OPC UA to DOOCS Bridge:

A Tool for Automated Integration of Industrial Devices into the Accelerator Control Systems at FLASH and European XFEL.

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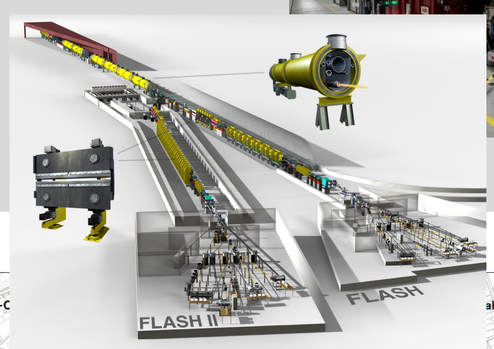
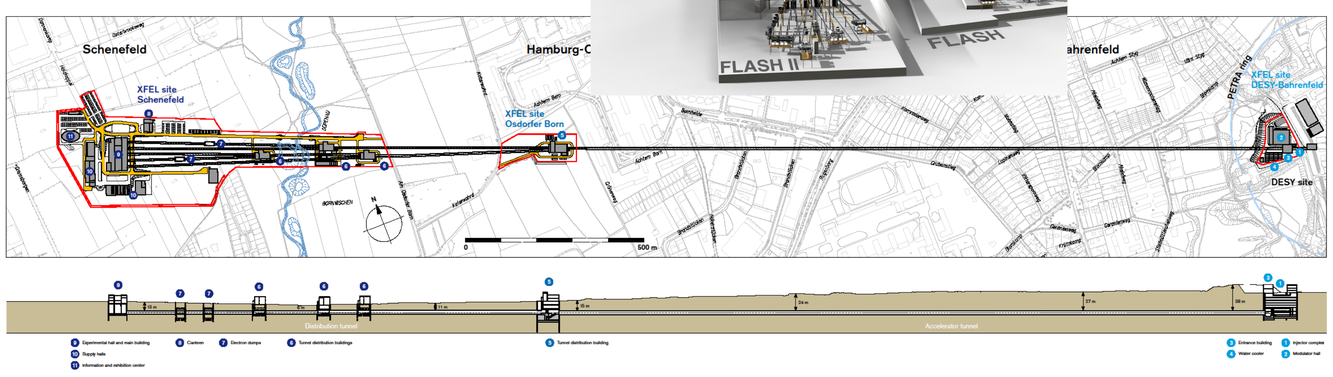
FLASH and European XFEL: Free-Electron Laser Facilities

- European XFEL: 3.4km
- FLASH: 300m
- DOOCS control system
  - 1000s of devices
  - 100s of computer nodes
- Devices are mix of
  - Commercial
  - In-house development
  - Collaborator's contribution



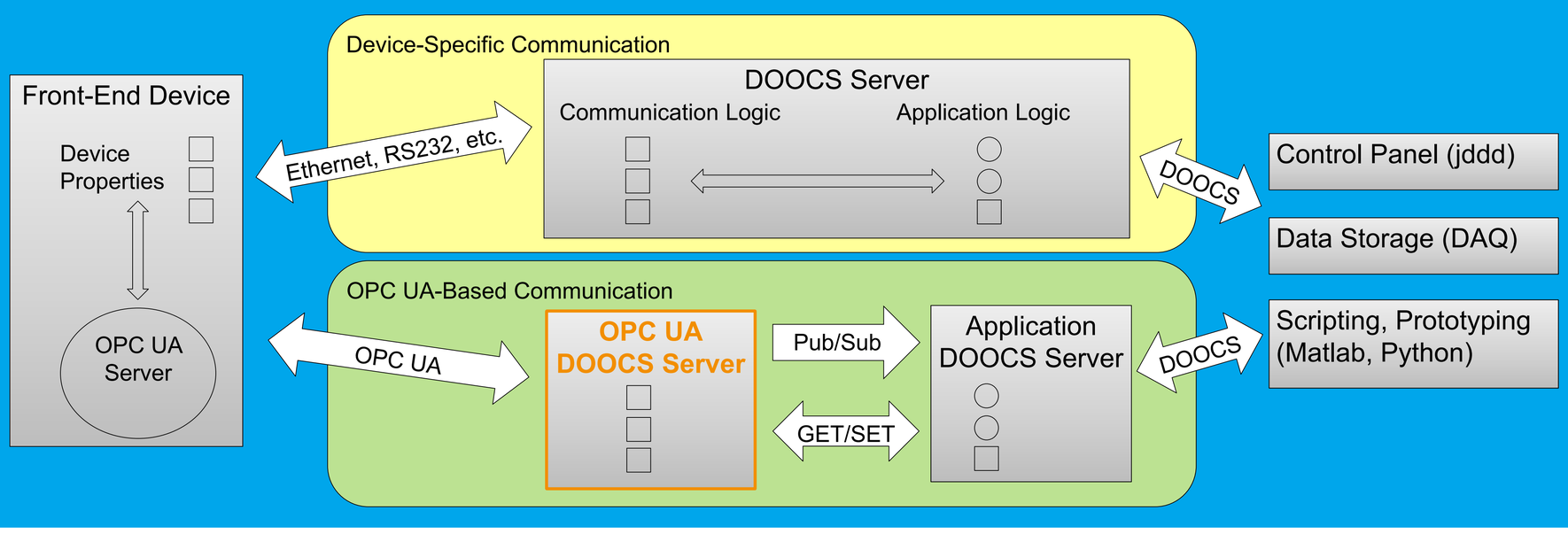


Open Platform Communication Unified Architecture (OPC UA)

A machine to machine communication protocol for industrial automation.

- Open - freely available and implementable without restrictions or fees
- Cross-platform - not tied to one operating system or programming language
- Focus on communicating with industrial equipment and systems for data collection and control
- Robust security (Encryption, Authentication)
- Integrated information model
- Service-oriented architecture (SOA)

OPC UA to DOOCS Server Architecture



Every new hardware needs a communication module implementing the device's protocol as part of its DOOCS integration.

By separating communication and application logic, the communication module can be device-agnostic and is reusable. The device's properties are dynamically generated and available as DOOCS properties.

1. PLC Programm with Objects, Variables, Methods

Written in Structured Text or other programming languages.

```
FUNCTION_BLOCK FB_Amp
VAR
    fbPower      : FB_Element;
    bError AT%Q* : BOOL;
END_VAR
FUNCTION_BLOCK FB_Element
...
VAR
    iValue AT%I* : INT;
    iPublicMin   : INT;
    iPublicMax   : INT;
END_VAR
```

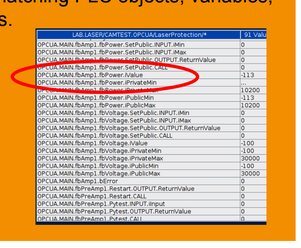
2. PLC Publishes OPC UA Information Model

Contains name/type information for objects, variables and methods.

```
OBJECT MAIN
  - OBJECT fbAmp1
      - OBJECT fbPower
        - VARIABLE iValue INT16
        - VARIABLE iPublicMin INT16
      - METHOD setPublic
          - INPUTARGUMENT iMin INT16
          - INPUTARGUMENT iMax INT16
          - OUTPUTARGUMENT returnValue
BOOL
    - OBJECT fbVoltage
    - VARIABLE bError BOOL
  - OBJECT fbPreAmp1
    - ...
```

3. DOOCS Properties Generated from Information Model

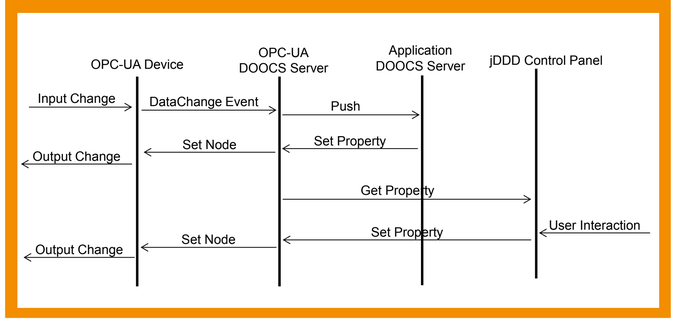
Types matching PLC objects, variables, methods.



4. jddd Control Panel

Objects, variables, methods integrated in control system, here displayed in user interface.

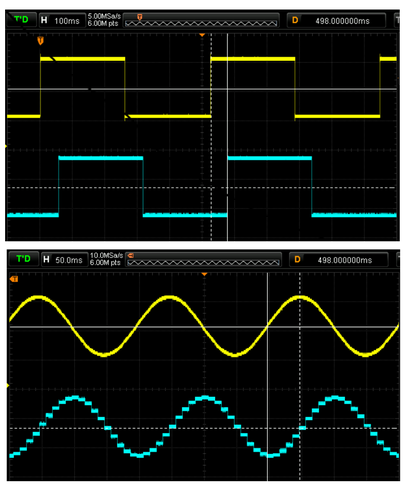
5. Event-Based OPC UA Communication

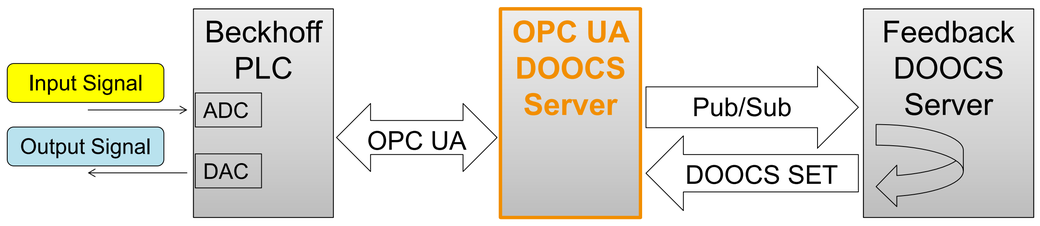


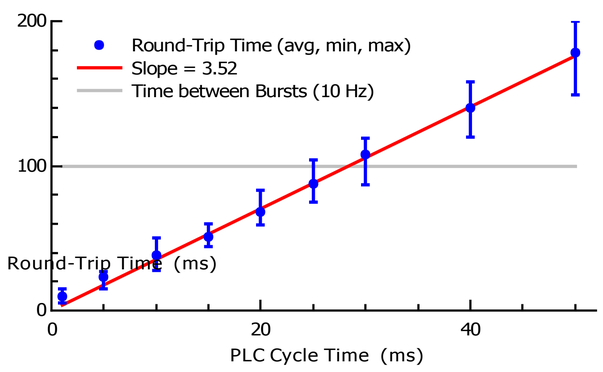
Performance Metrics

DOOCS-Based Feedback: Round-Trip Time vs. PLC Cycle Time

Digital and analog input signals.





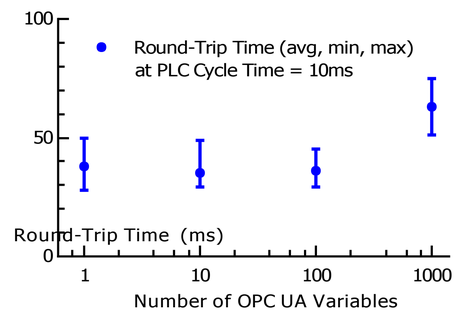


Test parameters:
- Beckhoff CX5140 PLC
- 2 Hz square input signal, sweep 0.2 Hz.
- Client update-period 1ms.
- Measure rising-edge delay between input and output signals.

Test results:
- Round-trip time is proportional to PLC cycle time in the measured range.
- 10 Hz feedback requires cycle time <= 20ms

Feedback: Behavior Under Load

Test parameters:
- Same set-up as before.
- Fixed PLC cycle time 10 ms.
- Changing number of 16bit variables that update with changing input signal.



Test results:
- Round-trip time remains constant until the system is „overloaded".
- System load with 1000 variables: ~70% CPU, ~13MB/s ethernet.

Conclusions:
- CPU load is the limiting factor for scaling.
- Code performance improvements might be possible.
- Using many small variables is a „worst-case" scenario. Arrays or other „large" variable types are more efficient.

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