Introduction –Cryptographie et Sécurité des Communications–

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- MSc in Computer Science - Grenoble 2001
- PhD in CS at INPGrenoble - Programming of Critical Reactive Systems
- Associate Professor at INSA Lyon since 2007.
- (past) Research topics:
  - at Grenoble, Turku (Finland), Rennes, and Lyon: Models of concurrency and computations, programming languages, performance analysis for parallel multi-core architectures.
  - at CEA-Grenoble (2017-2020): **Counter-measures against physical (side-channel, fault-injection, etc) attacks**
- Current Research: **operating systems** and programming languages **for** addressing so-called **frugality**, Phenix Citi[1]
- Teaching at the IF department: Computer Architecture, Operating Systems, Compiler Construction

[1] `https://phenix.citi-lab.fr/`

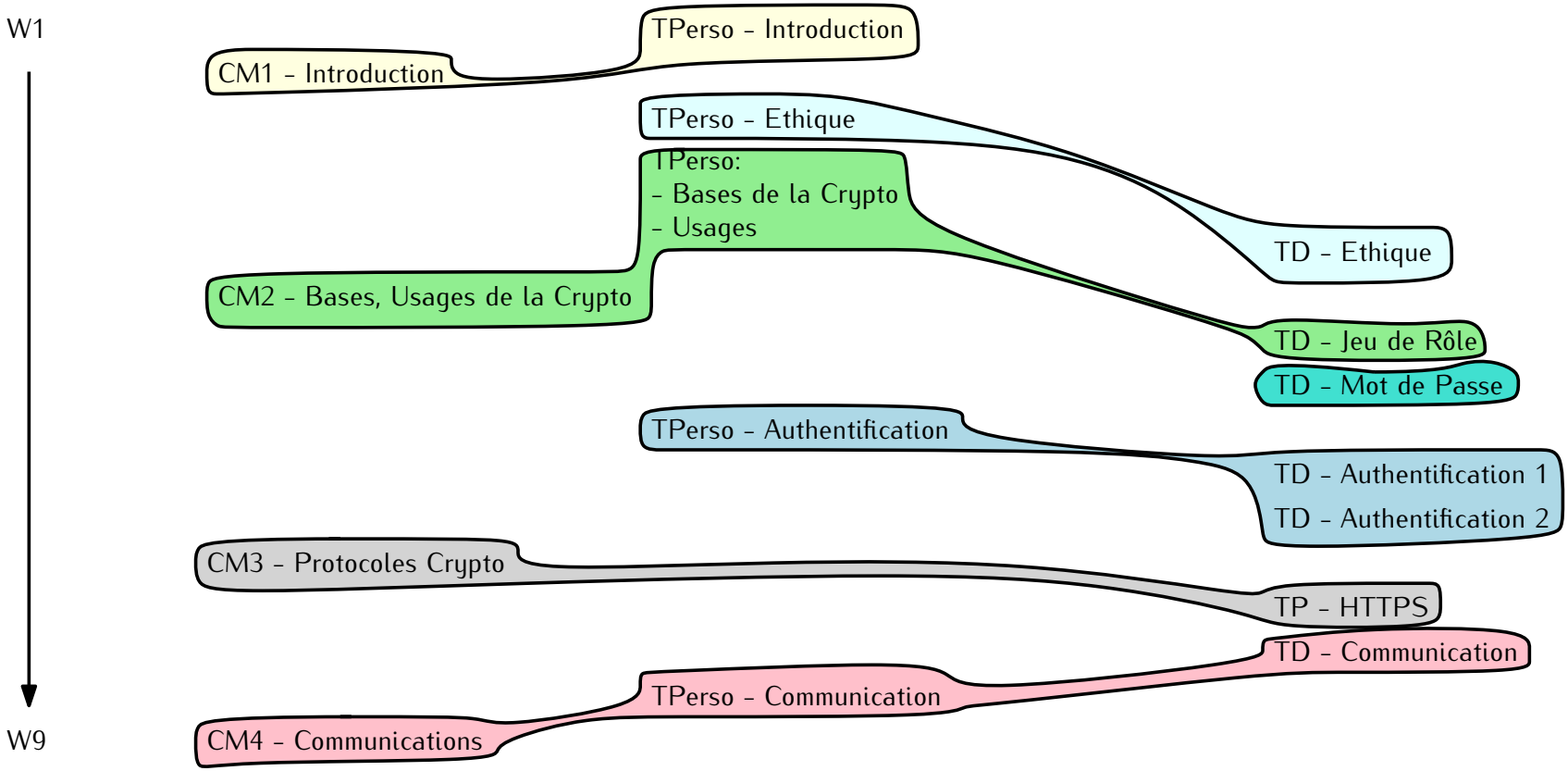
[2] `lionel.morel.ouvaton.org/`

Course Objectives

Give you some “necessary and sufficient” background on:

- Cryptography
- Cryptographic protocols
- Public-key infrastructures
- Ethical issues

Course Plan


W1
W9
CM1 - Introduction
TPerso - Introduction
TPerso - Ethique
TPerso:
- Bases de la Crypto
- Usages
CM2 - Bases, Usages de la Crypto
TD - Ethique
TD - Jeu de Rôle
TD - Mot de Passe
TPerso - Authentification
TD - Authentification 1
TD - Authentification 2
CM3 - Protocoles Crypto
TP - HTTPS
TD - Communication
TPerso - Communication
CM4 - Communications

Information Security

- **Information security** $\triangleq$ practice of protecting information by mitigating information risks[3]
- Need to protect all elements dealing with information: computers, networks, people
- Security covers a lot of different aspects: physical security, social engineering, communication security, etc.
- $\triangleq$ practice that allows to maintain the CIA triad (see next)

[3] https://en.wikipedia.org/wiki/Information_security

The CIA Triad

- **Confidentiality**: Information is not made available or disclosed to unauthorized individuals, entities, or processes.[4]
- **Integrity**: Information is not modified in an unauthorized or undetected manner. Also called **anti-tampering**.
- **Availability**: Information is available when it is needed.

[4] Beckers, K. (2015). Pattern and Security Requirements: Engineering-Based Establishment of Security Standards.

Threats

- A **threat** is a potential negative action or event that can result in unwanted impact to a computer system, application or user information.
- A **threat model** is a set of properties that characterize threats associated to a particular environment. Often implies **security requirements** on a system.

Vulnerabilities

- A **vulnerability** is a weakness which can be exploited by an attacker to access unauthorized information or to compromise the attacked system's behavior
- The **attack surface** of a system/application is the set of (known) vulnerabilities exposed by it to a potential attacker.

Attacks

- **Attack** = Attempt to exploit a vulnerability
- Attack can be:
  - Passive (eavesdropping, side-channel, etc)
  - Active (worm, faults, etc)
  - Denial-of-service
- When the attack is successful, we say the system is **compromised**

Trust

- **Trust** = Degree to which an entity (person, system, hardware, software) is going to behave as expected
- A **Trust model** describes which entity(ies) is/are trusted and at which level.

Threats and attack techniques - Examples

- Eavesdropping, Trojans, Worms, Viruses
- Buffer Overflows, Spoofing, MITM attacks, Replay attacks,
- Shoulder surfing, Dumpster diving,
- Password attacks (brute-force, dictionnary based), malicious-code attacks,
- Side-channel attacks: cache, timing, power-monitoring, etc.

Defenses - a quick panorama

- Cryptography
- Secured communication protocols
- Code and Data Encryption
- Physical shielding
- White-box cryptography

Definition - Communication Security

Communication Security $\triangleq$ discipline of preventing unauthorized interceptors from accessing telecommunications in an intelligible form, while still delivering content to the intended recipients. [5]

[5] https://en.wikipedia.org/wiki/Communications_security

Cryptology

Cryptology, is the science of practice and study of techniques for secure communication in the presence of adversarial behavior.

- **Cryptography**: Practice and study of techniques for secure communication in the presence of adversarial behavior.
- **Cryptanalysis**: Process of analyzing information systems in order to understand hidden aspects of the systems.
- **Cryptology = Cryptography + Cryptanalysis**

In this course, we mainly focus on **Cryptography**.

A brief history of cryptography

- Keeping message secret has always been a (powerful) men's concern ...
- ... but (at least today) it's also of every person's interest.
- ... because there is no "I got nothing to hide"

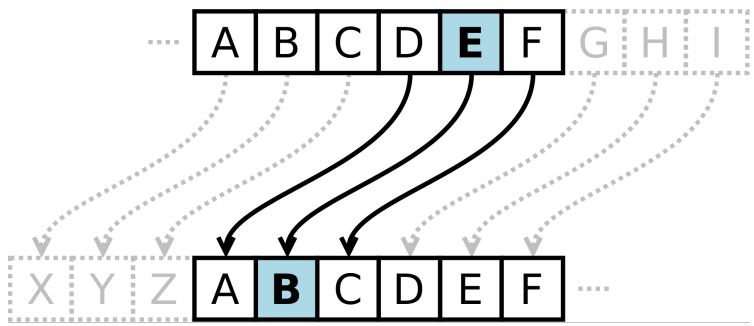
History (1) Caesar cipher

- Substitution cipher
- Each letter is encoded with its order in the alphabet: A$\rightarrow$0, B$\rightarrow$1, ..., Z$\rightarrow$26
- We choose a **fixed *shift value*** *sh*
- To **encrypt**, each letter P_i in Plaintext is replaced by the corresponding shifted letter:

$$\boldsymbol{E(P_i) = (P_i + sh)\ \textbf{mod 26}}$$

- To **decrypt**, each letter C_i in the Ciphertext is converted back with :

$$\boldsymbol{D(C_i) = (C_i - sh)\ \textbf{mod 26}}$$



History (1) Caesar cipher

- Encryption and decryption are cheap
- Easy to crack with frequency analysis
- Sufficient when no-one around can read :)

One-time pad

- Substitution cipher
- Choose a **random key** K as least as long as the plaintext
- To **encrypt**, each letter P_i in Plaintext is replaced by the corresponding shifted letter:

$$\boldsymbol{E(P_i) = (P_i + K_i) \bmod 26}$$

- To **decrypt**, each letter C_i in the Ciphertext is converted back with :

$$\boldsymbol{D(C_i) = (C_i - K_i) \bmod 26}$$

One-time pad - Pros and Cons

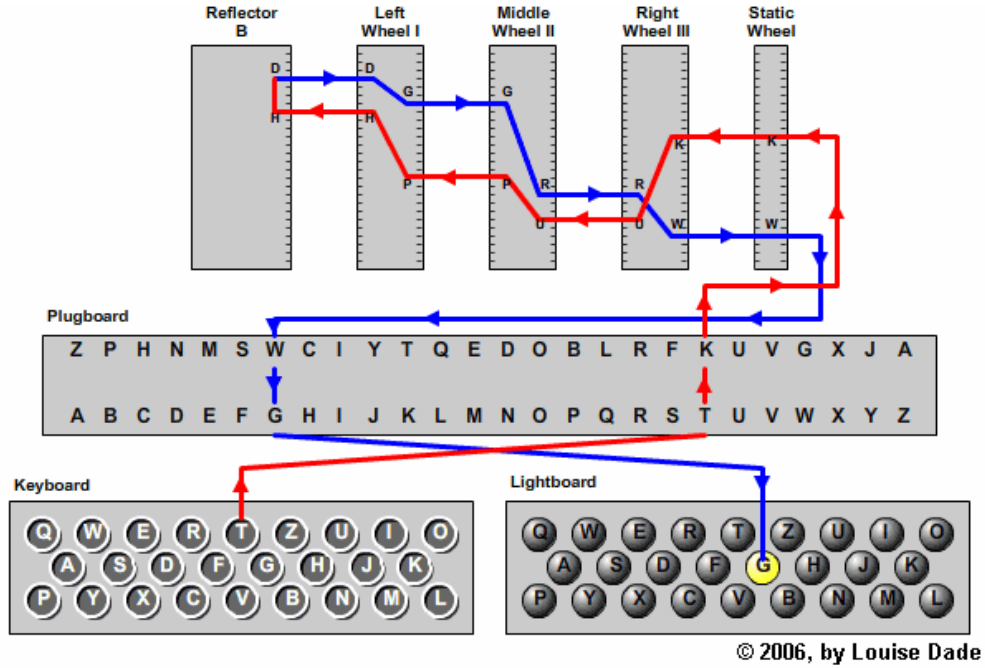
- ➕ Proven secure
- ➕ Even to frequency analysis
- ➕ Encryption and decryption are cheap
- ➖ Key must be as long as the plaintext ...
- ➖ Key must be kept secret
- ➖ Key must not be lost (not by one character)
- ➖ Key must be truly random

Enigma

- Invented at the end of WWI
- Used extensively by Nazi Germany during WWII
- First cracked by Polish services during the early 30s ...
- ... the by British-led effort at Bletchley Park, including Alan Turing.

Enigma - How does it work?

- Substitution cipher



Enigma - How does it work?

- **Every day**, the machine is reset to a pre-established configuration:
  - Rotors choice (3 or 4 or 5 amongst 6 possible)... = 20.
  - Rotors permutation 26^3
  - Rotors initial positions 26^3
  - Plugboard setting: 150.10^{12}
- **Every message** contains a rotors position the machine should be reset to before decrypting the rest of the message.

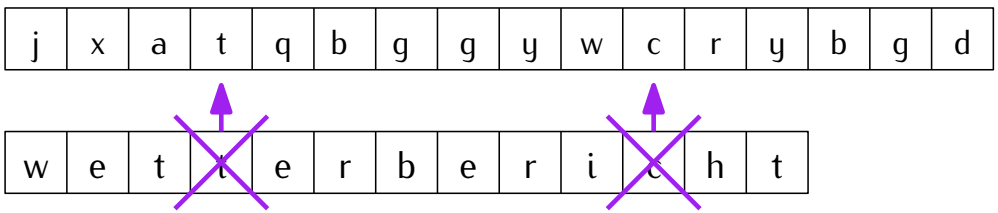
Enigma - breaking the machine

- To brute-force Enigma is unpractical: 150 millions millions combinations
- A letter is encrypted into a different letter every time ....
- ... but never to itself !! **Main flaw**
- Try to guess a word or phrase in a message (and Germans military did use reccurring messages, like weather reports)
- ...

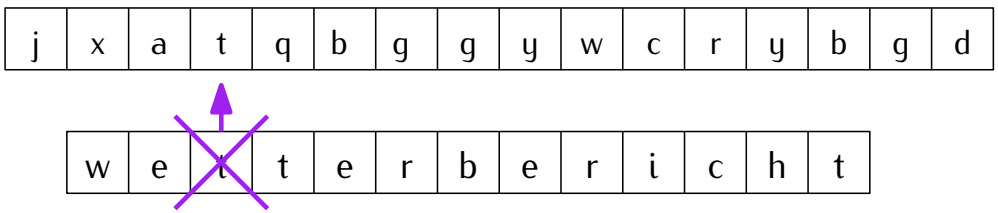
Enigma - breaking the machine

j	x	a	t	q	b	g	g	y	w	c	r	y	b	g	d

Enigma - breaking the machine



Enigma - breaking the machine



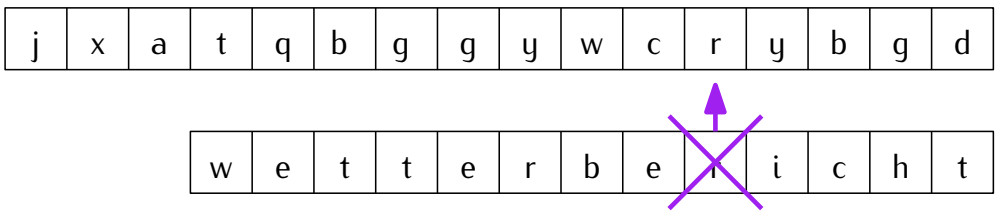
Enigma - breaking the machine

j	x	a	t	q	b	g	g	y	w	c	r	y	b	g	d

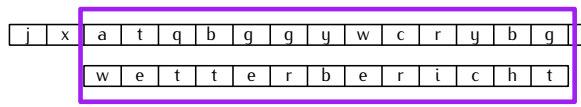
w	e	t	t	e	r	b	e	r	i	c	h	t

OK !

Enigma - breaking the machine

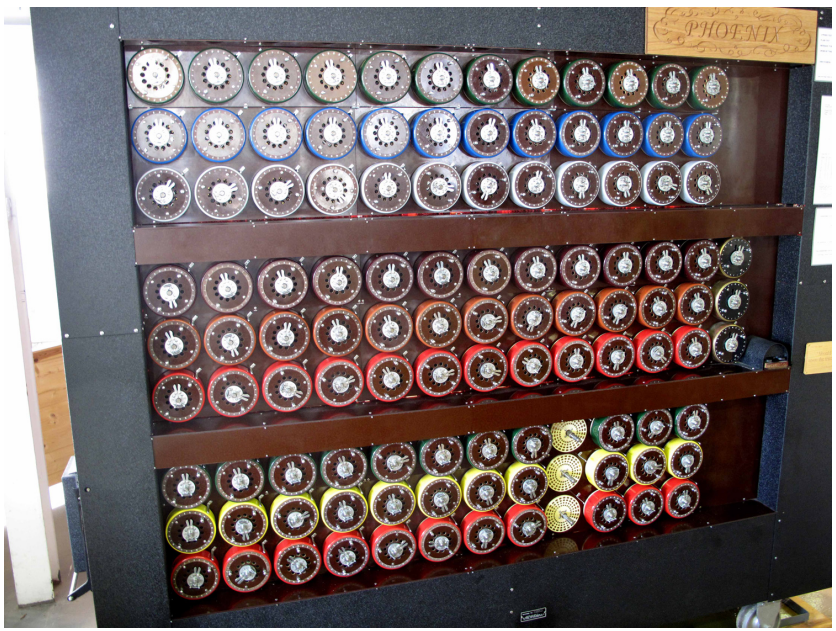


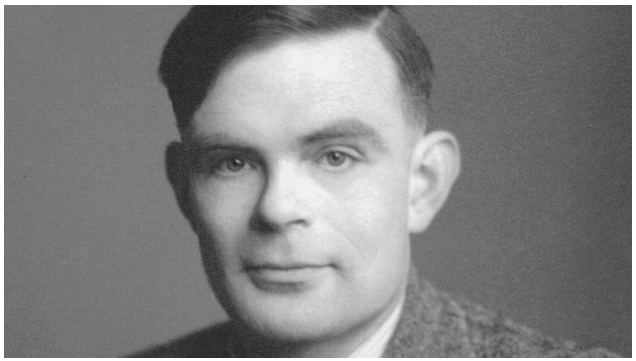
Possible Solutions



Enigma - breaking the machine

- Adding a couple more properties, evict impossible configurations.
- Scan through the remaining combinations using **the Bombe** : electro-mechanical machine able to “play” 36 Enigma equivalent “in parallel”.
- In the end .... guess the key (wheel starting positions + plugboard) in less than 20minutes per day.





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[6] watch `https://en.wikipedia.org/wiki/The_Imitation_Game`

Next time - Cryptography

- Symmetric cryptography
- Asymmetric cryptography
- Key sharing