Rethinking PLCs: INDUSTRIAL ETHERNET FOR LARGE-SCALE REAL-TIME DISTRIBUTED CONTROL APPLICATIONS

Birgit Plötzeneder on behalf of the ELI Beamlines CS Team
ELI: Distributed laser research infrastructure in Czech Republic, Hungary, Romania

User facilities, just under construction
Scope

Laser Building

Support Rooms
First Floor

- **L1** 100 mJ / 1kHz
- **L2** 1PW / 20 J / 10 Hz
- **L3** PW / 30 J / 10 Hz
- **L4** 10 PW / 1.5 kJ
- Cryogenic systems, power supply cooling, auxiliary systems

Lasers
Ground Floor

- **E1** Material & Bio-molecular Applications
- **E2** X-ray Sources
- **E3** Plasma Physics
- **L4c** Compressor
- **E4** ELIMAIA Ion Acceleration
- **E5** Electron and Photon Sources
- **E6**

Experimental Halls
Basement
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Python
Beckhoff
Xilinx
MTCA
B&R
Linux
TANGO

C++
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Python
WhiteRabbit
Beckhoff
Xilinx
MTCA
B&R
C++
LabVIEW
EPICS
MRF
Rockwell
Rethinking PLCs:
INDUSTRIAL ETHERNET FOR LARGE-SCALE REAL-TIME DISTRIBUTED CONTROL APPLICATIONS

Birgit Plötzeneder
on behalf of the ELI Beamlines CS Team
High Level CS

Linux

C++

TANGO

Languages like C++, Python,..
Classical servers, often virtualized OS
Middlewares like EPICS, TANGO..
SCADA

OPC

Custom: TCP/IP, libraries,....

- Common Bus (Profibus etc)
- Hardwired

PLCs in the field

Often: IEC 61131-3
Proprietary software
Small, isolated control nodes
(CPU + some modules, small
industrial Ethernet networks)
Slow process control
We like that PLCs are cheap, reliable, modular and fault-tolerant “hard” real time control solutions, even in challenging environments.

But:
- Not a lot of CS engineers can do C++, LabVIEW and PLC. **Multiple skillsets** have to be developed, SD environments maintained.
- **Interfaces are costly** (manpower) and often awkward.

=> PLCs are often almost standalone local control units with a thin connection to the main CS.
Multiple vendors opened their stacks because they want to extend their ecosystem and encourage companies to create new modules. We like Beckhoff (EtherCAT) and B&R (Powerlink).

2) Kick out the CPU, write an alternative master for instead, and distribute the stack over the entire facility network.

3) Profit.
How this looks in real life

Server Room

Random server (Linux RT)

Dedicated NIC

TANGO

Average span: 250m
Longest distance: 450m
Largest operational system: 40 sub-units

Modules are distributed over entire facility, connected to a dedicated fibre network*

*B&R has modules with LC connectors!
Dedicated, managed switches are best. We had some timeouts with cheap hardware.
How this looks in real life

Fieldbus-API
  - PowerLink
  - EtherCAT

Purpose: Control the bus Abstraction of stacks provided by Beckhoff + B&R

CS-IO
  - Motor
  - DIO
  - AIO
  - Communication
    - ...

Purpose: Implement typical modules

TANGO-Servers

LabVIEW Integration
Purpose: Integrate Into the facility
How this looks in real life

1) Set up physical hardware

2) Configure topology + registers with Automation Studio/System Manager

3) Fieldbus-API: Start (via TANGO Server) starts physical modules in the background

4) Fieldbus-API: Discover (via TANGO Server) returns collection of CS-IO modules (generates dynamic TANGO Attributes)

5) Commands: CSIO.dosomething, FieldBus.sync (in a loop)
Where are we now

1) Largest setup: Beamline with 40 modules, ca 250m span, 10ms cycle time

2) Laser Interfaces: Vacuum + MSS
   - Runs on National Instruments cRIO, ardwired signal exchange
   Install a B&R head inside their rack, connect fibre - done.
   New signal = just add a module.
Where do we want to go

This is a large-scale functional prototype, but not quite ready.

1) We want a TANGO Server for every module instead of dynamic attributes inside of one server.

2) We need to rework our top layer abstraction: We have nice generic motor / DIO /.. GUls and APIs. We haven't yet combined this with the fieldbus API. The end user shouldn't know what they are dealing with..

3) Performance: Limitations and performance has to be quantified more accurately.
Thanks for the attention!

Our team is hiring!

CS Engineers with C++/Linux

System Admin

...

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