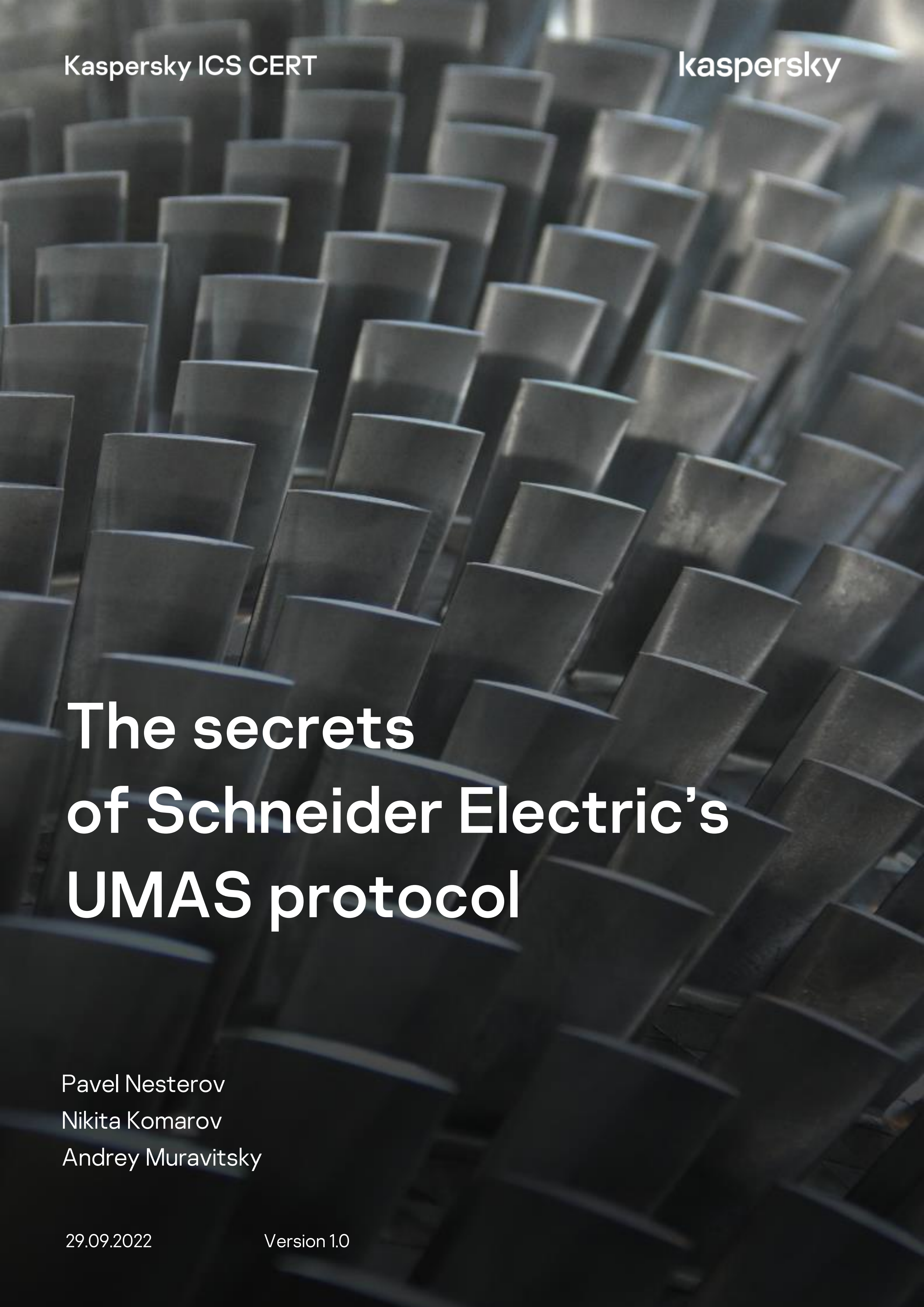

Kaspersky ICS CERT

The secrets of Schneider Electric's UMAS protocol

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UMAS (Unified Messaging Application Services) is a proprietary Schneider Electric (SE) protocol that is used to configure and monitor Schneider Electric PLCs.

Schneider Electric controllers that use UMAS include Modicon M580 CPU (part numbers BMEP* and BMEH*) and Modicon M340 CPU (part numbers BMXP34*). Controllers are configured and programmed using engineering software – EcoStruxure™ Control Expert (Unity Pro), EcoStruxure™ Process Expert, etc.

In 2020, a vulnerability, CVE-2020-28212, was reported, which could be exploited by a remote unauthorized attacker to gain control of a PLC with the privileges of an operator already authenticated on the controller. To address the vulnerability, Schneider Electric developed a new mechanism, Application Password, which should provide protection against unauthorized access to PLCs and unwanted modifications.

An analysis conducted by Kaspersky ICS CERT experts has shown that the implementation of the new security mechanism also has flaws. The CVE-2021-22779 vulnerability, which was identified in the course of the research, could allow a remote attacker to make changes to the PLC, bypassing authentication.

It was established that the UMAS protocol, in its implementation prior to the version in which the CVE-2021-22779 vulnerability was fixed, had significant shortcomings that had a critical effect on the security of control systems based on SE controllers.

As of the middle of August 2022, Schneider Electric has released an update for the EcoStruxure™ Control Expert software, as well as for Modicon M340 and Modicon M580 PLC firmware, which fixes the vulnerability.

This report describes:

- the implementation of the UMAS protocol that does not use the Application Password security mechanism;
- authentication bypass if Application Password is not enabled;
- the principles on which the Application Password security mechanism is based;
- mechanisms that can be used to exploit the CVE-2021-22779 vulnerability (authentication bypass where Application Password is configured).
- operating principles of the updated device reservation mechanism.

The conclusion provides remediations and recommendations from Schneider Electric on addressing the authentication bypass vulnerability, as well as Kaspersky ICS CERT recommendations.

If you would like to request additional information or to share your thoughts on issues discussed in this article, please write to ics-cert@kaspersky.com.

Snort rules are available on the Kaspersky Threat Intelligence (ICS Reporting) portal.

Object of research

UMAS (Unified Messaging Application Services) is Schneider Electric's proprietary protocol used to configure, monitor, collect data and control Schneider Electric industrial controllers.

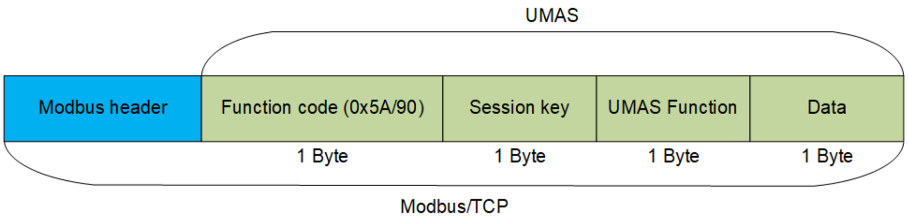
UMAS is based on a client-server architecture. In the process of our research, we used the EcoStruxure™ Control Expert PLC configuration software as the client part and a Modicon M340 CPU controller as the server part.

UMAS protocol

Network packet structure

UMAS is based on the Modbus/TCP protocol.

Structure of the UMAS protocol



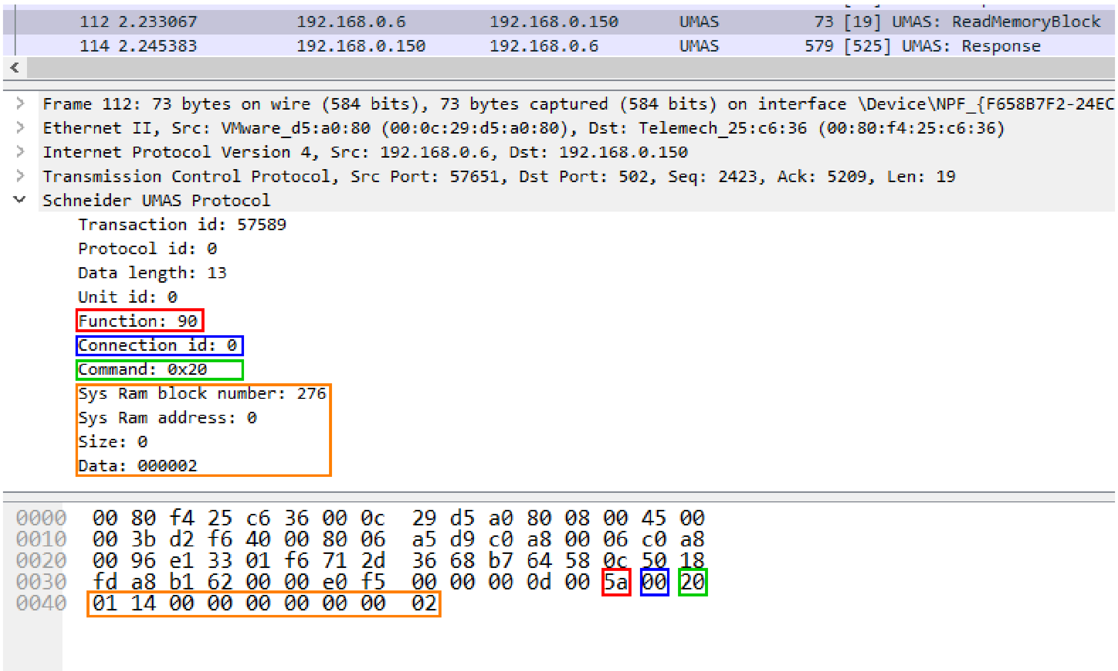
Specifications of the Modbus/TCP protocol include reserved Function Code values that developers can use according to their needs. A complete list of reserved values can be found in the official documentation.

Schneider Electric uses Function Code 90 (0x5A) to define that the value in the Data field is UMAS compliant.

The network packet structure is shown below, using a request to read a memory block (pu_ReadMemoryBlock) on the PLC as an example:

- Red: Function Code 90 (0x5A)
- Blue: Session Key 0 (0x00) (see Session key)
- Green: UMAS Function 20 (0x20) (see UMAS protocol functions)
- Orange: Data

Each function includes a certain set of information in Data, such as offset from the base memory address, size of the data sent, memory block number, etc.

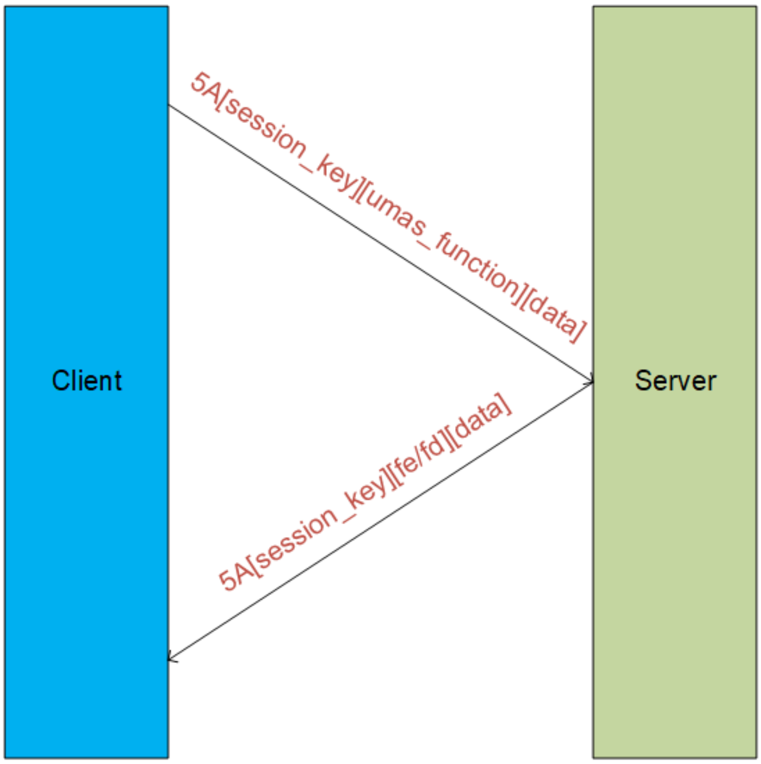


```
  112 2.233067     192.168.0.6      192.168.0.150    UMAS        73 [19] UMAS: ReadMemoryBlock
  114 2.245383     192.168.0.150    192.168.0.6      UMAS       579 [525] UMAS: Response

> Frame 112: 73 bytes on wire (584 bits), 73 bytes captured (584 bits) on interface \Device\NPF_{F658B7F2-24EC
> Ethernet II, Src: VMware_d5:a0:80 (00:0c:29:d5:a0:80), Dst: Telemech_25:c6:36 (00:80:f4:25:c6:36)
> Internet Protocol Version 4, Src: 192.168.0.6, Dst: 192.168.0.150
> Transmission Control Protocol, Src Port: 57651, Dst Port: 502, Seq: 2423, Ack: 5209, Len: 19
v Schneider UMAS Protocol
     Transaction id: 57589
     Protocol id: 0
     Data length: 13
     Unit id: 0
     Function: 90
     Connection id: 0
     Command: 0x20
     Sys Ram block number: 276
     Sys Ram address: 0
     Size: 0
     Data: 000002

0000  00 80 f4 25 c6 36 00 0c  29 d5 a0 80 08 00 45 00
0010  00 3b d2 f6 40 00 80 06  a5 d9 c0 a8 00 06 c0 a8
0020  00 96 e1 33 01 f6 71 2d  36 68 b7 64 58 0c 50 18
0030  fd a8 b1 62 00 00 e0 f5  00 00 00 0d 00 5a 00 20
0040  01 14 00 00 00 00 00 00  02
```

Network communication

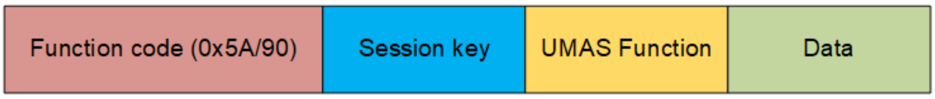
UMAS also inherits the Modbus client-server architecture. A structural diagram of the communication between the client and the server is provided below.

Communication between the client (EcoStruxure™ Control Expert) and server (PLC)


Client
5A[session_key][umas_function][data]
Server
5A[session_key][fe/fd][data]

In a UMAS network packet, Function Code 0x5A is immediately followed by the Session Key.

UMAS network packet structure



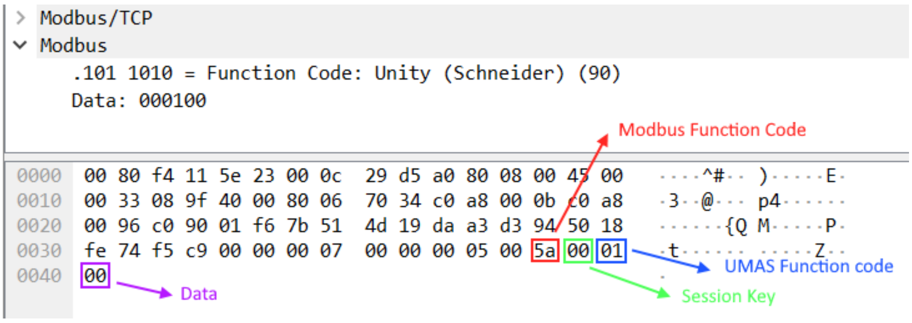
Function code (0x5A/90) | Session key | UMAS Function | Data

Below we examine the communication between a client and a server (a PLC, also referred to below as “device”) by analyzing a sample real-world traffic fragment.

The screenshot below shows a packet containing the function **umas_QueryGetComInfo(0x01)** sent from the client (EcoStruxure™ Control Expert) to the server (the PLC).

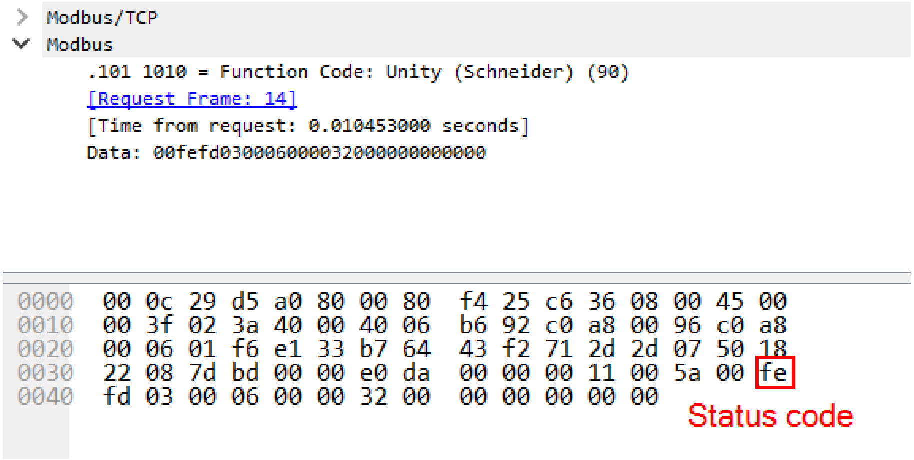
Structure of the function:

```
TCP DATA – Modbus Header – 0x5A – session – 01(UMAS function code) –
00(data).
```



```
> Modbus/TCP
v Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: 000100

0000  00 80 f4 11 5e 23 00 0c  29 d5 a0 80 08 00 45 00   ····^#·· )·····E·
0010  00 33 08 9f 40 00 80 06  70 34 c0 a8 00 0b c0 a8   ·3··@··· p4······
0020  00 96 c0 90 01 f6 7b 51  4d 19 da a3 d3 94 50 18   ······{Q M·····P·
0030  fe 74 f5 c9 00 00 00 07  00 00 00 05 00 5a 00 01   ·t······ ·····Z··
0040  00                                                 ·
```

The device should send a response to each request received. The screenshot below shows the device’s response to the client’s request:



```
> Modbus/TCP
v Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    [Request Frame: 14]
    [Time from request: 0.010453000 seconds]
    Data: 00fefd0300060000320000000000

0000  00 0c 29 d5 a0 80 00 80  f4 25 c6 36 08 00 45 00
0010  00 3f 02 3a 40 00 40 06  b6 92 c0 a8 00 96 c0 a8
0020  00 06 01 f6 e1 33 b7 64  43 f2 71 2d 2d 07 50 18
0030  22 08 7d bd 00 00 e0 da  00 00 00 11 00 5a 00 fe
0040  fd 03 00 06 00 00 32 00  00 00 00 00 00
```

The status code is the status of execution by the device of the function sent to it by the client in the previous request. The value “fe” corresponds to successful execution of the function, “fd” – to an error. These values are present in each response sent by the device to the client’s request containing a function. The status code is always located immediately after the session key.

Reservation procedure

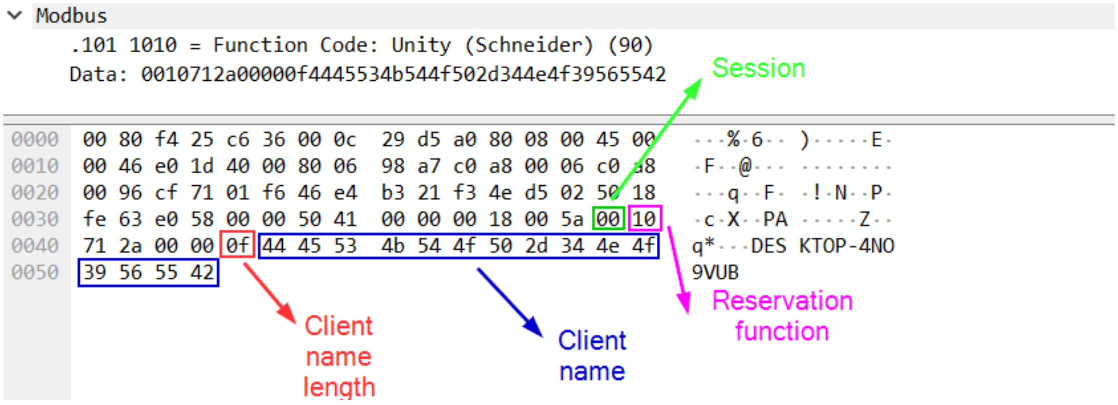
A “reservation” procedure is required to make changes to a PLC. The procedure acts as authentication.

Only one client (e.g., an engineering workstation) can reserve a device at any specific time for configuration or status monitoring. This is required to prevent changes from being made to a device in parallel without coordination.

The screenshot below shows a request from the engineering software to the PLC to perform the device reservation procedure in its basic variant that does not use the Application Password security mechanism.

The **umas_QueryTakePLCReservation(0x10)** function is used to reserve a device.

To reserve a device, the client sends a request containing the 0x10 function to the device. The request includes the name of the client reserving the device and the value equal to the length of that name.



```
Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: 0010712a00000f4445534b544f502d344e4f39565542

0000  00 80 f4 25 c6 36 00 0c  29 d5 a0 80 08 00 45 00   ···%·6·· )·····E·
0010  00 46 e0 1d 40 00 80 06  98 a7 c0 a8 00 06 c0 a8   ·F··@··· ········
0020  00 96 cf 71 01 f6 46 e4  b3 21 f3 4e d5 02 50 18   ···q··F· ·!·N··P·
0030  fe 63 e0 58 00 00 50 41  00 00 00 18 00 5a 00 10   ·c·X··PA ·····Z··
0040  71 2a 00 00 0f 44 45 53  4b 54 4f 50 2d 34 4e 4f   q*···DES KTOP-4NO
0050  39 56 55 42                                        9VUB
```

Session key

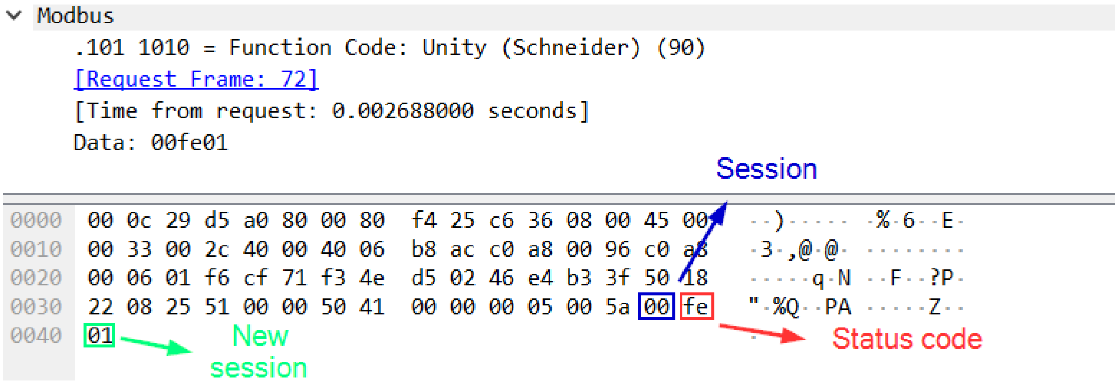
Upon completing the reservation, the device sends the value of the new one-byte session key to the client. The key is subsequently used to authorize device modification requests.

With the release of new firmware versions, the session creation mechanism has undergone some changes, namely:

- In firmware versions prior to 2.7, the session key for a Modicon M340 device after its reservation had the fixed value 0x01;
- In firmware versions 2.7 or later, the session key for a Modicon M340 device had a random value, i.e., from 0 to 0xFF, as the session key is 1 byte in size.

Until the reservation procedure is completed, a service session with the value “0x00” is used. Functions that do not require reservation can be executed in that session.

The device’s response, which includes the status code (0xfe) and the **new session key**, looks as follows:

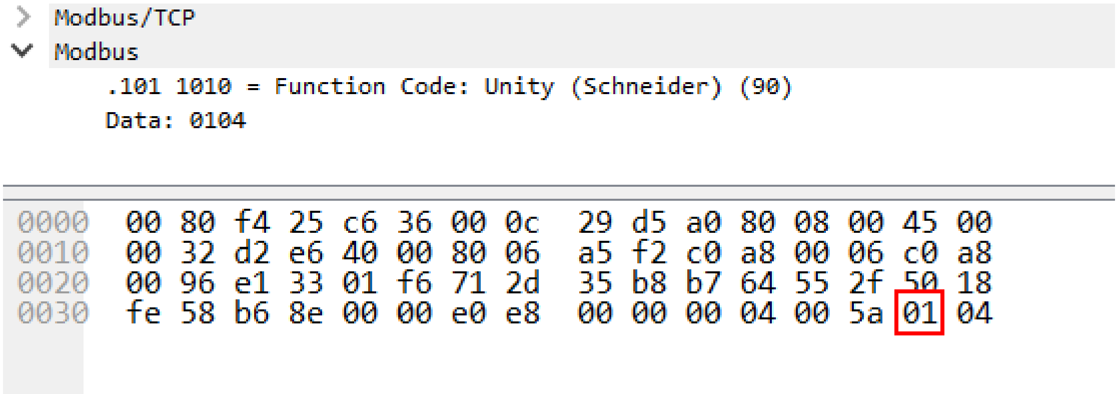


```
⌄ Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    [Request Frame: 72]
    [Time from request: 0.002688000 seconds]
    Data: 00fe01

0000  00 0c 29 d5 a0 80 00 80  f4 25 c6 36 08 00 45 00   ··)····· ·%·6··E·
0010  00 33 00 2c 40 00 40 06  b8 ac c0 a8 00 96 c0 a8   ·3·,@·@· ········
0020  00 06 01 f6 cf 71 f3 4e  d5 02 46 e4 b3 3f 50 18   ·····q·N ··F··?P·
0030  22 08 25 51 00 00 50 41  00 00 00 05 00 5a 00 fe   "·%Q··PA ·····Z··
0040  01                                                 ·
```

The status code “fe” means that the reservation procedure was successful.

In this case, the device sends the new session key value. The new session key is used in all subsequent requests during the current “reserved” session.

The following screenshot shows a request from a client to the device using the new session key immediately after the device’s successful reservation. In this example, the request uses the **ex_GetPlcStatus(0x04)** function.



```
> Modbus/TCP
⌄ Modbus
     .101 1010 = Function Code: Unity (Schneider) (90)
     Data: 0104

0000  00 80 f4 25 c6 36 00 0c  29 d5 a0 80 08 00 45 00
0010  00 32 d2 e6 40 00 80 06  a5 f2 c0 a8 00 06 c0 a8
0020  00 96 e1 33 01 f6 71 2d  35 b8 b7 64 55 2f 50 18
0030  fe 58 b6 8e 00 00 e0 e8  00 00 00 04 00 5a 01 04
```

The reservation procedure plays the role of authentication when making changes to a device. This means that the mechanism is critically important from the security viewpoint.

Issues related to reserving a device in the default configuration and using security features are covered in the following sections.

UMAS protocol functions

The UMAS protocol has numerous functions for communicating with target devices. Functions can be divided into two groups:

1. Functions that require reserving the device. As a rule, these are functions that make changes to the PLC.
2. Functions that do not require device reservation. Such functions do not make any changes to the PLC and do not affect its operation.

An abbreviated list of functions available in the UMAS protocol is shown below. Information on the need to reserve the device for the functions listed below is relevant to firmware version 3.30 for Modicon M340 devices without the use of the Application Password security mechanism.

Functions used in the device reservation process

1. 0x10 – umas_QueryTakePLCReservation – reserves the device.
2. 0x11 – umas_QueryReleasePLCReservation – releases the device from reservation.
3. 0x12 – umas_QueryKeepPLCReservation – reservation status.

Functions that require device reservation

Initialization functions

0x01 – umas_QueryGetComInfo – UMAS message initialization.

Functions used to request information about a device

1. 0x02 – pu_GetPlcInfo – requests information about the device
2. 0x04 – pu_GetPlcStatus – queries the PLC status
3. 0x06 – pu_GetMemoryCardInfo – requests information about the device’s SD card

Functions for downloading and uploading PLC strategies

A strategy is a set of instructions and data used by the PLC to perform its main function, that is, to control terminal equipment, e.g., to automate a certain industrial process.

1. 0x30 – pumem_BeginDownload – initializes an upload from the PC to the PLC.
2. 0x31 – pumem_DownloadPacket – uploads a strategy block from the PC to the PLC.
3. 0x32 – pumem_EndDownload – ends the upload from the PC to the PLC.

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4. 0x33 – pumem_BeginUpload – initializes a download from the PLC to the PC.
5. 0x34 – pumem_UploadPacket – downloads a strategy block from the PLC to the PC.
6. 0x35 – pumem_EndUpload – ends the download from the PLC to the PC.

Functions that do not require device reservation

Function that reads information from device memory

0x20 – pu_ReadMemoryBlock – reads PLC memory block.

Function that writes values to device memory

0x21 – pu_WriteMemoryBlock – writes PLC memory block.

Functions that control the state of the PLC

The following functions can be used to start or suspend the operation of the PLC. These functions do not require reservation if the Application Password security mechanism is not activated, in which case the device will successfully handle a request using a service session (0x00) (see Session key).

Unless the Application Password setting is enabled, an attacker can use these functions to stop the PLC, thereby causing significant damage to the industrial process.

1. 0x40 – ex_StartTask – Start PLC operation.
2. 0x41 – ex_StopTask – Stop PLC operation.

CVE-2020-28212: authentication bypass without Application Password

The main issue with the basic reservation mechanism that does not use Application Password is that an attacker can use the session key to send requests and change the device's configuration.

In firmware versions prior to 2.7 for Modicon M340 devices, the session key has the same value each time the device is reserved and is equal to "0x01". This means that attackers can make changes on the device by calling the relevant functions after reserving the device themselves or after the device has been reserved by a legitimate user.

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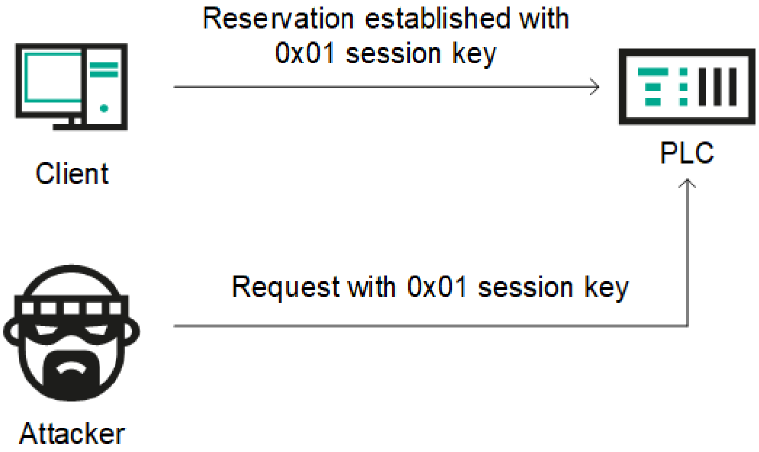
The attack workflow is shown in the diagram below:


Reservation established with 0x01 session key
Client
PLC
Request with 0x01 session key
Attacker

Remote threat actor attack workflow. Modicon M340 firmware version prior to 2.7, device reserved by an engineer

If the device has not been reserved at the time of an attack, the attacker can use the **umas_QueryTakePLCReservation(0x10)** function to reserve the device in order to make changes to it.

With Modicon M340 firmware versions 2.7 or later, the session key takes a random value after device reservation. However, the session key is one byte in length, which means there are only 256 possible session ID values. This enables a remote unauthorized attacker to brute-force an existing ID of the session between a legitimate user and the PLC.

To carry out this type of attack, a remote attacker needs to send a series of network requests on port 502/TCP of the PLC with different session ID values and look at responses returned by the PLC. If the correct session ID was sent, the attacker will get status code `0xfe`, which means that the request was fulfilled successfully. Otherwise, the attacker will get status code `0xfd`.

The operations described above can be implemented using any programming language – an attacker does not have to use EcoStruxure™ Control Expert or any other dedicated software to communicate with the device.

Application Password

To mitigate the CVE-2020-28212 vulnerability, the exploitation of which could allow a remote unauthorized attacker to gain control of the PLC with the privileges of an operator already authenticated on the PLC, Schneider Electric developed a new security mechanism. Schneider Electric believed that implementing an improved security mechanism that used cryptographic algorithms to compute the session ID and increasing the session ID length would prevent brute-force attacks that could be used to crack single-byte session IDs.

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Starting with firmware version 3.01 for Modicon M340 devices, Schneider Electric actively developed security mechanisms to prevent attackers from abusing UMAS functions to make changes to device operation. To implement authentication between the client and the device, Application Password should be enabled in project settings ("Project & Controller Protection"). The mechanism is designed to provide protection against unauthorized access, unwanted changes, as well as unauthorized downloading or uploading of PLC strategies.

After activating the mechanism using EcoStruxure™ Control Expert, the client needs to enter the password when connecting to a device as part of the reservation procedure.

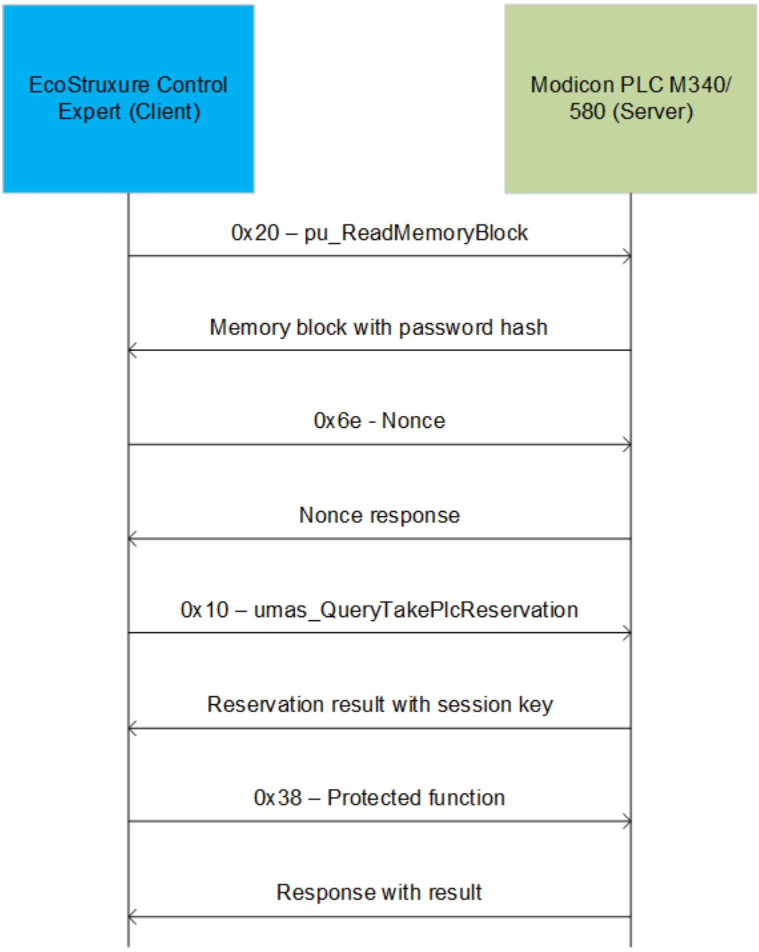
Application Password also makes changes to the reservation mechanism itself. These changes are discussed in the sections below.

Authentication bypass with Application Password

Unfortunately, an analysis conducted by Kaspersky ICS CERT experts has shown that the implementation of the new security mechanism also has flaws. The vulnerability identified during the research, CVE-2021-22779, could allow a remote attacker to bypass the authentication mechanism and use functions that require reservation to make changes to the PLC.

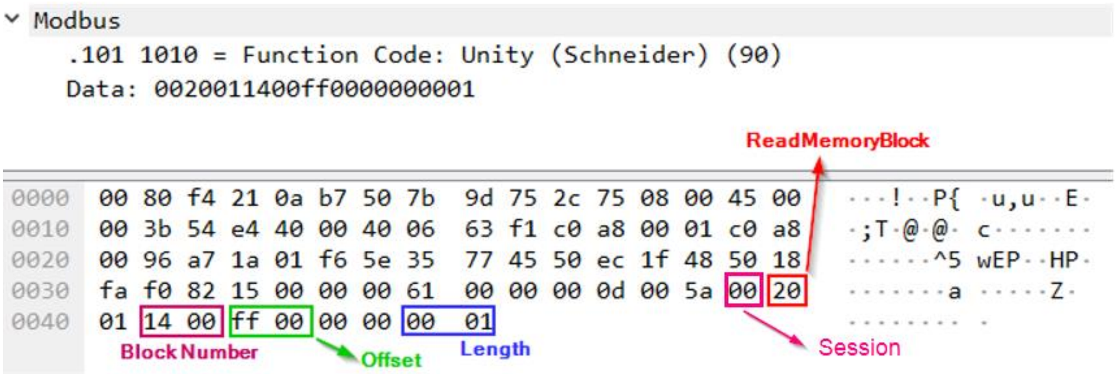
To grasp more fully what the shortcomings of the 'improved' security mechanism are, let's look at the authentication and PLC reservation process in greater detail. The new security mechanism is based on exchanging a randomly generated byte sequence (a nonce) between the client and the server and subsequently producing a single session secret. The diagram below shows the sequence of requests sent and responses received.

Device reservation sequence with Application Password enabled


EcoStruxure Control Expert (Client)
Modicon PLC M340/ 580 (Server)
0x20 – pu_ReadMemoryBlock
Memory block with password hash
0x6e - Nonce
Nonce response
0x10 – umas_QueryTakePlcReservation
Reservation result with session key
0x38 – Protected function
Response with result

Below we look at the process in more detail.

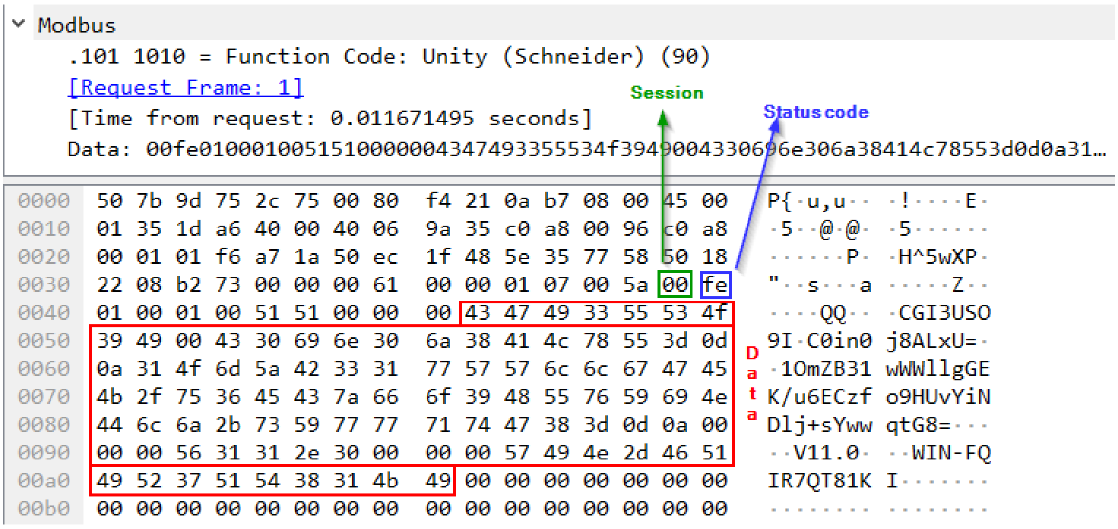
After establishing a TCP session, the EcoStruxure™ Control Expert software sends a request to the PLC (port 502/TCP) to read a memory block using UMAS function 0x20, which does not require authentication.



```
⌄ Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: 0020011400ff0000000001

0000  00 80 f4 21 0a b7 50 7b  9d 75 2c 75 08 00 45 00   ···!··P{ ·u,u··E·
0010  00 3b 54 e4 40 00 40 06  63 f1 c0 a8 00 01 c0 a8   ·;T·@·@· c·······
0020  00 96 a7 1a 01 f6 5e 35  77 45 50 ec 1f 48 50 18   ······^5 wEP··HP·
0030  fa f0 82 15 00 00 00 61  00 00 00 0d 00 5a 00 20   ·······a ·····Z·
0040  01 14 00 ff 00 00 00 00  01                        ········ ·
```

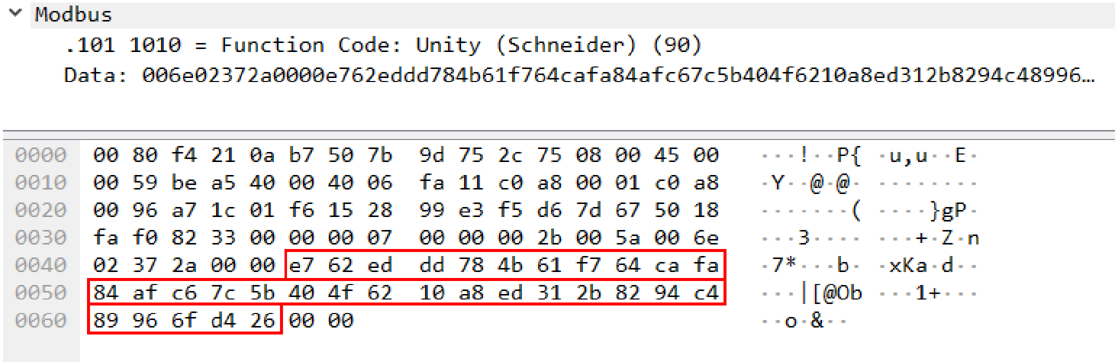
Next, the client receives a response from the PLC. The memory block is needed for further computation since it contains two base64 strings that make up a password hash.



```
˅ Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    [Request Frame: 1]
    [Time from request: 0.011671495 seconds]
    Data: 00fe0100010051510000004347493355534f394900433069 6e306a38414c78553d0d0a31…

0000  50 7b 9d 75 2c 75 00 80  f4 21 0a b7 08 00 45 00   P{·u,u·· ·!····E·
0010  01 35 1d a6 40 00 40 06  9a 35 c0 a8 00 96 c0 a8   ·5··@·@· ·5······
0020  00 01 01 f6 a7 1a 50 ec  1f 48 5e 35 77 58 50 18   ······P· ·H^5wXP·
0030  22 08 b2 73 00 00 00 61  00 00 01 07 00 5a 00 fe   "··s···a ·····Z··
0040  01 00 01 00 51 51 00 00  00 43 47 49 33 55 53 4f   ····QQ·· ·CGI3USO
0050  39 49 00 43 30 69 6e 30  6a 38 41 4c 78 55 3d 0d   9I·C0in0 j8ALxU=·
0060  0a 31 4f 6d 5a 42 33 31  77 57 57 6c 6c 67 47 45   ·1OmZB31 wWWllgGE
0070  4b 2f 75 36 45 43 7a 66  6f 39 48 55 76 59 69 4e   K/u6ECzf o9HUvYiN
0080  44 6c 6a 2b 73 59 77 77  71 74 47 38 3d 0d 0a 00   Dlj+sYww qtG8=···
0090  00 00 56 31 31 2e 30 00  00 00 57 49 4e 2d 46 51   ··V11.0· ··WIN-FQ
00a0  49 52 37 51 54 38 31 4b  49 00 00 00 00 00 00 00   IR7QT81K I·······
00b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ········ ········
```

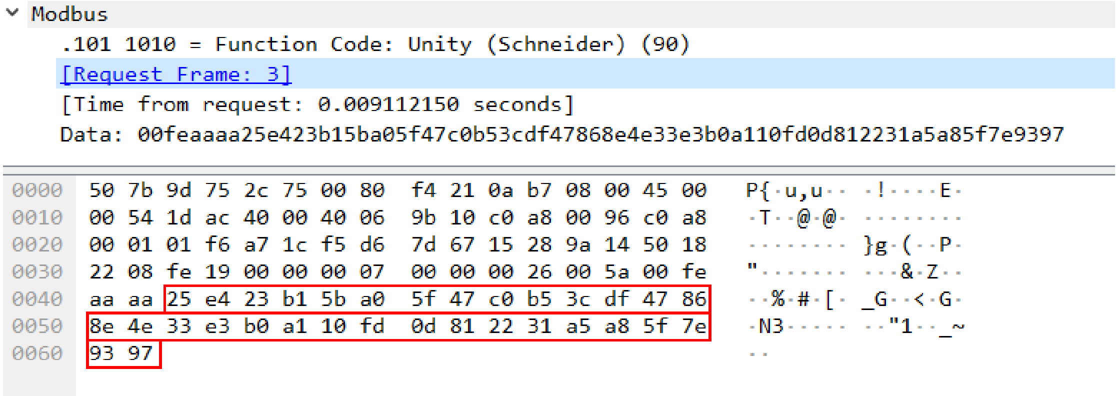
After this, EcoStruxure™ Control Expert generates a random byte sequence (a nonce) that is 32 bytes in length and sends it to the PLC.



```
˅ Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: 006e02372a0000e762eddd784b61f764cafa84afc67c5b404f6210a8ed312b8294c48996…

0000  00 80 f4 21 0a b7 50 7b  9d 75 2c 75 08 00 45 00   ···!··P{ ·u,u··E·
0010  00 59 be a5 40 00 40 06  fa 11 c0 a8 00 01 c0 a8   ·Y··@·@· ········
0020  00 96 a7 1c 01 f6 15 28  99 e3 f5 d6 7d 67 50 18   ·······( ····}gP·
0030  fa f0 82 33 00 00 00 07  00 00 00 2b 00 5a 00 6e   ···3···· ···+·Z·n
0040  02 37 2a 00 00 e7 62 ed  dd 78 4b 61 f7 64 ca fa   ·7*···b· ·xKa·d··
0050  84 af c6 7c 5b 40 4f 62  10 a8 ed 31 2b 82 94 c4   ···|[@Ob ···1+···
0060  89 96 6f d4 26 00 00                               ··o·&··
```

In response to receiving the nonce, the PLC also sends a byte sequence (a nonce response) to EcoStruxure™ Control Expert, which is also 32 bytes long.



```
˅ Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    [Request Frame: 3]
    [Time from request: 0.009112150 seconds]
    Data: 00feaaaa25e423b15ba05f47c0b53cdf47868e4e33e3b0a110fd0d812231a5a85f7e9397

0000  50 7b 9d 75 2c 75 00 80  f4 21 0a b7 08 00 45 00   P{·u,u·· ·!····E·
0010  00 54 1d ac 40 00 40 06  9b 10 c0 a8 00 96 c0 a8   ·T··@·@· ········
0020  00 01 01 f6 a7 1c f5 d6  7d 67 15 28 9a 14 50 18   ········ }g·(··P·
0030  22 08 fe 19 00 00 00 07  00 00 00 26 00 5a 00 fe   "······· ···&·Z··
0040  aa aa 25 e4 23 b1 5b a0  5f 47 c0 b5 3c df 47 86   ··%·#·[· _G··<·G·
0050  8e 4e 33 e3 b0 a1 10 fd  0d 81 22 31 a5 a8 5f 7e   ·N3····· ··"1··_~
0060  93 97                                              ··
```

Importantly, the nonce response computed on the PLC side depends only on the byte sequence received from EcoStruxure™ Control Expert (the nonce) and no additional random element is used to generate the response. In other words, the same response is always sent to the same nonce.

In the next step, EcoStruxure™ Control Expert uses the same nonce and response to compute the SHA 256 hash, which is required to reserve the PLC.

The hash is computed as follows:

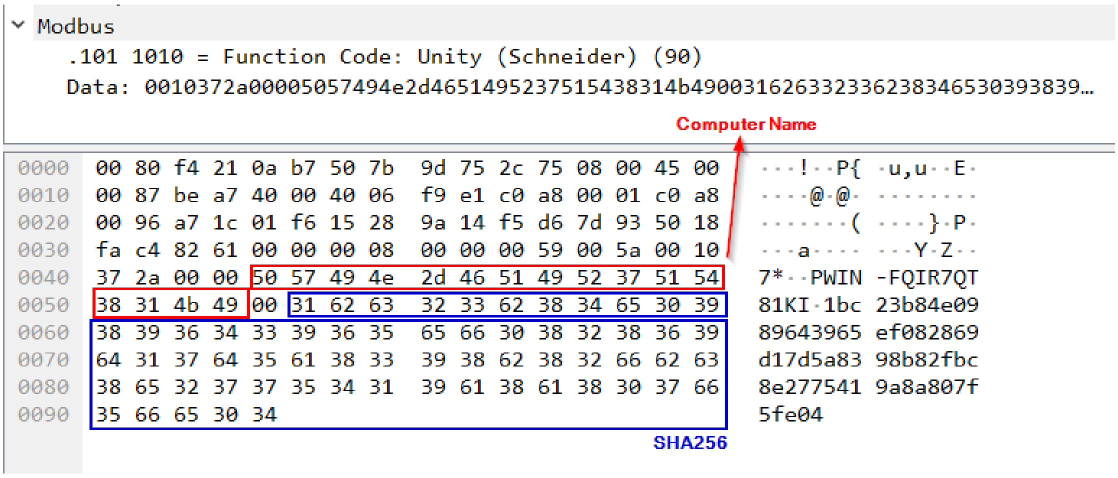
```
SHA256 (PLC nonce response + base64 strings (password hash) from PLC'
s memory block + EcoStruxure Control Expert nonce)
```

Using the data from the above examples, the hash computation looks as follows:

```
SHA256("\x25\xe4\x23\xb1\x5b\xa0\x5f\x47\xc0\xb5\x3c\xdf\x47\x86\x8e\
x4e\x33\xe3\xb0\xa1\x10\xfd\x0d\x81\x22\x31\xa5\xa8\x5f\x7e\x93\x97"
+ "\x43\x47\x49\x33\x55\x53\x4f\x39\x49\x00\x43\x30\x69\x6e\x30\x6a\x
38\x41\x4c\x78\x55\x3d\x0d\x0a\x31\x4f\x6d\x5a\x42\x33\x31\x77\x57\x5
7\x6c\x6c\x67\x47\x45\x4b\x2f\x75\x36\x45\x43\x7a\x66\x6f\x39\x48\x55
\x76\x59\x69\x4e\x44\x6c\x6a\x2b\x73\x59\x77\x77\x71\x74\x47\x38\x3d"
+ "\xe7\x62\xed\xdd\x78\x4b\x61\xf7\x64\xca\xfa\x84\xaf\xc6\x7c\x5b\x
40\x4f\x62\x10\xa8\xed\x31\x2b\x82\x94\xc4\x89\x96\x6f\xd4\x26") = 1b
c23b84e0989643965ef082869d17d5a8398b82fbc8e2775419a8a807f5fe04
```

Ultimately, PLC reservation is performed using the ASCII representation of the computer's name and the SHA256 hash computed earlier.

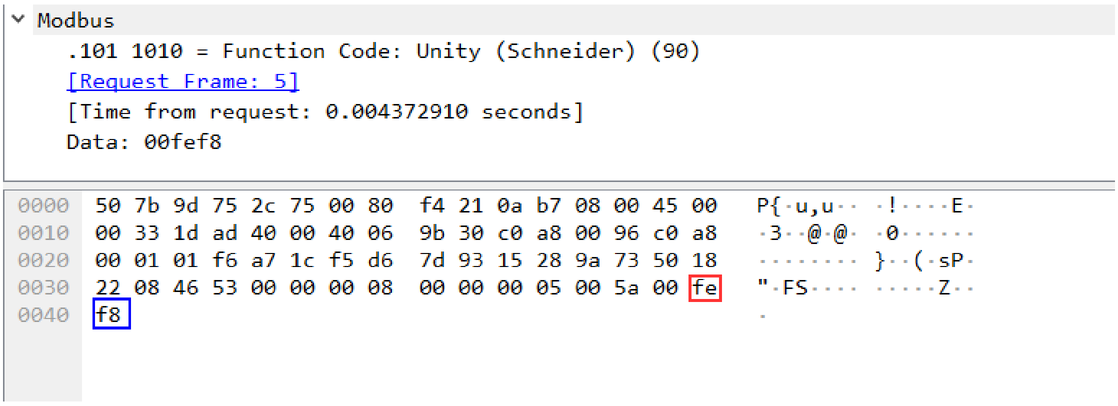
```
PWIN-FQIR7QT81KI + '\x00' + 1bc23b84e0989643965ef082869d17d5a8398b82f
bc8e2775419a8a807f5fe04
```



```
Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: 0010372a00005057494e2d4651495237515438314b49003162633233623834653039383…

0000  00 80 f4 21 0a b7 50 7b  9d 75 2c 75 08 00 45 00   ···!··P{ ·u,u··E·
0010  00 87 be a7 40 00 40 06  f9 e1 c0 a8 00 01 c0 a8   ····@·@· ········
0020  00 96 a7 1c 01 f6 15 28  9a 14 f5 d6 7d 93 50 18   ·······( ····}·P·
0030  fa c4 82 61 00 00 00 08  00 00 00 59 00 5a 00 10   ···a···· ···Y·Z··
0040  37 2a 00 00 50 57 49 4e  2d 46 51 49 52 37 51 54   7*··PWIN -FQIR7QT
0050  38 31 4b 49 00 31 62 63  32 33 62 38 34 65 30 39   81KI·1bc 23b84e09
0060  38 39 36 34 33 39 36 35  65 66 30 38 32 38 36 39   89643965 ef082869
0070  64 31 37 64 35 61 38 33  39 38 62 38 32 66 62 63   d17d5a83 98b82fbc
0080  38 65 32 37 37 35 34 31  39 61 38 61 38 30 37 66   8e277541 9a8a807f
0090  35 66 65 30 34                                     5fe04
```

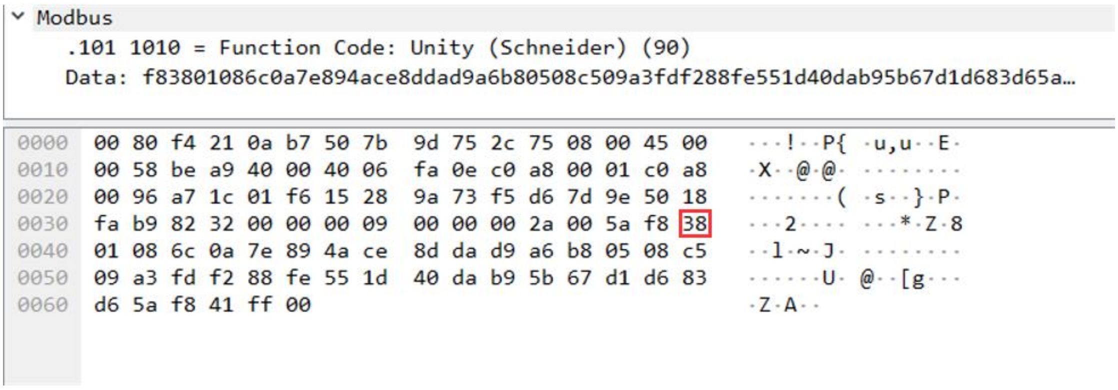
If the request is successfully fulfilled, the PLC will return session ID (`0xf8` on the screenshot below) to EcoStruxure™ Control Expert.



```
Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    [Request Frame: 5]
    [Time from request: 0.004372910 seconds]
    Data: 00fef8

0000  50 7b 9d 75 2c 75 00 80  f4 21 0a b7 08 00 45 00   P{·u,u·· ·!····E·
0010  00 33 1d ad 40 00 40 06  9b 30 c0 a8 00 96 c0 a8   ·3··@·@· ·0······
0020  00 01 01 f6 a7 1c f5 d6  7d 93 15 28 9a 73 50 18   ········ }··(·sP·
0030  22 08 46 53 00 00 00 08  00 00 00 05 00 5a 00 fe   "·FS···· ·····Z··
0040  f8                                                 ·
```

This session ID will subsequently be used to send Security function (`0x38`) protected commands to the PLC.



```
Modbus
    .101 1010 = Function Code: Unity (Schneider) (90)
    Data: f83801086c0a7e894ace8ddad9a6b80508c509a3fdf288fe551d40dab95b67d1d683d65a…

0000  00 80 f4 21 0a b7 50 7b  9d 75 2c 75 08 00 45 00   ···!··P{ ·u,u··E·
0010  00 58 be a9 40 00 40 06  fa 0e c0 a8 00 01 c0 a8   ·X··@·@· ········
0020  00 96 a7 1c 01 f6 15 28  9a 73 f5 d6 7d 9e 50 18   ·······( ·s··}·P·
0030  fa b9 82 32 00 00 00 09  00 00 00 2a 00 5a f8 38   ···2···· ···*·Z·8
0040  01 08 6c 0a 7e 89 4a ce  8d da d9 a6 b8 05 08 c5   ··l·~·J· ········
0050  09 a3 fd f2 88 fe 55 1d  40 da b9 5b 67 d1 d6 83   ······U· @··[g···
0060  d6 5a f8 41 ff 00                                  ·Z·A··
```

It can be seen from the above analysis of the PLC reservation process using the new and improved mechanism that the new method is by no means secure since all computation is performed on the client side (i.e., by EcoStruxure™ Control Expert), while the “secret” can be obtained from the PLC without authentication.

The fact that the PLC always sends the same response to the same nonce received from the client is an additional shortcoming of the mechanism, which enables an attacker to carry out a Replay attack using network traffic between a legitimate client (the operator) and the server (the PLC) captured earlier in the process of PLC reservation.

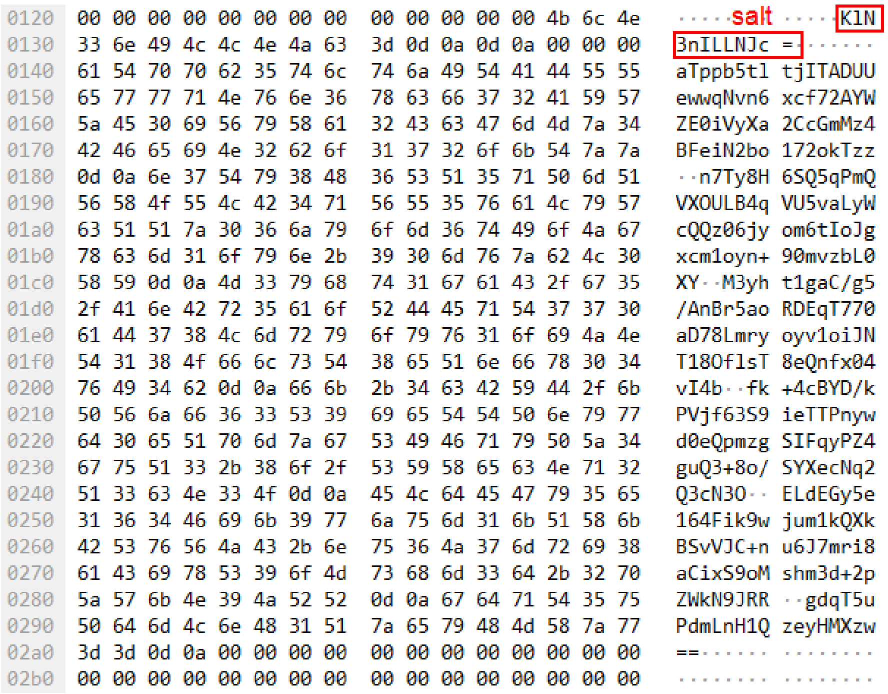
Updated reservation procedure with Application Password

At the time of publication, Schneider Electric had released updates for EcoStruxure™ Control Expert software (version 15.1), Modicon M340 PLC firmware (version 3.50), and Modicon M580 PLC firmware (version 4.02).

These updates fix the vulnerability described in the Authentication bypass with Application Password section.

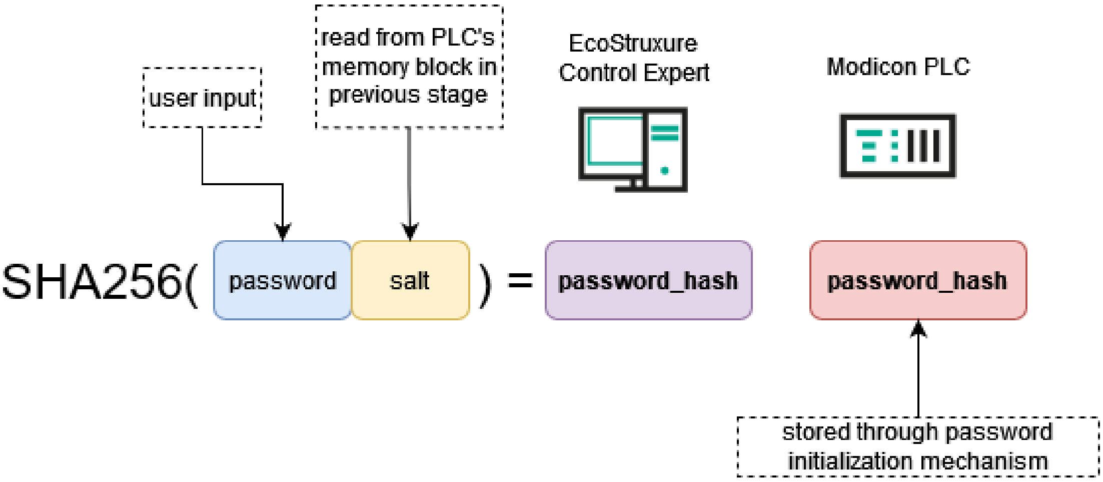
This section describes the updated reservation procedure used after the vendor had fixed the vulnerability.

During the PLC reservation procedure, a total of 0x534 bytes are read from memory block 0x14 in two requests, using UMAS function **pu_ReadMemoryBlock(0x20)**, which does not require authentication. In the earlier version of the reservation mechanism, that memory segment contained the password hash, but in the new version it contains a salt and a ciphertext.

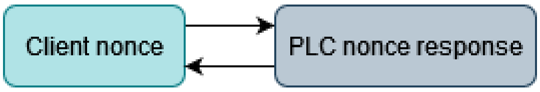


```
0120  00 00 00 00 00 00 00 00  00 00 00 00 00 4b 6c 4e   ········ ·····KlN
0130  33 6e 49 4c 4c 4e 4a 63  3d 0d 0a 0d 0a 00 00 00   3nILLNJc =······
0140  61 54 70 70 62 35 74 6c  74 6a 49 54 41 44 55 55   aTppb5tl tjITADUU
0150  65 77 77 71 4e 76 6e 36  78 63 66 37 32 41 59 57   ewwqNvn6 xcf72AYW
0160  5a 45 30 69 56 79 58 61  32 43 63 47 6d 4d 7a 34   ZE0iVyXa 2CcGmMz4
0170  42 46 65 69 4e 32 62 6f  31 37 32 6f 6b 54 7a 7a   BFeiN2bo 172okTzz
0180  0d 0a 6e 37 54 79 38 48  36 53 51 35 71 50 6d 51   ··n7Ty8H 6SQ5qPmQ
0190  56 58 4f 55 4c 42 34 71  56 55 35 76 61 4c 79 57   VXOULB4q VU5vaLyW
01a0  63 51 51 7a 30 36 6a 79  6f 6d 36 74 49 6f 4a 67   cQQz06jy om6tIoJg
01b0  78 63 6d 31 6f 79 6e 2b  39 30 6d 76 7a 62 4c 30   xcm1oyn+ 90mvzbL0
01c0  58 59 0d 0a 4d 33 79 68  74 31 67 61 43 2f 67 35   XY··M3yh t1gaC/g5
01d0  2f 41 6e 42 72 35 61 6f  52 44 45 71 54 37 37 30   /AnBr5ao RDEqT770
01e0  61 44 37 38 4c 6d 72 79  6f 79 76 31 6f 69 4a 4e   aD78Lmry oyv1oiJN
01f0  54 31 38 4f 66 6c 73 54  38 65 51 6e 66 78 30 34   T18OflsT 8eQnfx04
0200  76 49 34 62 0d 0a 66 6b  2b 34 63 42 59 44 2f 6b   vI4b··fk +4cBYD/k
0210  50 56 6a 66 36 33 53 39  69 65 54 54 50 6e 79 77   PVjf63S9 ieTTPnyw
0220  64 30 65 51 70 6d 7a 67  53 49 46 71 79 50 5a 34   d0eQpmzg SIFqyPZ4
0230  67 75 51 33 2b 38 6f 2f  53 59 58 65 63 4e 71 32   guQ3+8o/ SYXecNq2
0240  51 33 63 4e 33 4f 0d 0a  45 4c 64 45 47 79 35 65   Q3cN3O·· ELdEGy5e
0250  31 36 34 46 69 6b 39 77  6a 75 6d 31 6b 51 58 6b   164Fik9w jum1kQXk
0260  42 53 76 56 4a 43 2b 6e  75 36 4a 37 6d 72 69 38   BSvVJC+n u6J7mri8
0270  61 43 69 78 53 39 6f 4d  73 68 6d 33 64 2b 32 70   aCixS9oM shm3d+2p
0280  5a 57 6b 4e 39 4a 52 52  0d 0a 67 64 71 54 35 75   ZWkN9JRR ··gdqT5u
0290  50 64 6d 4c 6e 48 31 51  7a 65 79 48 4d 58 7a 77   PdmLnH1Q zeyHMXzw
02a0  3d 3d 0d 0a 00 00 00 00  00 00 00 00 00 00 00 00   ==······ ········
02b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ········ ········
```

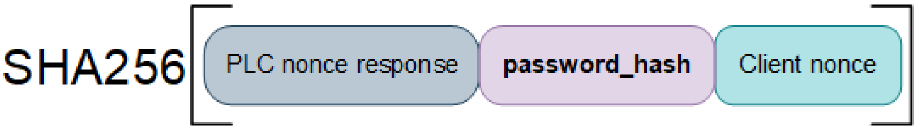
When the client (EcoStruxure™ Control Expert) has obtained the salt value for hashing, it can start the PLC reservation procedure. The client computes the SHA256 hash of the password entered by the user with the salt obtained at the previous step to compute the password hash.


user input
read from PLC's memory block in previous stage
EcoStruxure Control Expert
Modicon PLC
SHA256(
password
salt
) =
password_hash
password_hash
stored through password initialization mechanism

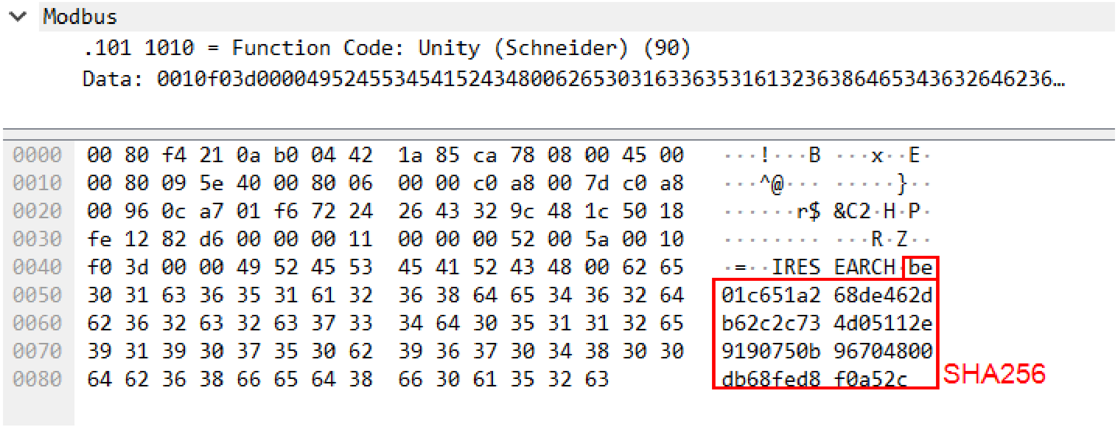
The next step is the nonce exchange between the client and the PLC.



In the final step, the client computes the SHA256 hash that is to be used to reserve the device. The hash is computed from the PLC nonce, the password hash and the client nonce.



The screenshot below shows a request from the client (EcoStruxure™ Control Expert) to the PLC to reserve the device using the SHA256 hash computed in the final step.



```
∨ Modbus
      .101 1010 = Function Code: Unity (Schneider) (90)
      Data: 0010f03d0000495245534541524348006265303163363531613236386465343632646236…

0000  00 80 f4 21 0a b0 04 42  1a 85 ca 78 08 00 45 00   ···!···B ···x··E·
0010  00 80 09 5e 40 00 80 06  00 00 c0 a8 00 7d c0 a8   ···^@··· ·····}··
0020  00 96 0c a7 01 f6 72 24  26 43 32 9c 48 1c 50 18   ······r$ &C2·H·P·
0030  fe 12 82 d6 00 00 00 11  00 00 00 52 00 5a 00 10   ········ ···R·Z··
0040  f0 3d 00 00 49 52 45 53  45 41 52 43 48 00 62 65   ·=··IRES EARCH·be
0050  30 31 63 36 35 31 61 32  36 38 64 65 34 36 32 64   01c651a2 68de462d
0060  62 36 32 63 32 63 37 33  34 64 30 35 31 31 32 65   b62c2c73 4d05112e
0070  39 31 39 30 37 35 30 62  39 36 37 30 34 38 30 30   9190750b 96704800
0080  64 62 36 38 66 65 64 38  66 30 61 35 32 63         db68fed8 f0a52c
```

SHA256

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In the earlier version of the reservation mechanism, the main problem was that the "secret" used to reserve the device was computed entirely on the client side (i.e., by EcoStruxure™ Control Expert). In the corrected implementation of the mechanism, memory block 0x14 of the PLC does not contain the password hash used to compute the "secret", i.e., the final SHA256 hash.

Conclusion

Our analysis shows that the implementation of the UMAS protocol in Modicon M340 firmware versions prior to 3.50 had significant shortcomings that critically affected the security of automation systems based on Schneider Electric solutions.

According to shodan.io data, the number of Modicon M340/M580 devices available online is greater than 1000. This is obviously just the tip of the iceberg.

Vendor recommendations

The vendor recommends following the remediation provided for EcoStruxure™ Control Expert in the SEVD-2021-194-01 security advisory and using the Application Password mechanism to ensure complete remediation of this issue.

Kaspersky ICS CERT recommendations

In addition to the recommendations provided by the vendor, Kaspersky ICS CERT strongly recommends monitoring critical UMAS functions at traffic level, for example, using IDS or dedicated solutions for monitoring industrial network traffic, identifying and analyzing network anomalies. It is obvious that such functions as device reservation, stopping the device or downloading/uploading strategies are critically important and can be abused by an attacker to disrupt the industrial process.

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