Industrial Networks
The way out of the labyrinth

Prof. Dr. Hubert Kirrmann
ABB Corporate Research,
Baden, Switzerland

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Back to the roots

It all began in 1985....
13 years of Fieldbus standardization …

Produced chaos: countless “standards” (IEC 8-headed monster, IEEE, EIA, CENELEC,...)
UNE PAGAILLE MONSTRE... (A mayhem)
LES GUERRES ASTERIXIENNES

La ruse d’Astérix, Panoramix et Obélix a réussi au-delà de toute espérance. Après avoir bu la potion magique du druide, les Goths se combattent les uns les autres avec acharnement. C’est le récit de ces guerres que nous désirons vous conté afin que vous les compreniez bien.

L’arme préférée des combattants. Elle fit des ravages.

Cette carte vous permettra de bien suivre le déroulement des opérations.

Interoperable System Project

Profibus Nutzer Organisation
WorldFIP
Fieldbus Foundation

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Results

About 20 “standard” (and hundreds of proprietary) field buses are in use today.

Some are not any more offered in new products, but must still be maintained.

Since the life expectancy of the plants is some 40 years (or more), many face now retrofit problems – and shortage of people which still know how they work.

(Does somebody remember how BitBus works?)
The integrator's nightmare

Ethernet 100 Mbit/s
- Bridge
- LS
- LS
- LS
- PM
- PM
- GW
- GW

Ethernet 10 Mbit/s

V-Sercos

Interbus

Interbus

H-Sercos

AF100 TWP

Arcnet

AF100 coax
AF100 coax
AF100 coax

Arcnet

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"According to ARC, Ethernet could serve as the harmonization force behind reducing the number of available standards for field networks" (icsmagazine 1999)
What makes “Industrial” Ethernet?

- **Process variables**
  - Soft real-time (above layer 3), ~10 ms (switched Ethernet)
  - Hard real-time (layer 2) deterministic, ~1 ms (special hardware)

- **Clock synchronization**
  - Soft (above layer 3) ~1 ms (NTP)
  - Hard (at layer 1) ~1 µs (special hardware)

- **Redundancy**
  - Soft (above layer 2) RSTP, IP (switches and rings)
  - Hard (at layer 1/2) Seamless: PRP / HSR (special hardware)

- **Physical medium**
  - Benign RJ45 (switches and rings)
  - Harsh ST, DB9, M12, IP64 (special hardware)

What makes Industrial "Ethernet"?

- Hardware compatibility with standard PC, IP/TCP/UDP
- Use of available ASICs as Ethernet controller (three manufacturers)
- Use of general purpose switches and network management tools
- Observable through EtherReal / WireShark

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Today’s situation

Due the jurisprudence of 1999, IEC could not stop proliferation of “Industrial Ethernet Standards”, citing “market demand” as an excuse (translate: “ego, nationalism and trade barriers”).

“Any National Committee has the right to submit an Automation Network: a working group has no power to judge its technical soundness or its added value.” (an IEC official)

IEC 61784 (process and discrete automation)

<table>
<thead>
<tr>
<th></th>
<th>Automation Network</th>
<th>Country</th>
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<tbody>
<tr>
<td>2</td>
<td>ControlNet (EtherNet/IP)</td>
<td>USA</td>
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<tr>
<td>3</td>
<td>Profibus, Profinet</td>
<td>Germany</td>
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<td>4</td>
<td>P-NET</td>
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<td>TCnet</td>
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<td>18</td>
<td>SafetyNET p</td>
<td>Germany</td>
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This, in addition to existing "standards" in other domains (FF's H3, IEC61850, TTEthernet, AFDX...)

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2nd world war of the buses, by Lauzier

«standardisation is the continuation of war by other means»
The dream of “one wire through the factory” is over

… but to be honest, even if the same protocol would be used everywhere the automation network would need partition anyhow for:

- encapsulation of subsystems (modularity)
- fail-independence and containment, security.
- traffic balancing and limitation, especially of multicast traffic

- in addition to technical obsolescence… who knows which media will emerge in 15 years ?

so , even going wireless would not be a solution to unification

but at least, we would like to share the same infrastructure (= Ethernet Coexistence).
Can different protocols at least coexist on the same link layer?

In principle yes, but even those who claim to use “plain Ethernet and IP” differ by:
- network management (SNMP, MMRP, GRMP, LLDP)
- clock synchronization (IEEE 1588 v1 / v2),
- redundancy schemes.
- engineering tools

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Industrial Networks – The way out of the labyrinth
We have to live with diversity today
Three situations

1) Vertical integration
2) Horizontal integration
3) Device integration
Supervisory Level

Control Network

Process Level (Island)

Horizontal and vertical communication

Supervisory to devices

Hard real-time traffic device-to-device

Engineering

SCADA

gateway firewall

internet

clock
Horizontal communication is time- and dependability- critical.

Devices on a horizontal bus are normally homogeneous, so interoperability is less of an issue

A small fraction of the traffic flows horizontally from LAN to LAN.

Most data are processed, not just transferred, i.e. a signal that is sent on one bus is computed from signals from the other bus.

IP (layer3) routing makes little sense for horizontal communication – real-time traffic is normally carried directly on layer 2

This is not a killer application for coexistence.
Intermediate nodes also perform data reduction, otherwise the upper layers would not be able to cope with the traffic. So here also, direct routing from the upper layers is not indispensable.
Device integration

Only engineering and device management (e.g. FDT/DTM, FDI) needs transparent routing from top to bottom.

Source: OVDA
Can OPC connect the networks?

- Application software can copy from OPC to OPC
- One OPC server per industrial ethernet
- Works in principle, but delays are long, even if all servers run on the same PC… and OPC UA is even slower.
Our PLCs become gateways / concentrator

- Processor
- Communication interfaces
- I/O
- Control Network
- Profinet
- ModBus
- Profibus
- IEC 61850

some do not need I/Os anymore…
PLC as gateway both for horizontal and vertical traffic

Control network

Field network server

Field network client

Control network server

PLC

Field network server

Field network server
PLCs are multi-stack devices

The PLC can act as vertical and horizontal communication gateways, they can reduce information and sometime do IP routing

but each stack has its own engineering tool….
Object models and gateway

When connecting different networks, how does the engineer know that the same variable is named on different networks:

PLC3; Slot4; Unit4; DIO2  Dataset 1232, offset 16  “GeneUr.Voltage”

We do not want to operate at the bit /I/O point level! (this is always possible but very time-consuming)
The labyrinth
The way out: try the third dimension
The 3rd dimension

Even if we are unable to connect the busses directly, we must be able to engineer and configure them out of one single project database and let them exchange information by a layer above.

The objective are:

- reduce the amount of engineering involved
- map semantically the levels
- integrate pre-engineered parts of the plant
- exchange information between the different engineering tools
Naming all elements in a substation (IEC 61346)

The first step is to agree on a unified name scheme, such as IEC 61346. For electrical substations, the naming of all equipment is standardized. Similar naming schemes exist for Power Plants (KKS).

E1.W1.Q2.QA1

bay 1
bay 2
bay 3
bay 4
Wind turbine objects (IEC 61400-25)

every conformant wind turbine must exhibit these objects!
To XML exchange formats

```xml
<?xml version="1.0"?>
<Substation name="AA1" desc="Substation">
  <VoltageLevel name="A1" desc="Voltage Level">
    <Bay name="A01" desc="Bay" sxy:dir="horizontal">
      <Node iedName="AA1TH1" idInst="LBO" lnClass="LPHD" lnInst="1" />
      <Node iedName="AA1TH1" idInst="LBO" lnClass="ITCI" lnInst="1" />
      <Node iedName="AA1TH1" idInst="LBO" lnClass="LLNO" lnInst="1" />
    </Bay>
  </VoltageLevel>
  <VoltageLevel name="C1" desc="Voltage Level">
    <Voltage multiplier="k" unit="V">380</Voltage>
  </VoltageLevel>
  <VoltageLevel name="H1" desc="Voltage Level">
    <Voltage multiplier="k" unit="V">33</Voltage>
    <Bay name="Q03" desc="Trafo LV" sxy:dir="vertical">
      <ConductingEquipment name="QA1" desc="Circuit Breaker" type="CBE" sxy:dir="vertical">
        <Terminal connectivityNode="AA1/H1/Q03/H1" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H1" />
        <Terminal connectivityNode="AA1/H1/Q03/H5" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H5" />
      </ConductingEquipment>
      <ConductingEquipment name="BU1" desc="Voltage Transformer 2 Sec. 3 Phase" type="VT" sxy:dir="vertical">
        <Terminal connectivityNode="AA1/H1/Q03/H1" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H6" />
      </ConductingEquipment>
      <ConductingEquipment name="TrafoLV" desc="Line In/Out" type="IFL" sxy:dir="vertical">
        <Terminal connectivityNode="AA1/H1/Q03/H6" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H6" />
      </ConductingEquipment>
      <ConductingEquipment name="B11.2" desc="Current Transformer" type="CTR" sxy:dir="vertical">
        <Terminal connectivityNode="AA1/H1/Q03/H3" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H3" />
        <Terminal connectivityNode="AA1/H1/Q03/H4" substationName="AA1" voltageLevelName="H1" bayName="Q03" cNodeName="H4" />
      </ConductingEquipment>
    </Bay>
  </VoltageLevel>
</Substation>
```
And mapping to physical devices

Physical Device

PISA_Q0_L3

Logical Device Q0_L3/
circuit breaker control
and protection

Logical Device B_L3/
buss bar control
and protection

This is the physical holder of the information at run-time.
We need an engineering system supported by standards

- Meta-language
- Naming scheme
- Library of building blocks
- Engineering rules
- Mapping to communication
- Communication protocols

Exchange format between peer engineering tools

Exchange format for configuration tools (engineering chain)
Some domains have standards…

IEC 61400-25: Communications for monitoring and control of wind power plants – Information exchange models

IEC 61850: Communication networks and systems for power utility automation

Part 1 to 9: Substations

Part 7 - 410: Hydroelectric power plants

Part 7 - 420: Distributed energy resources (DER)

IEC 61968-9: Common Information Model for distribution management

IEC 61970: Common Information Model for Energy Management System

of growing importance for smart grids, deregulated markets…

investment in object definition: over 1000 MY.
But there is still work to be done

Domain-specific models for continuous process, manufacturing, robotics… are required.

Some frameworks have been set up by:

• STEP (ISO 10303)
• CAEX (IEC 62424)
• ECSI (IEC 62264)
• AutomationML, …

Much more work is needed to populate models with domain-specific know-how
Sounds complex

Indeed, but for small plants we do not need the heavy tools

“Demos” are useless, we need solutions that scale.

This approach paves the way to pre-engineered parts of the plant.

Then we can forget the bus wars.

But let’s avoid the model war.

- even if all use UML, this does not mean they have the same understanding and layering (e.g. some mix static and dynamic engineering)

- there exist already models (e.g. FF, BacNet,...) that must be remodelled.

- working groups tend to develop with the models they understand, even UML is too complex for some (why can’t we use XML ?)
Conclusion

1) Industrial Ethernet takes over the horizontal communication between PLCs but the classical field busses do not disappear, Ethernet is just some more.

2) The Automation Network fight will continue on the wireless communication, market protection, technology evolution and obsolescence sustain diversity.

3) The basic communication methods are known, there is no point in inventing new protocols or marginal improvements to existing ones.

4) We do not really need more bandwidth since the process time constants and the speed of light did not increase much in thirty years. Costs is the issue.

5) The way out of the labyrinth is to go to the 3rd dimension and create domain-specific primary object models that allow to cope with diversity.

6) The mapping of these objects to the different communication schemes should be the task of every technology provider.

7) For this we need a theoretical framework for the modeling, a common understanding and education, and a lot of patient work by the domain experts.