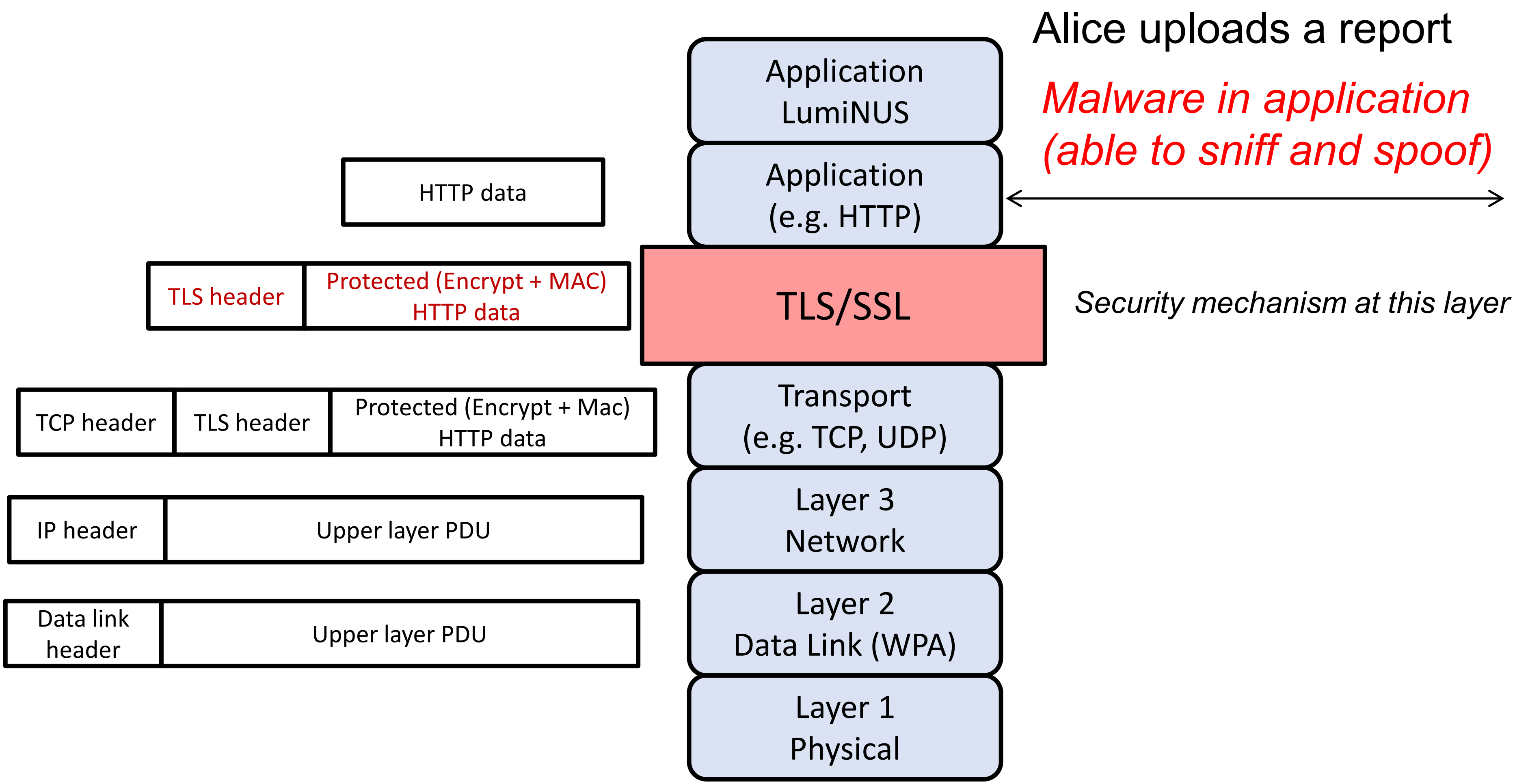
Attack Scenario 2: Attacker at Application Layer

- Suppose that there is an adversary at the **application layer**
- For example, a malicious JavaScript is injected into LumiNUS and being executed by Alice's browser

Question: Can the malicious script learn:

1. Alice's report?
2. *Alice's MAC address?*

Attack Scenario 2: Attacker at Application Layer



2. WPA2

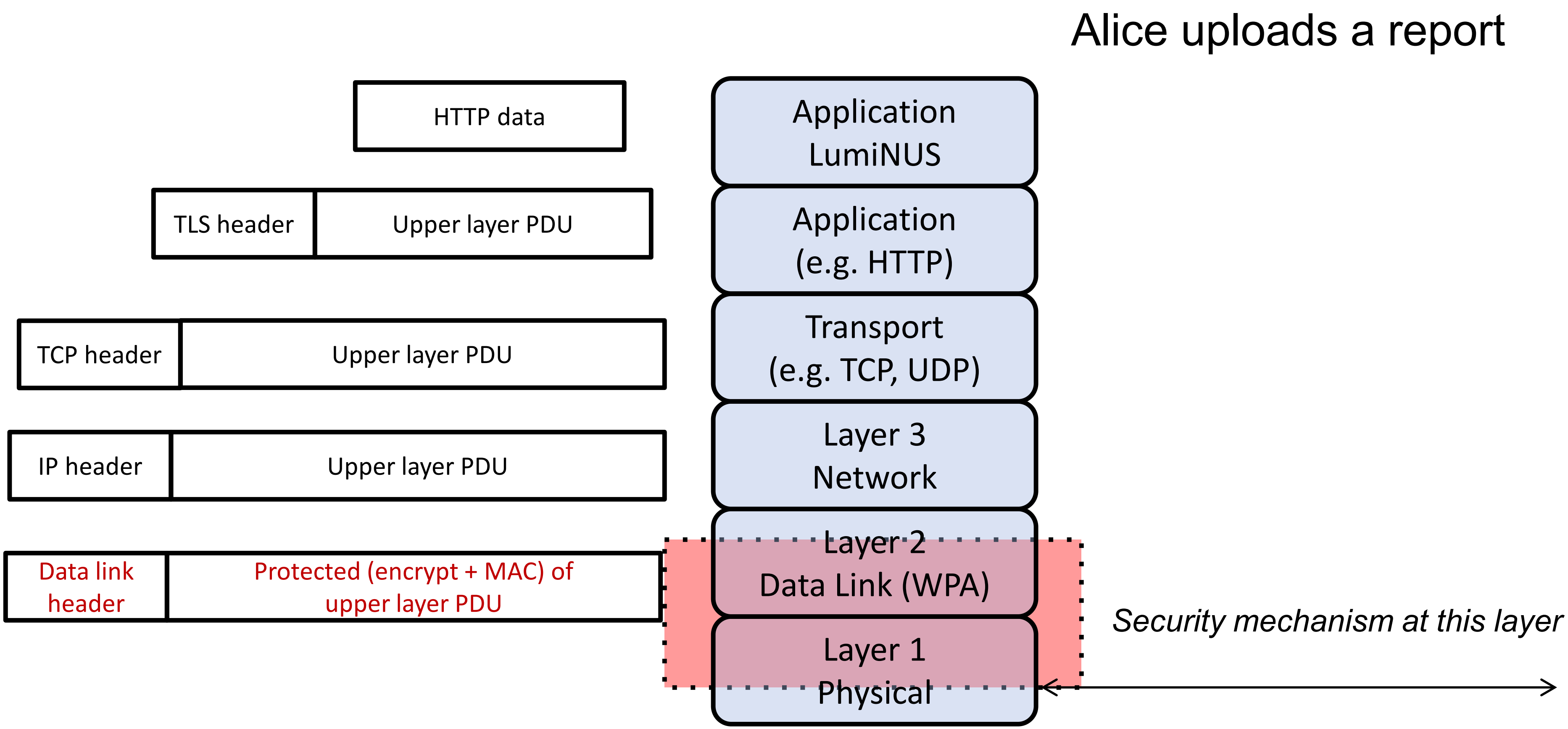
WiFi Protected Access II (WPA2):

- A popular protocol employed in home WiFi access point
- More secure than WEP (broken), WPA

The protections provided:

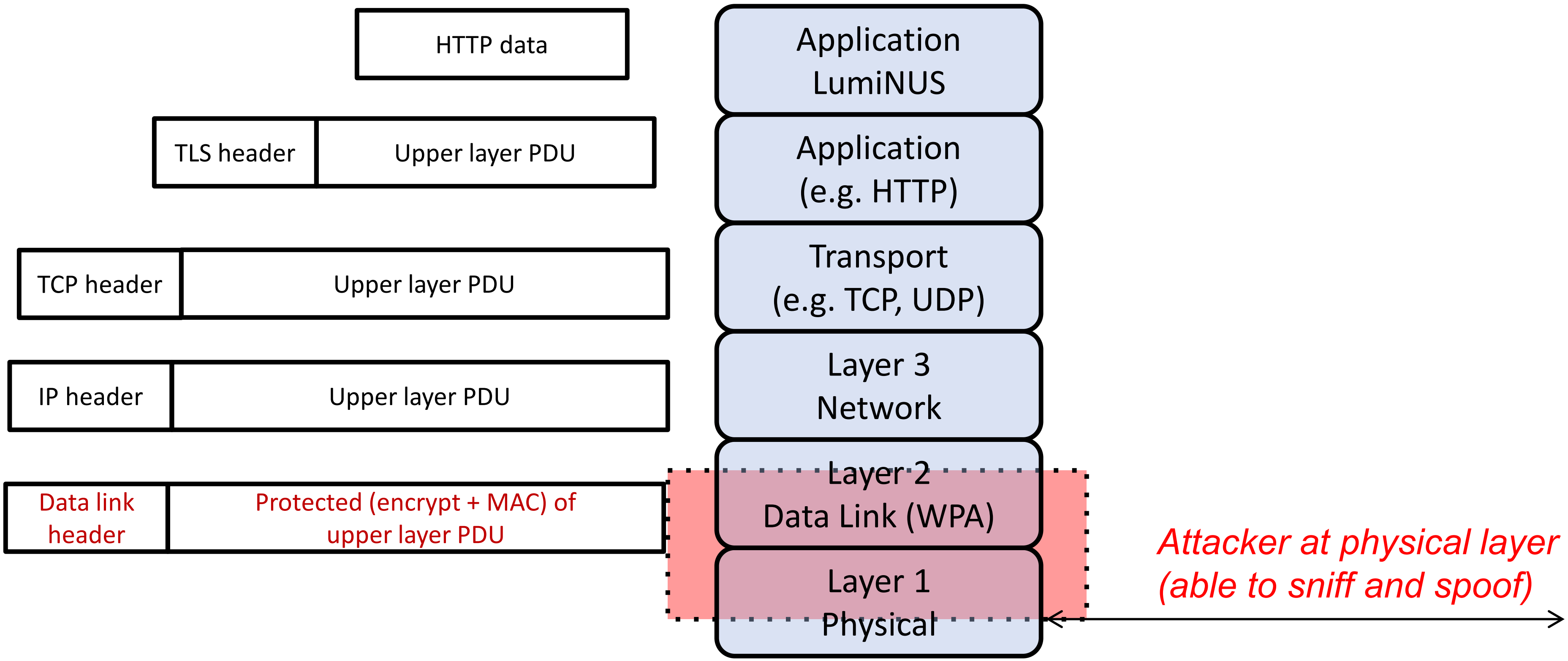
- WPA2 provides protection at layer 2 (link) and layer 1 (physical)
- Note: *not* all information in layer 2 are protected

WPA2 and Network Layers



Attacker at Physical Layer

Alice uploads a report

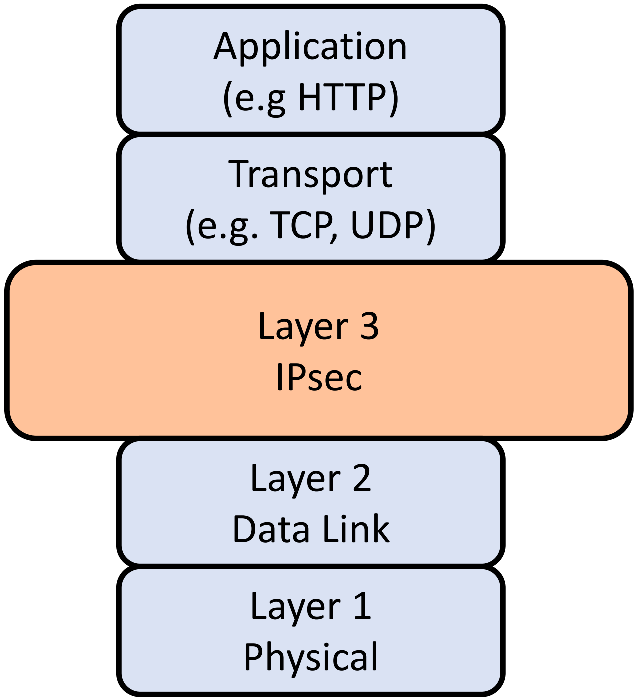


Question: Can the attacker learn:

1. *Alice's report?*
2. *The fact that Alice is visiting LumiNUS website?*
3. *The MAC address (link layer)?* not clear

3. IPsec

- IPsec provides **integrity/authenticity** protection of IP address, but *not* confidentiality
- Hence, attackers are unable to “spoof” the source IP address
- But they can still learn the source and destination IP addresses of the sniffed packets



Remarks on IPsec

IPsec is a mechanism whose goal is *to protect the IP layer*

Its description:

- "**Internet Protocol Security** (**IPsec**) is a protocol suite for securing Internet Protocol (IP) communications by authenticating and encrypting each IP packet of a communication session. IPsec includes protocols for establishing mutual authentication between agents at the beginning of the session and negotiation of cryptographic keys to be used during the session. IPsec can be used in protecting data flows between a pair of hosts (*host-to-host*), between a pair of security gateways (*network-to-network*), or between a security gateway and a host (*network-to-host*).[1]
- Internet Protocol security (IPsec) uses cryptographic security services to protect communications over Internet Protocol (IP) networks. IPsec supports network-level peer authentication, data origin authentication, data integrity, data confidentiality (encryption), and replay protection.
- IPsec is an end-to-end security scheme operating in the Internet Layer of the Internet Protocol Suite, while some other Internet security systems in widespread use, such as Transport Layer Security (TLS) and Secure Shell (SSH), operate in the upper layers at Application layer. Hence, only IPsec protects any application traffic over an IP network. Applications can be automatically secured by IPsec at the IP layer."

-Wiki

Question

Question: Explain the underlined sentences

- "**Internet Protocol Security** (**IPsec**) is a protocol suite for securing Internet Protocol (IP) communications by authenticating and encrypting each IP packet of a communication session. IPsec includes protocols for establishing mutual authentication between agents at the beginning of the session and negotiation of cryptographic keys to be used during the session. IPsec can be used in protecting data flows between a pair of hosts (*host-to-host*), between a pair of security gateways (*network-to-network*), or between a security gateway and a host (*network-to-host*).[1]
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-Wiki

5.6 Protection: Firewall

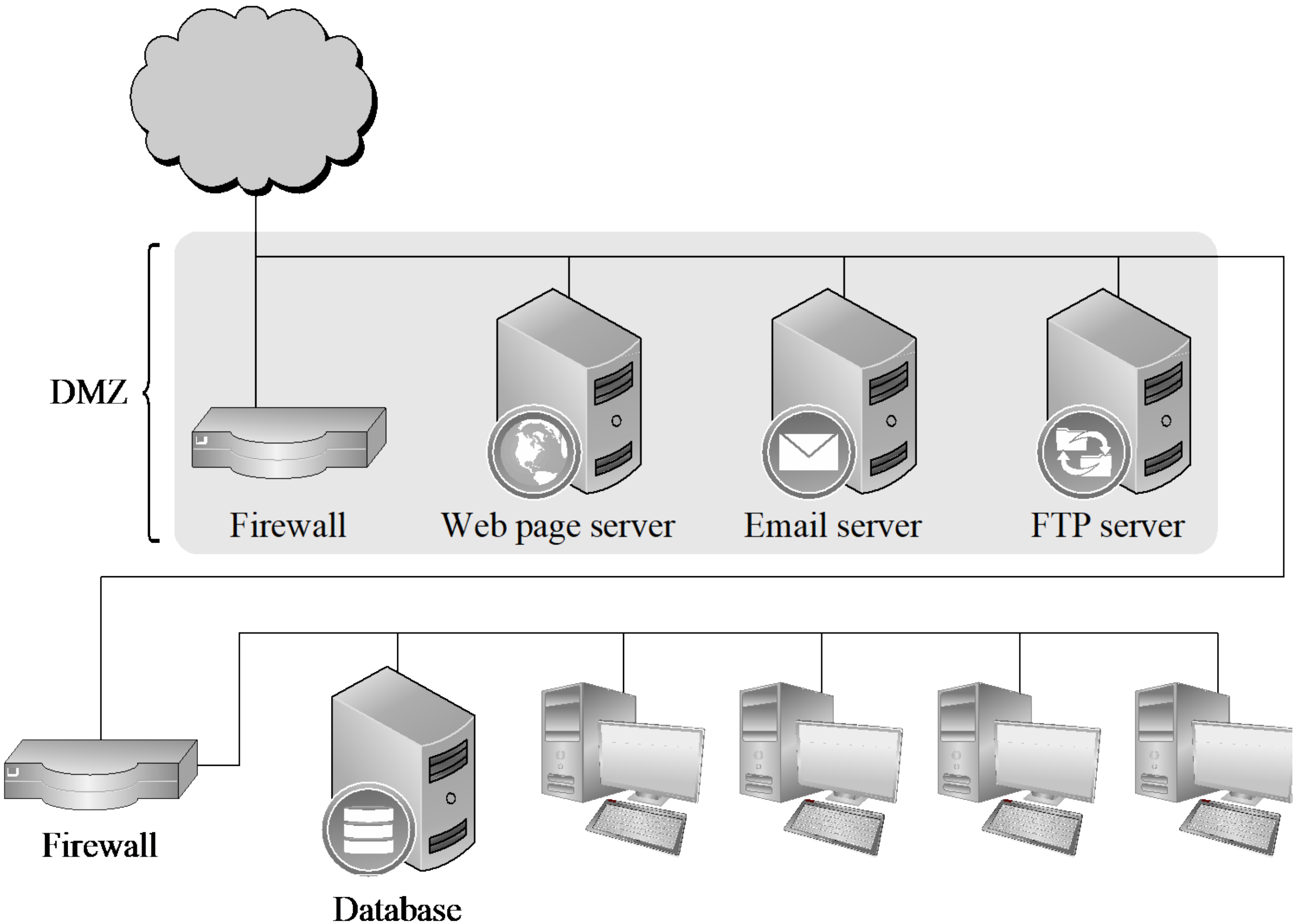
Motivation

- Having SSL/TLS and WPA2 is still *not* sufficient to protect the network:
  - There are concerns of **DOS** that they can't prevent
  - Many services and applications can't be protected by SSL/TLS & WPA2: e.g. **DNS spoofing**
    (It is not practical, due to efficiency, to establish SSL/TLS to the DNS server for DNS query)
- There is a need to control **the flow of traffic** between networks, especially between the untrusted public network (Internet) and the trusted internal network

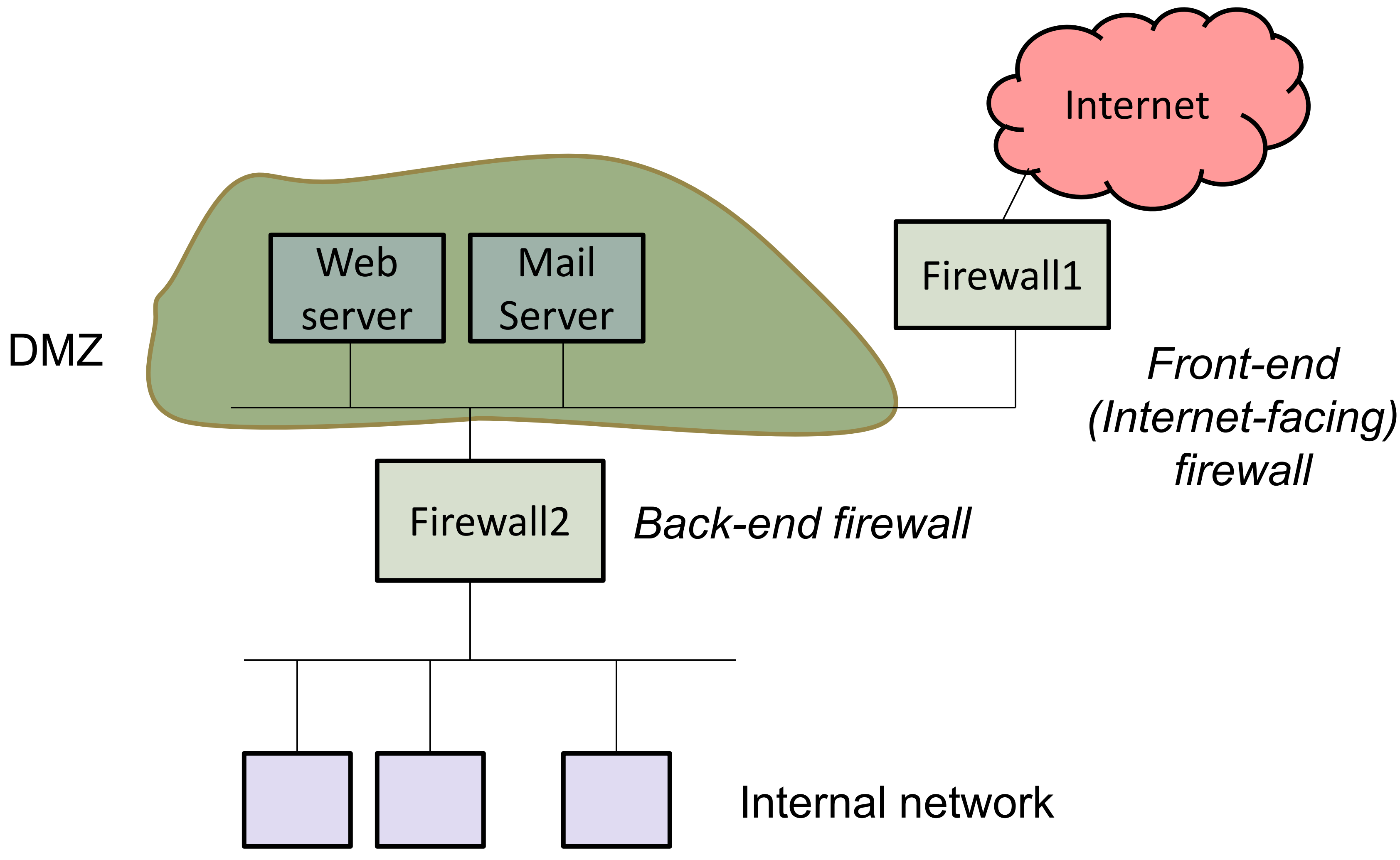
Firewall

- Firewall:
  - Sits at border between networks
  - Looks at addresses, services, other characteristics of traffic
  - Controls what traffic is allowed to enter the network (ingress filtering), or leave the network (egress filtering)
- **Definition**: *"Firewall are devices or programs that control the flow of network traffic between networks or hosts that employ differing security postures."*
  (From "Guidelines on Firewalls and Firewall Policy", NIST, special publication 800-41 http://csrc.nist.gov/publications/nistpubs/800-41-Rev1/sp800-41-rev1.pdf.)
- **DMZ (Demilitarized Zone)**:
  - A small sub-network that exposes the organization's external service to the (untrusted) Internet
  - The original military term: an area between states in which military operations are not permitted

Demilitarized Zone (DMZ)



Typical 2-Firewall Setting



Firewall Design (Read [PF] pg 453)

- A firewall enforces a **set of rules** provided by the network administrator
- Examples of rules for Firewall2 (back-end firewall):
  - Block HTTP
  - Allow from Internal network to Mail Server: SMTP, POP3
- Examples of rules for Firewall1 (front-end firewall):
  - Allow from anywhere to Mail Server: SMTP only
- How the rules are to be specified differs on different devices and software
- The next slide gives a typical design/configuration (from [PF] pg. 453)

Sample Firewall Configuration

Rule No	Protocol Type	Source Address	Destination Address	Designation Port	Action
1	TCP	*	192.168.1.*	25	Permit
2	TCP	*	192.168.1.*	69	Permit
3	TCP	192.168.1.*	*	80	Permit
4	TCP	*	192.168.1.18	80	Permit
5	TCP	*	192.168.1.*	*	Deny
6	UDP	*	192.168.1.*	*	Deny

* (any) matches **any** value

The table is processed in a **top-down manner**

The **first matching rule** determines the action taken

Hence: put your most specific rule *first*, and put your most general rule *last*

Types of Firewall

The textbook [PF] lists **6** types of firewalls

The literature, including NIST's document (NIST 800-41), usually groups firewalls into **3 types**:

1. **(Traditional) packet filters**:
   - Filters packets based on information in *packet headers*
2. **Stateful-inspection (packet filters)**:
   - Maintains a *state table* of all active connections
   - Filters packets based on active connection states
3. **Application proxy**:
   - Understands application logic
   - Acts as a relay of application-level traffic

(Details are not required for this module)

Comparison of Firewall Types [PF]

Optional

Packet Filter	Stateful Inspection	Application Proxy	Circuit Gateway	Guard	Personal Firewall
Simplest decision-making rules, packet by packet	Correlates data across packets	Simulates effect of an application program	Joins two subnetworks	Implements any conditions that can be programmed	Similar to packet filter, but getting more complex
Sees only addresses and service protocol type	Can see addresses and data	Sees and analyzes full data portion of pack	Sees addresses and data	Sees and analyzes full content of data	Can see full data portion
Auditing limited because of speed limitations	Auditing possible	Auditing likely	Auditing likely	Auditing likely	Auditing likely
Screens based on connection rules	Screens based on information across multiple packets—in either headers or data	Screens based on behavior of application	Screens based on address	Screens based on interpretation of content	Typically, screens based on content of each packet individually, based on address or content
Complex addressing rules can make configuration tricky	Usually preconfigured to detect certain attack signatures	Simple proxies can substitute for complex decision rules, but proxies must be aware of application's behavior	Relatively simple addressing rules; make configuration straightforward	Complex guard functionality; can be difficult to define and program accurately	Usually starts in mode to deny all inbound traffic; adds addresses and functions to trust as they arise

5.7 Protection:
Network Security Management

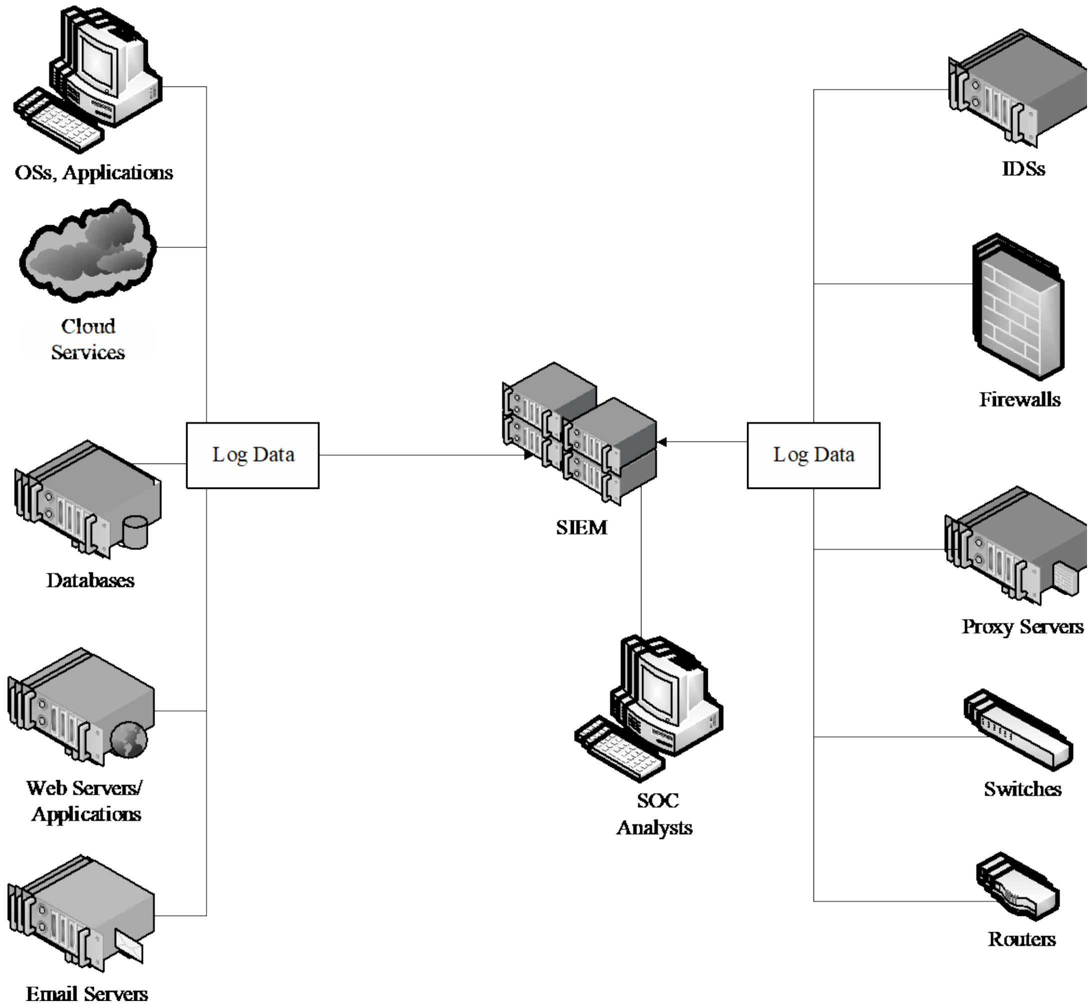
Network Security Management

There is a need to *continuously* monitor and adjust network characteristics
(Details on this are omitted. See [PF6.9])

Some terms:

- **Security Operations Center (SOC)**:
  - A centralized unit in an organization that monitors the IT systems and deals with security issues
- **Security Information and Event Management (SIEM)**:
  - Pronounced as "SIM"
  - Provides **real-time analysis** of security alerts generated by network hardware and applications
  - May include the following **capabilities**:
    data aggregation & correlation, event alerting, compliance report generation, forensic analysis

Security Information and Event Management (SIEM)



End of Part 1 of CS2107

- Were are halfway in the module:
  Great and thanks!
- Do enjoy your recess week
- Good luck for your Assignment 1!
- All the best for your mid-term quiz too!
- See you again in Week 7