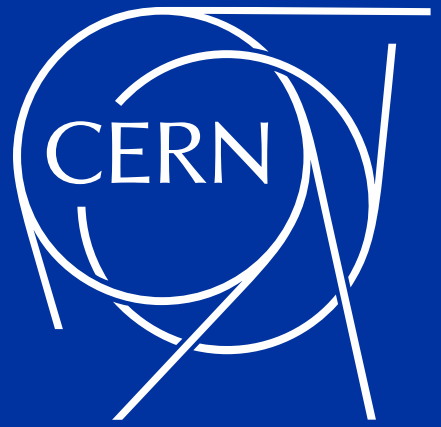


CTTB 2022 Fieldbuses Survey Results

Rodrigo Ferreira, Eva Gousiou, Jean-Charles Tournier, Slawosz Uznanski

Industrial Controls Forum – May 11th 2023

Context

CTTB mandates the Electronic and Industrial Controls forums to review the fieldbuses strategy

Purpose

Update of the recommendation for the use of fieldbuses at CERN (1996)

Consider new user requirements and fieldbus technology evolution

Scope

All types of fieldbuses used / planned to be used within ATS

RadTol and not RadTol, commercial and custom, recommended and others

Objectives

Review of fieldbus requirements within ATS as identified by the Fieldbus Working Group in 2013 (EDMS 1262875)

Identification of technical solution(s)

Update recommendation for the use of fieldbuses at CERN

Fieldbuses Review Approach

Three surveys

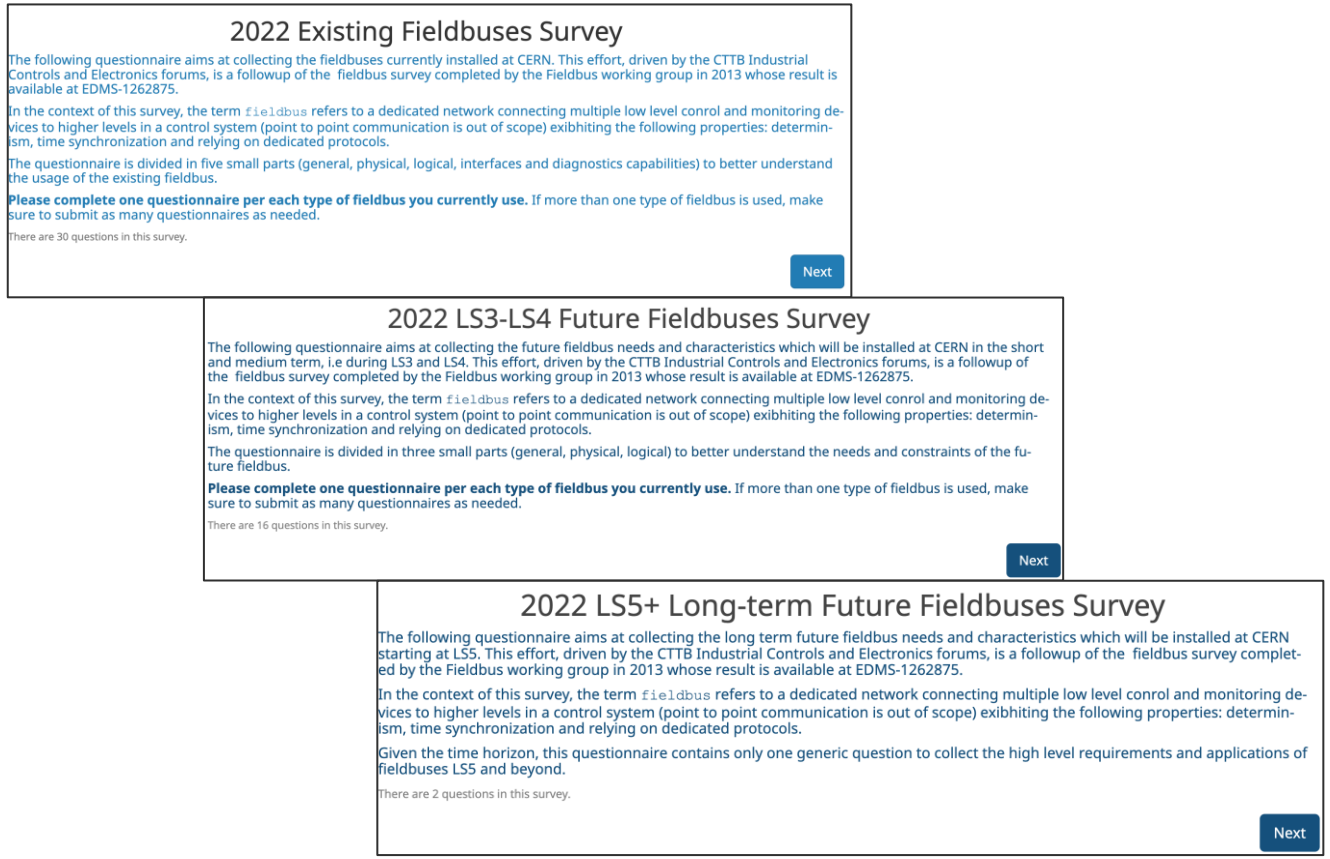
- Identify the current installations
- Identify the short-term needs and evolutions
- Identify the long-term requirements

Audience

- All groups within ATS
- Groups identified during the previous survey
- Inputs from the CTTB and user forums

Fieldbuses (and protocols) considered

- Dedicated network
- Connecting low-level control and monitoring devices
- Deterministic
- Dedicated or specific communication protocols
- Point-to-point, broadcast only and TN not considered



Timeline

July 2022

- CTTB mandates the Electronic and Industrial Controls forums to review the fieldbuses strategy
- Survey creation

August – October 2022

- Survey announced at CTTB
- Survey sent to all identified groups

November 2022 – February 2023

- Survey results collection and analysis

May 2023

- Recommendations discussion

Survey Results

Overview

11 Groups participating

BE

BE-CEM, BE-ICS

EN

EN/EL

SY

SY-ABT, SY-BI, SY-EPC, SY-RF

TE

TE-CRG, TE-MPE, TE-MSC, TE-VSC

~30 surveys completed in total

- Mostly on the current installations
- Few on LS3-LS4 requirements
- Very few on LS5+ requirements

Survey Results

Existing Fieldbuses

17 Fieldbuses Identified

Industrial

1. A/S Interface
2. CAN
3. EtherCAT
4. EtherNet/IP
5. FIPIO
6. IEC-61850
7. MIL-STD-1533
8. MODBUS
9. PROFIBUS
10. PROFINET
11. PROFIsafe
12. Serial RS232/422/485
13. 3G/4G Network

Custom

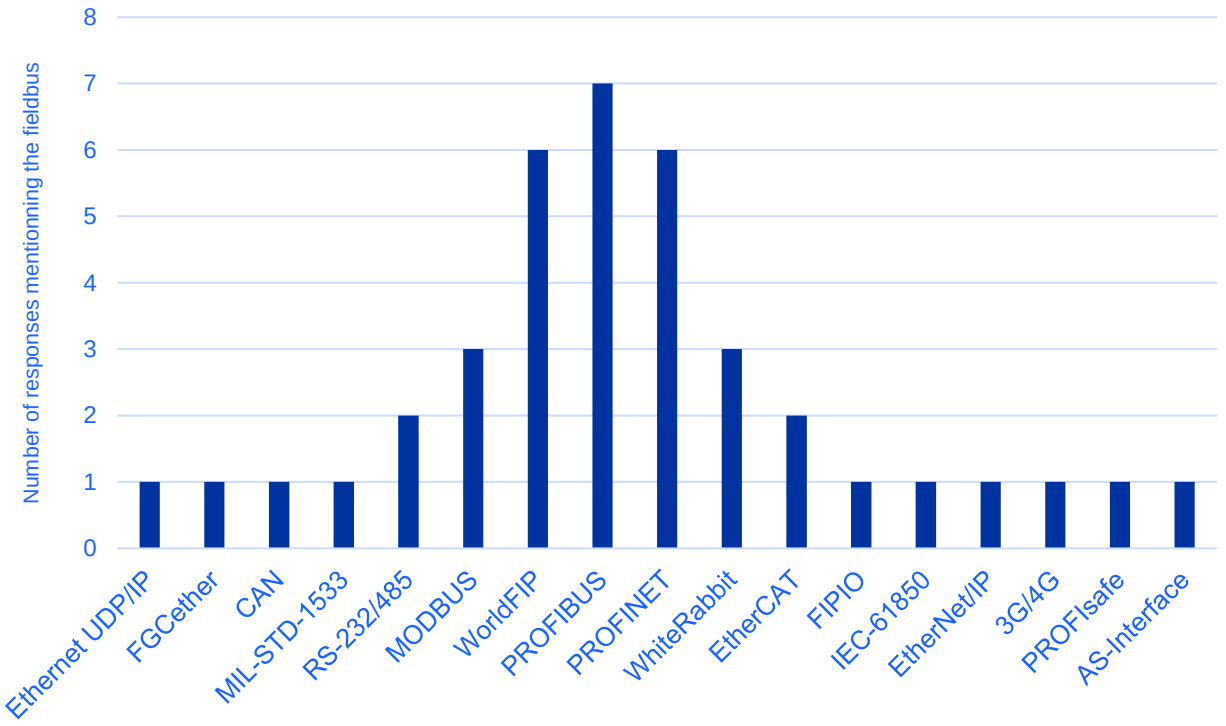
14. Ethernet UDP/IP
15. FGCether
16. White Rabbit
17. WorldFIP

Number of Users per Fieldbus

Number of times a fieldbus has been mentioned

Raw numbers to be taken with a grain of salt

But gives an overview of the fieldbus usage



Number of Users per Fieldbus

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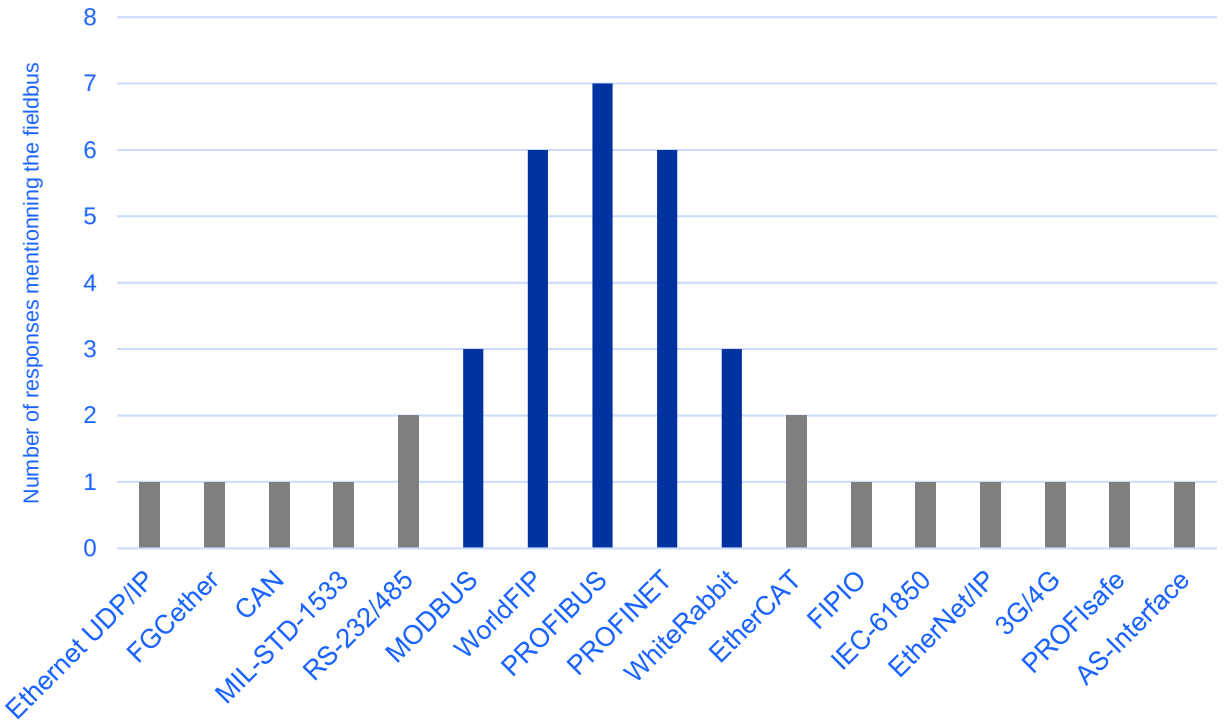
Few fieldbuses mentioned at least 3 times



Number of Users per Fieldbus

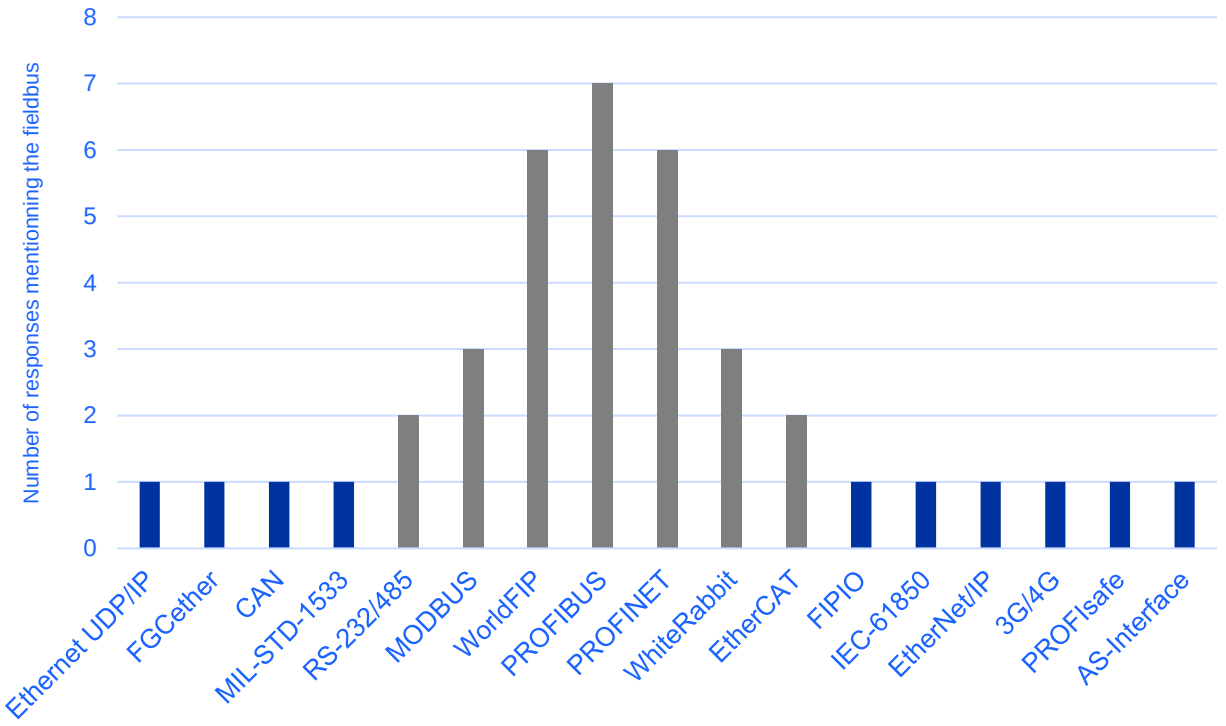
Number of times a fieldbus has been mentioned

Raw numbers to be taken with a grain of salt

But gives an overview of the fieldbus usage

Few fieldbuses mentioned at least 3 times

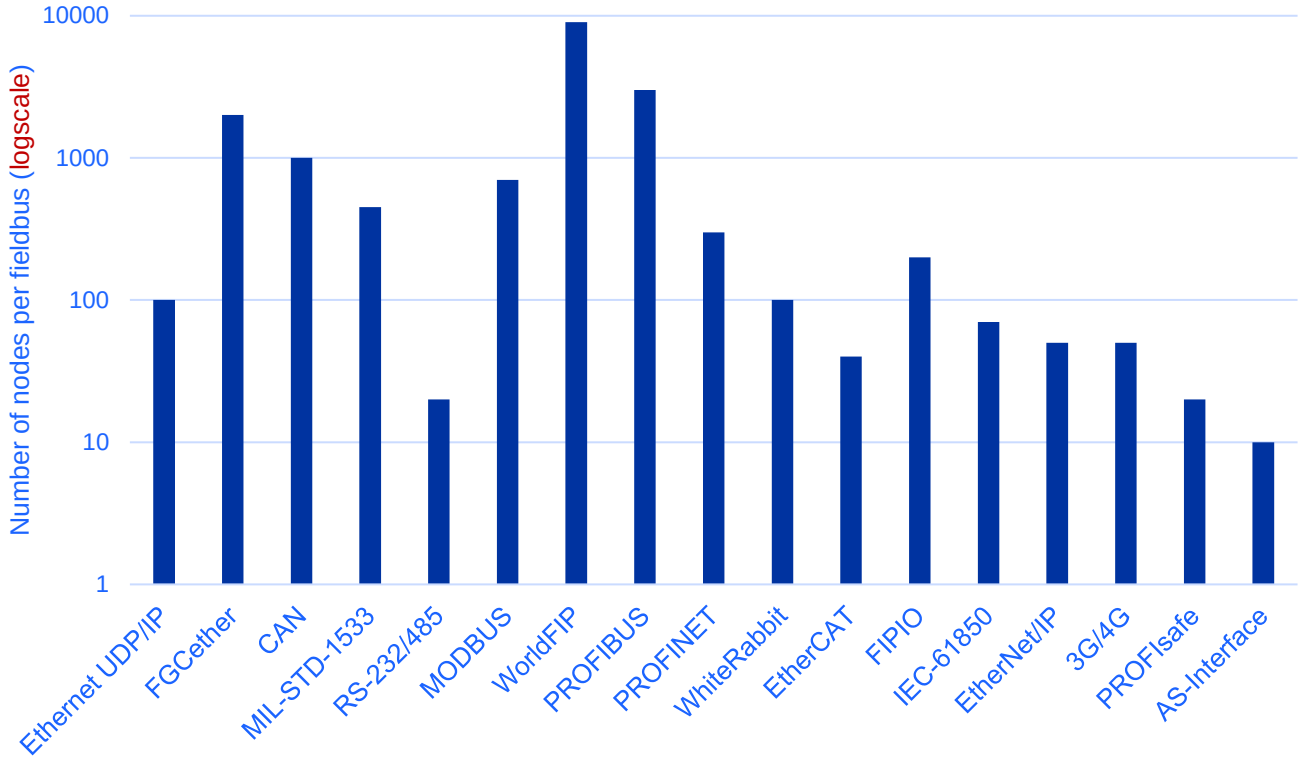
Many fieldbuses mentioned once



Number of Nodes per Fieldbus

Number of nodes given as order of magnitude

Watch out for the log scale

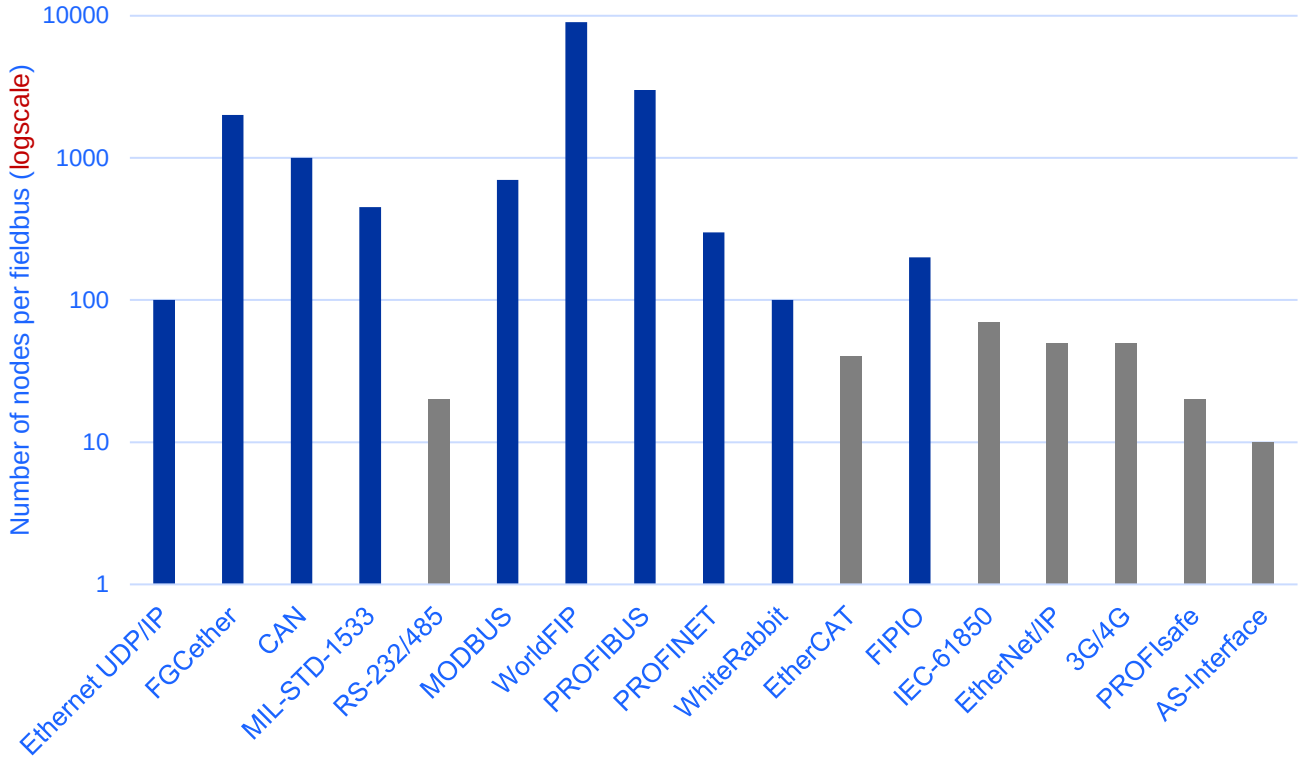


Number of Nodes per Fieldbus

Number of nodes given as order of magnitude

Watch out for the log scale

Ten fieldbuses have 100 nodes or more



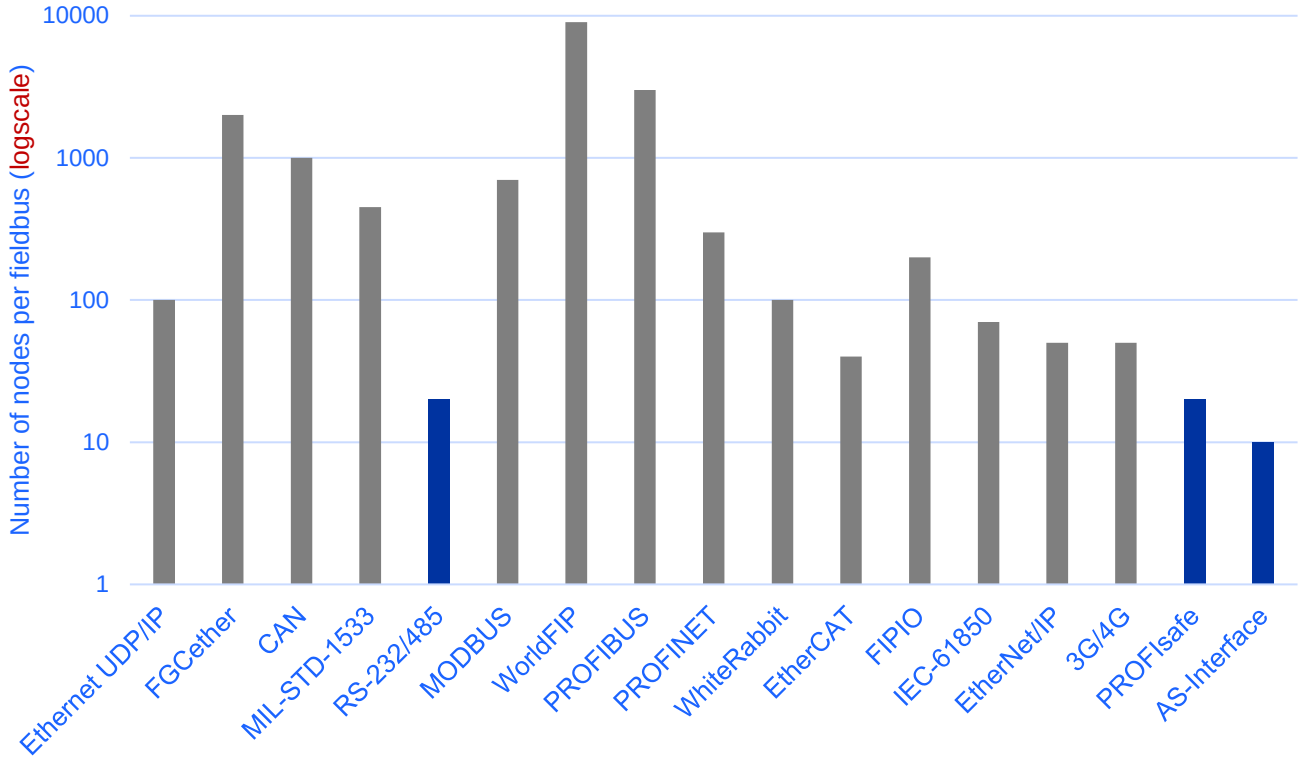
Number of Nodes per Fieldbus

Number of nodes given as order of magnitude

Watch out for the log scale

Ten fieldbuses have 100 nodes or more

Only 3 fieldbuses have 20 or less nodes



Fieldbuses Support
Central Support vs. Equipment Owner

Industrial

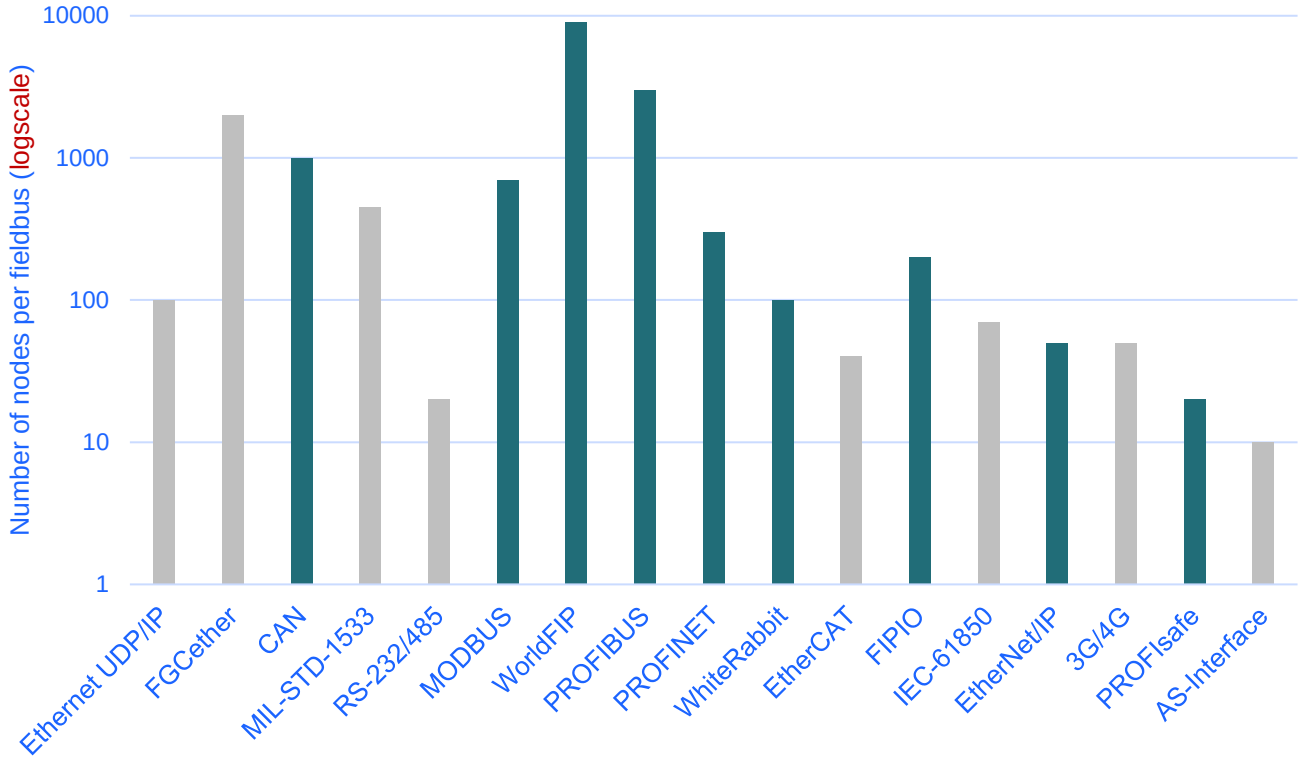
1. A/S Interface
2. CAN
3. EtherCAT
4. EtherNet/IP
5. FIPIO
6. IEC-61850
7. MIL-STD-1533
8. MODBUS
9. PROFIBUS
10. PROFINET
11. PROFIsafe
12. Serial RS232/422/485
13. 3G/4G Network

Custom

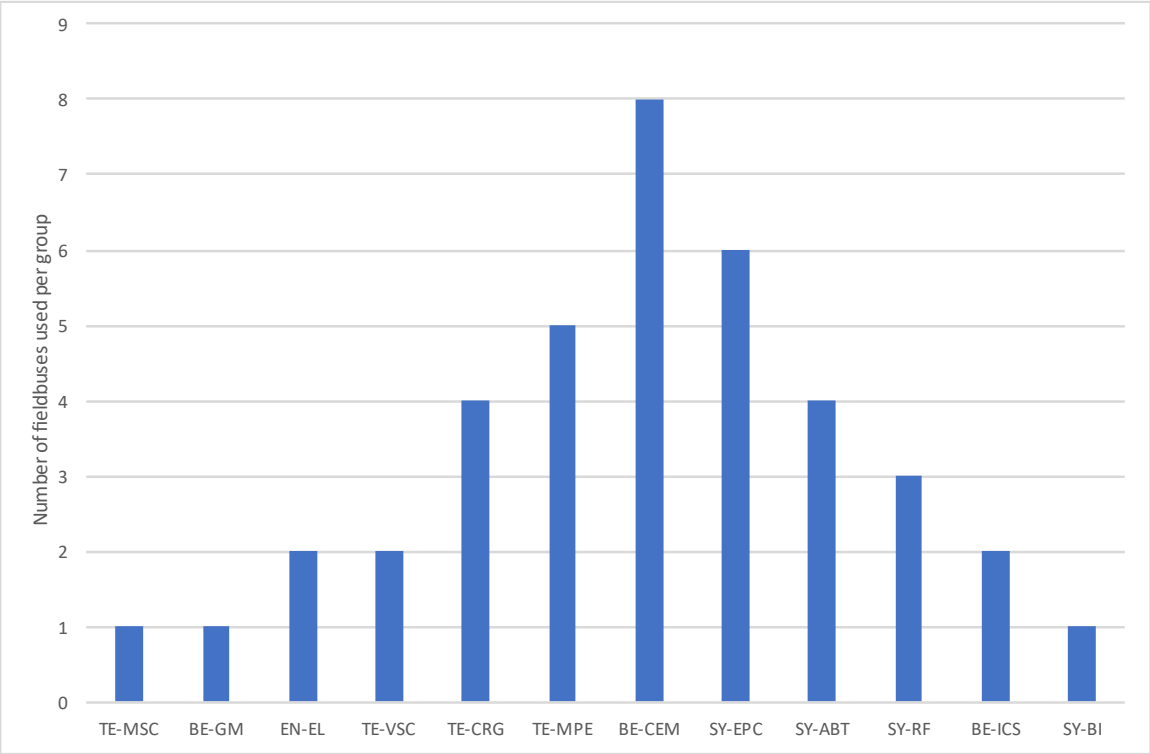
14. Ethernet UDP/IP
15. FGCether
16. White Rabbit
17. WorldFIP

Centrally Supported Fieldbuses

Fieldbuses with most nodes are mostly centrally supported



Number of Fieldbuses per Group



Most of the groups have two or more fieldbuses

Historical reasons, vendors choices, easiest solutions

BE-CEM

RadMon, OASIS/WRTD, BIDs

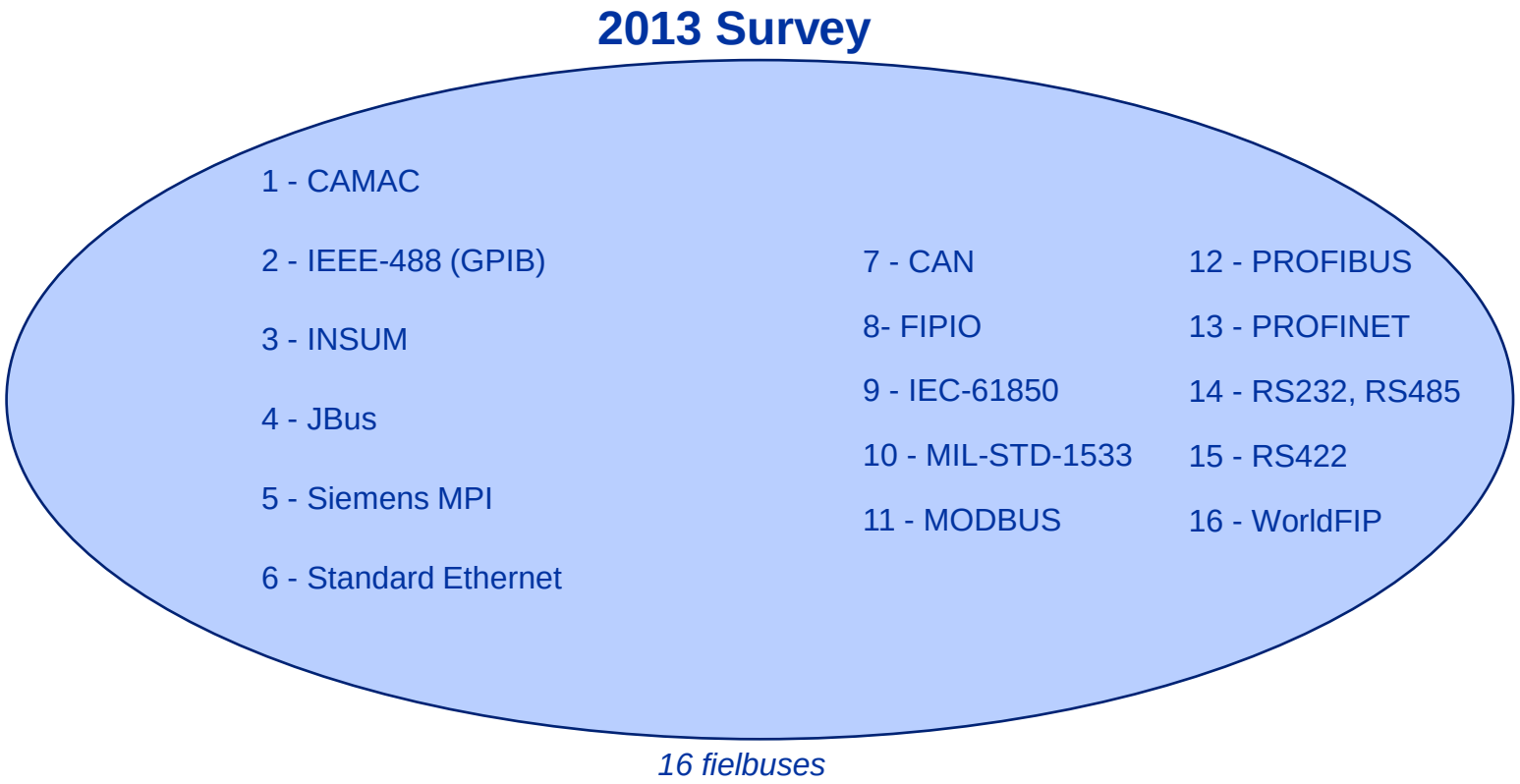
TE-MPE

QPS, SMP, WIC, PIC

BE-ICS

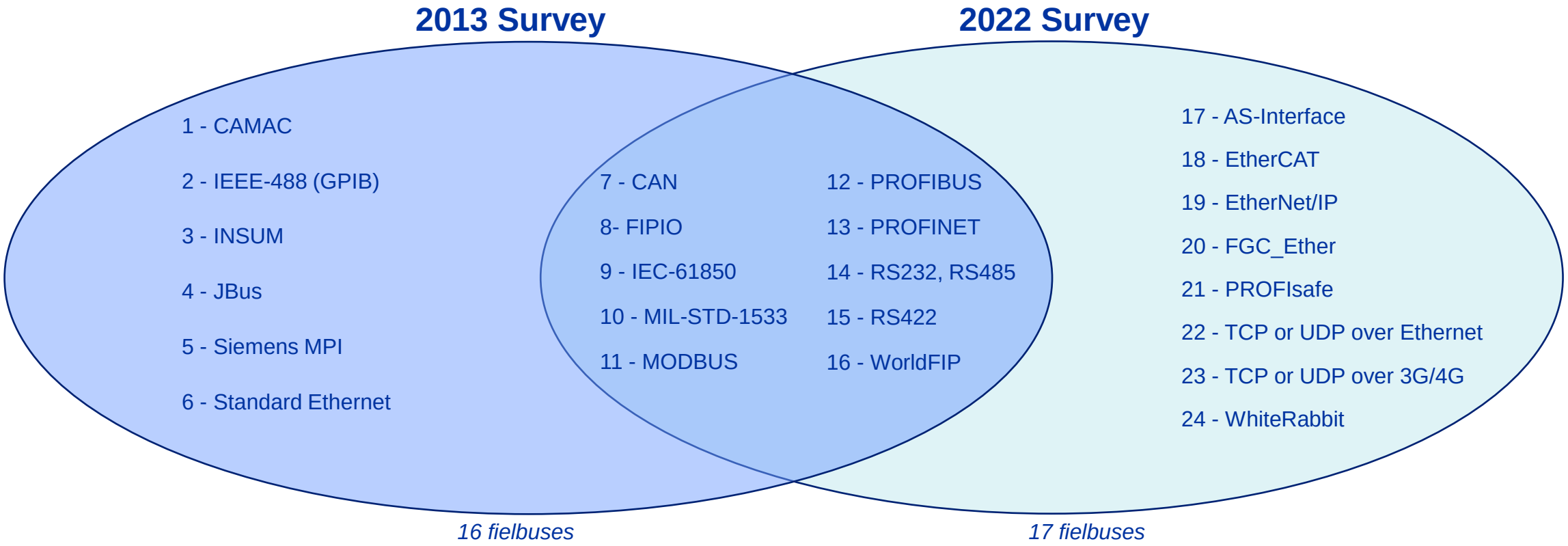
LHC Experiments, External Conditions

Evolution since 2013 Survey

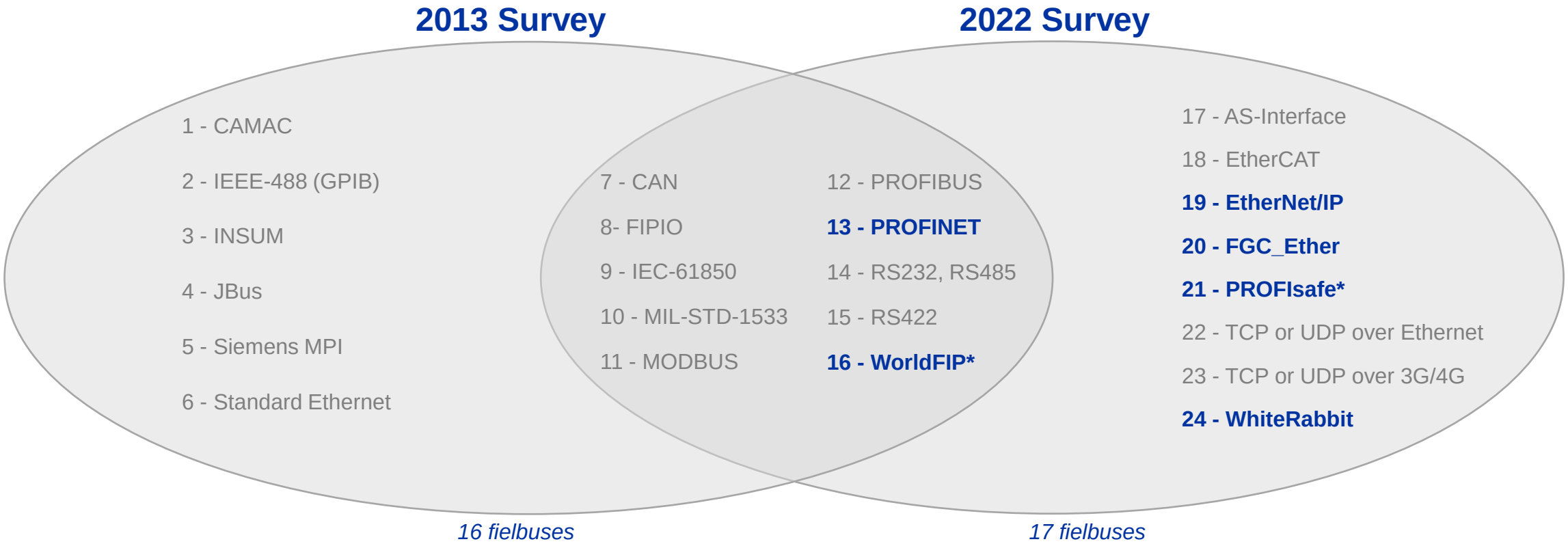


16 fielbuses

Evolution since 2013 Survey



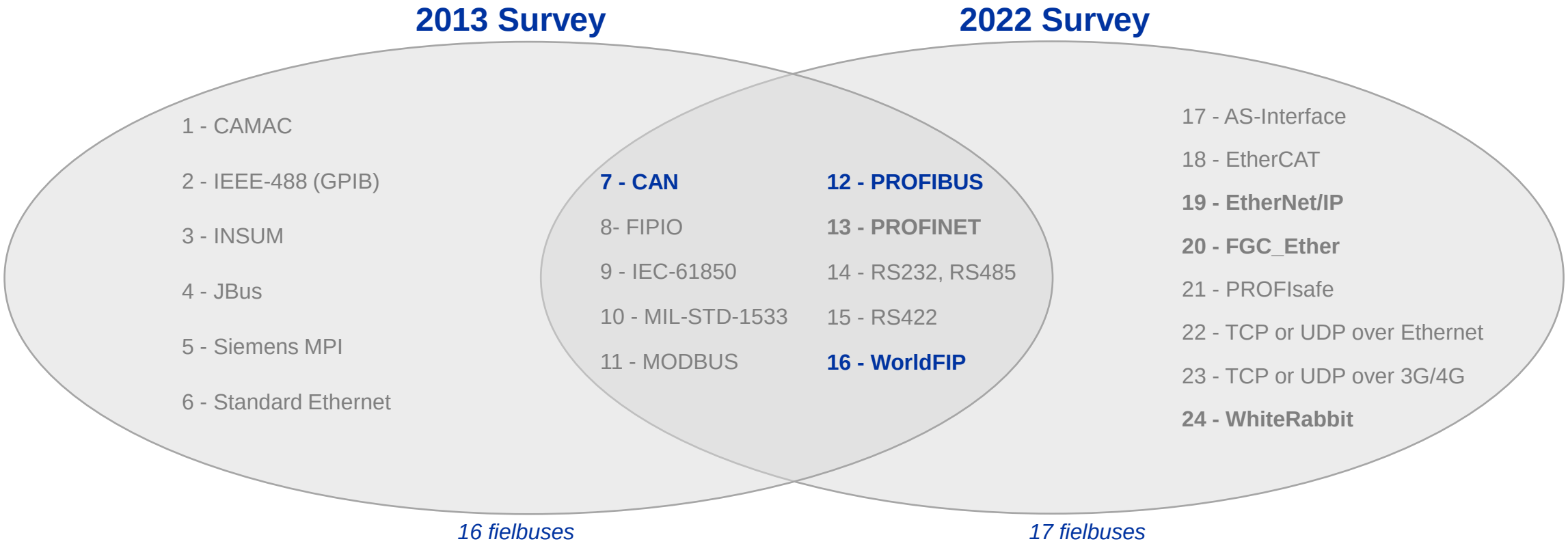
Fieldbuses Recommended in 2013



16 fielbuses

17 fielbuses

Fieldbuses Recommended in 1996



"*Recommendations for the use of fieldbuses at CERN in the LHC era*", Baribaud et al., Fieldbus Working Group, 1996, http://cdsweb.cern.ch/record/311229

Survey Results

LS3-LS4

LS3-LS4 needs - Industrial Fieldbuses

PROFIBUS replacement by PROFINET

TE-VSC, SY-EPC, TE-ABT

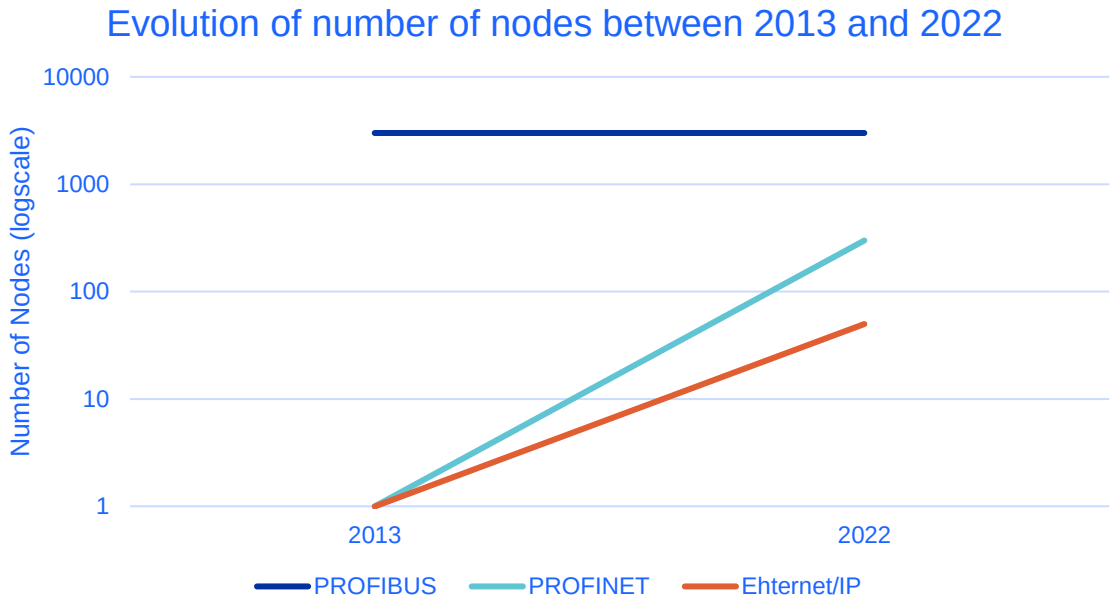
PROFIBUS still needs to be supported though

Decommissioning of serial protocols

SY-ABT

Industrial Ethernet with Custom electronics

WorldFIP - PROFINET translator supported by DI/OT



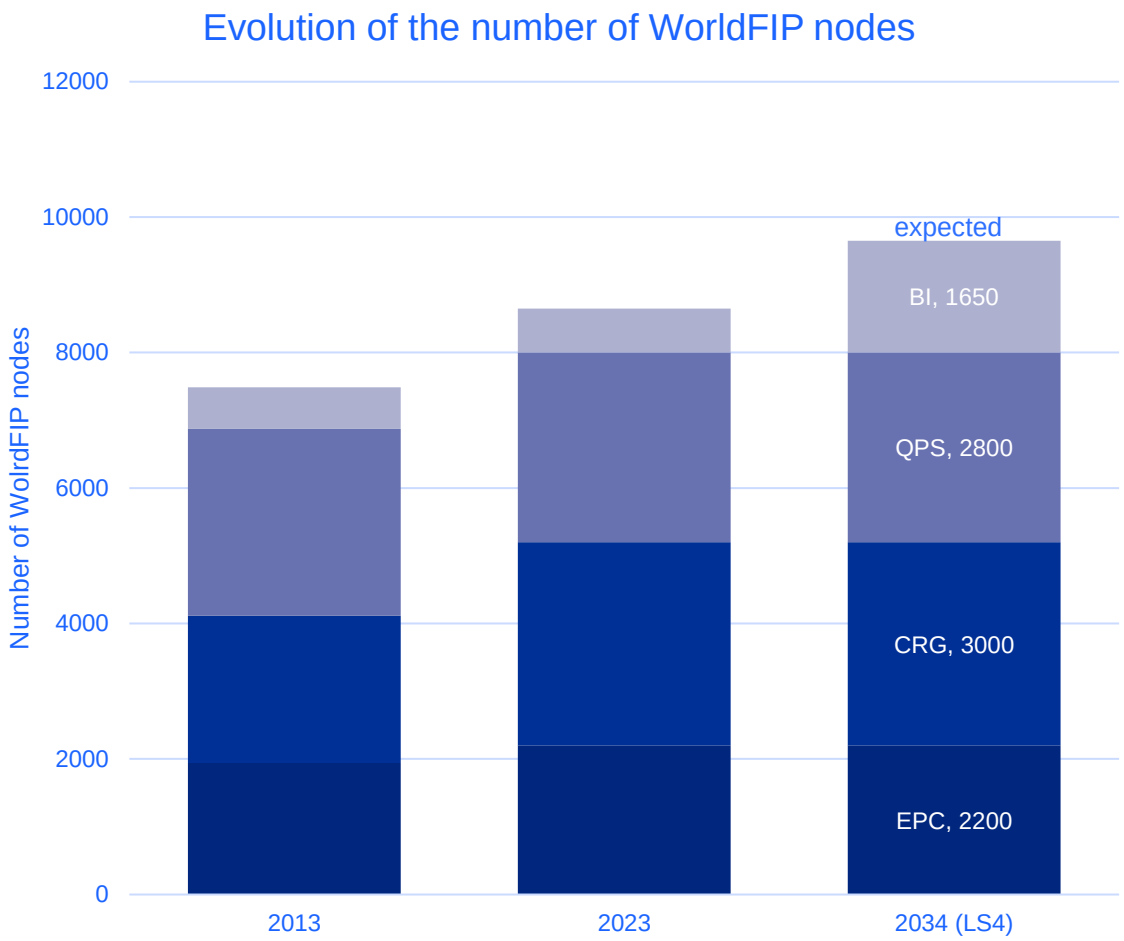
LS3-LS4 needs - Custom Electronics
Radiation Tolerant

Possible increase of WorldFIP installations

- WorldFIP supported by DI/OT (GM and WIC)
- Considered for BLM and BPM by BE-BI

No need for higher bandwidth for rad-tol fieldbus

- 2.5 Mbps seem sufficient for HL-LHC



LS3-LS4 needs - Custom Electronics
Nanosecond level synchronization

Increasing number of WhiteRabbit applications

General Machine Timing (GMT), potentially Beam Synchronous Timing (BST), Safe Machine Parameters (SMP), WR Trigger Distribution (WRTD), potentially RF Crab Cavities.

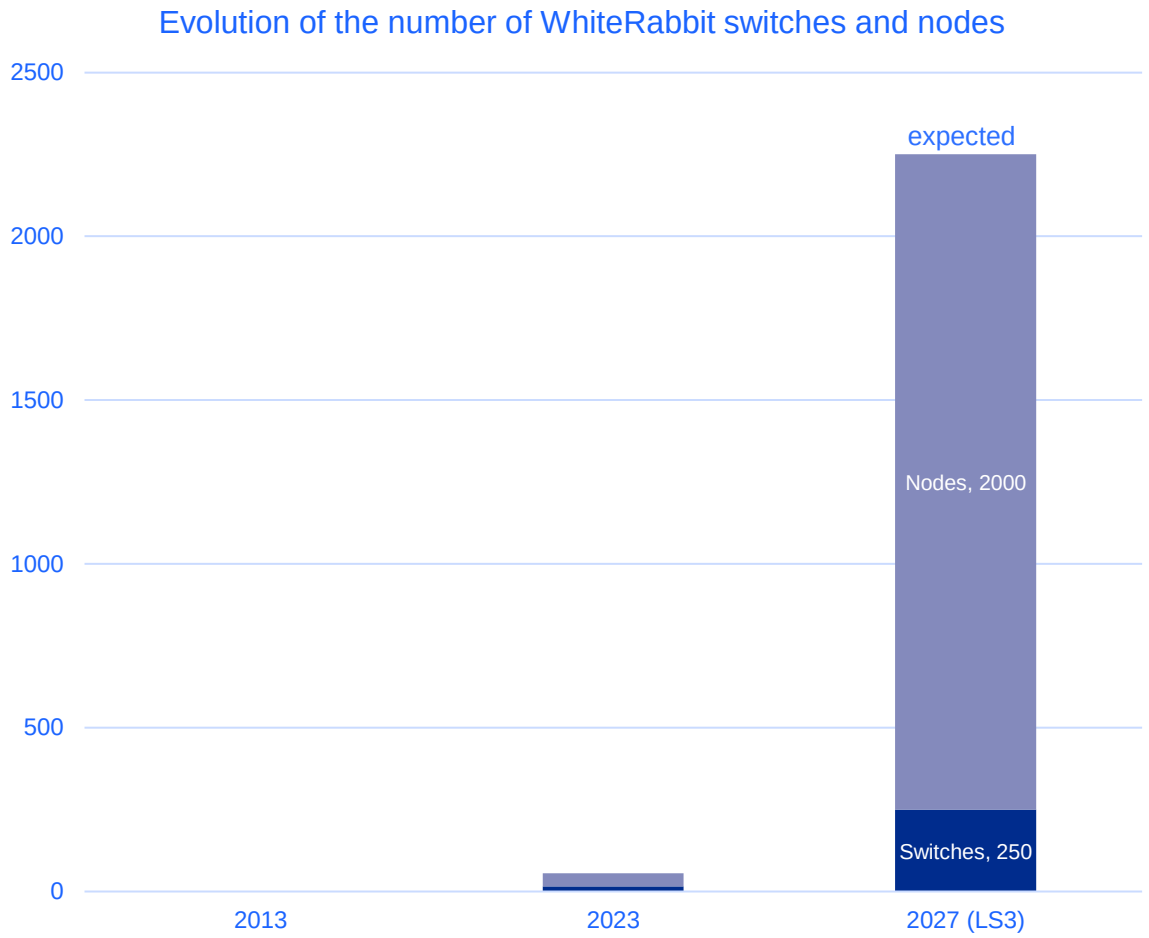
A CERN-wide WR network under deployment (mainly for GMT/BSToWR)

WR supported by DI/OT

Need for data transfers protocols over WhiteRabbit

Raw Ethernet or UDP layer

Efforts for standardization



LS3-LS4 needs - Custom Electronics
Microsecond level synchronization

Currently

FGC-ether: since Run2; Raw Ethernet + 50Hz

QPS: since Run3; UDP + PTP

Different implementations: off-the-shelf switches & some custom developments

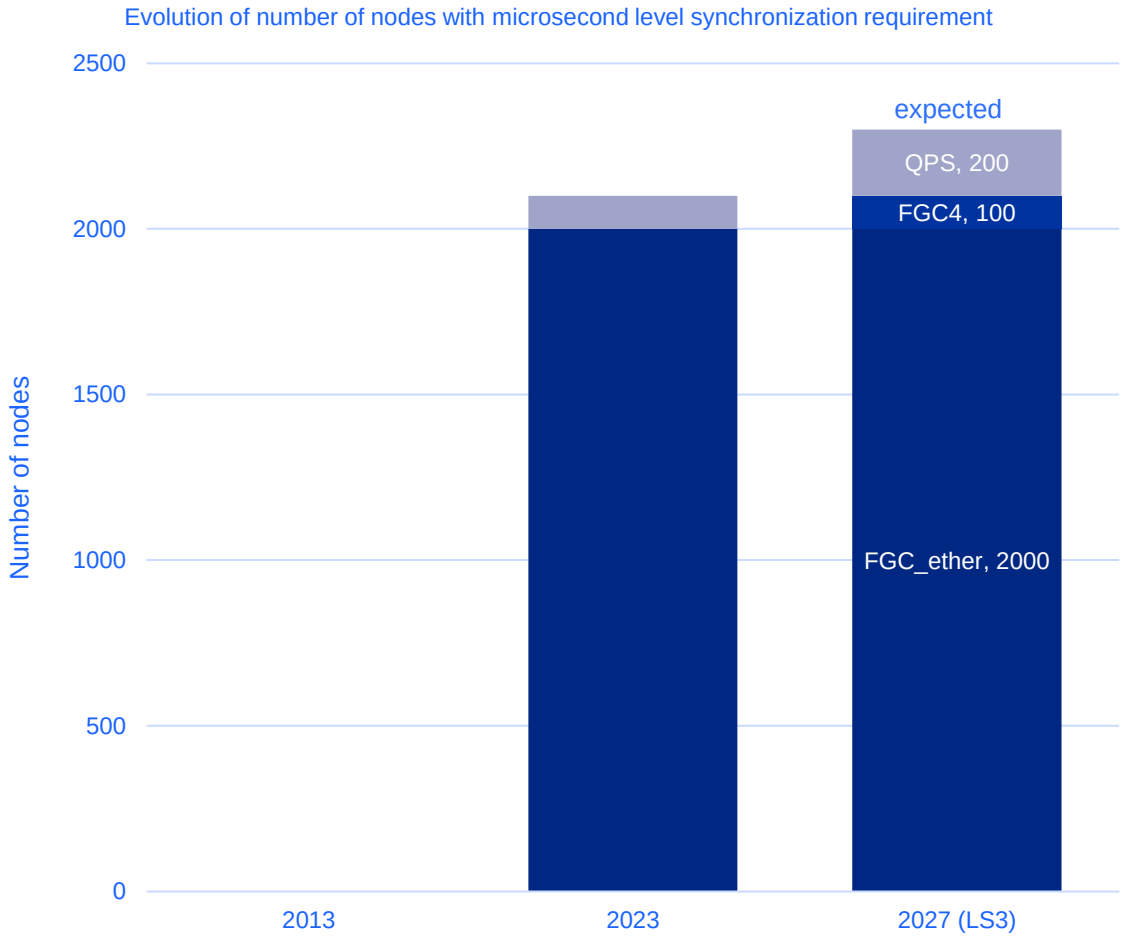
No centrally supported solution

LS3-LS4

Requests for centralised support: FGC4, QPS-extensions

Possible solution with off-the-shelf switches & one WR connection for PTP

Formalization & Resources to be discussed



Survey Results

LS5+

Long-term needs (LS5+)

Maintain support centrally supported fieldbuses

- WorldFIP, PROFIBUS, PROFINET, MODBUS
- Possibly more but not explicitly mentioned in the survey, e.g. CAN

Strong request to consider wireless fieldbuses (TE-VSC, TE-CRG, BE-CEM, SY-ABT)

- Harsh environment (EMC, etc.)
- Integration of IoT devices

Be ready for the increased amount of data and security (SY-ABT)

- Higher bandwidth, data compression, encryption
- Integration of IoT devices

Easier integration of PLCs in the Control System (SY-ABT)

- SoftPLC on FEC as PLC emulator

Recommendations

Proposal to the IC forum

Industrial Controls Fieldbuses

1. **Maintain the support of currently centrally supported fieldbuses**

   CAN, EtherNet/IP, FIPIO, MODBUS, PROFI(BUS/NET/ Safe), White Rabbit, WorldFIP

2. **Foster ethernet based fielbuses**

   Migrate from serial to ethernet based fieldbuses whenever possible for existing installations

   Ethernet based fieldbuses should be favored for new installations

3. **Explore wireless fieldbuses**

   Mandate a group to evaluate and validate existing solutions

   e.g. PROFINET over IEEE 802.11

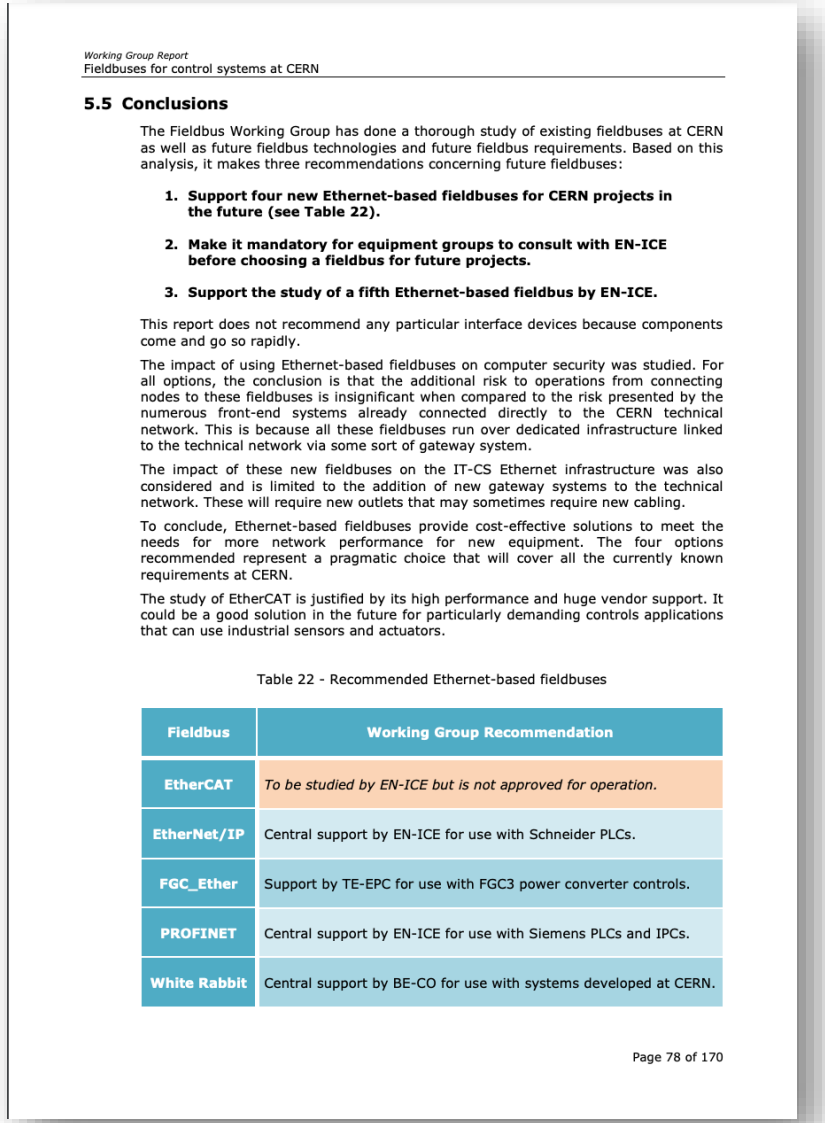
4. **Update the 2013 list of recommended fieldbuses**

   Add explicitly PROFIsafe to the list for safety system

   Add explicitly WorldFIP

   What about FGC_Ether? To be addressed by the Custom Electronic Forum?

   EtherCAT status study?



Working Group Report
Fieldbuses for control systems at CERN

5.5 Conclusions

The Fieldbus Working Group has done a thorough study of existing fieldbuses at CERN as well as future fieldbus technologies and future fieldbus requirements. Based on this analysis, it makes three recommendations concerning future fieldbuses:

1. **Support four new Ethernet-based fieldbuses for CERN projects in the future (see Table 22).**
2. **Make it mandatory for equipment groups to consult with EN-ICE before choosing a fieldbus for future projects.**
3. **Support the study of a fifth Ethernet-based fieldbus by EN-ICE.**

This report does not recommend any particular interface devices because components come and go so rapidly.

The impact of using Ethernet-based fieldbuses on computer security was studied. For all options, the conclusion is that the additional risk to operations from connecting nodes to these fieldbuses is insignificant when compared to the risk presented by the numerous front-end systems already connected directly to the CERN technical network. This is because all these fieldbuses run over dedicated infrastructure linked to the technical network via some sort of gateway system.

The impact of these new fieldbuses on the IT-CS Ethernet infrastructure was also considered and is limited to the addition of new gateway systems to the technical network. These will require new outlets that may sometimes require new cabling.

To conclude, Ethernet-based fieldbuses provide cost-effective solutions to meet the needs for more network performance for new equipment. The four options recommended represent a pragmatic choice that will cover all the currently known requirements at CERN.

The study of EtherCAT is justified by its high performance and huge vendor support. It could be a good solution in the future for particularly demanding controls applications that can use industrial sensors and actuators.

Table 22 - Recommended Ethernet-based fieldbuses

Fieldbus	Working Group Recommendation
EtherCAT	*To be studied by EN-ICE but is not approved for operation.*
EtherNet/IP	Central support by EN-ICE for use with Schneider PLCs.
FGC_Ether	Support by TE-EPC for use with FGC3 power converter controls.
PROFINET	Central support by EN-ICE for use with Siemens PLCs and IPCs.
White Rabbit	Central support by BE-CO for use with systems developed at CERN.

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Conclusion

Summary

Custom Electronics

- WorldFIP is the clear option for radiation tolerant environment
- WhiteRabbit is the clear option for nanosecond synchronization
- Request for a centrally supported microsecond synchronization solution

Industrial Controls

- Trend to move away from “old” fieldbuses, e.g. serial, PROFIBUS
- Clear request to explore wireless solutions

General

- Fieldbuses with most nodes are centrally supported
- Large variety of fieldbuses are currently in use despite the previous standardization efforts
- Many fieldbuses are used by only one group but have many nodes

Interviews would have been more effective than online surveys (but more time-consuming)

Next Steps

Update recommendations (WG and Forums)

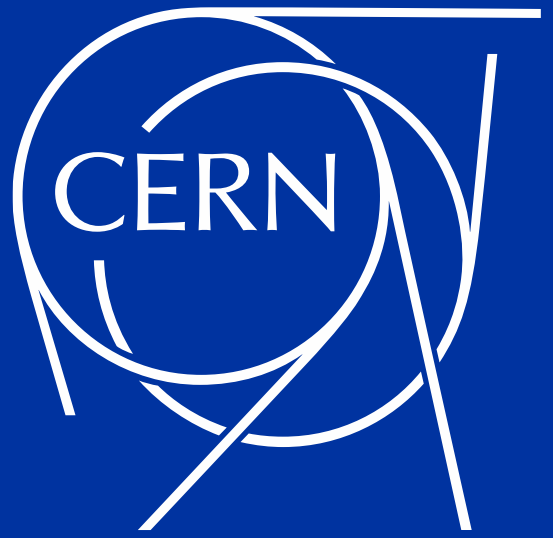
Recommendations to be endorsed/amended by the forums

Plan and share (CTTB)

Estimate of **resources** for the implementation of the recommendations

Establish **accountability** mechanisms

Communicate to the different stakeholders


CERN

IEC Standards

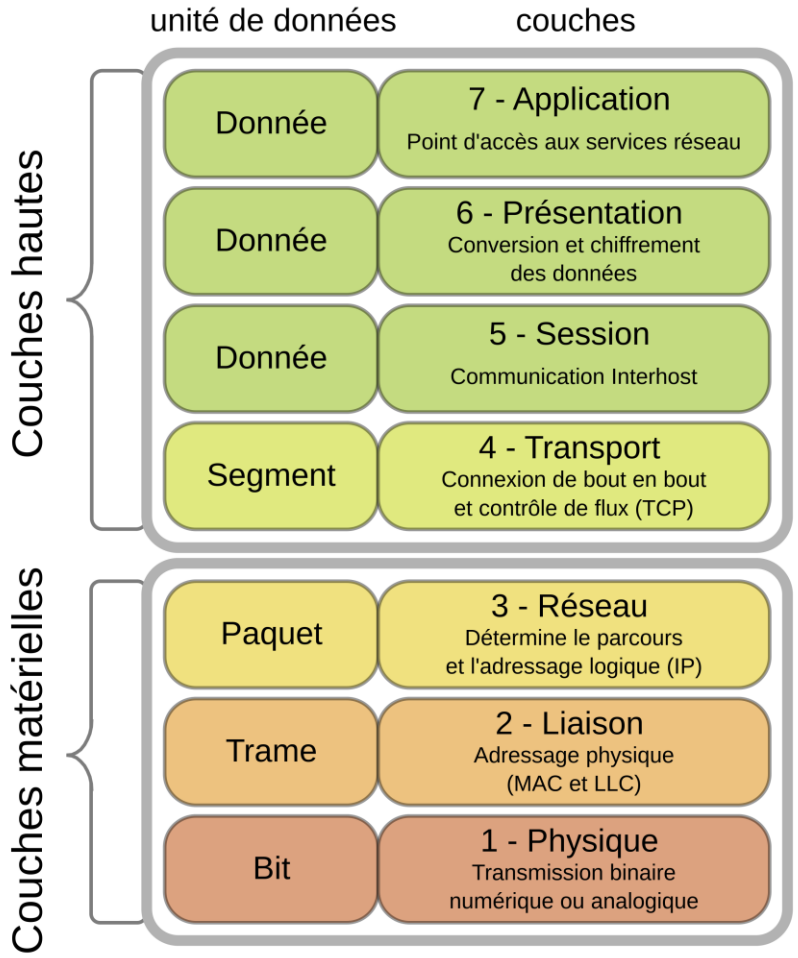
IEC 61158

- Industrial communication networks - Fieldbus specification, c.f. CERN Library link
- “Conceptually, a fieldbus is a digital, serial, multidrop, data bus for communication with industrial control and instrumentation devices such as – but not limited to – transducers, actuators and controllers. “
- “The IEC 61158 series specifies a number of fieldbus protocol types. Each protocol type is designed to permit multiple measurement and control devices to communicate on a shared medium. Devices communicate directly only with other devices of the same protocol type. “
- Specifies each layer of the OSI model
- Latest release dates from 2019 and lists up to 26 different types of protocols

IEC 61784

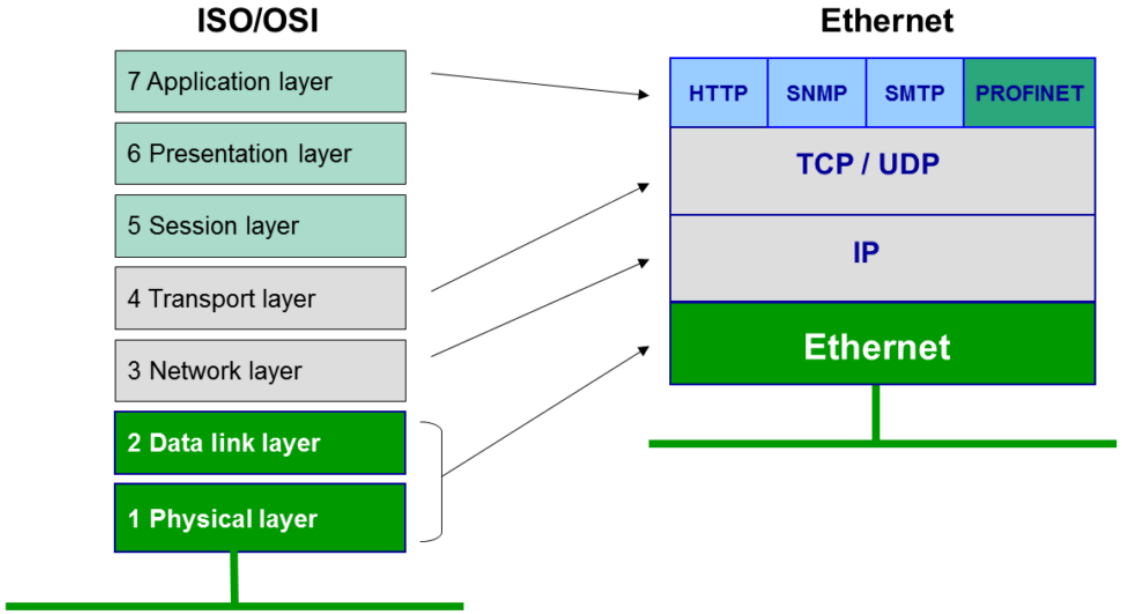
- Industrial communication networks – Profiles, c.f. CERN Library link
- Concrete implementation of IEC-61158
- Defines ControlNet, Ethernet/IP, DeviceNet, PROFIBUS DP/PA, PROFINET, WorldFIP, INTERBUS, CC-Link, Hart, SERCOS, etc.
- Access to the 2007 from the CERN library, but latest release from 2019

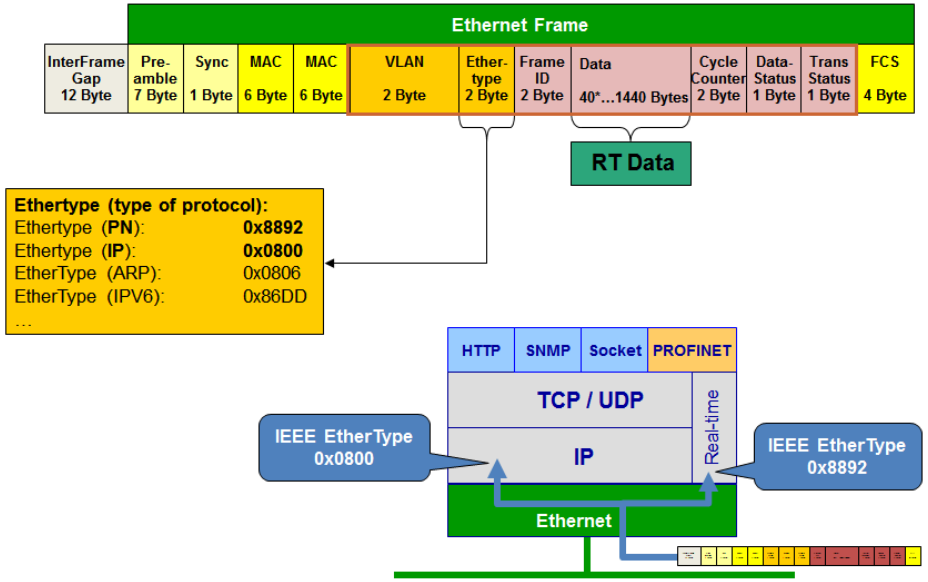
OSI Model



https://fr.wikipedia.org/wiki/Mod%C3%A8le_OSI

PROFINET





https://profinetuniversity.com/industrial-automation-ethernet/network-reference-model/