WAVESTONE

DYODE: Do Your Own DiodE

A DIY, low-cost data diode for ICS

BruCon, October 2017

Arnaud Soullié

Who are we?

Arnaud

@arnaudsoullie

- Pentest & research
- Interests
  - Windows Active Directory
  - ICS security
  - Wine tasting / Motorbike riding (we're not going to talk about it today)
- Talks & workshops
  - BlackHat Europe 2014
  - Hack In Paris 2015
  - BruCon 0x07
  - BSides Las Vegas 2015 / 2016
  - DEFCON 24 / 25 (ICS VILLAGE)

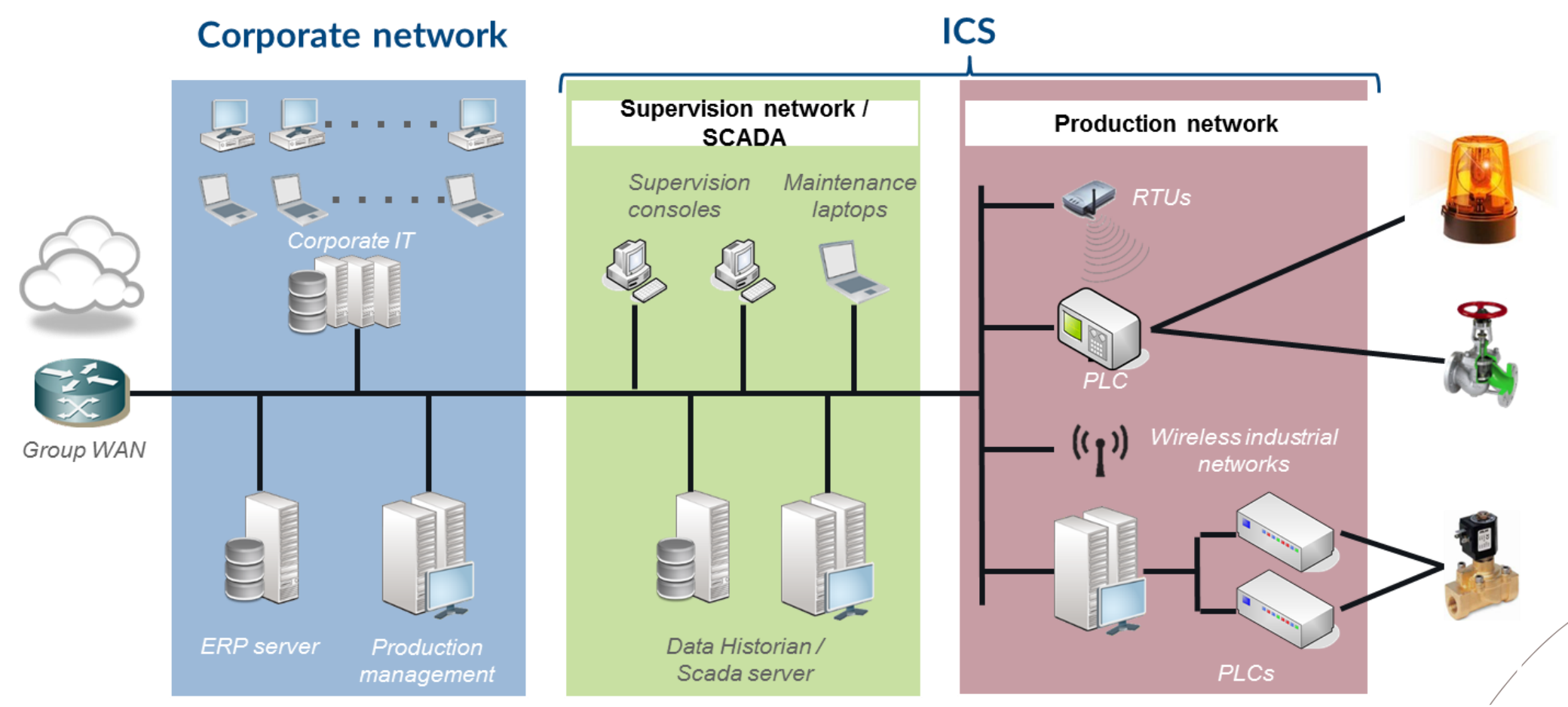
Manager @ WAVESTONE

Ary

- Advisory & audit (used to do pentests)
- Interests
  - Windows Security
  - Cryptophony
- Talks: IEEE ICC 2009, JSSI 2013 and 2014, SSTIC 2016, Bsides Las Vegas 2016
- Book Information Security, Eyrolles Edition [in French] – written with several authors including Arnaud

Tax exile @ $Big4 in Switzerland ;)

ICS 101


Corporate network
ICS
Supervision network / SCADA
Production network
Corporate IT
Supervision consoles
Maintenance laptops
RTUs
PLC
Wireless industrial networks
Group WAN
ERP server
Production management
Data Historian / Scada server
PLCs

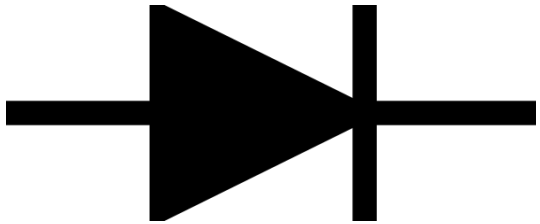
DATA DIODES 101

/ AKA “one-way gateway”

/ Use of light as the transport medium

/ PN junction prevents electrons from going backwards

➔ Security property is backed by physics. *Hack that*.



COMMERCIAL DATA DIODES

WHY THIS PROJECT ?

/ Feedback from lots of ICS security assignments

➔ *There are lots of needs for exchanging information between CORP and ICS*

/ Commercial data diodes exist, but are quite expensive

➔ *Security / cost trade-off , not easy to sell*

/ Examples

Predictive maintenance : send a 100kb file every 6 hours to a 3rd party

Cooling units : 3rd party needs to access a PLCs output in real-time for efficiency improvement

➔ *Data only needs to be exchanged one-way, but in these examples the high cost of a commercial Data Diode combined with business needs to exchange information, resulted in uncontrolled network connection between two networks*

DYODE PROJECT

- Based on existing work : Lagadec, Austin Scott, Robert Gabriel
- Low cost & DIY

  Use of standard hardware (COTS) and open-source software

  Target cost of 200$ per unit
- Objectives

  Proof of Concept

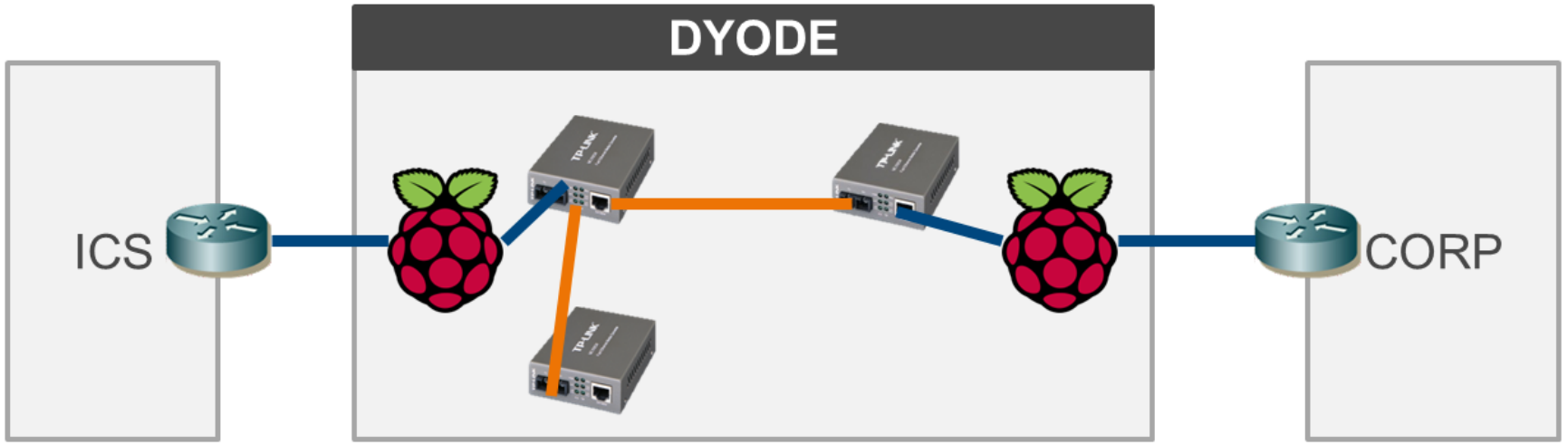
  Transparent, easy to deploy solution

  Share the results

DYODE project has no commercial intent, but an implementation by a vendor is authorized

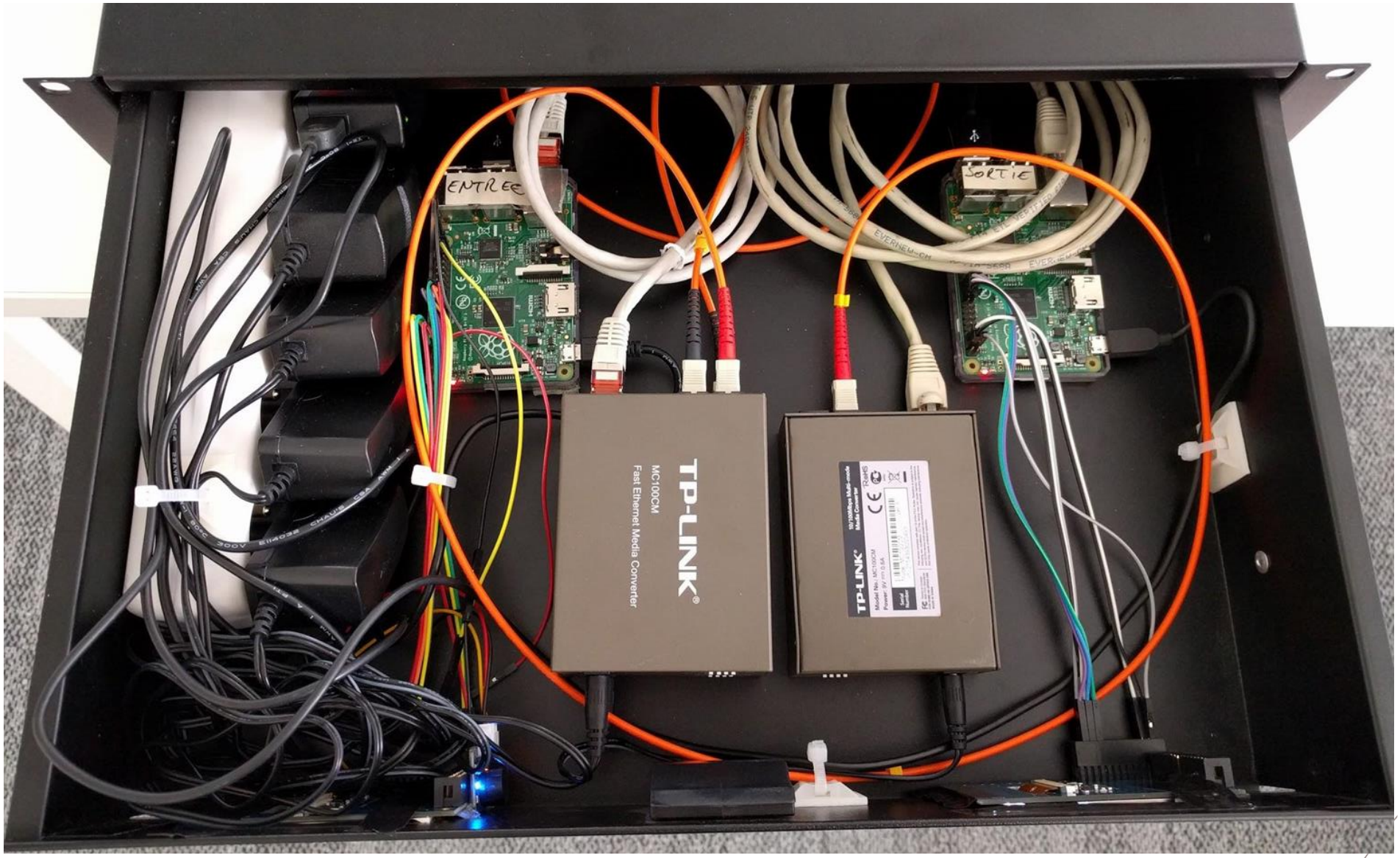
HARDWARE

- Use of copper-optical converters
- Use of a 3rd converter to fake a signal on the second (link failure protection)
- Raspberry Pis used for the "in" and "out" counters



HARDWARE

HARDWARE


ENTREE
SORTIE
TP-LINK
MC100CM
Fast Ethernet Media Converter
TP-LINK

SOFTWARE

Improve

Develop

Prototype

Latency improvement

Replace *udpcast* by a custom, naïve Python UDP socket implementation

Develop features

Development of data diode features on top of *udpcast* using Python

- File transfer
- Modbus
- Screen sharing

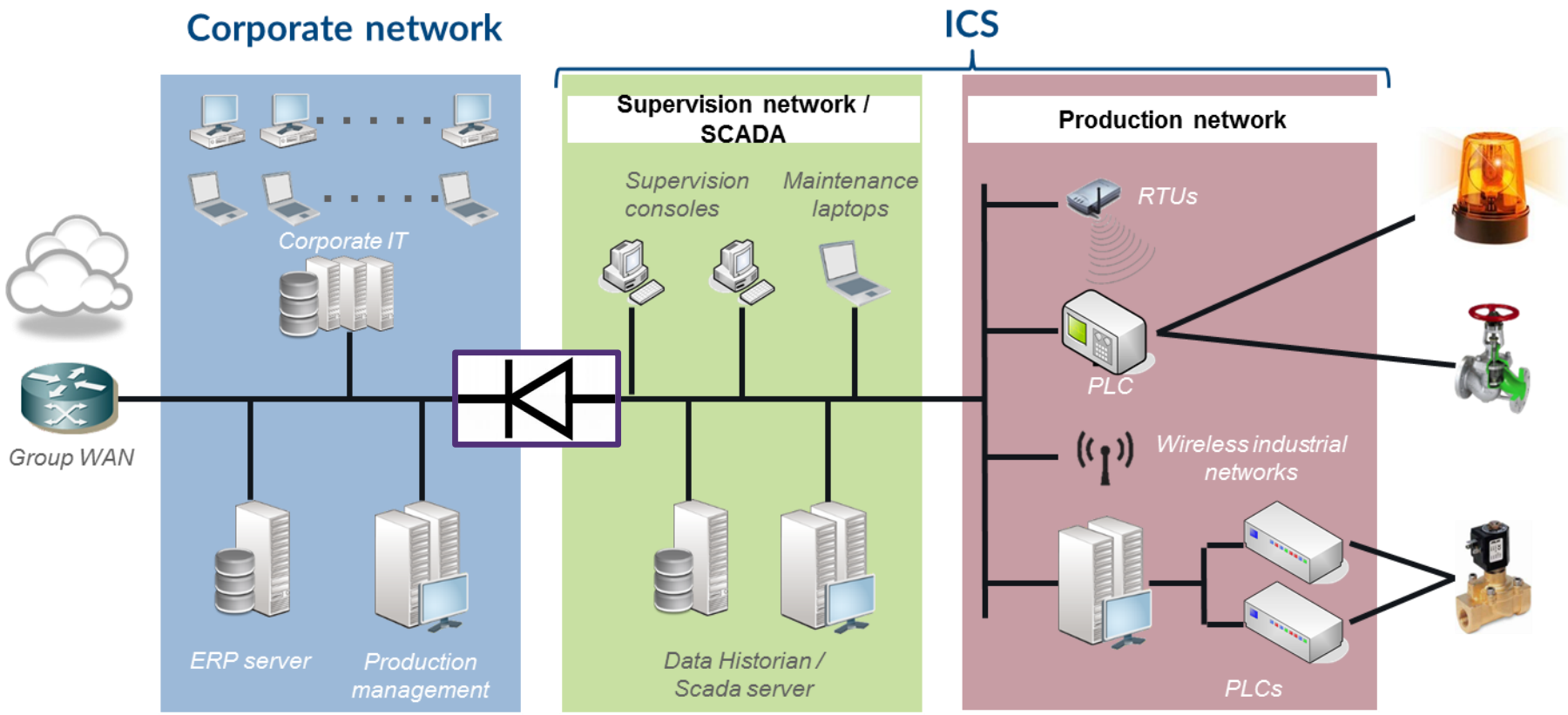
Quickly prototype

Use of *udpcast*, an open-source software that allows unidirectional file transfer

DEMO

[VIDEO] DEMO TIME!

DEMO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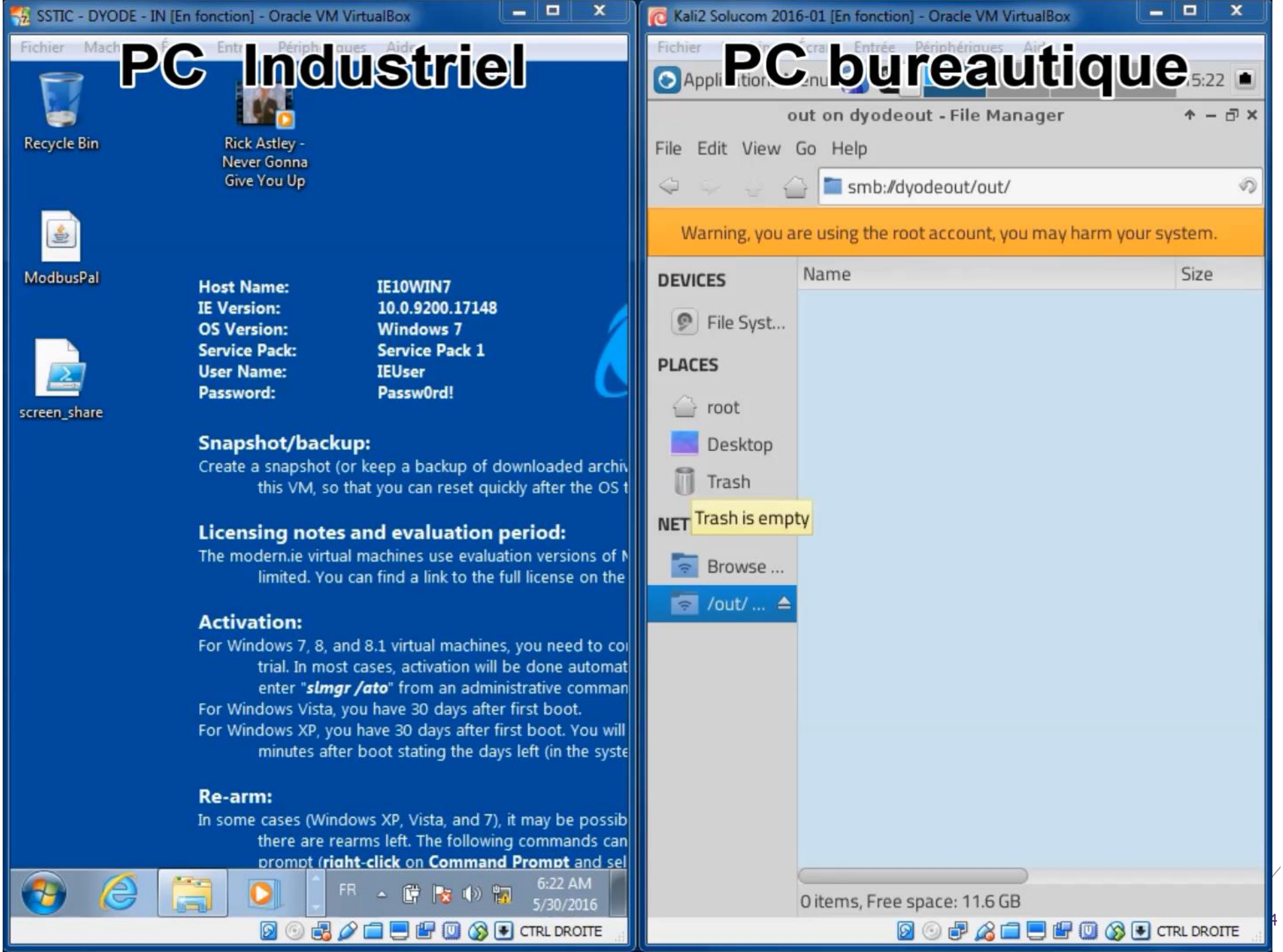
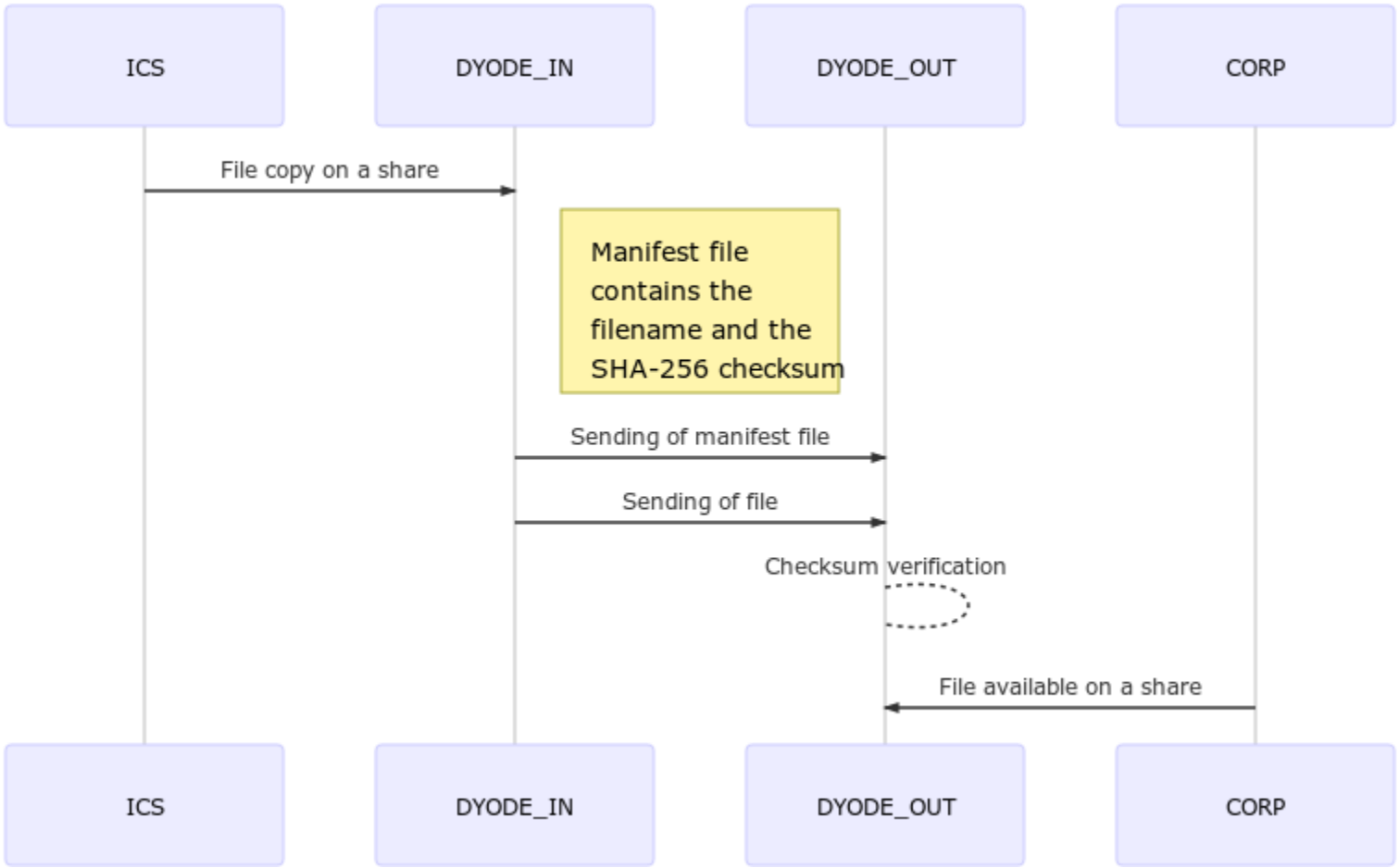
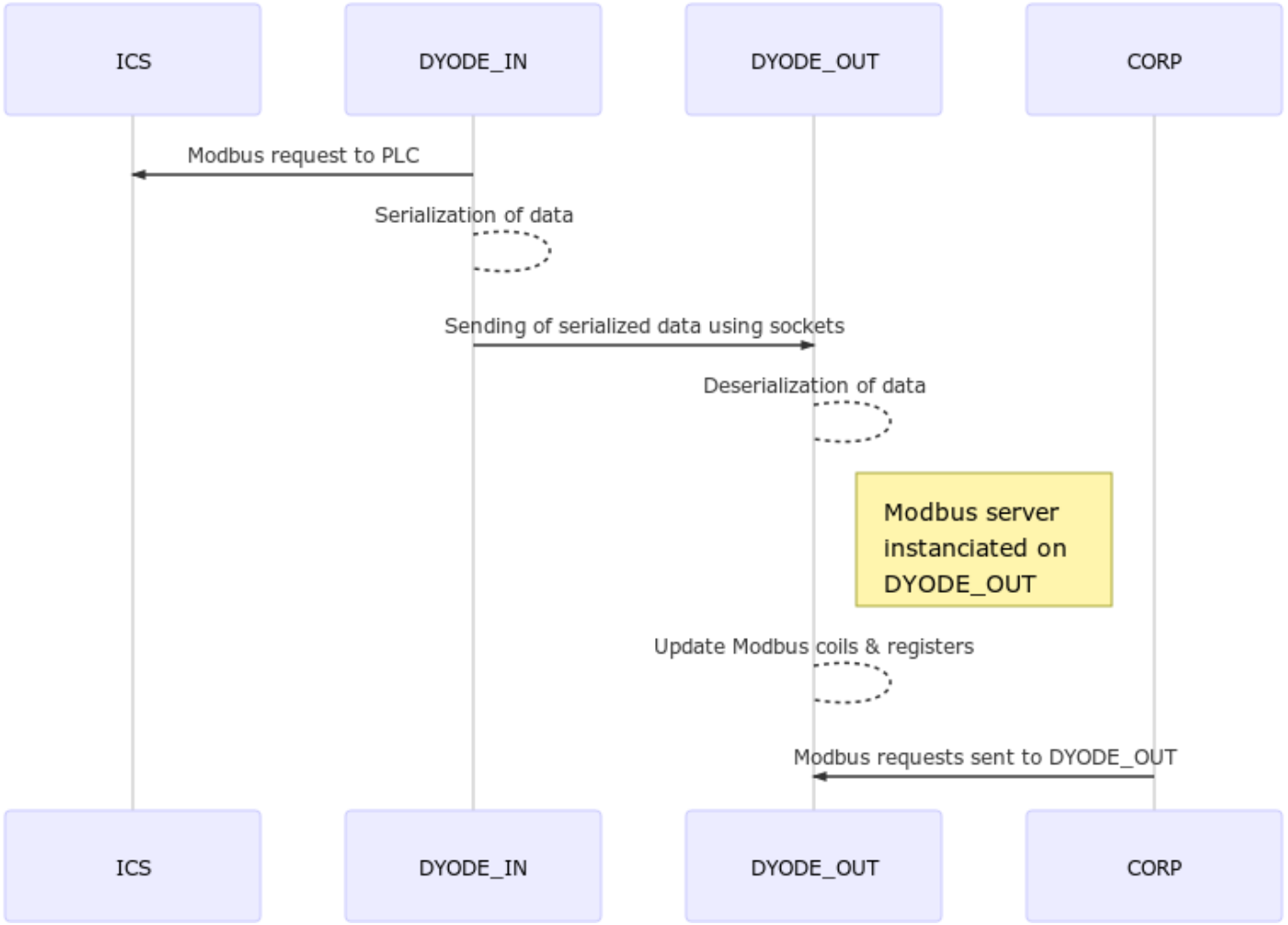

SSTIC - DYODE - IN [En fonction] - Oracle VM VirtualBox
PC Industriel
Recycle Bin
Rick Astley - Never Gonna Give You Up
ModbusPal
screen_share
Host Name: IE10WIN7
IE Version: 10.0.9200.17148
OS Version: Windows 7
Service Pack: Service Pack 1
User Name: IEUser
Password: Passw0rd!
Snapshot/backup:
Create a snapshot (or keep a backup of downloaded archiv
this VM, so that you can reset quickly after the OS t
Licensing notes and evaluation period:
The modern.ie virtual machines use evaluation versions of M
limited. You can find a link to the full license on the
Activation:
For Windows 7, 8, and 8.1 virtual machines, you need to co
trial. In most cases, activation will be done automat
enter "slmgr /ato" from an administrative comman
For Windows Vista, you have 30 days after first boot.
For Windows XP, you have 30 days after first boot. You will
minutes after boot stating the days left (in the syste
Re-arm:
In some cases (Windows XP, Vista, and 7), it may be possib
there are rearms left. The following commands can
prompt (right-click on Command Prompt and sel
FR
6:22 AM
5/30/2016
CTRL DROITE
Kali2 Solucom 2016-01 [En fonction] - Oracle VM VirtualBox
PC bureautique
out on dyodeout - File Manager
File Edit View Go Help
smb://dyodeout/out/
Warning, you are using the root account, you may harm your system.
DEVICES
File Syst...
PLACES
root
Desktop
Trash
Trash is empty
NET
Browse ...
/out/ ...
Name
Size
0 items, Free space: 11.6 GB
CTRL DROITE

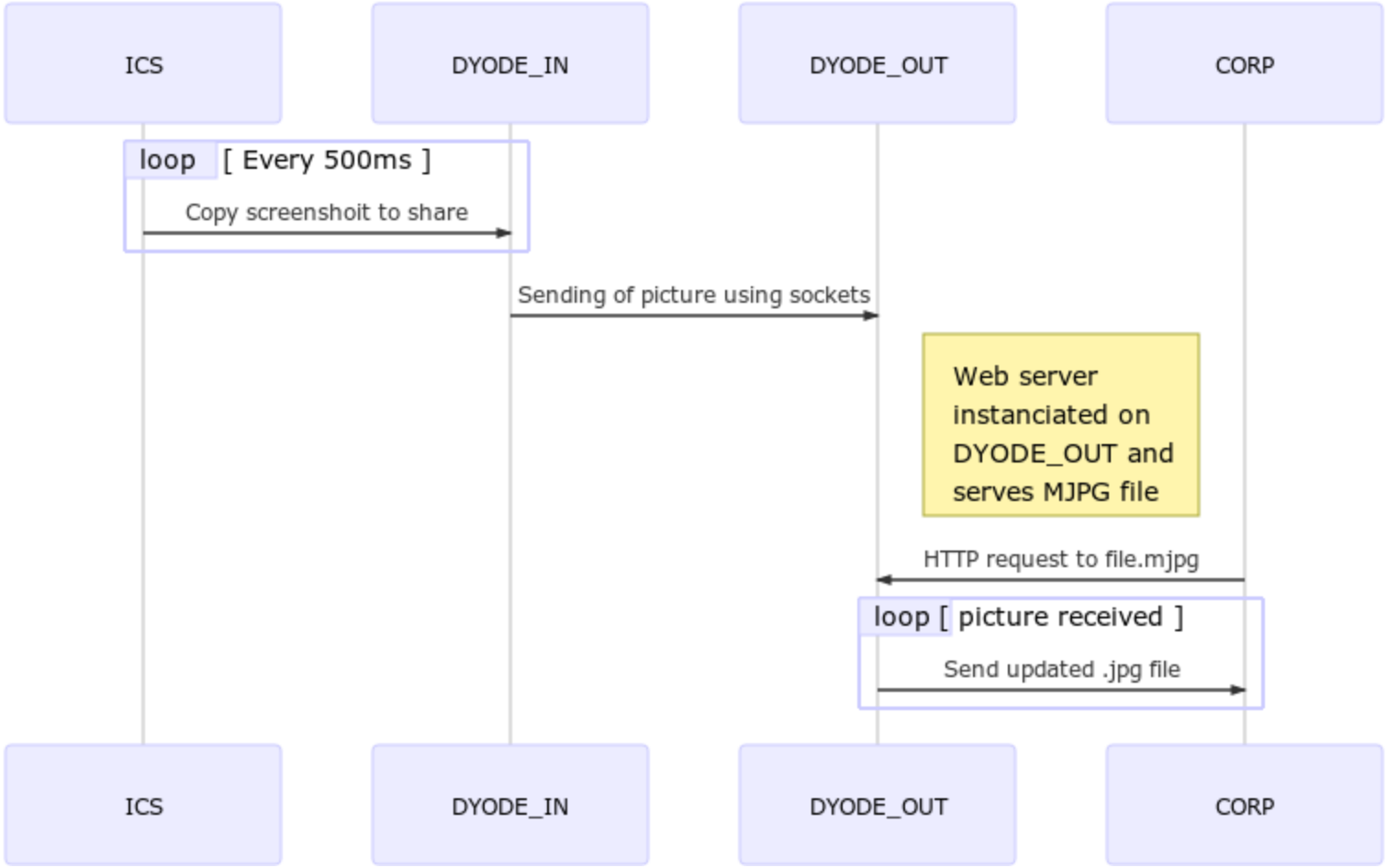
FILE TRANSFER WORKFLOW



MODBUS TRANSFER WORKFLOW



SCREEN SHARING WORKFLOW



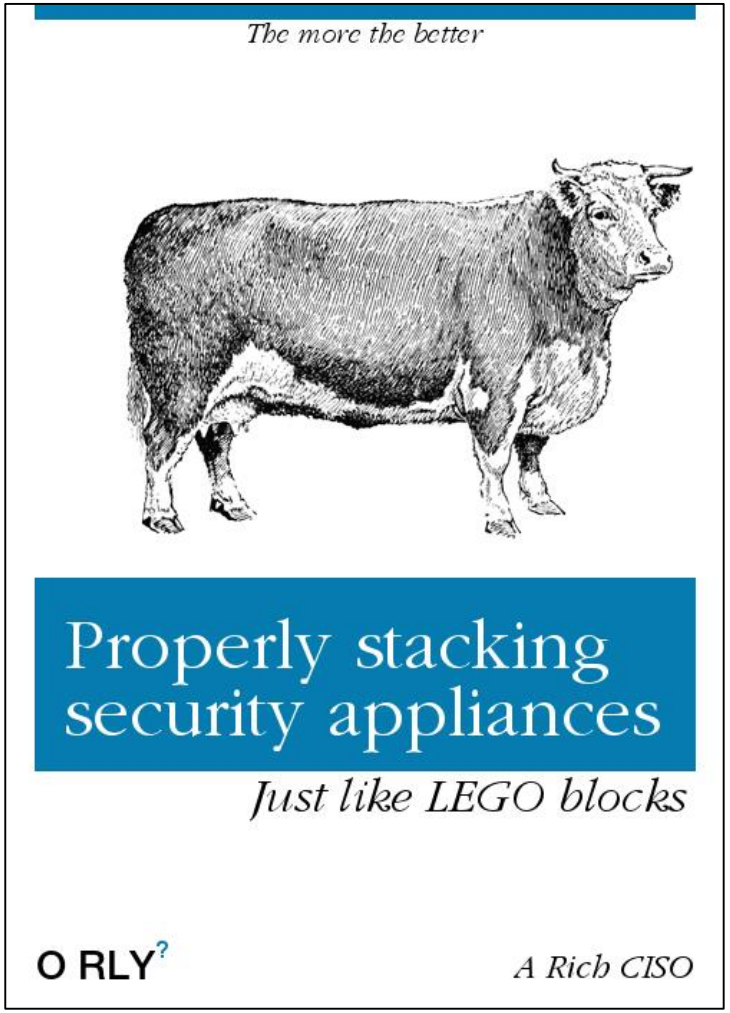
CONFIGURATION FILE

```
config_name: "Dyode test"
config_version : 1.0
config_date: 2016-05-04

dyode_in:
  ip: 10.0.1.1
  mac: b8:27:eb:89:1e:f3
dyode_out:
  ip: 10.0.1.2
  mac: b8:27:eb:b1:ff:ab

modules:
  "File share 1":
     type: folder
     port: 9600
     in: /home/pi/in
     out: /home/pi/out
```

```
  "Modbus PLC":
     type: Modbus
     port: 9400
     ip: 192.168.1.150
     port_out: 502
     registers:
       - 0-100
       - 400-450
     coils:
       - 0-10
       - 100-110
    "Screen_share_1":
     type: screen
     port: 9900
     in: /home/pi/screenz
     out: /home/pi/screenz
```

REAL COST

Component	Quantity	Cost
Raspberry Pi + power supply	2	92€
Copper-Optical converter	3	117€
Optical cable	2	15€
USB-Ethernet adapter	4	16€
Rack 19” 2U	1	59€
Screens	2	70€
Buzzer	1	5€
GRAND TOTAL		**374€**

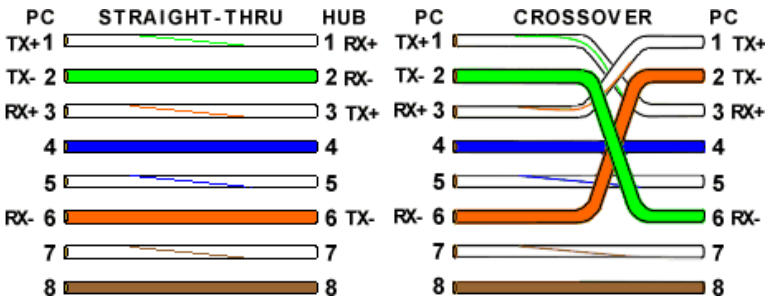



WE NEED TO GO
CHEAPER !
imgflip.com

WHY NOT JUST CUT THE CABLE?

Cutting the cable?

- Yes, it is possible to have a one-way gateway by using half-duplex mode on network interfaces and cutting the 2 RX of the Ethernet cable
- Seems simpler than the DYODE implementation



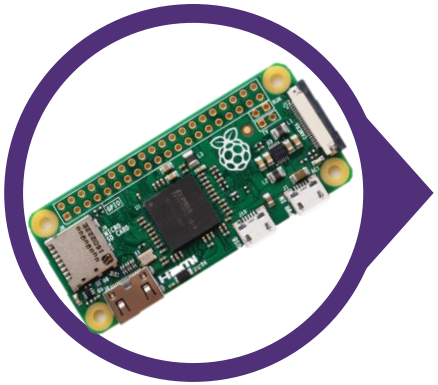
However

- You'll still need the "in" and "out" counters (Raspi) to use a one-way connection for TCP protocols
- In theory, advanced attacks may allow to send information the other way around, for example by switching ports "up" and "down"

IMPROVEMENTS > Reducing the cost

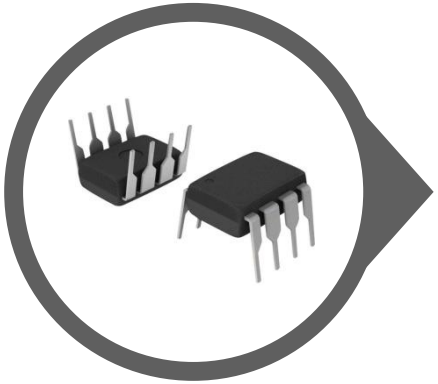
Most expensive components : in/out counters & optical converters

➔ *Let's change that !*



Replace classical RSPi by RSPi 0 (5$)

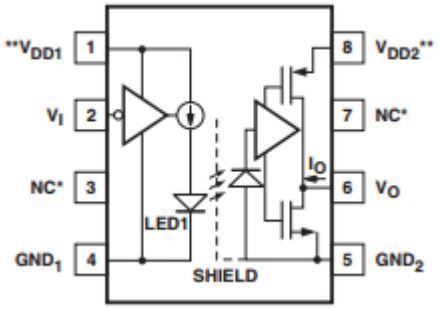
(When you can find one…)



Replace the Ethernet-FO converters by a serial connection with an optocoupler also called photocoupler

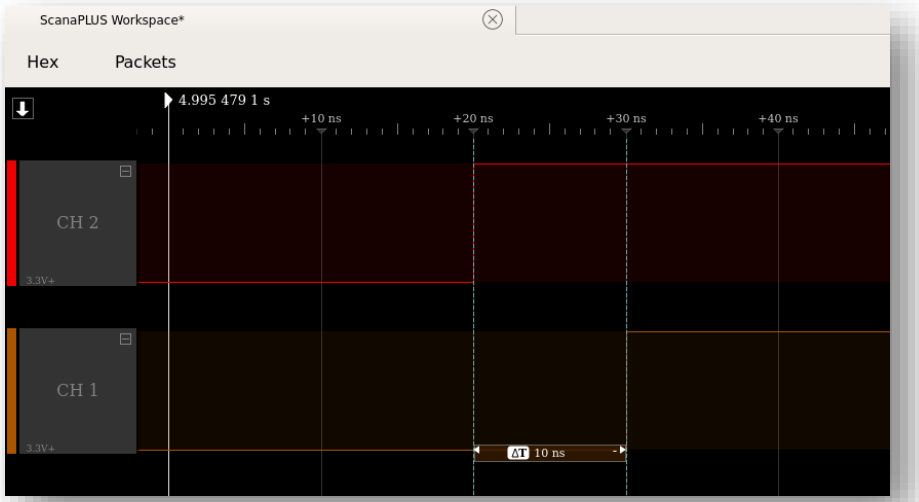
- Diode opto-isolator = LED + photodiode
- Very low cost solution (2€)
- Acceptable bandwidth for some usages (20ko/s)
- For very sensitive environments, do your own

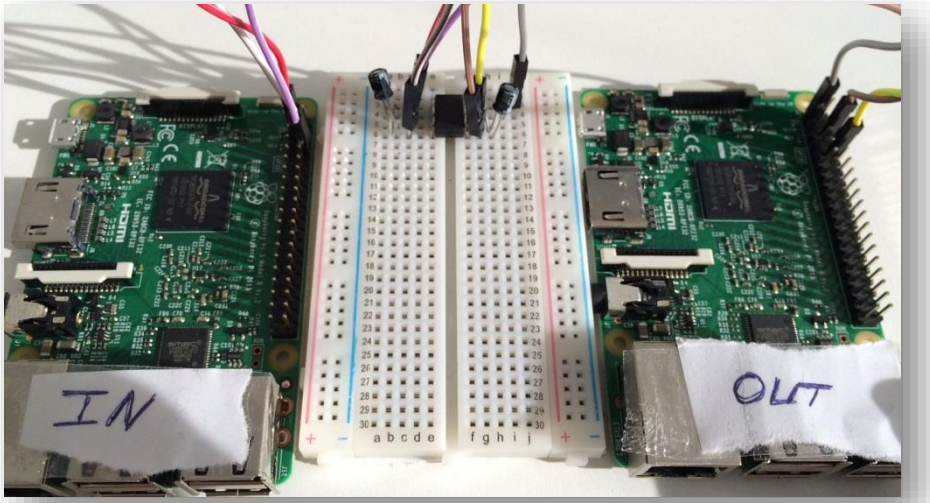
(it is harder to backdoor a LED than a black box circuit in epoxy)



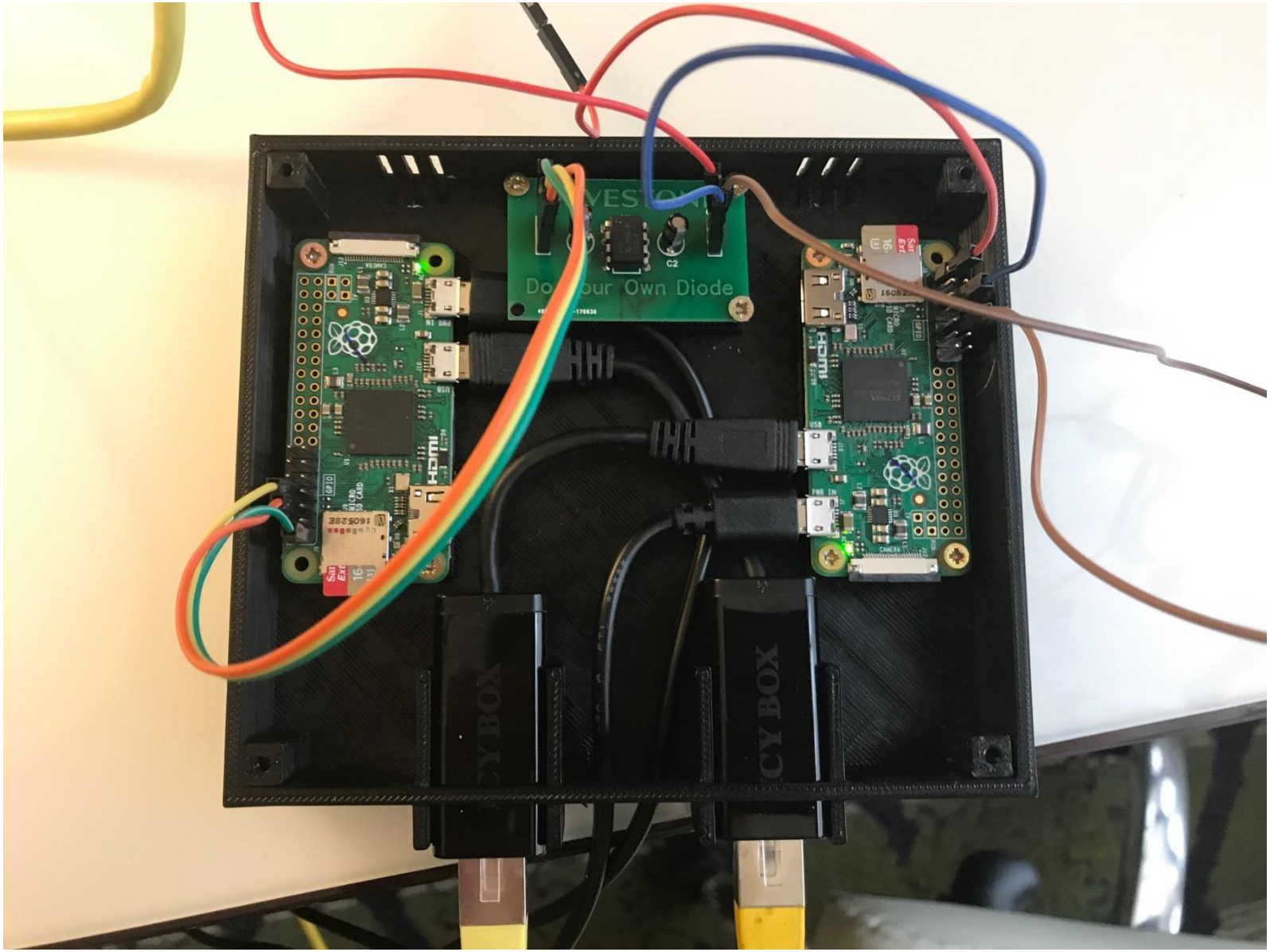
DYODE Ultra-low cost version

Component	Quantity	Cost
Raspberry Pi 0 + power supply + SD Card	2	32€
Optocoupler+capacitor+misc.	1	5€
MicroUSB-Ethernet adapter	2	30€
DIN Rail compatible box	1	12€
GRAND TOTAL		**80€**

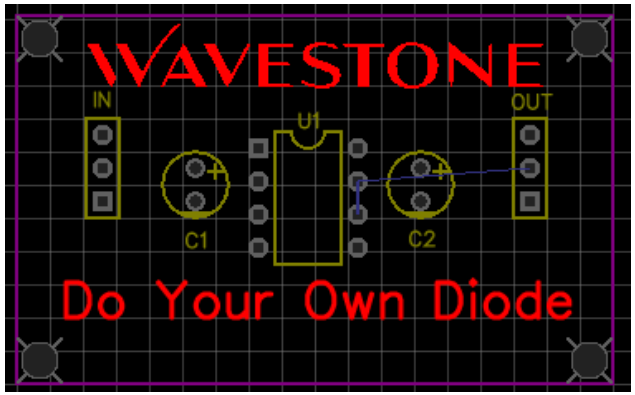




DYODE v2 final prototype

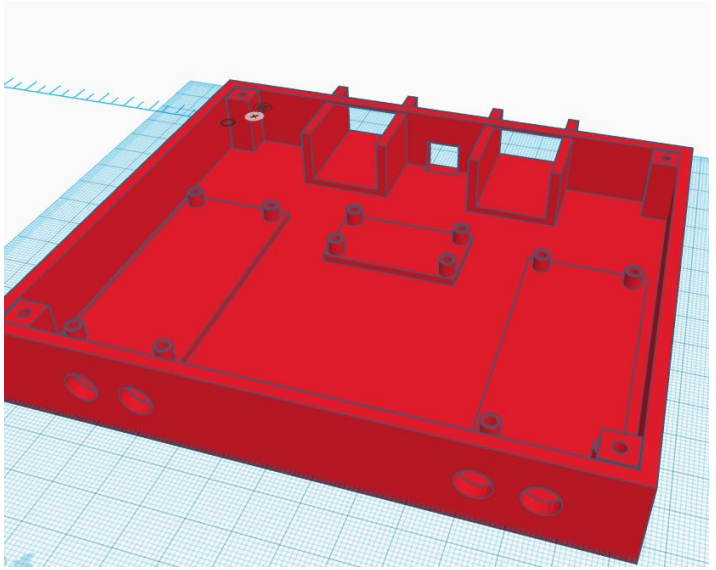


Hardware is open source as well !




```
*PADS-PCB*
*PART*
U1 DIP--8
IN HDR-3X1/2.54
[…]
C2 CAP-D5.0XF2.0

*NET*
*SIGNAL* U1_2
IN.2 U1.2
[…]
*END*
```

Netlist



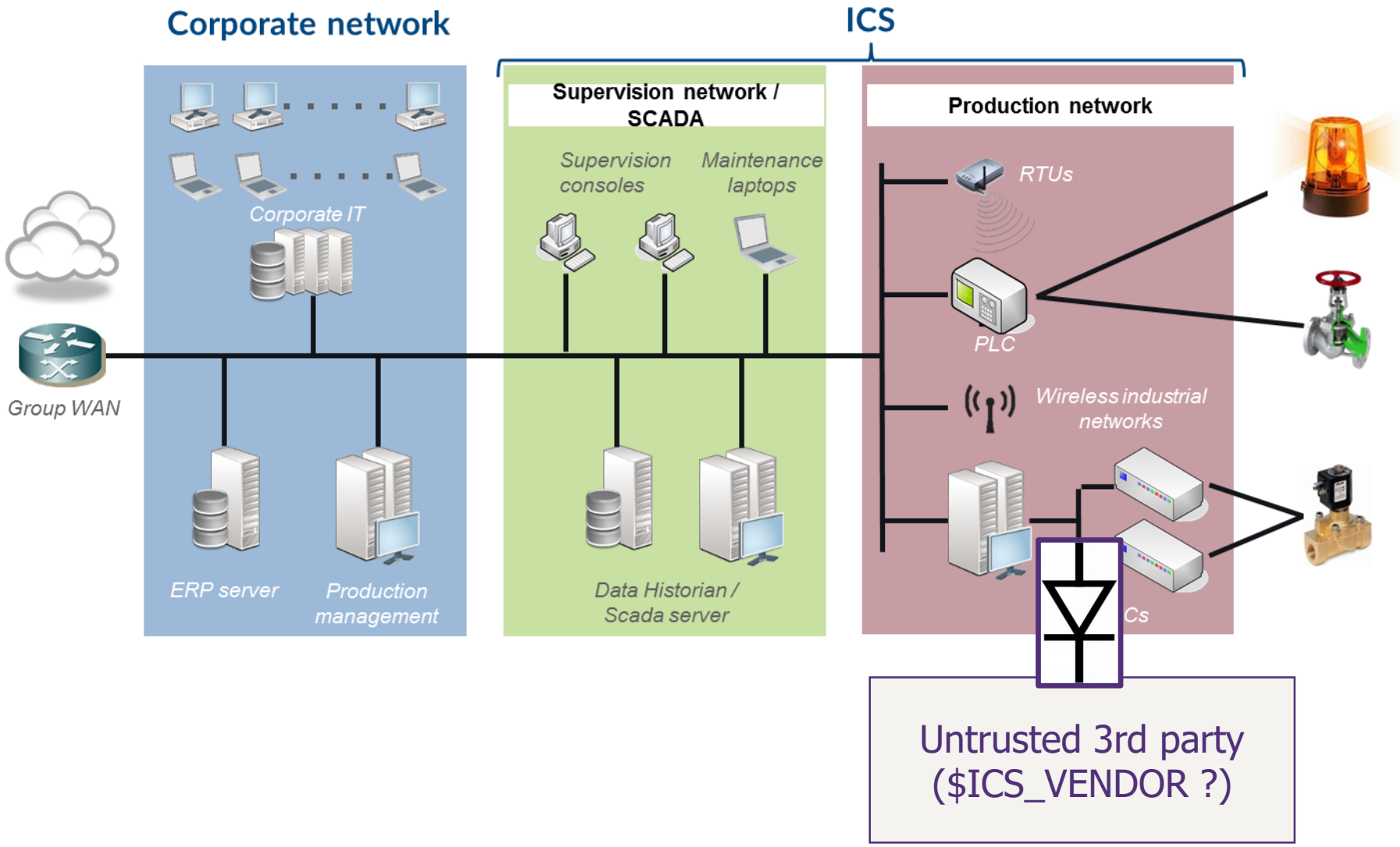
```
solid stl_item0  facet
normal 0 0 1    outer loop
vertex -56.25 23.799 9
vertex -56.5 24.232 9
vertex -56.561 23.561 9
endloop  endfacet  facet
normal 0 0 1    outer loop
vertex -55.112 21.051 9
vertex -54.982 20.568 9
[…]
```

STL file for 3D-printing the case

DEMO

[LIVE] DEMO TIME!

DEMO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Wireless industrial networks
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ERP server
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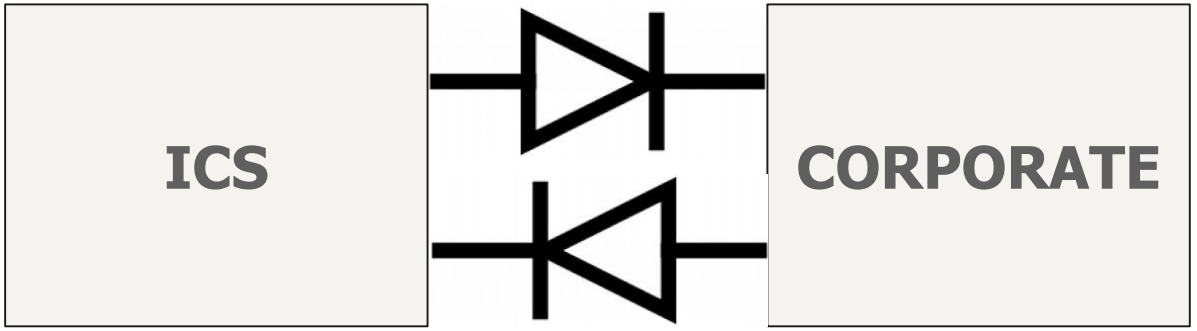
Untrusted 3rd party ($ICS_VENDOR ?)

SO, IS IT MAGICAL ?

- Nope.
- Most of the time, need to exchange data two ways:
  - CORP -> ICS for updates, docs
  - ICS -> CORP to export production data
- So you'll end up with two data diodes, one in each direction, which goes a bit against the principle...



THREAT MODELING (SIMPLIFIED)

What does DYODE guarantees?

No data will go from OUT to IN. That's all. Period.

What attacks are still possible?

The overall security of the solution still relies on logical hardening.

If the "out" corner is not secured, it might be possible for an attacker to

- Perform a Denial of Service
- Compromise the Raspi and modify the data

LIMITS

Performances

- Low speed, a few mbs
- High latency caused by flat file transfer

➔ *Replaced by a naive, native Python sockets implementation*

Side channels

- Side channels, especially based on electromagnetic leaks (TEMPEST) were not taken in consideration in the threat model
- However, EM leaks can be reduced with faraday cages
  ➔ *Re-use of forensics (relatively low cost) portable faraday cages used when handling phones?*

Gateway hardening

- In and out gateways are not especially hardened and can be compromised
- The target it only to prevent information flowing from ICS to CORP

Not compatible with safety-critical environments (yet)

Roadmap

Modbus/S7 integrity control

- Acting as an application firewall in whitelist mode to check the correctness of the parameters

Link status monitoring - Heartbeat

- Ex: Using a cronjob + a SNMP trap on the receiver side

File integrity checking (1/2)

- Level1: perform a file validation by the receiving gateway, either with an AV (basic) or a specific parser/converter such as Lagadec's Exefilter or CIRCLean or against specific hashes for binaries
- Level2: use a dedicated device for file parsing which can be further hardened (the exposition can be limited to the parsing component, the TCP/IP stack and a limited number or entry points)
- Level3: Use Qubes OS throwable VM

Other protocols

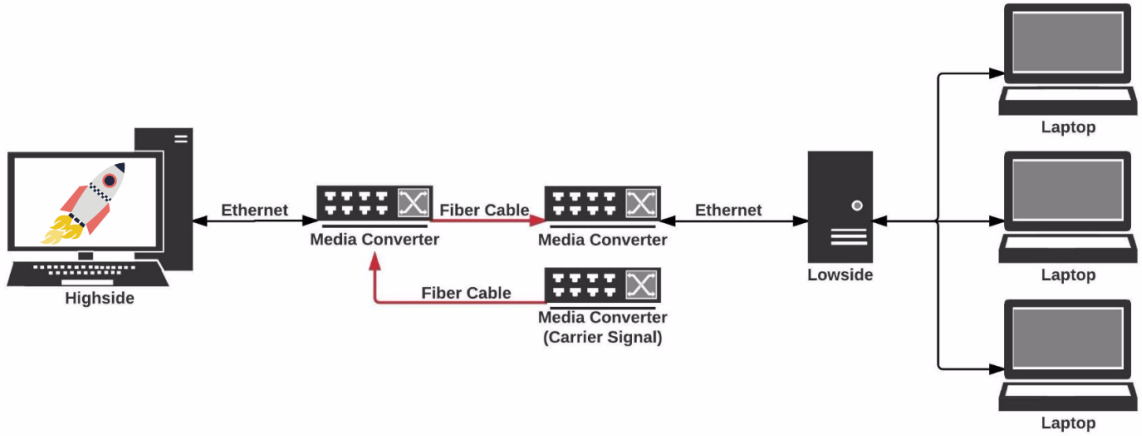
- Add support for SNMP, Syslog, CIFS, SMTP, FTP, SFTP, etc

Traceability of the transfers

- Level1: generate hash of the files/values transferred
- Level2: use 2 DYODE and 3 RSPi (in, out and crypto-signer); the RSPi in the middle combined with an OpenPGP card can generate the hashes and add a signature

Current deployments

- Similar setup, different implementation (.NET) made by one of our clients
- Used in a summer internship for Virginia Space
  #ohmygawddyodeintospace
  https://github.com/EBUJOLD/data-diode



- Tests in progress at another client to isolate safety PLCs from the DCS

Conclusion

It works.

As demonstrated [*if the demo did not fail*] DYODE answers to safe data exchange needs

It's cheap.

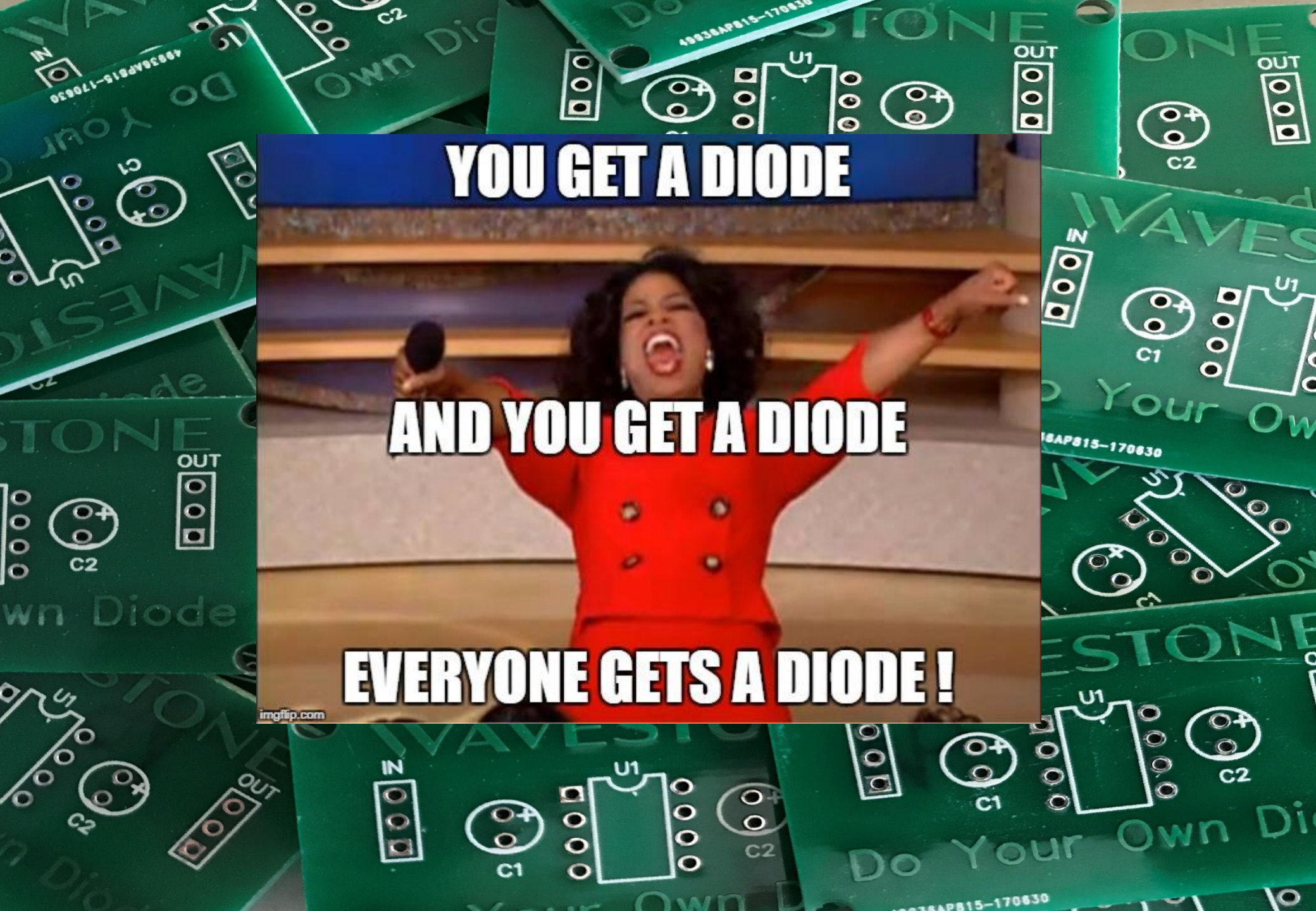
300€ for the v1

80€ for the v2

Contribute !

We need contributions to make the product more reliable and add features

https://github.com/wavestone-cdt/dyode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