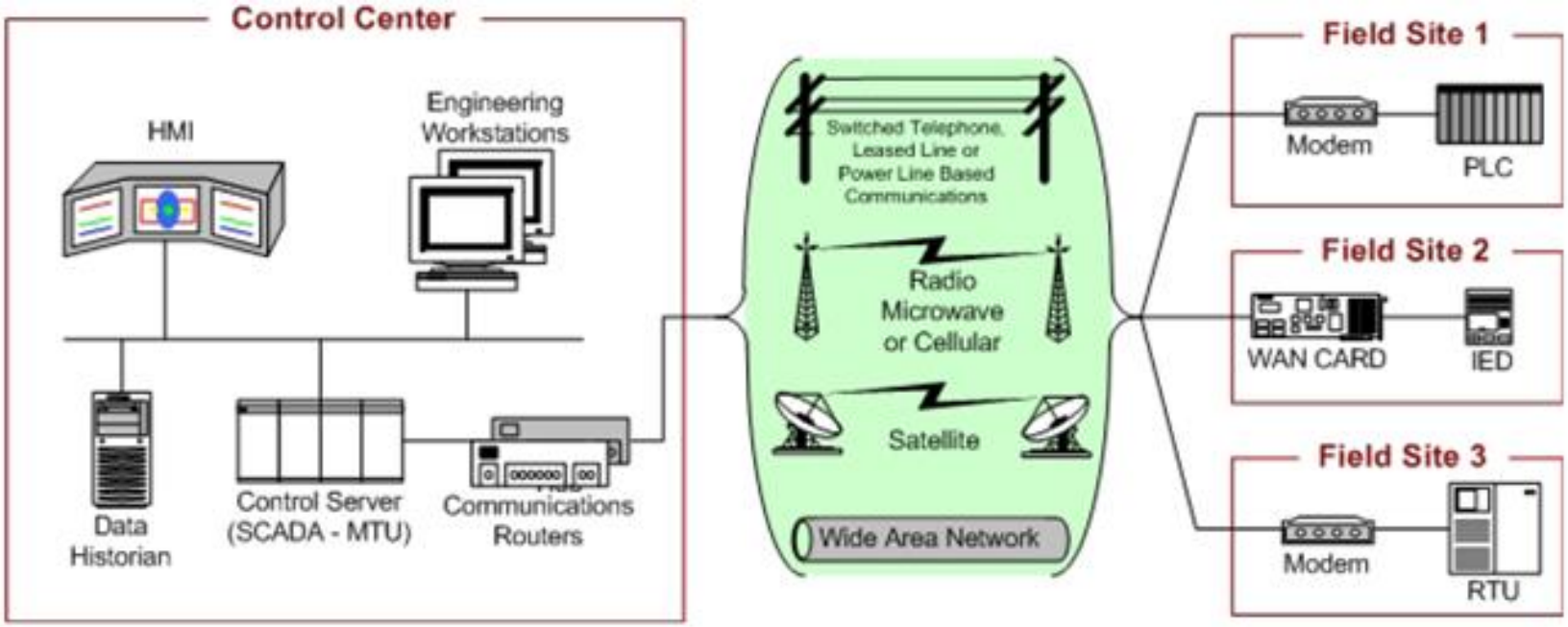
Industrial control systems malware and integrity

Results from the Preemptive research project

Critical Infrastructures (CI) and Industrial Control Systems (ICS)

- CI are infrastructures that are essential for the functioning of a society and its economy
  - e.g., electricity, gas, telecommunications, water, dams, nuclear plants, public health, transportation, financial services, food...
- CI usually rely on Industrial Control Systems (ICS)
  - different vulnerabilities with respect to regular IT

Industrial Control Systems (ICS)



- the organization also have a regular IT network for administration, sales, etc.
  - … with regular security problems

The Preemptive research project

- Preemptive: “Preventive Methodology and Tools to Protect Utilities”

  - focus on cybersecurity of “utilities”: companies managing electricity, water, gas

  - objectives
    - **prevention** and **detection**
    - **methodology** and **technology**
    - final testbed

The Preemptive research project

- Preemptive is founded by the EU (FP7)
  - 12 european (+israel) partners (5 research + 7 industry)
  - 6 “end users” (utility operators)
  - three years (ends Feb 2017)
- many results
  - a specific risk assessment methdology
  - many specific IDS/IPS tools
- we focus on the results of uniroma3

ICS Security: specific aspects

- very peculiar technology
  - SCADA-related software
  - embedded system
  - usually not mastered by regular hacker **(good)**

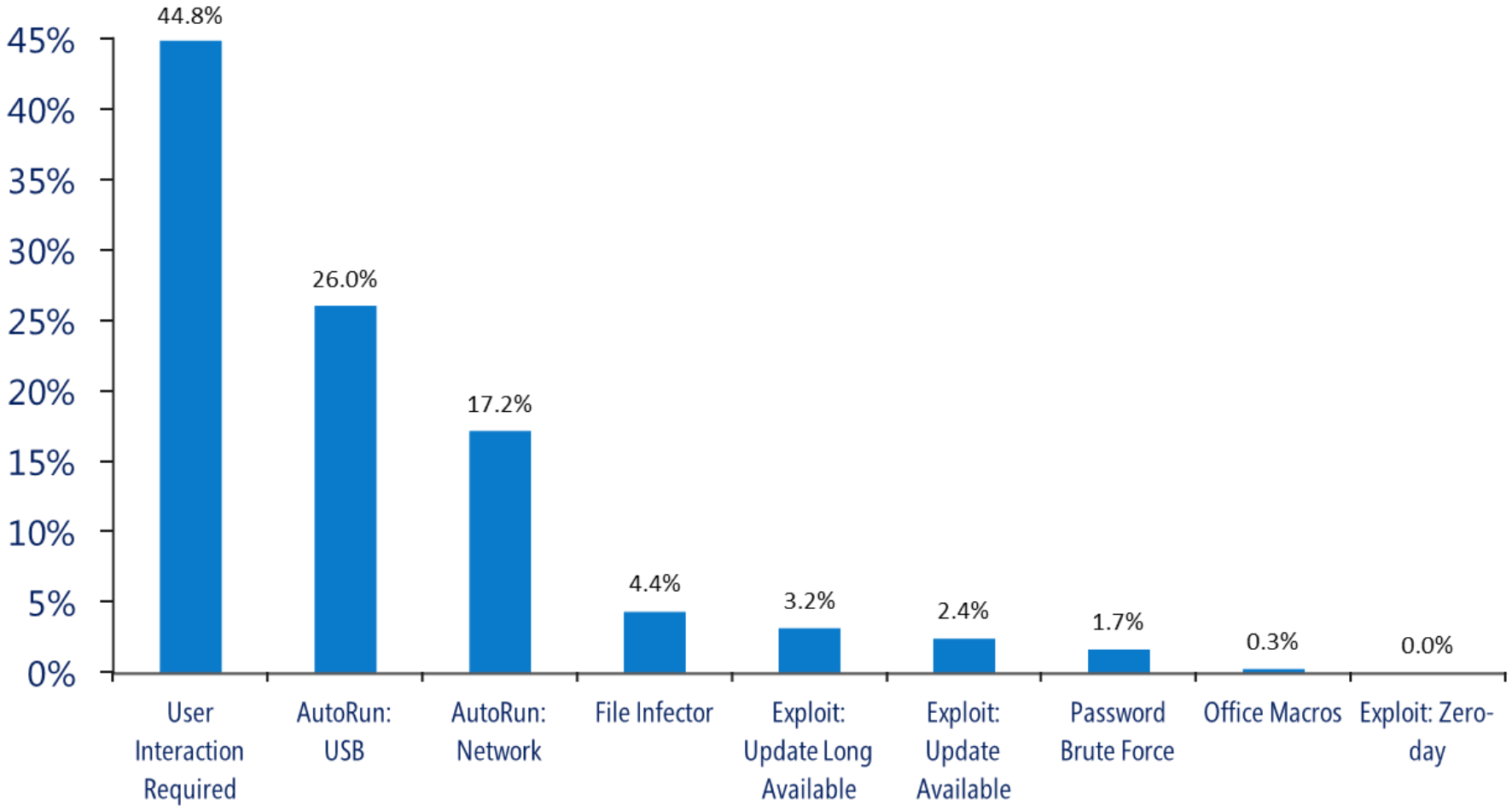
- **built for safety - not for security**
  - not to be resilient to malicious software attacks **(bad)**
- old systems, rarely patched/updated **(bad)**
  - patching is costly
- elective targets for specific attackers
  - terrorists, opposing governments, intelligence agencies **(bad)**
  - **much larger resources** than regular hackers **(bad)**
  - **Advanced Persistent Threats, APTs (bad)**

parentesi su malware e APTs

malware

- qualsiasi software che si comporti in modo illecito o malevolo nei confronti dell'utente
- tipicamente associati a un meccanismo di propagazione
  - sociale o tecnologico
- moltissime tipologie e varianti
  - classificazione molto complessa
  - più che una classificazione del software si classificano le tipologie di “comportamento”
    - virus, trojan, worm, rasomware, AdWare, SpyWare, ecc.
    - es. un malware può essere contemporaneamente trojan e virus

propagazione



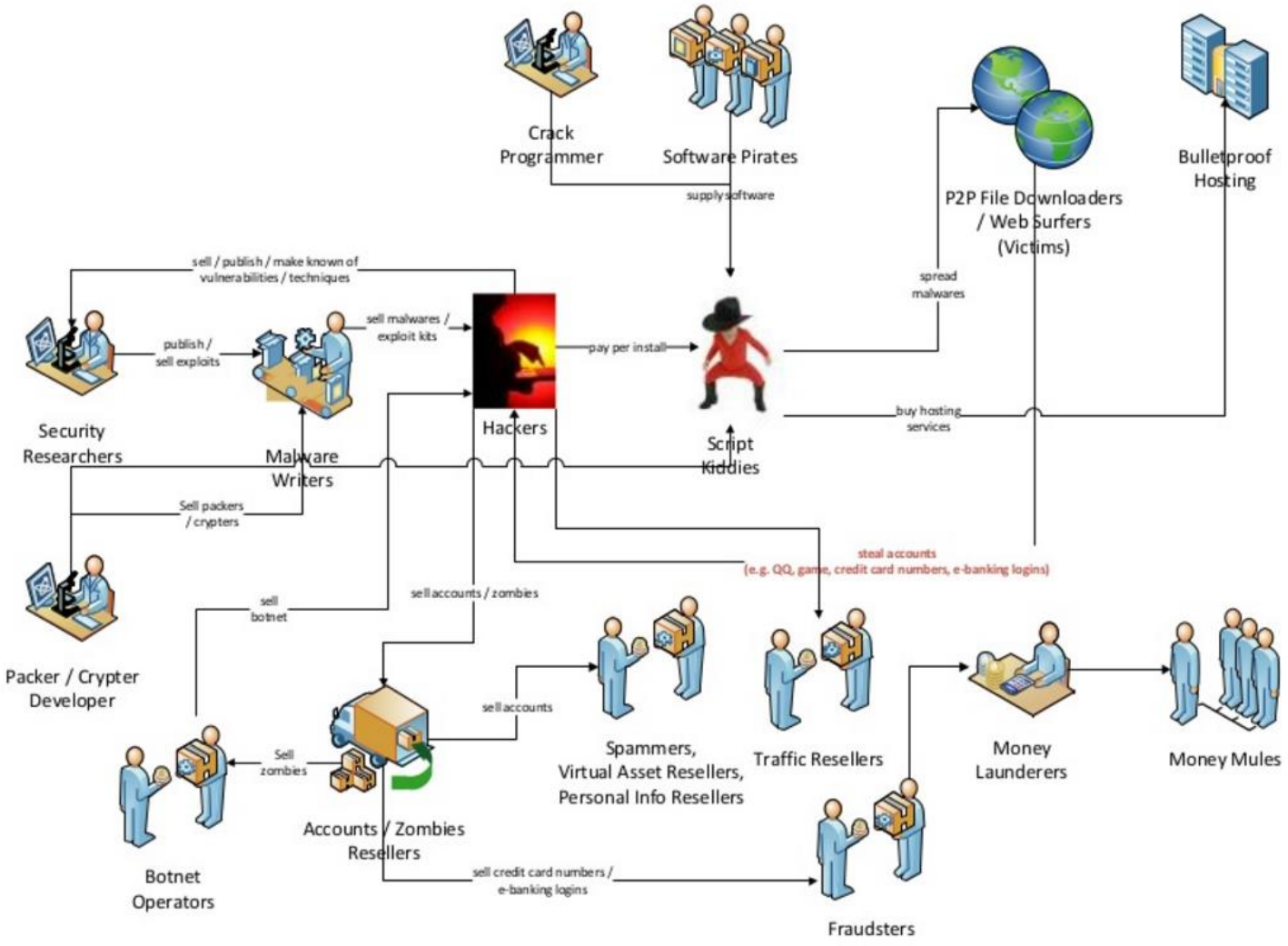
fonte Microsoft, SIRv11 2011

zombies e botnet

- alcuni malware rimangono in attesa che il sistema sia utilizzato da un hacker (installano una backdoor)
  - tipicamente trojan, virus o worm
- un sistema infetto è detto zombie
- una rete di zombies comandabili coerentemente è detta botnet
- spesso gli zombies sono comandati mediante Internet Relay Chat (IRC botnet)
- usi
  - 50-80% dello spam viene da zombies
    - risparmio di banda, indirizzi diversi confondono gli antispam
  - Distribute DoS (attacchi famosi a Yahoo, eBay, ecc)
  - click frauds (siti con annunci “pay per click”)
  - hosting di siti di phishing

- fonte: http://en.wikipedia.org/wiki/Zombie_computer

Cybercrime Black Market and ecosystem

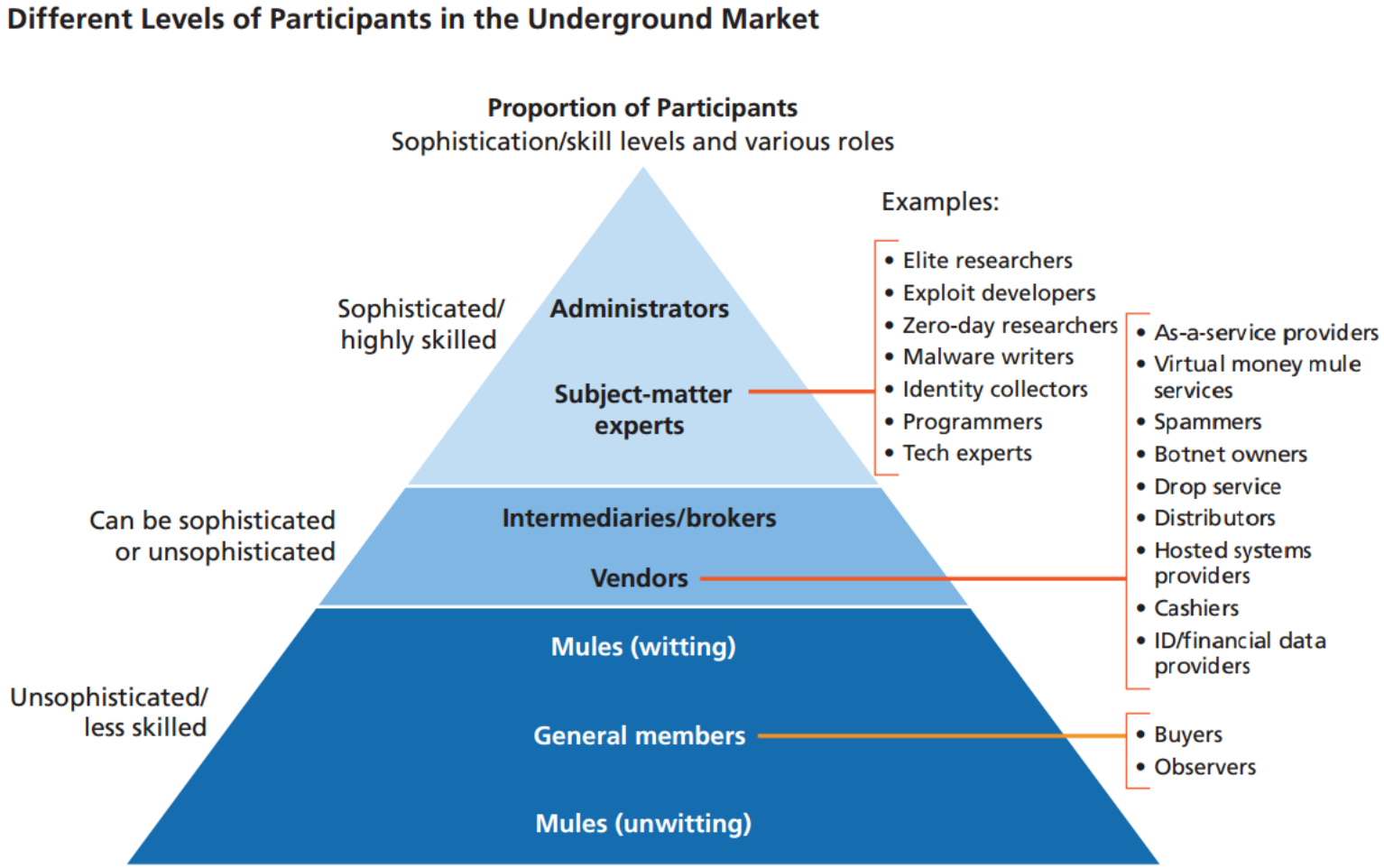


the market

Fonte: kaspersky (2009)

- botnet: $50 to thousands of dollars for a continuous 24-hour attack.
- Stolen bank account details vary from $1 to $1,500 depending on the level of detail and account balance.
- Personal data capable of allowing the criminals to open accounts in stolen names costs $5 to $8 for US citizens; two or three times that for EU citizens.
- A list of one million email addresses costs between $20 and $100; spammers charge $150 to $200 extra for doing the mailshot.
- Targeted spam mailshots can cost from $70 for a few thousand names to $1,000 of tens of millions of names.
- User accounts for paid online services and games stores such as Steam go for $7 to $15 per account.
- Phishers pay $1,000 to $2,000 a month for access to fast flux botnets
- Spam to optimise a search engine ranking is about $300 per month.
- Adware and malware installation ranges from 30 cents to $1.50 for each program installed. But rates for infecting a computer can vary widely, from $3 in China to $120 in the US, per computer.

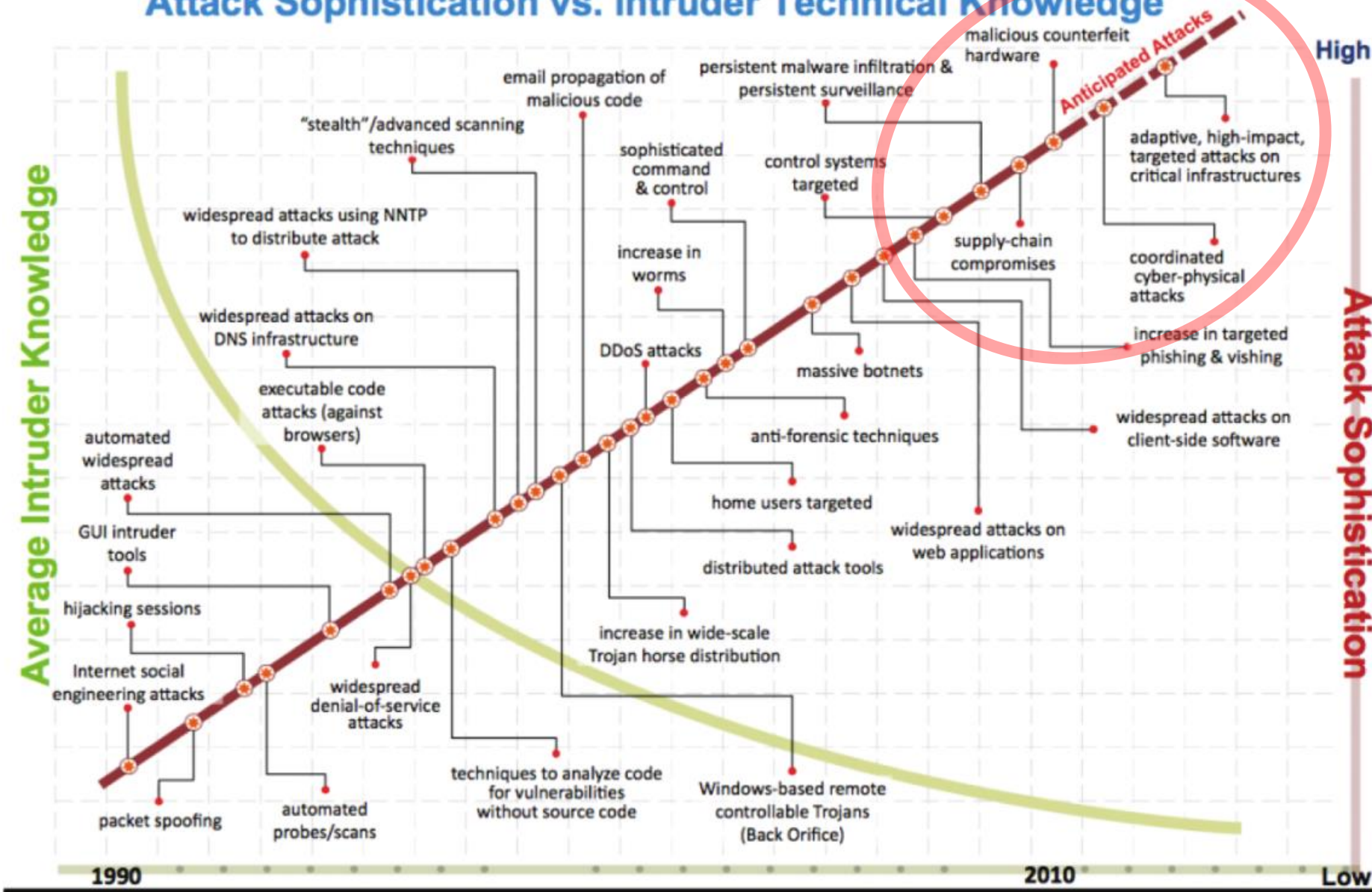
market participants - levels



RAND - Markets for Cybercrime Tools and Stolen Data, 2014

evolution

APTs



Advanced Persistent Threats (cyberwar)

- organizzazioni (es. governi) capaci di minacciare continuativamente un obiettivo
  - con mezzi informatici ma non solo
- obiettivi
  - compromissioni di sistemi industriali (stuxnet)
    - primo rootkit per sistemi SCADA
  - reperimento di informazioni (flame)
    - screenshot, voice recording, remote control
- virus sofisticati
  - sfruttamento di vari zero-day threats
  - sfruttamento di collisioni MD5
  - infezioni su varie tecnologie (es. bluetooth, PLC, scada)

Advanced Persistent Threats

peculiarities of APTs

- malware usually operated by very big organizations
- no direct profit but political or market advantages
- leverage insiders for info gathering and initial attack
- knowledgeable
  - about specific industrial processes
  - about deployed countermeasures (e.g. antivirus evasion)
- trade time for stealth (slow attacks)
- based on zero-days
  - e.g. procured on the black market
  - leverage public cloud facilities

famous APTs

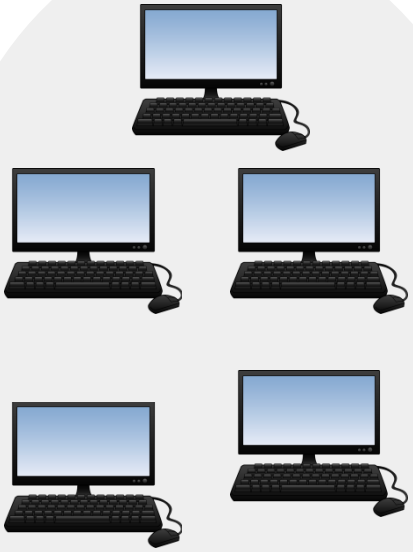
- Stuxnet (2010)
  - target: iranian uranium enrichment facilities
  - spreads through USB storage and regular IT systems
  - **specifically infects SCADA servers and embedded systems**
    - change control parameters of centrifuges to induce excessive vibration
  - hide from antivirus
  - exploits several new vulnerabilities
  - cryptographic attack
- others: Duqu (2011), Flame (2012), Duqu 2.0 (2015)
- apt.securelist.com (kaspersky)

fine parentesi

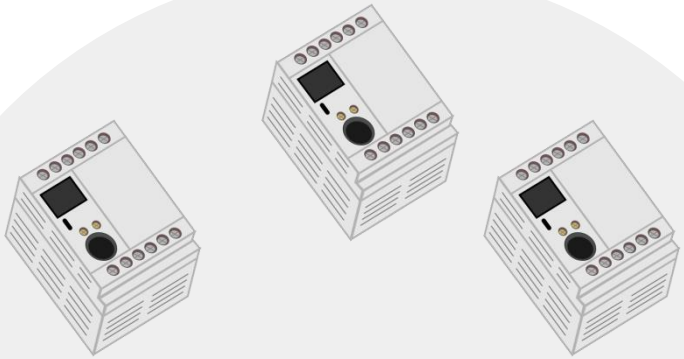
Integrity techniques for ICS protection and USB security

two “realms”

Regular IT

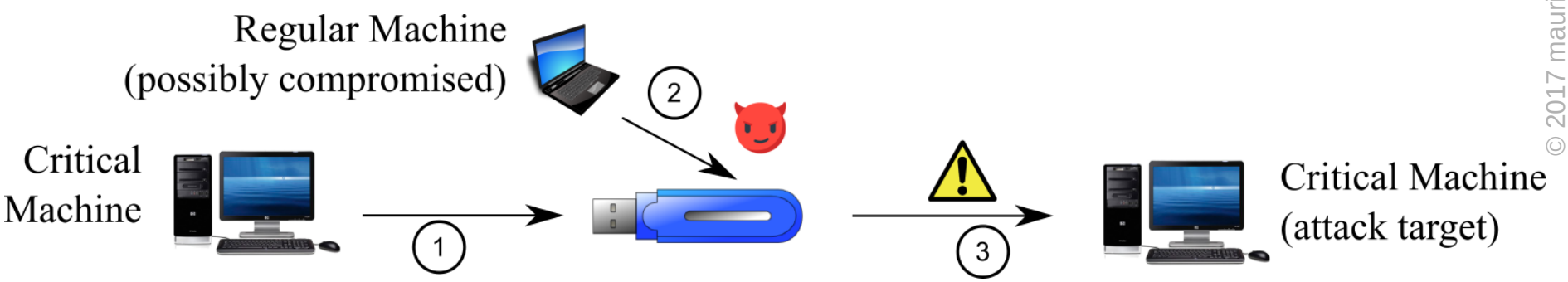


Industrial Control System



problem setting

- regular IT: considered insecure
- ICS: must be protected from APTs that can easily reach regular IT
- ICS loosely connected
  - USB memory sticks are used
- USB memory are used promiscuously
- USB memory is a spreading vector for APT



idea

- use the Biba integrity model
  - high integrity level: ICS
  - low integrity level: regular IT
- for USB memory, we cannot rely on file system access control
  - why???....

filesystem access control is useless

- USB sticks are used promiscuously on untrusted computers (e.g., employee devices)
- access control is not trusted in these devices
- we cannot be sure that nobody tamper with critical data
- hence, we cannot use file system access control
  - we use cryptographic methods: signature

problems for USB filesystem signature/integrity

- composite data
  - what about deletion or reverting to previous version of a single file?
- common approaches
  - signing each file separately
    - does not detect file deletion/restoration
    - inefficient for large files
  - signing each block separately
    - does not detect restoration of single blocks
  - signing the whole filesystem
    - effective tampering detection
    - highly inefficient: O(n) time for update, O(n) time for check, where n is the total amount of data stored, we aim at have O(m) for update and check, where m is the data read or written

parentesi: merkle hash tree

Authenticated Data Structure (ADS)

- a data structure that speed up hash computation and checks
- useful when
  - the dataset the hash is computed on (n) is large
  - the changed data m are small (m<<n)
  - the retrieved data m are small (m<<n)
- typical hypothesis
  - client of an ADS can keep a hash (constant size) in a trusted environment
  - client of a ADS can use a large amount of untrusted storage

ADS typical usage

- by using an ADS, client can detect tampered data before they are used
  - e.g., before they cause problem in business processes
- typical application
  - cloud storage
    - legal proof of correctness or tampering
    - service level agreement verification
  - backup check

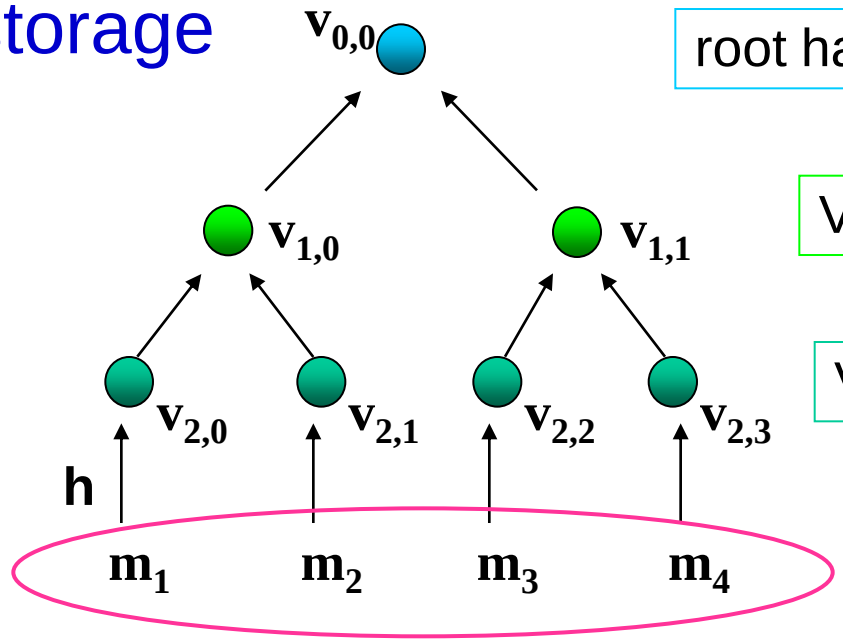
many different ADSes

- Easy example: authenticated list
  - each element e contains an info e.x and a cryptographic hash e.h and pointers e.prev e.next
  - e.h = hash(e.prev.h | e.x)
  - efficiency: append O(1), check O(n)
- Merkle Hash Tree
- Authenticated Skip Lists

- static and dynamic

MHT: how does it work

- a (balanced) tree
- each node *v* contain a hash for the data associated with leaves below *v*
- client keep only the root hash in a trusted storage



root hash= $V_{0,0} = h(V_{1,0} \mid V_{1,1})$

$V_{1,1} = h(V_{2,2} \mid V_{2,3})$

$V_{2,2} = h(m_3)$

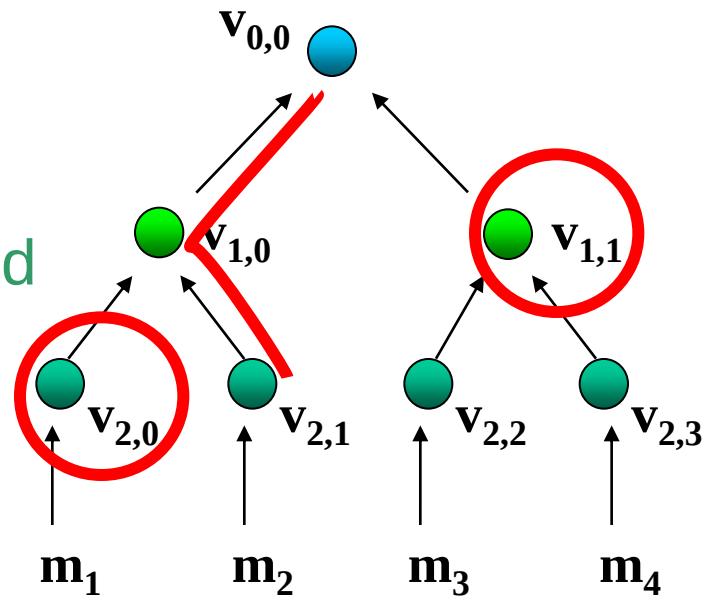
$V_{2,3} = h(m_4)$

data must be ordered

h(.) is a cryptographic hash function

MHT: integrity proof

- proof for m_i:
  - consider the path from m_i to root
  - the proof is made of the siblings of the nodes in that path
- example: proof for m_2
  - $\mathbf{v}_{2,0}$ $\mathbf{v}_{1,1}$
- check:
  - assume that client has a trusted version of the root hash (RH)
  - RH = h(h($\mathbf{v}_{2,0}$ |h(m_2)) | $\mathbf{v}_{1,1}$)
  - compare
    RH == trusted RH



MHT: check semantic

- client is sure that the data of the reply comes from the dataset associated with the trusted version of the root hash

MHT: efficiency

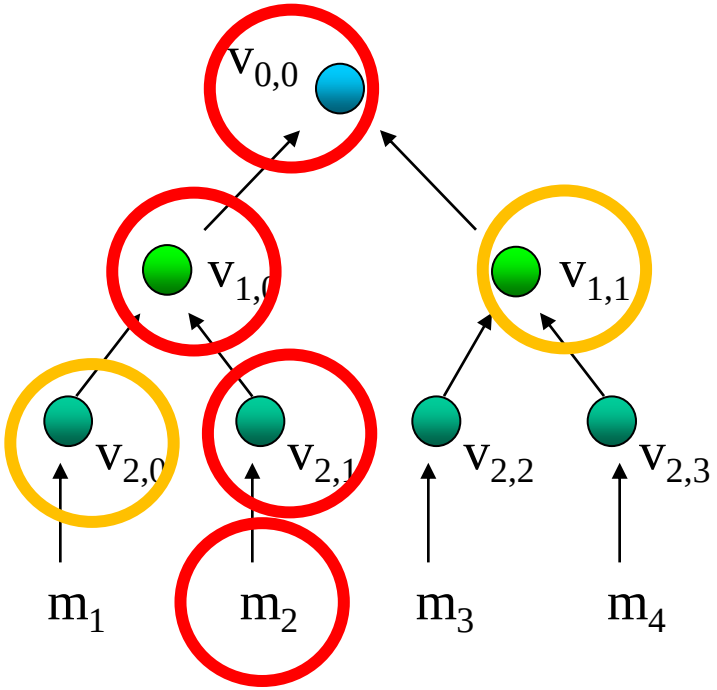
- for a balanced MHT creating and checking a proof is efficient
- let *n* the size of the stored data
- length of the proof is O(log *n*)

MHT: update

- we have to update m_i to a new version m_i'
  - root hash will change as well as several internal hashes
- procedure
  - compute proof *p* for m_i and check it
  - update the hashes of the path to root starting from m_i using content of *p*
  - update trusted root hash

MHT: update

- example: update m_2 to a new version m_2'

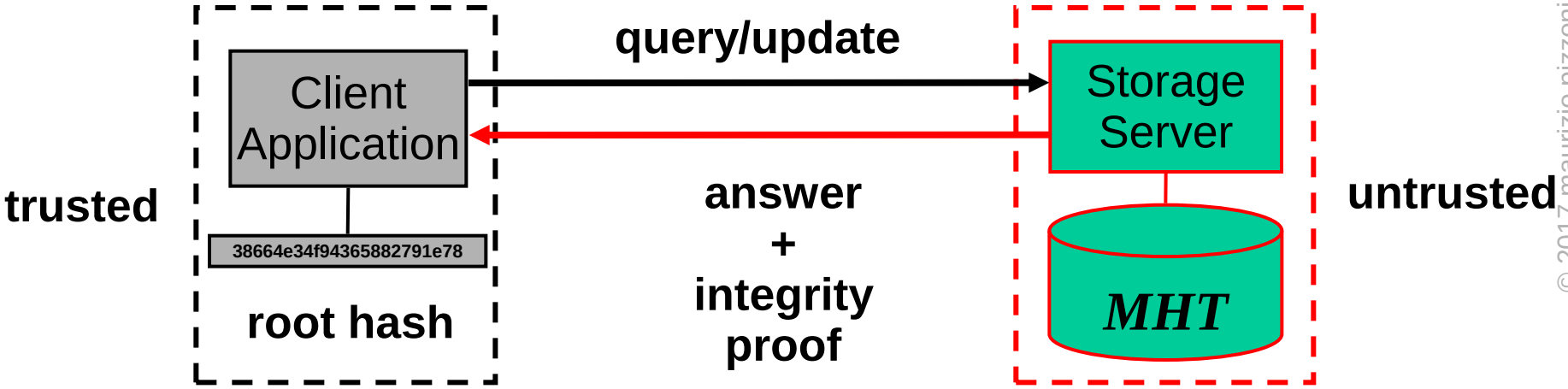


updated
from proof

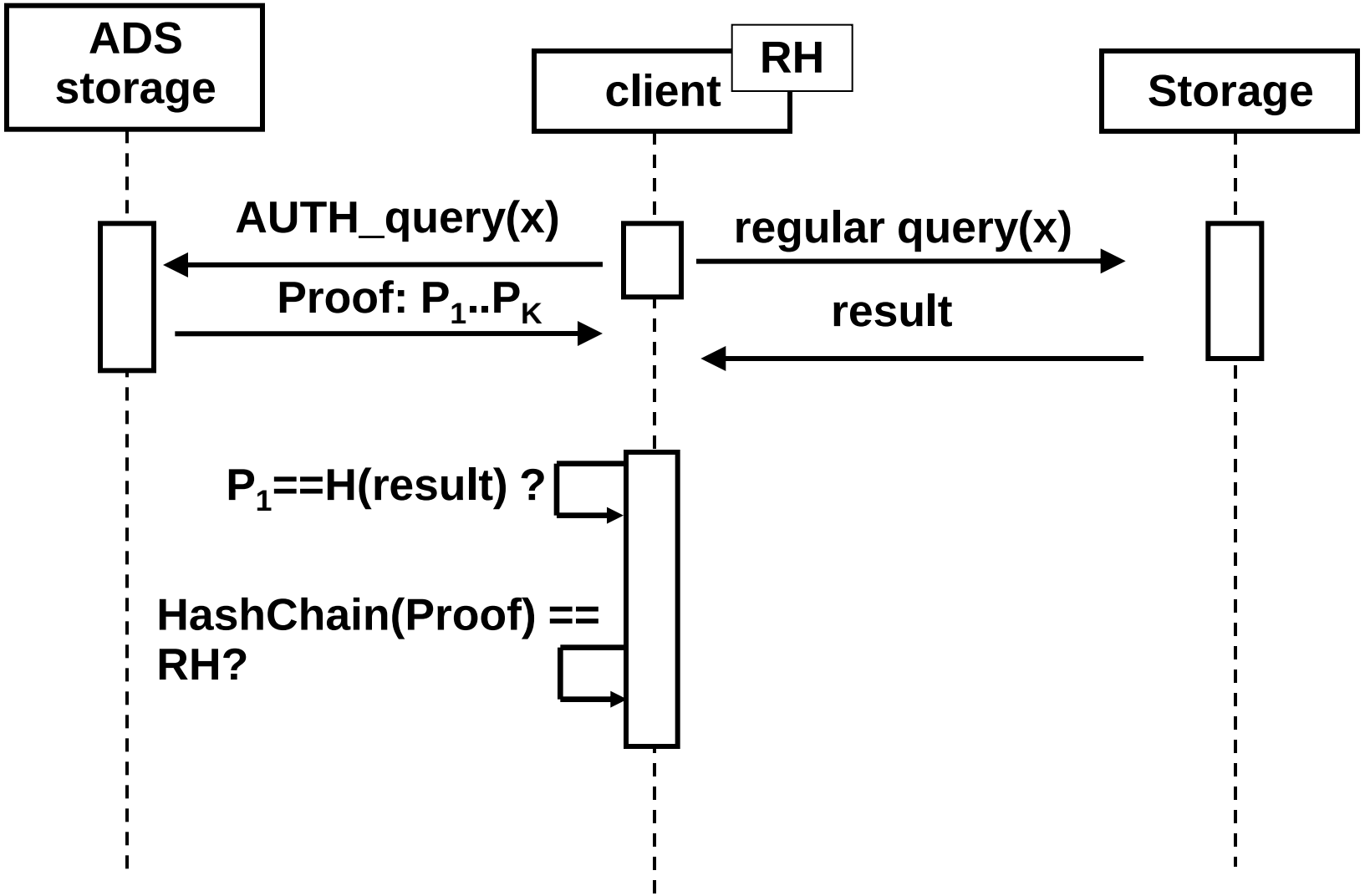
- O(log *n*) time for balanced trees

ADS use case: check of cloud behaviour

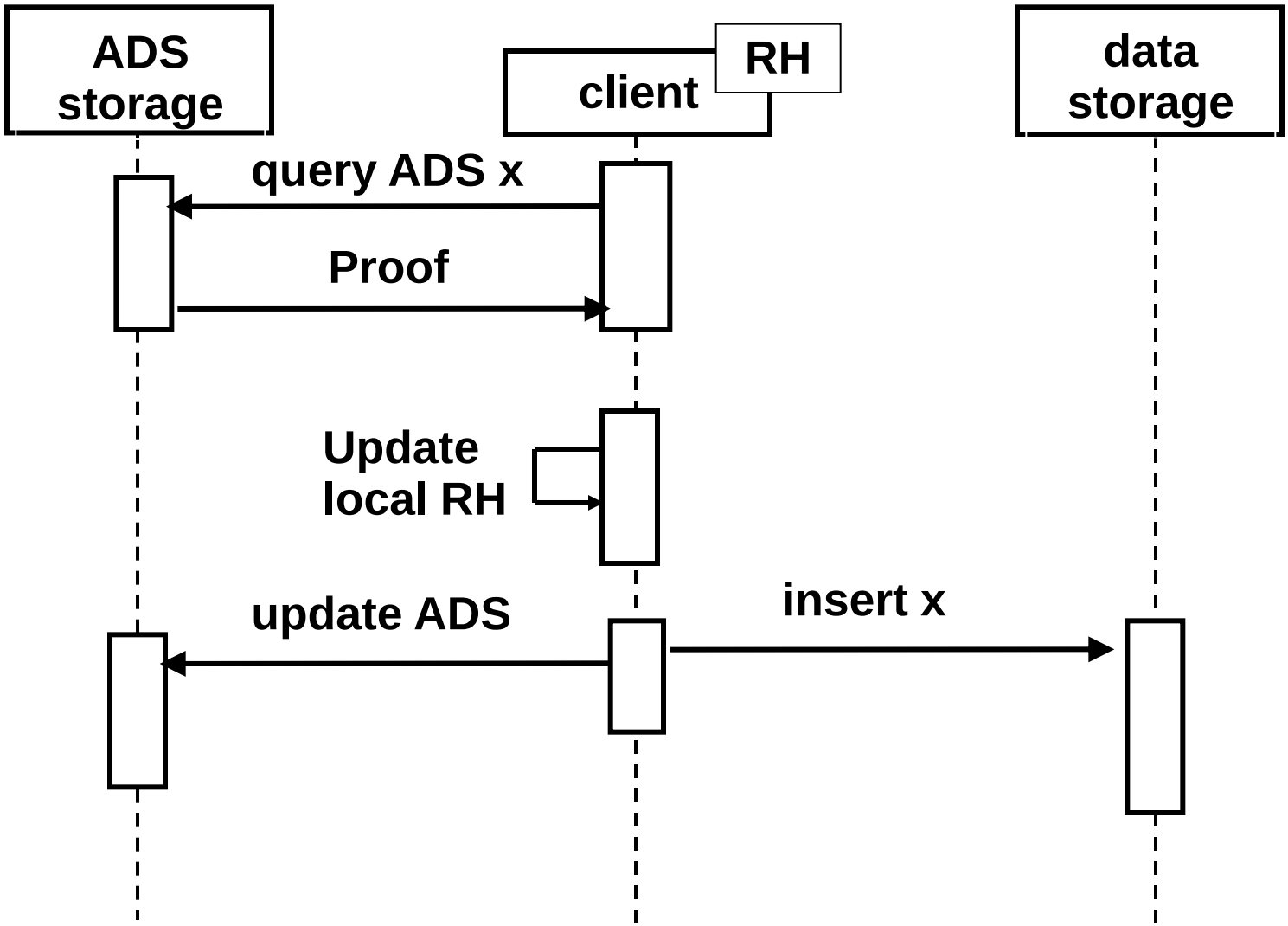
- client stores root hash locally
- ADS can be stored in cloud too
- ADS can be applied to regular cloud storage
  - i.e., storage might not know about ADS



ADS authenticated query protocol



ADS authenticated update protocol



security remarks

- tampering with the ADS cannot lead to undetected data tampering
- to break the protection a has collision must be found

- if an ADS is lost, it can be re-created from data
- essentially an ADS is only a speed-up tool

fine parentesi

efficient filesystem integrity

- by using ADS we obtain
  - integrity check that detect any kind of tampering
  - efficiency comparable to any index data structure
- a MHT for integrity of files and directories can be represented by means of files and directories
  - ADS stored in the same USB storage

architecture of the Host Integrity System

- two realms: critical and regular
- only critical machines are equipped with an "**Integrity Manager**"
  - checks that only genuine data are read
  - write proof that data are genuine
  - based on hash and signature
- USB memory sticks
  - any regular hardware
  - a **secure zone** is identified (a directory)
  - critical machines can only read from secure zone

special operations

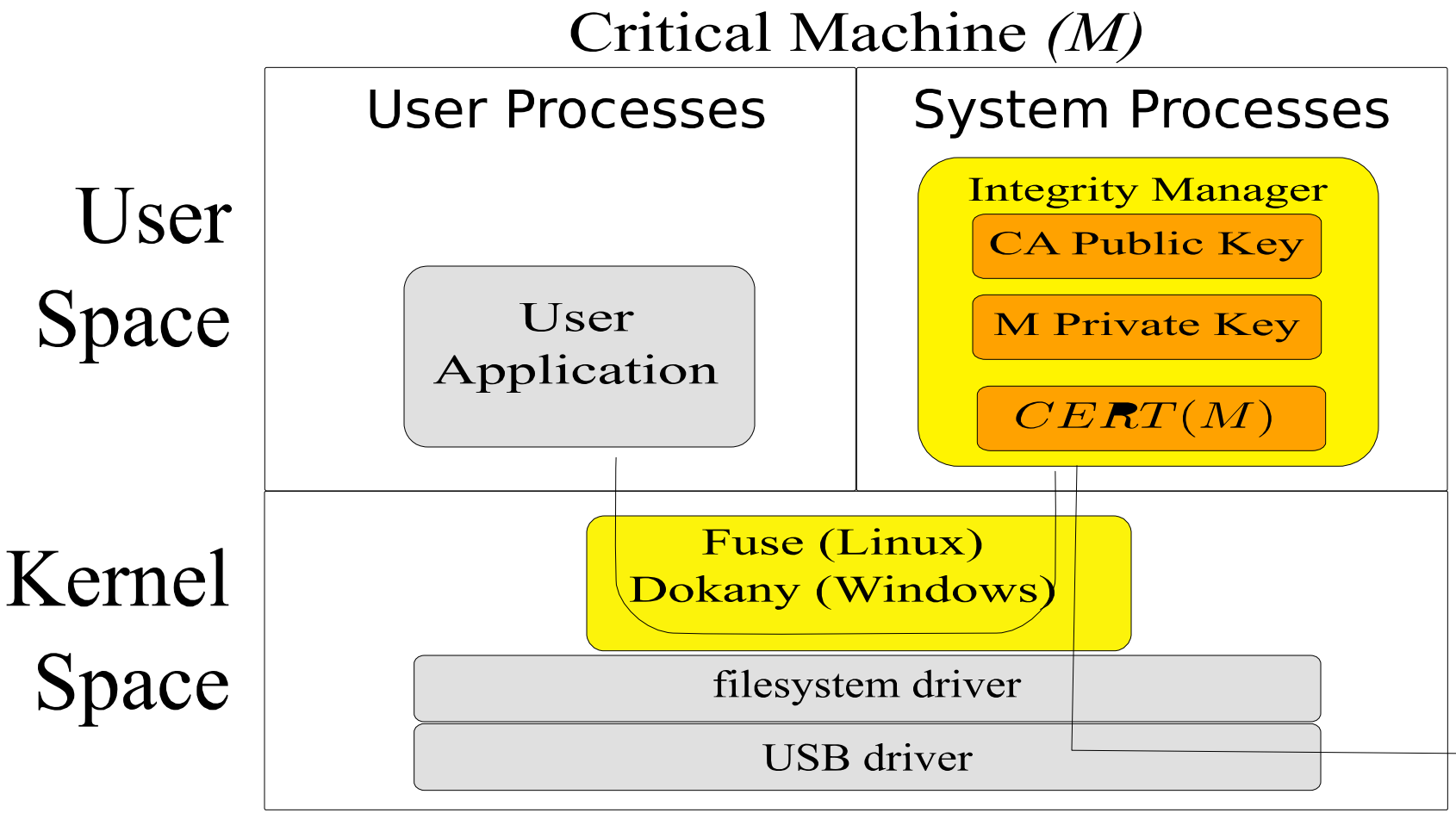
- processes in critical machines read and write USB memory sticks through the **Integrity Manager**
  - redefinition of system call semantic for ADS and root hash handling

other elements

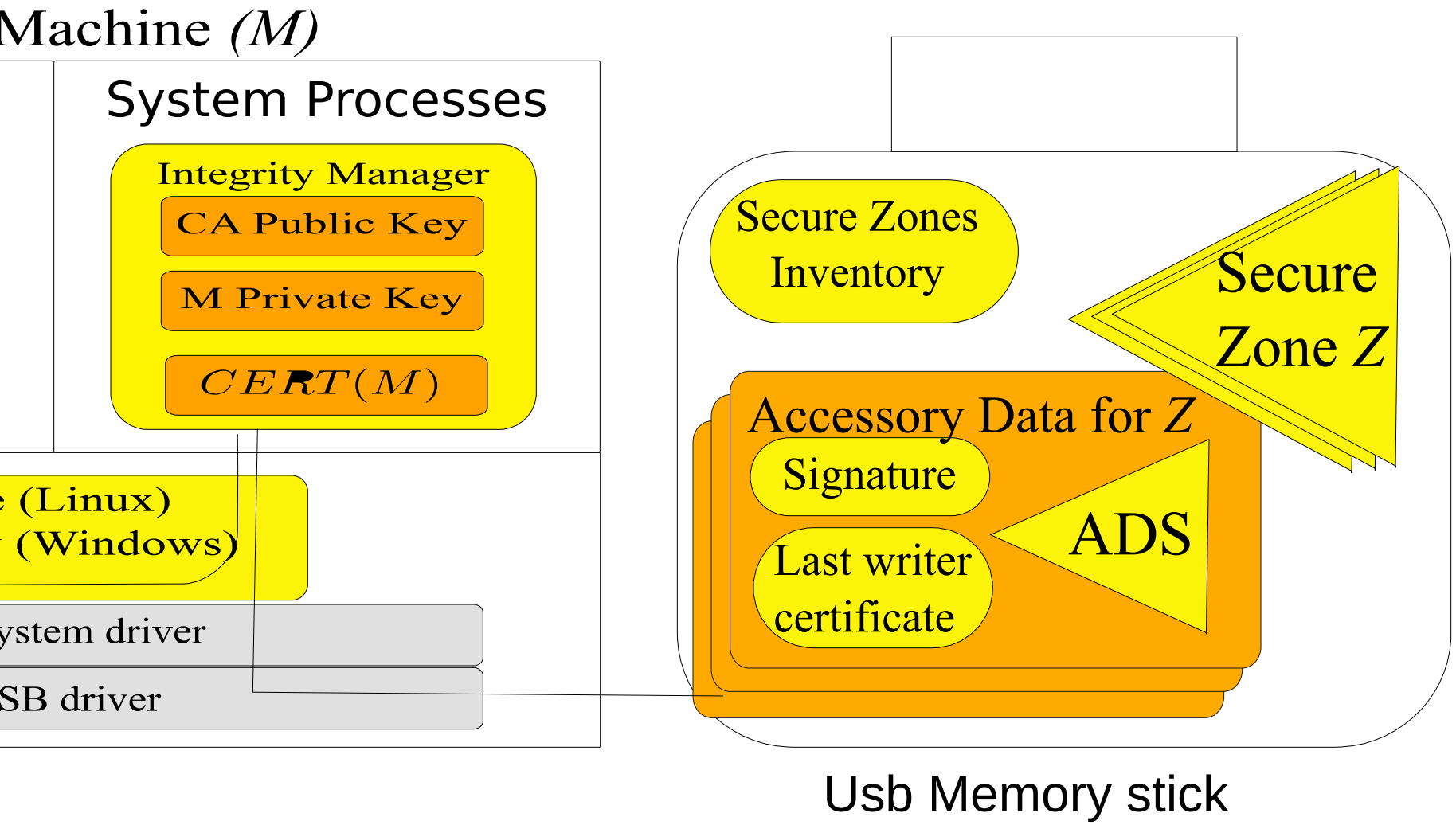
- each host M a private/public key
- Certification Authority (CA)
- root hash is signed by private key and written in the memory stick
  - …along with certificate of M

- possible support of many secure zones
- initial creation of an empty secure zone

architecture



architecture



gatekeeper

- distributed implementation of the Biba model (no need for networking)
- how to import data/software into the critical realm? special machine: gatekeeper
- **gatekeeper**
  - like a critical machine but can read any data (and write it into a secure zone)
  - can implement a “complete mediation” for check possibly malicious data before they enter into the critical realm

security remarks

- restoring of a previous backup is not considered an attack
- USB memory stick is considered passive
  - no protection against firmware attacks (unless they show tampered data)

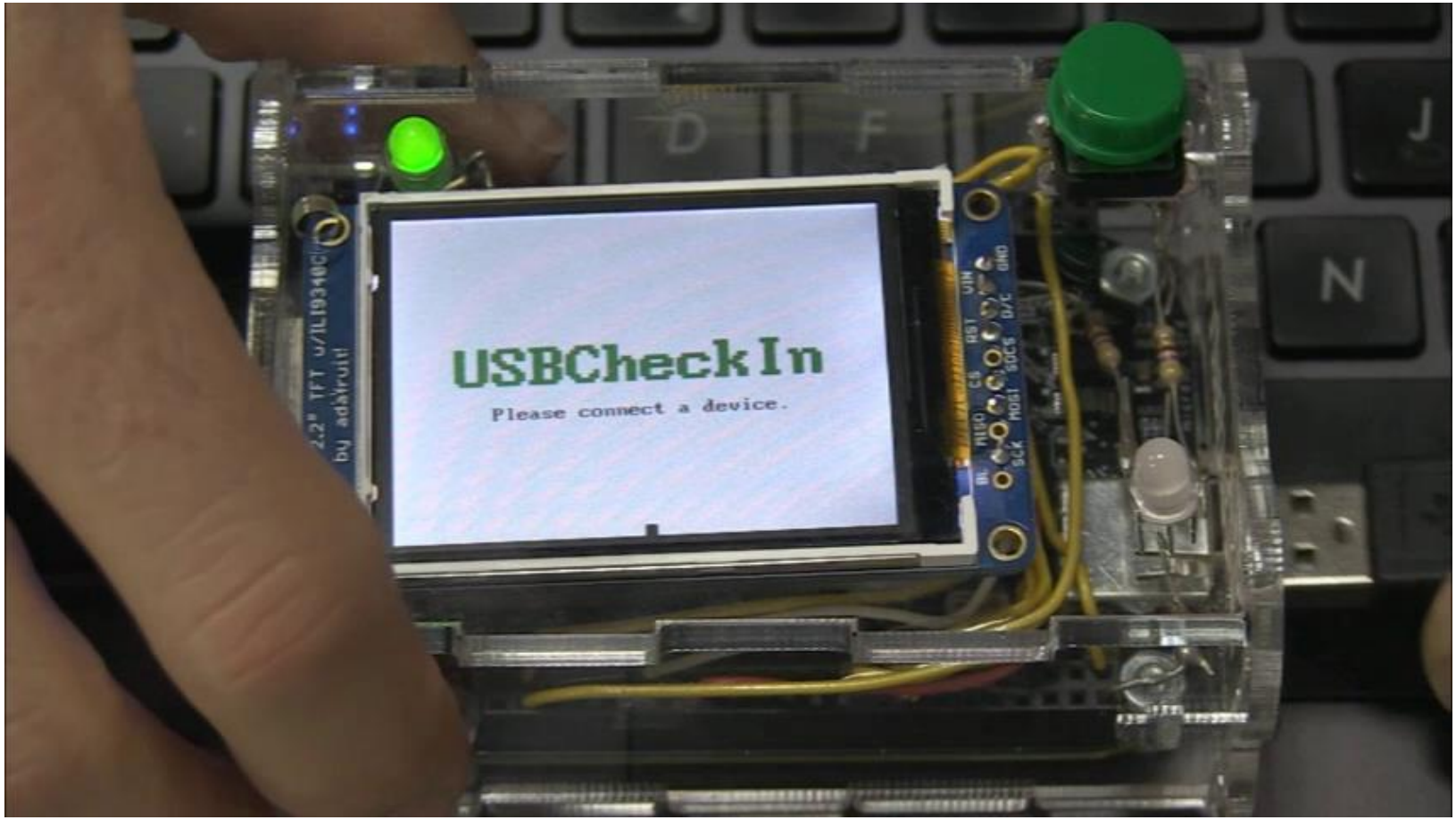
USB firmware attack: BadUSB

- a malicious USB stick declare to be a keyboard
- when inserted into a PC start to “type” commands possibly
  - downloading software (malware)
  - executing software
  - changing configurations
  - typing to create malicious scripts and execute them

protection: USBCheckIn

- it is an hardware that prevents “malicious typing”
- when a USB device pretend to be a keyboard the user is asked to type specific codes
- it is a sort of Captcha for USB devices

USBCheckIn: startup



USBCheckIn: keyboard authorization