Digital Forensics and Cybercrime

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Part I

Cybercrime: threats, modus operandi, underground economy, financially-motivated malware

Chapter 1

Cybercrime: Threat Landscape

Working on security we work on **risk**, which is composed of different elements:

$$Risk = Asset \times Vulnerabilities \times Threats$$

The risk is the statistical and economical evaluation of the exposure to damage because of the presence of vulnerabilities and threats.
With no threats there are no risks, because it is the only thing that can nullify this equation. Assets and vulnerabilities are never absent.
With no *Threat model* we're completely misguided on the management of our system in terms of security.

1.1 Threat landscape

Threats can be roughly divided along three directions:

Internal vs External treaths an internal treath comes from the inside of the organization, it is part of the organization, while an external one don't.

Generic vs Targeted many security threats are generic:

- Generic threats: when you walk towards the underground, you're subjected to pickpocketers: they don't pick you because it's you, you're one of the others, it is a generic treath.
  Generic threats are not linked to us by definition, they are linked to us because we look alike somebody easy to be pickpocketed, not because we were the target.
- We can also consider also threats which are not so very generic: aggressions for sexual reasons are more targeted to one gender than one other, while still being generic.

- Targeted threats: specifically designed against us: criminals target **that specific company** *(e.g. the know how for racing cars, i want to steal from THAT company in particular).*

These directions also affect the kind of attacker: pickpocketers vs highly "professional" skilled stealer of information

Financially motivated vs Anything Else we divide:

- **financial attackers** *(which are the most of them)*,
- **other attackers** *(governments, secret services, hacktivists..)*.

Financially motivated attackers has 2 important positive characteristics:

- **easy to predict:** you look at valuable goods from companies and you can predict who the attackers can be *(e.g. ransomwares)*
- **they're relatively easy to handle:** just deny them the opportunity to take money, like making it too costly wrt what they want to earn.
  Notice that what is easy to understand is how to handle them, not to actually handle.

Non financially motivated ones are more difficult to handle:

- We cannot make them too costly or too risky *(e.g. Russians vs Ukraine's Donbass power plant: they have an entire state funding them, and they cannot be arrested for it)*, they have more money and they can take more risks
- If they're internal, they already know about the company and its security systems.
- The more motivated is the attack, the more determinated is the attacker

1.1.1 A gartner quadrant of threats

	Generic	Specific
Internal	**disgruntled**[1] employee	**socially-engineered or disonhest** employee *(financially motivated)*
External	Criminals, usually looking to make money *(financially motivated)*	A variety of advanced hackers *(mostly financially motivated)*

- **Generic internal threats:** a disgruntled employee who wants a raise, has something against his colleagues, was fired ...
  The treath doesn't need to be linked on what the organization does.
- **Specific internal attacks:** former employee stealing from old employer and bringing to the new one, it also exists a specific job which consists in being hired from companies just to steal from them.
  Or, employee can also be *social-engineered* into behaving like attackers.
- **Generic external attackers:** attackers which want to earn quick money, they aim to things which are common for all companies, like stealing money from bank accounts and so ....
  They are mostly motivated by financial reasons.
- **Specific external attackers:** industrial spies which aim for money, or governments or terrorists aiming for the destruction of a power plant near Donetsk.

The most important quadrant is than the one which comprends disonhest or social engineered people *(human factor)*: our instinct say us that we need to protect from the outside because we are clan-based animals, and we have our group of trustworthy animals *(our clan)* to which we are positively implicitly biased. **Think about the most famous security technologies:**

- Firewalls are meant to keep people out
- Antiviruses are meant for generic attacks, they use a generic list of malwares

Most of our security technologies protect against external attackers.

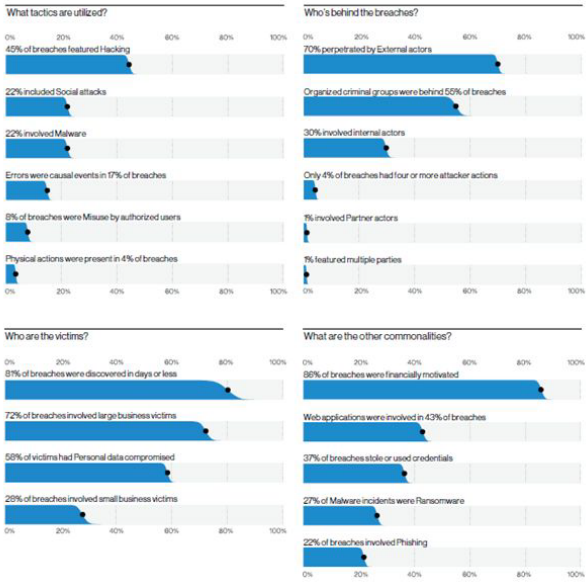
1.1.2 Examples of internal treaths

A bit more on:

- **Reckless or socially engineered employees:** in security we often have a wrong perception of the *human element*.
  When a company gets infected by a malware because a user clicked on a link or something similar, we blame the *stupid* user for it. But, actually it's not fault of the employee: it is fault of who had the responsibility to manage the fact that a threat was present and it had to be controlled.
  Since there will always be someone to click on links, our job is to make sure that they doing it doesn't cause damages to the organization.
  e.g. in aviation they study human factor to understand what to do to don't let people make mistakes: in airplanes cockpits there are different levers with different shapes, them are exactly shaped the same in different kinds of planes, it is a standard, and the reason is because people lost their lives because of similar levers.
  The solution wasn't to train pilots, but to make the threat difficult to happen.

- **Thirty-party users:** they're for example consultants that work in a company for a long time, where they actually do jobs very similar to the ones of the actual employees while not being true employees of the company.

1.1.3 Data breaches and targeted attacks



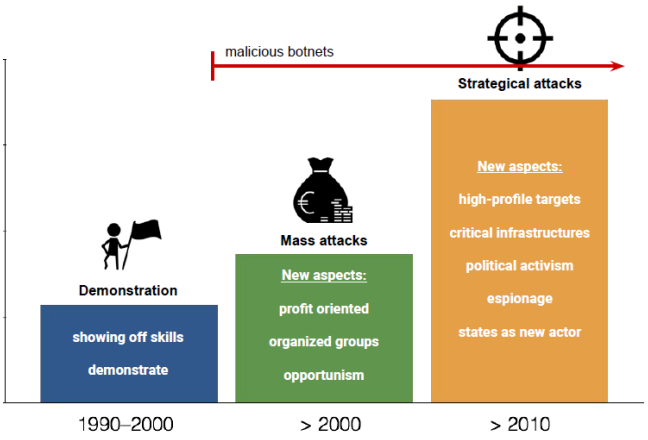
Verizon has a big sample of incidents made to their customers:

- The largest part of the attacks features hacking of some sort, the second larger chunk comprends social attacks.
- The 70% of breaches are perpetrated by external actors. This means that 30% of them starts from the inside, an incredibly high percentage.
  Consider that data are skewed[2], in the real world the internal attacks can be even more! *(remember the external threats reasoning, rationality (data) tells us that a lot of threats come from the inside, while our instinct guide us to be aware of the outside)*
- The 86% of them were financially motivated, 14% which are not, are a lot too!

These data are biased and are not representative of the true reality of threats, because simply they're not all collected. This collection can still help us to rationally think on how to manage the overall situation.
Keep in mind that some security incidents are specifically designed to be difficultly found, a lot of them has never been. This means that there is an entire set of breaches that no one ever investigated.
We measure attacks that we investigated/detected, and this is called the **observation bias**:
Other attacks by their nature be discovered, *(e.g. Dos, ransomware . . .)* that's the reason why they are so prevalent in our statistics: they are observed.

[2] biased

1.2 Brief history of malicious software



Over the last few decades attacks and attackers changed:

- **1990-2000:** most of the attacks were meant to show skills and explore
- **2000-2010:** with the birth of the Internet, massive, profit oriented attacks born. In this period were born also groups working as profitable enterprises of cybercrime.
- **2010-today:** attacks evolved: mass attacks kept happening, but now a lot of them are high profile financial attacks *(before: ransomwares, i ask small amount of money to single persons. now: ransomware attack specific companies to get a lot of money)*

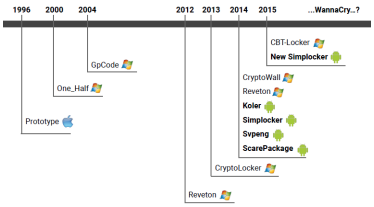
1.3 Financially motivated attackers

Today financially motivated attackers are the "mass", they're interested in monetizing their attacks in possibly two ways:

- **Direct Monetization:**
  - Credit card/bank account frauds
  - Ransomware attacks
  - Crypto-miners
  - Fake antiviruses: they show you warnings that say your computer is infected, and to pay to activate the premium version to get rid of the malware. In reality they are just fake programs asking you to pay for a license.
  - Premium calls: back in the days when you called to connect to the provider, someone managed to change the number to let you call a costly one.
- **Indirect Monetization:**
  - Abuse of computing resources
  - Information gathering (stealing of account infos to sell them)
  - Making the machines part of a botnet to rent or sell the botnet

1.4 Direct monetization: ransomware attacks

1.4.1 Brief history of ransomware



In 1996, a paper describing a crypto-malware that was exactly a ransomware was published about 15 years before CryptoLocker which was the first really successful one.
They just *"looked into the crystal ball"* of what in the future would be valuable: taking as hostage digital valuables could become a good way to steal money.
Then something happened:
the internet in 1996 was really different than the one of 2013, ransomwares needed a way for the user to pay a ransom in a way that was easy to perform. The preferred way to perform payments on internet is with credit cards, but this kind of payments have two important difects:

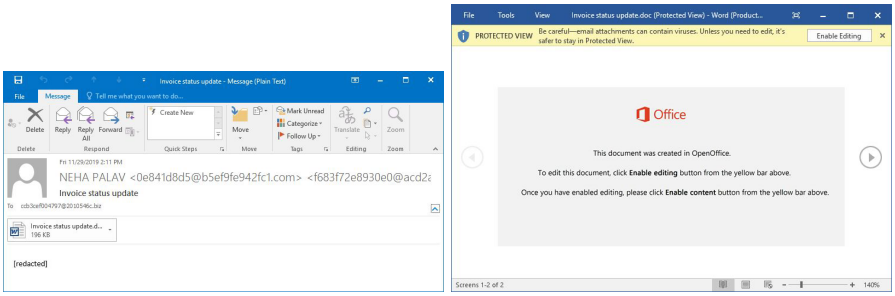
- they are trackable
- they are refundable when fraudolent

Then a new suitable way for payments was born: **cryptocurrencies**.
They perfectly fit this need: they are easily accessible, and payments are not reversible.

1.4.2 Ransomware screenshot and social meanings

Look at the structure of the timer: it is made to let you to percieve urgency. The stress of the urgency makes human take bad decisions, with the timer running you're more prone to pay because you feel that you have limited time. In social engineering attacks, urgency is always an important part. *(think about ultimatums in diplomacy, job offers with time limits, poltrone e sofà...)*

1.4.3 How to get infected



(a) (b)

Looking at the images we can see an interesting example:

- User receives an e-mail with a short text that contains some sensitive information and an attachment which is social engineered in a way that many people would click
- Microsoft Office shows a message to try to prevent code execution, but the user is prone to click "Enable" because the text contained in the document makes him think that's the right thing to do, even if a lot of grammar errors are present and the whole situation looks suspicious

One could have said that the user must had to be trained to not click, but the reality is that he is not understanding what's happening on his computer.
We can't train a generic user to not click: if your job is to open invoices received by e-mail, there is no way you can be trained.
Even if we train him to click only on what is coming from attendible e-mail addresses, if the *"attendible"* part was hijacked?
What we really should do is to figure out a way that when someone clicks enable, this won't cause any damage. Of course, to train the user to let this happen the less frequent possible is good, but not the main thing to do.

1.4.4 Encryption mechanism: how do ransomware work

Once the malware starts running on target computer, it generates a random symmetric key[3], usually one per file, and it encrypts each file with it.
The symmetric key itself it's encrypted with a public key, of an asymmetric key pair generated on the server of the group that runs the malware. The private key is stored on the server, and it will released only when the ransom is payed.
Most of this process is automated: when cryptocurrencies are transferred to the criminals' address, the server releases the key associated to it. Different keys to allow the attackers to decrypt only a part of the samples to demonstrate that they can do it.

[3] used both to encrypt and decrypt information

1.5 Indirect monetization: Botnets

The word botnet comes from the words *robot* and *network*. A botnet is composed by few hundreds to millions of infected devices which run some sort of malware they got by opening an infected email attachment, by plugging an infected USB drive, visiting an infected website *(these are examples of ways to get infected)*
Each botnet has a **botmaster** who controls and rents it out to perform tasks *(denial of service, spamming, phishing campaigns, crypto mining ...)*, and his only objective is to earn money by renting them.
The significant challenge with this type of crime is that each bot per-se is not dangerous for the machine itself, but for other machines, and since the cost of cleaning up a machine falls on its owner, some can decide to not do anything about. This cost can be seen as a small fee to be payed by *the community* to get everybody safe. Like a vaccination, some cases of infected machines are not a big trouble for the community, while a lot of them can be really dangerous for everybody.

1.5.1 Rise of the bots

Back in the days botnets were used to control IRC chats *(see IRC wars)*. Then instead of using the compromised machines to control the chat, botmasters started to use the chat to control the bots.
In 1999, there was one of the first DDoS attacks, which was against University of Minnesota and used at least 227 bots.
In the 2000s DDoS attacks against high profile websites *(Amazon, CNN, eBay ...)* got huge media coverage.

1.5.2 Geolocalization of botnets command and control

Rank	Country	Q2 2020	% Change Q on Q
#1	United States	896	7%
#2	Russia	812	32%
#3	Netherlands	337	61%
#4	Germany	185	7%
#5	Singapore	131	157%
#6	France	108	35%
#7	Great Britain	89	37%
#8	China	74	-15%
#9	Bulgaria	72	38%
#10	Hungary	70	New Entry

This chart shows the number of new botnet C&Cs detected by *Spamhaus* in the second quarter of 2020, and the increase wrt the first one.
By keeping in mind the *observation bias*, we can also introduce another kind of bias which is called **heatmap effect**: we're biased on the density of the population and on how much data we collect from a certain country.
In this kind of charts we'll always have U.S.A. on top, because there's more penetration in the internet, and also this kind of things is tracked. While we'll have less data from less technological advanced states or *perfectly democratic countries* like Russia or the P.R.C. which can result in lower positions while in reality being the first ones.
Here we see an important increase of C&C from The Netherlands:

- it is possible that **something is on**
- or simply that some Netherlands organization decided to participate in this data collection feeding a lot of *new* data

Funny thing about Russia and P.R.C: Russian people hack russian computers too, while P.R.C citizens don't hack into their fellows machines.

1.5.3 Type of (botnet) malware families

Rank	Q2 2020	% Change Q on Q	Malware Family	Description
#1	436	772%	AgentTesla	Credential Stealer
#2	290	-46%	Lokibot	Credential Stealer
#3	169	New entry	RedLineStealer	Credential Stealer
#4	156	51%	NanoCore RAT	Remote Access Tool (RAT)
#5	112	-27%	Gozi	e-banking Trojan
#6	98	-5%	AZORult	Credential Stealer
#7	92	1%	RemcosRAT	Remote Access Tool (RAT)
#8	74	23%	njrat	Remote Access Tool (RAT)
#9	74	New entry	DanaBot	Credential Stealer
#10	69	17%	ArkeiStealer	Credential Stealer
#11	67	63%	KPOTStealer	Credential Stealer
#12	62	New entry	IcedID	e-banking Trojan
#13	61	New entry	AveMaria	Remote Access Tool (RAT)
#14	55	-18%	Adwind	Remote Access Tool (RAT)
#15	51	21%	NetWire	Remote Access Tool (RAT)
#16	47	New entry	QNodeService	Remote Access Tool (RAT)
#17	47	57%	RaccoonStealer	Credential Stealer
#18	46	-4%	Pony	Credential Stealer
#19	45	105%	AsyncRAT	Remote Access Tool (RAT)
#20	43	New entry	Zloader	Loader

Every botnet in general can be used to do any sort of things, but they're used to do only one of them:

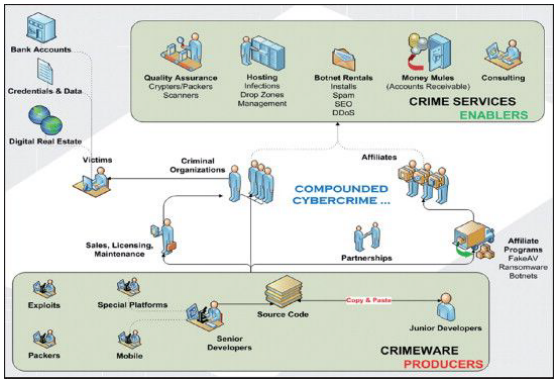
- **Credential Stealers:** used to steal sensitive credentials.
- **Banking Trojans:** credential stealers specifically designed to perform stealing of bank accounts information. *(Gozi is the most common one, Zeus the most important one)*
- **Remote Access Tools:** basic botnet oriented malware, which allows to control a computer in order to perform whatever.
- **Loaders:** specifically designed to allow a botmaster to load a program of whatever sort on a computer. Maybe a client ask you to install a certain malware on a lot of computers, and you can do it with a loader.

We talk about families because there are criminal groups that only develop their source code, and who performs the attacks buys the code and personalizes it for the specific purpose they need.
So we can consider three businesses: how to develop them, how to configure them, how to use them.
There is a market for services related to malwares and cyber attacks *(cybercrime as a service, underground market...)* structured around the needs of cyber criminals. This market is fueled by the money that these schemes make. Some of these money pays for the tools used to make that money.

1.6 The cybercrime ecosystem

The status quo consists in **organized groups** performing **various activities:**

- Development and procurement of exploits
- Site infection
- Victim monitoring
- Selling *exploit kits*



These ecosystems can exists because some of the activites done are not illegal: developing exploits per-se is not illegal, selling one is not illegal, the usage of them may be or may be not illegal. Even the services related to the configuration of malware are not illegal, while execution and operation may be. If you're sufficiently shielded and you run these *businesses* in countries that cannot persecute you, we can even know your name and surname but you cannot be arrested.

- Developers write the source code for malwares with the help of packers and exploits developers
- Crime service enablers:
  - Quality assurance makes sure that antiviruses don't detect their software
  - Bulletproof hosting is a kind of *close-an-eye* hosting, *(e.g. russina business networks)* with permit certain suspect activities over their infrastructure, they're sort of borderline organization with lot of regular customers, and some bad ones

1.6.1 Identity sales

People's identities are sold on the black market. They are worth because they can be used for fraud, to open bank accounts used for money laudering for example. The more they're useful, the more they are worth. Worth 50 dollars for you that sell it, the one who pays is going to use them for fraud which is worth more. The black market is fueled from an enormous amount of money that people stole.

1.6.2 Drive by download

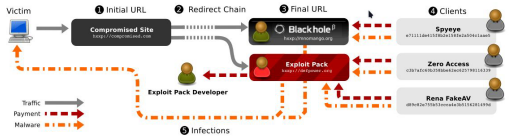


Figure 1: The drive-by-download infection chain. Within the exploit-as-a-service ecosystem, two roles have appeared: *exploit kits* that aid miscreants in compromising browsers (❹), and *Traffic-PPI* markets that sell installs to clients (❺) while managing all aspects of a successful exploit (❶,❷,❸).

This is another way in which malwares are installed:
an exploit breaks into your browser and executes code on your machine. This requires your browser to be vulnerable and for you to visit a compromised website with the exploit running *(streaming, cracks of programs websites,...)*.
The most compromised are *factually illegal websites*: you're not scared of the strange url if you are in need to see the last movie in streaming, download the expensive program's crack, this is in contrast with a normal situation like going to amazon to buy shoes.
But, *traps* can be also present in legitimate websites.
What actually happens is that the users endup in a series of redirects, called **redirect chain**, which will endup in a visit to a website running what is called **exploitation pack** for your browser.

1.6.3 Exploitation kits sales

This kind of kits is sold in the dark web by well known organizations, take *Blackhole* as example:
they were buying exploits from developers to earn 10s of millions per month renting them.
Their boss, surprisingly called Dmitry "Paunch" Fedotov, was arrested in 2013 after years of running the website.

1.6.4 Monetization on the dark web

Monetization takes a lot of forms, one of them is stealing credit card numbers to sell them for a relatively small price.
The hackers get *easy and fast* money, while the buyers need to use the real

money on the cards to buy expensive objects or to start frauds because they can be easily refunded. *(apple computers, ethnic travel example..)*.

1.6.5 Cybercrime and perception

Online, you detach people from the picture. It's actually easier to commit crimes, it's easier to crack a program instead of stealing a car, lot of cyber criminals would never be criminals in the real world. But when you do cybercrime, your perspective is different: you have another perception of what you're doing, that's the reason because crime happens more online.
Ethical people understand the consequences of their actions, and may decide to not do them, but someone can not care about what can happen as a consequence of their actions and perform them anyways:
in the Jamal Khashoggi case, the exploiter which wrote the code for the spyware that ended up to make him killed, would never kill someone. But the consequences of his actions did.

1.6.6 Money mules and money laundering

Most cybercrimes end up with a digital form of money, which crimials want to bring in a physiscal form, completely disconnected from what they did in principle.

- They can pay invoices to companies somewhere in the world, which in a certain way makes sure that the money come back clean. *(traditional way)*
- They can make use of **money mules**

Money mules are intermediary people which by purpose or not make earnings coming from cybercrime clean money.
Accomplished ones may be people that have nothing to lose *(prejudiced, poor people . . .)*, they just open bank accounts by their names and get the money transferred and then withdrawn and handed to criminals.
Some of them may also open accounts by somebody else's name using identities that may be stolen with an attack and bought online. They're most difficult to catch because the Police needs to be actually there while they are withdrawing money.
Unaccomplished ones may be people which are fooled by things like the Nigerian prince scam: they get the money on their bank account, send 70% of them to criminals in packages or by moneytransfer, and keep 30%. Most of the cases they get arrested and have to pay back all the money, also the ones they don't own no more.
Buying and selling of goods *(ricettazione)*, videogames curriencies, . . . , are other ways to perform money laundering.

Chapter 2

Cryptocurrencies: abuses and forensics

We talk about cryptocurrencies in the way they are used in cybercrime.

2.1 Bitcoin and blockchain

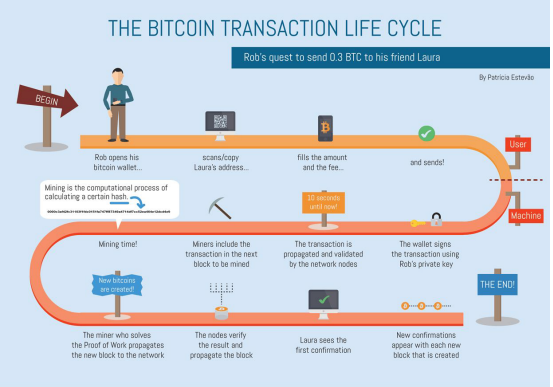
Bitcoin is an attempt to create **electronic cash**: a digital currency that has lots of properties that physical money have, one of them is **no central authority**. What Satoshi Nakamoto wanted to have is an electronic distributed ledger[1].
Having no central authority is a really hard problem to solve *(byzantine consensus)*, he did it with **the blockchain**.
The blockchain is a **shared, append-only, trustable** ledger of all coins transactions. The limits of distributed consensus defined in the Byzantine Problem and CAP Theorem are solved using the technique of **proof-of-work**.

2.2 Wallet and addresses

A wallet is the software that allows to manage and store the **public** and **private** keys for each of the user's bitcoin addresses. To create and sign transactions, track the balance.
A bitcoin address is an alphanumeric string which identifies a *point* where you can send bitcoin to, and where they can be sent from. In order to know how many Bitcoin are *stored* in that key you need to go to the origin of all the transactions and track the flow of them to understand how much of them are there now. This computations is not really efficient but can run without central authority, so the only reason for using a blockchain is if it is really so important to get a way out of a central authority.

[1] ledger=registro

2.3 The bitcoin transaction life cycle

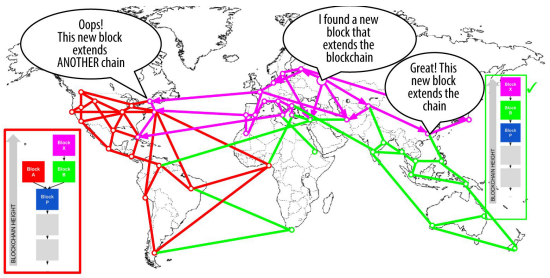


As soon as the transaction is on the immutable ledger, the money are on the other address. How do we ensure that this is the only transaction done with those Bitcoins?
Our immutable ledger must be consolidated, with a central authority that would have been easy, how do we agree with no central authority? We need a history that cannot be modified, and to do this we talk about mining.
Mining is the process to generate a block containing all the transactions, and to append it to the blockchain.

2.4 Mining

Miners compete to generate a new valid block that solves a complex mathematical problem bybruteforce: the solver is then rewarded a fixed number of BTC. It is a computational demanding activity: miners put a set of transactions in the new block, put there a destination for the reward and then start bruteforcing the block to find a sha256 hash of it which starts **with a certain number of zeros**. The more zeros, the more difficult is the process.
When a block is added to the blockchain, the other miners stop bruteforcing their blocks and start to compute the hash of another one, to link it to the last found block. The difficulty increases more and more, the reward got smaller and smaller but BTC value gets larger and larger.
Besides of the reward you get, you can also put a fee you want to receive from the transactions you included in the block. Since reward is becoming smaller, fees are becoming larger. Now the fees make small transactions unfeasible.

2.5 Fork events



Sooner or later two miners will get a solution at more or less the same time. This causes a fork where the situation is that for some miners the blockchain ends with block A and for some others with block B.
Now the blockchains are two, and sooner or later some miner will find a solution and append a new block in one of them. The rule says that **the longest blockchain is the true one**. As soon as one blockchain becomes longer, all the miners move to that leaving the other one sadly alone.
This is done because in order to revert a payment you'd need to go back on your block, go ahead mining until your blockchain is the longest one: this means that you would compete with all the other miners. To be sure that a certain transaction is there and cannot be canceled, you must wait that the block in which it finds itself is a couple blocks behind the last one.

2.6 Bitcoin and black market

Bitcoin immediately started to be used for black markets. Because you had a way to pay without an infrastructure.

2.6.1 Pseudo-anonimity

The first reason to use Bitcoin for black markets is **anonimity**.
In reality Bitcoin is actually **pseudonymous**: the identifier for the transactions is not directly connected to an identity, but to an address which can be seen as a username.
Every entity generates multiple keys for themselves, so more pseudonyms. This pseudonimity is robust because addresses don't refer in any way to their owners. Transactions are public by the way, and this is a terrible property if you're interested in anonimity; while addresses are not connected to people, there is something that connects addresses related to the same person:

- transaction can have multiple keys as input, if a transaction has multiple inputs, very likely that the inputs are all owned by the same entity

- Bitcoin works in a way in which you cannot spend less than the whole amount of bitcoin you have in your address, to send a smaller amount to somebody, you'd generate a transaction with two outputs:
  - The destination address
  - A new address called Shadow Address which is owned by the same person who started the transaction, where the rest of the currency is sent.

Until 2013, a bug made very easy to know which of the two outputs in a transaction were the shadow address, hence making easier to track their correlations. It was then possible to track addresses in a way in which keys belonging to the same entity were collapsed in large sets. When you have one of those addresses connected to somebody's name you can actually connect all the others in the set to him.

Silk Road Example

Silk Road was a black market which used BTC as currency, it was ran by someone under the name of *"Dead Pirate Roberts"*.
It was found out that someone using the nickname *"altoid"* were advertising Silk Road on different websites, and with the same nickname earlier in the past was also hiring developers for a PHP project. *(which then became Silk Road)*
In that specific post, altoid was asking to contact him at *"rossulbricht at gmail dot com"* if interested.
He also posted a request for help which included PHP code with his address in it: 1LDNLreKJ6GawBHPgB5yfVLBERi8g3SbQS[2], which then was found to be associated with Silk Road
Ross Ulbricht was arrested in 2013.

2.6.2 Why do people use Bitcoin for ransoms?

For these two characteristics:

- BTC transactions, in contrast with common electronic payment systems, are irreversible.
- To use other kinds of digital payments you need an infrastructure *(bank account...)*, with cryptocurrency you just need an address.

[2]today there are 20 dollars of Bitcoin

Part II

Fraud detection and analysis

Part III

Digital Forensics principles

Chapter 3

Introduction to Digital Forensics

3.1 What does forensics mean?

- **Forensics** is the application of scientific analysis to reconstruct evidence.
- **Digital Forensics** is one of the disciplines of forensics, is the application of scientific analysis methods to digital data, computer systems, and network data to reconstruct evidence.

Forensics is strongly related with laws: different jurisdiction means different procedures.

3.2 The Daubert standard (USA)

Generally speaking, we can have two sources of evidence:

- physical evidence
- eyewitness testimony

To provide physical evidence, an expert is allowed to give an opinion in court because of the fact that he is an expert, and the use of scientific methods is the reason why he is listened to.
How do we define what an expert is?

3.2.1 The Daubert Standard

We define as expert witness someone who has witness because of its own experience.
The Daubert standard define an expert witness as follows:

A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

- The expert's scientific, technical, or other specialized knowledge will help the trier of fact[1] to understand the evidence or to determine a fact in issue;
- The testimony is based on sufficient facts or data;
- The testimony is the product of reliable principles and methods; and
- The expert has reliably applied the principles and methods to the facts of the case.

Reliable principles and methods means that they are scientifically found. You need an expert to use scientific method to establish those facts:

3.2.2 What is scientific? (Italy)

- Galileo: scientific means repeatable, you actually make an experiment to demonstrate that something can happen
- Popper: scientific means falsifiable, if you're able to create, at least in your mind, an example which proves the opposite of a statement, then the statement is scientific.
  - Example: *Stefano is a kind person* is not a scientific statement, because it is not falsifiable.

Some of the questions are not falsifiable, hence not scientific. An example is a criminal which keeps images of kids on his own computer. Did he do it willingly or not? This is not falsifiable.
What is possible to do is to look at the folder to see if it was opened multiple times, look at the file to see if it was in the browser's cache or in a specific folder on the criminal's computer.

3.2.3 Daubert Test for scientific

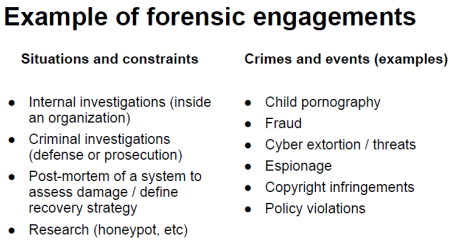
Factors to consider (USA) to establish if something is scientific or not:

- Whether the theory or technique employed by the expert is generally accepted in the scientific community
- Whether it has been subjected to peer review and publication
- Whether it can be and has been tested
- Whether the known or potential rate of error is acceptable; and
- Whether the research was conducted independent of the particular litigation or dependent on an intention to provide the proposed testimony.

[1] the judge

3.3 Example of forensic engagements

We do forensics for different situations in different contexts



Depending on which part of the lawsuit you're working for: *("prosecutor", "judge", "lawyer")*, the things that you can do are different.
The procedures has always to be contextualized in what are the purposes and which constraints the purpose has.
Crimes:

- The first investigated crime is the one that has to do with children. The reason why is that it is one of the easiest to prosecute.
- Fraud is the second one. Prosecuting fraud is difficult because there is a large amount of them which are perpetrated by people who live in countries where the laws kind of permit it. It is still denounced because people can get their money back.
- Cyber extortion is the crime which consists into stealing personal data to get money from them. Extortion happens with family, work related, revenge cases.

There exist also a lot of non-cyber crimes which involve digital components:

- Search for traces in digital devices in murder cases
- Tracking or geo-localization of mobile devices

Digital components can be fundamental.

3.4 Phases of an investigation (Pollitt)

- Source acquisition: how we preserve digital evidence
- Evidence identification: how we analyze digital evidence
- Evaluation: how we take evidence and pack with the specific case
- Presentation: how we put togheter all of this in a court

Part IV

Acquisition, analysis, evaluation and presentation of evidence

Chapter 4

Acquisition

Forensics was born in the USA, it borders with law so it was developed with US laws in mind.
The legal system of USA and the EUs ones are extremely different, and so is the court approach:

- In the U.S. most of the cases are tried by juries of peers, the judge works to make the court work. In fact, the judge is the one to decide if evidece is admissible or not. If not admissible, that could not be talked about from jury and lawyers or taken into account. Admissibility of scientific evidece is completely based on the concept of **chain of custody**: *tracking where the evidence was taken, who was in custody, where was it stored, who analyzed it, what was done to it.* If that is broken, evidence becomes inadmissible.
- In Italy is the judge the one who takes the decision. The jury exists only in Corte d'Assise and it is made by people extracted from a certain set. Is the judge to evaluate the admissibility of the evidence, it is inadmissible only if it was taken in violation of laws.

By the way, the Counsil of Europe has an international law agreement called **Convention of Budapest on cybercrime**, it was written in 1999, and was incorporated in the Italian law in 2008. Also international standards from ISO/IEC can be applied.

4.1 Brittleness of digital evidence

Digital evidence is **brittle**[1], it is because if it is modified there is no way to tell. In other words, it is not **tamper evident**[2]. This means that there is no way to say if the chain of custody was violated.
Digital evidence can also be fake created:

[1] fragile
[2] non mostra segni di manomissione anche se manomessa

- By changing for example the clock of a computer, it is possible to create a fake file which was modified in a different time, and there is no way to figure out if that happened.

We need an entire process of acquisition to create ways to make digital evidence as far as possible tamper evident, there is a need to ensure:

- Legal compliance: evidence must comply with the laws.
- Ethical behavior from all parties: even the police can act unhetical
- Detection of errors in good faith
- Detection of natural decay

4.2 The usage of hashes in digital forensics

Hash function are used to record the state of an object at a given step of acquisiton. It is constantly checked to ensure authenticity and non-tampered state of that at any further phase of acquisition. They are used to *"freeze"* the crime scene.

- We don't know what happened before that first step
- We can only tell if something has been tampered, but not what has been tampered. We also cannot restore data if tampered.
- Hashes are used to prove that something has been modified, but cannot tell what.

Since evidence is going to be stored on a certain media, hashes must be put in another place *(e.g. writing them on a physical register is the most frequent, or use digital signatures).*

4.3 Hardware and software for acquisition

- Hardware:
  - Removable HD enclosures or connectors with different plugs
  - Write blocker
  - External disks
  - USB, firewire, SATA, e-SATA controllers if possible
- Linux: extensive native file system support, ease of accessing drives and partitions without mounting them

4.4 Bitstream images

What we want to acquire, if possible, is a **bitstream image**, a bit-by-bit clone of the original evidence media. The main reason is because if we only copy the allocated content we potentially lose information stored in the unallocated part of the disk. This is called a **forensic clone** or clone copy or image of the disk.

4.5 Basic procedure of acquisition

- Disconnect the media from the original system, if possible
- Connect the source media to the analysis station, if possible with a write blocker
- Compute the hash of the source:
  - Linux: *#dd if=/dev/sda conv=noerror,sync — sha256sum*
  - conv=noerror means *"keep going even if the system generated some errors"*
- Copy the source:
  - Linux:
  - *#dd if=/dev/sda of=/tmp/acquisition.img conv=noerror,sync*
- Compute the hashes of the source and the clone
  - Linux: *#dd if=/dev/sda conv=noerror,sync — sha256sum*
  - *#sha256sum /tmp/acquisition.img*
- Compare the three hashes

If the hashes are different, it means that the copy didn't happened correctly or that you tampered with the drive, or that some damaged block read broke it, or that some damaged block reads everytime something different ...
It could be also good to compute MD5 and SHA-1 hashes, for redundancy and backward compatibility.

4.5.1 Challenges: time

A typical hard drive capacity today is 1TB. Transfer speeds are in the order of 600MB/s *(SATA 3)*, but mechanical drives reach an average of 80MB/s *(SSDs are actually fast as SATA3)*, USB connectors are up to 100MB/s.
This means that for a 1TB drive you can expect to wait several hours to complete a copy or to run a hash. Tools like **embedded duplicators** or software like dcfldd can make this run in parallel to save time.

4.5.2 Challenges: size

File systems limit to 4TB mostly for the size of a file. If a drive is larger, it has to be spliced in more files.
Space is also needed to keep data for all the devices used in an investigation, which can be in the order of the hundreds of terabytes, that's why NAS or SAN systems are common in forensic shops.
Sometimes it can be also useful to move images across a network, for exaple by using netcat to listen for a stream generated by the computer which is taking the acquisition.

4.5.3 Challenges: encryption

Many machines use encryption. In some cases the key for decription is stored on the motherboard of the computer, and so the image became useless without the computer.

4.6 Alternative procedures

4.6.1 Alternative 1: booting from live distribution

Sometimes it is mandatory to work directly on the actual machine, because of systems with weird connectors, RAID devices or because of specific investigation constraints.
In these cases it is possible to live-boot the system using a Linux distribution targeted for forensic analysis, like *Tsurugi* or *BackBox*[3].
This process has to be performed with great care, different systems have different ways to access the boot menu, and if by chance the original operating system is booted, it may be cause a loss of useful data.

4.6.2 Alternative 2: Target powered on

For many reasons can happen that the target machine is turned on:

- Maybe it is running a critical service for the company we're working for
- Maybe it was seized while turned on

Working with a powered on machine is called **live forensics**. Can we turn it off? Probably not if the machine is a critical one. Should we turn it off? Maybe not if we're trying to do live analyisis of an intruder. We want to exclude an intruder? We can disconnect the network.
Since the machine is turned on, our actions are going to modify its state, our commands, even turning the machine off will change it, because of the operating system's operations.

[3]The reason why we use specific distribution, is because we do not want to overwrite linux swap partitions on the media

Now the prospective changed, before we thought of evidence as immutable as possible, now we don't.
Since our actions are going to tamper with the state of the system, we need to **document what we did** *(to preserve chain of custody (USA))*, here we don't have the safeguard of the hash. Work in volatility order:

- Dumping the memory may be useful, for example most of the break-in attacks are file-less.
- So is saving runtime information: network, process information, etc...
- Consider encryption before turning the machine off *(maybe the device can become unusable after)*
- Finally, disk acquisition

If possible, perform the acquisition without a shutdown, if not, if the machine has to be reboot after, shut it down properly. If it is not crytical it is possible to pull the plug to not tamper the disk.

Useful commands

- Network data: *"ifconfig -a ; netstat -anp ; route -n ; arp"*
- Process data (to store process information): *"ps aux ; lsof file"*
- Users data: *"who; last; lastlog"*
- Memory acquisition: *"Mantech mdd, win32dd, Mandiant Memoryze"*

4.6.3 Alternate 3: live network analysis

In enterprise environments if we want to observe an attacker *live* whithout him being scared of our actions, we can use two observation points that are outside of the machine: logs and network traffic *(we'll have a separate class)*

4.6.4 New Challenges (separate classes)

- Forensics in cloud environments
- Mobile forensics
- SSD drives work different than magnetic drives

Chapter 5

Identification

The purpose of Identification is to perform actions that can fall anywhere in computer science.
We'll look at either the methodologies and specific forensics cases.
Tipically we use Linux:

- extensive native file system support
- we can just dump a disk image as a file with linux, and we can mount the copy as if it were a drive, also read only to prevent writing and keep the copies not touched.

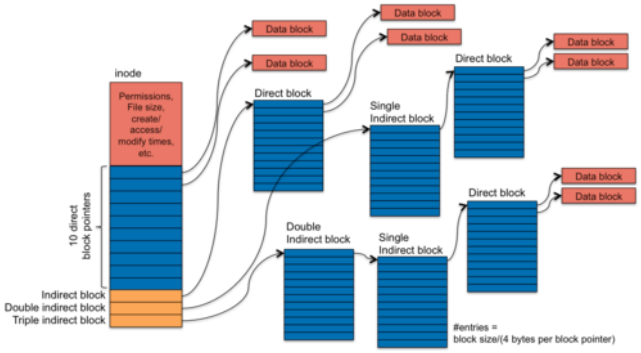
Why not Windows? Nobody uses windows by itself. It must be confined, it stinks.

- It tampers with drives by automatically mounting them and writing on them.
- No image handling or hotswapping of drives.
- No support for non Windows filesystems.

The best thing to do is to use linux as host with windows as guest on virtual machines:

- Work the images with Linux, mount them read-only and exporting them via Samba or vmware *"not persistent"* to Windows.
- Use specific windows tools

Keep in mind that sharing something like this, is doing it file level: any utility that analize drives cannot work in this way.



5.0.1 What does scientific mean?

We defined scientific as repeatable. Any other expert will be able to perform the same experiment, on a clone of the image, obtaining the same results I obtained. The experiment is not just a black box tool with an input and an output, the expert must be able to perform the same analysis by hand (at least in theory). This means that analysis software needs to be open sourced, and possibly free. Proprietary or "law enforcement only" tools can be used but the analysis must be performed again with something repeatable. *(Judges, Lawyers, Marescialli, they can access the source for "law enforcement only" tools).*

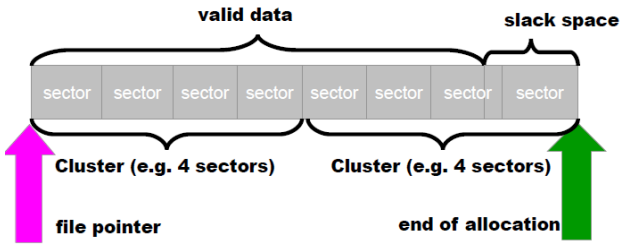
5.0.2 What does analyisis mean?

During the analysis phase, we may need to apply many techniques from computer science, that's the reason because people goes to a forensic expert. Forensic experts are able to do analysis because they are competent in computer science in general. They can also be ethically prone to call other experts in fields in which they're not so expert.

5.1 Recovery of deleted data

Data/evidence may have been voluntarily or unvoluntarily deleted because time passed, because of the OS, because the drive was formatted, because the drive was faulty. In many of these cases, we may be able to reconstruct all or part of the information, which is one of the most typical tasks computer forensics experts perform.
Let's look at the UNIX file system again for the millionth time to recall basic elements on data storage by OSs:

A file system is a way to organize the space on a drive to store information. It's an archive-like thing. The basic idea is to have units of information *(files)*, to put on the storage drive, and then to have an index of what is stored and where. Following the index I can find the place where things are stored.
Whithout the index I may not reach them *(if they were deleted)* but they can



still be stored:
when we delete a file the operating system just marks the file as deleted and just doesn't shows it no more. The actual data will go away when overwritten by other files.
Indexes and data will go away randomly and independently from each other, statistically on a large hard drive there is a good possibility that metadata goes away before data blocks.

5.1.1 Disk Geometry

tracks, cylinders . . . When reading and writing, the minimum portion of a track is called sector, each drive has a different sector size, and the OS can't manage it for each of the existent models.
OS's filesystems are made to work on clusters of sectors *(NTFS uses 4kb clusters)*, independently of the real dimension on the drive. So, storing for example a file of size 5kb needs 1 cluster of 4kb + a fourth of a cluster, and leaves the remaining part as unused slack space.
In the slack space there can possibly be remainances of old files, obviously they can be small portions, so only small files can be retrieved *(e-mails, text files . . .)*, while other filetypes can't because they need to be full to be read *(images, encrypted files . . .)*
Sectors are one after the other, if we place a file on a drive there is a good possibility that all the sectors of it are one after the other, so by scanning *(cramming)* the drive can be possible to find them and restore them too.
The issues are with fragmented files, it was a big problem on small drives, now in most cases drives are so large to not fragment and most of OS's try to not break files for performance reasons. There still are techniques to find fragments of files and restore them.
Another issue is with encrypted, compressed files. In those cases we really need the file to be complete to be able to read them.
Headerless files because they were taken away header or footer cannot be interpreted. Headerless compressed/encrypted files are unpracticable.

5.1.2 Free software tools for data recovery

- TSK and Autopsy can perform data recovery under linux, they support NTFS, FAT, FFS, EXT2, EXT3..
- Foremost can perform file recovery trough carving
- gpart, testdisk can perform partition recovery
- photorec can seek specifically for images or videos

5.2 Antiforensic techniques

They are techniques designed to create confusion in the analyst and/or defeat tools and techniques used by analysts.

- Transient techniques: aim to confuse or mislead the analyst, can be defeated if detected
- Definitive techniques: make impossible to recover data

5.2.1 Critical failure points

Acquisition *(usage of tools for repeatable cloning and custody)* and identification *(usage of tools for analysis of file systems, data reconstruction and carving)* Interfering, it is possible to compromise the process. We talk about transient anti-forensics if we interfere with identification, definitive anti-forensics if we interfere with acquisition.

5.2.2 Timeline tampering (definitive)

Files' metadata store also information about modified, accessed, created dates *(MAC)* + Entry Changed (E) value on NTFS.
A typical way to use these data is to take all of the MAC entries of all files in the drive and put them in reverse order starting from the most recent, to display a so-called timeline.
As we go back, since every action overwrites the previous value we just will see the last one, as far we go, old data are shown because they maybe were stored and never touched.
MAC information can be modified to make them appear separated, close, randomized or moving them completely out of scope.
MAC though are not inforced by the OS, they're only declarations. There exist tools just to change these values, those values are not there for security reasons. In Unix you can use the touch command to change the thing for example, and there is no track of this, we can have a drive with manipulated access times.
So, as forensic experts we cannot guarantee that these values are correct, and if we use them to support or not support theories we must keep in mind.

5.2.3 Countering file recovery (definitive)

File recovery uses data remnants, but some tools can perform *secure deletion*:

- they can overwrite blocks, fill not allocated parts and/or slack spaces with zeros
- they can go on specific blocks and overwrite them

Encrypted drives can create problems with file recovery, also because they're managed in a way which is different from the usual filesystem's usage of the blocks.
Virtual machines, when dynamically allocating drives *(which are actually files)* have they to shrink if data are deleted and to enlarge when new data is written, often implicitly countering file recovery.

The talk

Gutmann in the 80's said that probably it was possible to understand if a zero was written in a sector or a one was, because of the magnetism. In reality it was difficult to do that (impossible) even in the 80s, with nowadays dense disks it is certainly not possible.
But we still have the Gutmann patterns to *"erase"* disk contents.

5.2.4 Fileless attacks (definitive)

Many modern attacks tend to be fileless, with no traces on the disk at all.
For instance, Metasploit's meterpreter is injected in a process' memory space, and gives attacker control without writing anything to disk. So, if the machine is off, the evidence is lost, the only thing that can save us is to dump the memory of the machine, if possible, in our acquisition phase.

5.2.5 Filesystem insertion (transient)

Data placed where there's no reason to look for them, in particular inside filesystem metadata. Inside a partition table there is space for $\sim$ 32KB of data.
In ext2/3:

- RuneFS can write in bad block inodes
- WaffenFS adds a fake ext3 journal in an ext2 partition
- KY FS uses directory inodes
- Data Mule FS puts data in padding and metadata structures of filesystem ignored by forensic tools

5.2.6 Log analysis ($\sim$ transient)

On most machines one of the big sources of info for forensic analysis are logs.
Logs tend to be long text files with structured text inside, so they can be manually scrolled or checked by use of regular expressions or scripts.
If attackers can inject stuff in the logs (very likely), they can try to make your scripts fail, or even to exploit them.
Maybe they use an username that contains a linebreak character, the line would be skipped (theoretically example).
Techniques which are transient in the sense that they're trying to confuse the analysis tools. In reality however some of them could be modified in the way in which the log becomes definitive.

5.2.7 Partition table tricsk (transient)

"sci-fi"
Partitions can be uncorrectly aligned, this may be enough to make a forensic tool to fail.
Adding a number of extended partitions which can be managed by the Operating Systems but not by forensic tools, or a sufficiently large number of logical partitions in an extended one to make the tools fail.
Transient techniques like this work well when for example the drives are a lot and the analyst has no clue of where evidence can be. But, with a small number of drives, if an expert knows what to search for and where to, most of the times he can find the evidence.

Chapter 6

SSD Forensics

6.1 SSD technology

Today, most of the drives are SSDs. SSDs are storage drives made of NAND flash memory chips, which are faster, and were cheaper than an Hard Drive.
By the point of view of the Operating System, there is no difference between *"talking with"* an SSD or an HDD, but the two technologies are slightly different.
NAND flash memory though, has a limited lifetime, and there is the need to manage how to make them to last longer, another difference is that those kind of memory's blocks are only **fully writable/erasable**, so we don't see slack space in this kind of drives.
When a block is re-written, it has to be *blanked* before, this is a big disadvantage for forensic experts.
What manages SSD behaviour is the FTL controller, which fakes for example to the Operating System the SSD as working as an HDD. It manages a lot of things:

- **Write caching**: it keeps data in a cache and writes them on the SSD only when needed, to preserve blocks life.
- **Trimming**: it blanks no more useful blocks any time it is idle. (even with write locker connected)
- **Garbage Collection**: they were able to figure out what to delete when Trimming wasn't supported by Operating Systems.
- **Data Compression**: they can store more data in less space, to preserve blocks life.
- **Data Encryption/Obfuscation**
- **Bad Block Handling**
- **Wear Leveling**: they manage blocks in a way to make them be in the same deterioration state.

Part V

Ethics elements

Part VI

Optional: casi studio specifici