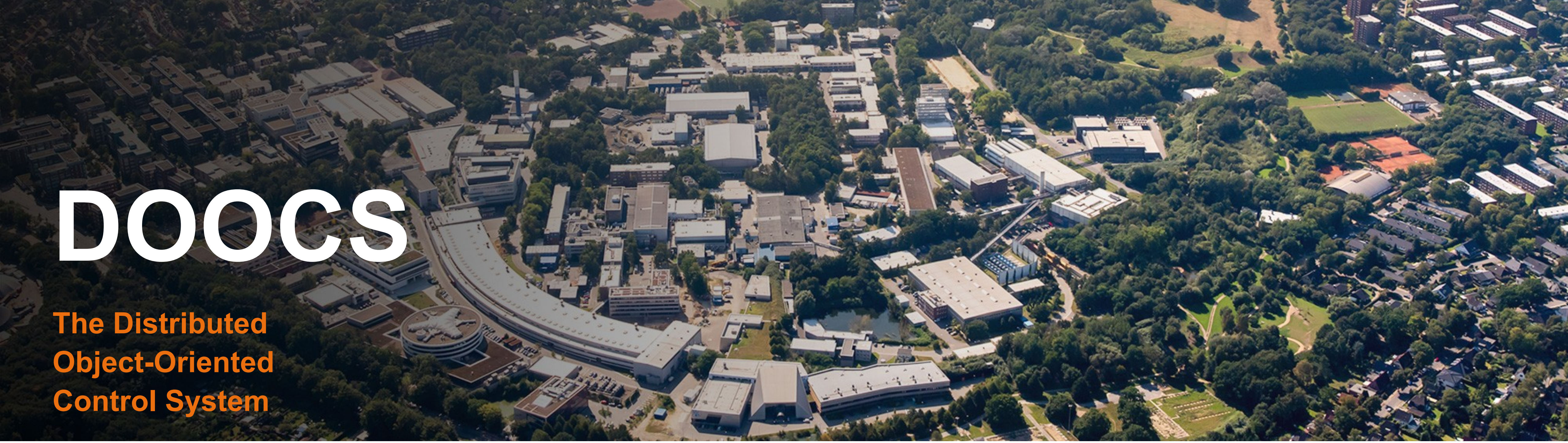

DOOCS

The Distributed Object-Oriented Control System

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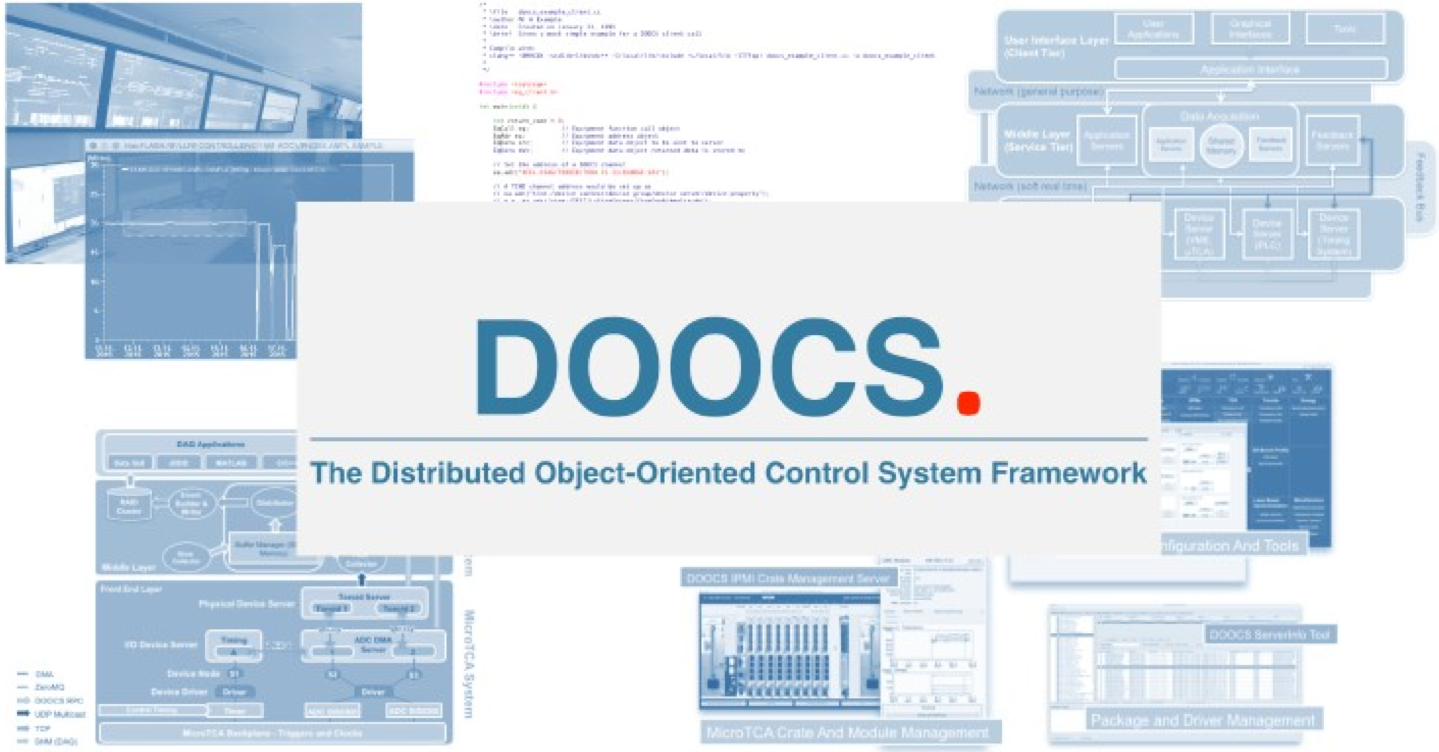
Hamburg, 4.9.2025

HELMHOLTZ

DESY.

Outline



DOOCS.
The Distributed Object-Oriented Control System Framework

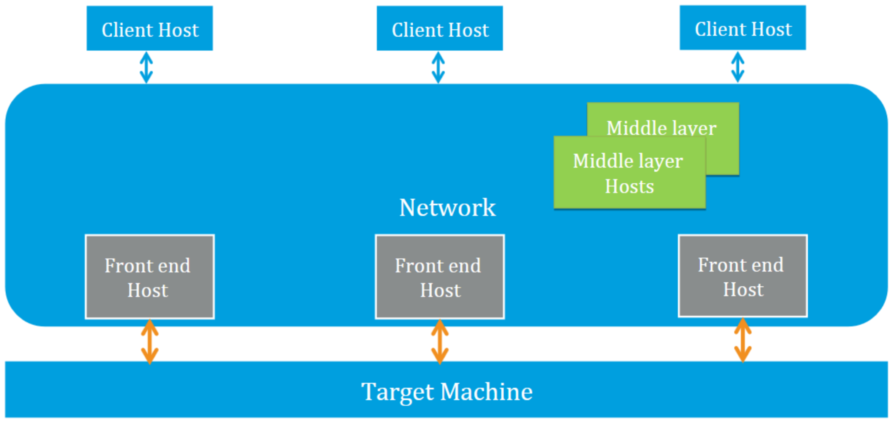
Basic concepts

Introduction

DOOCS - The Distributed Object-Oriented Control System

- Versatile **software framework** for creating accelerator-based **control system applications**
  - e.g. simple temperature monitoring, high-level controls, feedback of beam parameters
- Distributed **client-server architecture** combined with device-oriented view

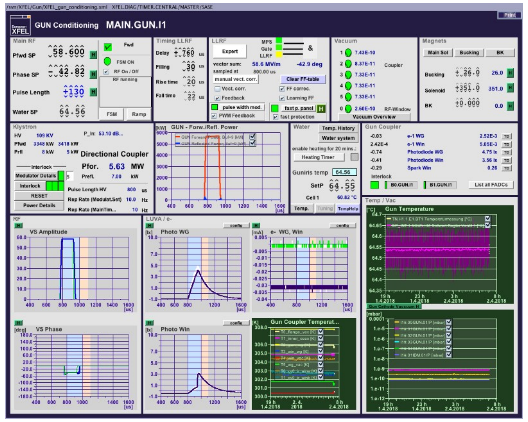
- **Control system parameters** are accessible via network calls
- Transportation layer based on **RPC/XDR** or **ZeroMQ** protocol
  - RPC: synchronous protocol, robust & efficient data transfer
  - ZMQ: independent layer, will replace RPC in the future

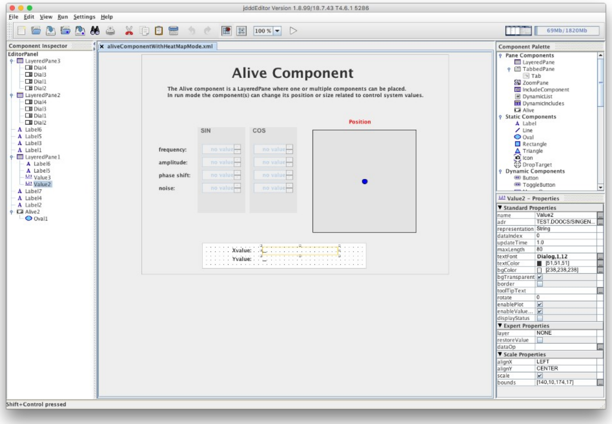


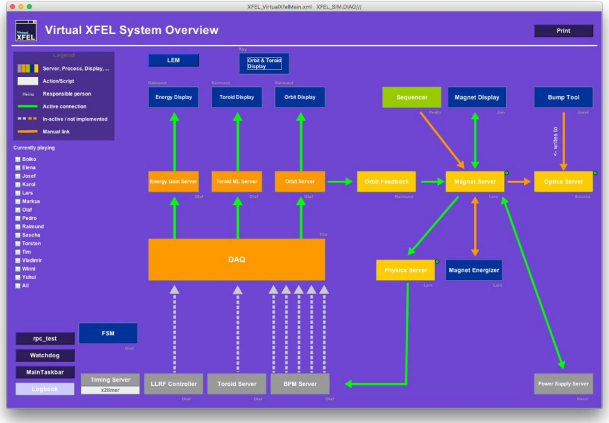
Introduction

DOOCS - The Distributed Object-Oriented Control System

- The DOOCS framework is written in **C++**
- Freely available under GNU GPL v2.1
- Libraries for client applications in **C++**, **Java**, **Python**, **MATLAB**, … exist
- **Graphical user interface** implemented as a lightweight Java application (JDDD)







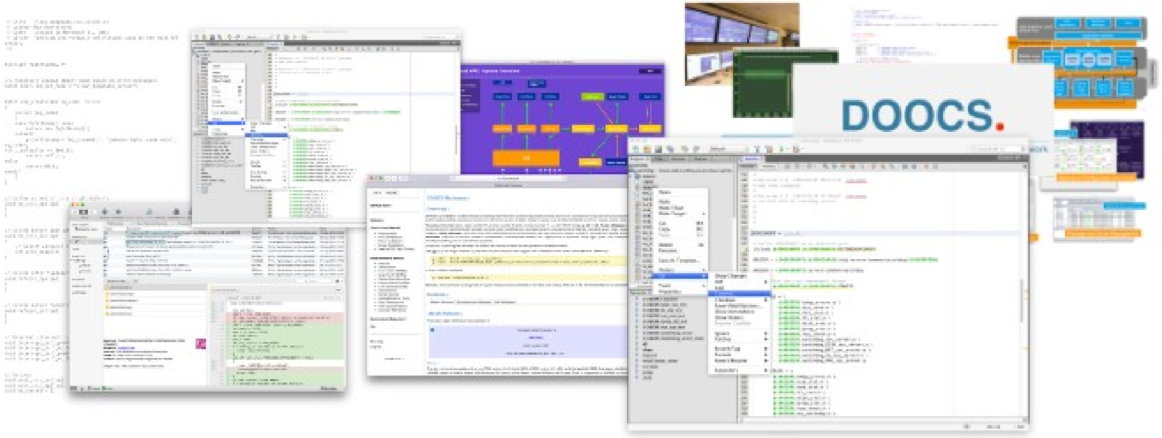
Development

- Stable DOOCS release about every **2 months**
  - Latest release version is v25.7
- **Nightly builds** for all platforms (DESY internal)
- Package repository for **Linux** (.deb) and **MacOS**

- Development on self-hosted **GitLab** instance
  - Heavy use of GitLab features like workflows, code reviews

- Uses **Meson** build system (only *doocs4py* uses CMake)
- Unit tests implemented with **catch2** framework

Basic Concepts



- Focus on operating particle **accelerator facilities**
- **Object-oriented** design paradigm → devices & data are objects

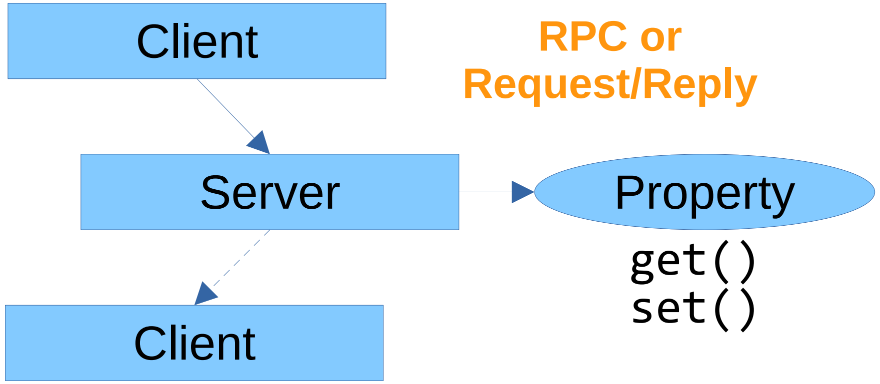
- Basic entity is a **device** → control system hardware or virtual logic
- Server application contains one or more **location** instances
- Each instance holds the **properties** of the (hardware/virtual) device
- Properties are access points to the communication network
  → represent **control system parameters**

- The **naming scheme** adheres to a four-string identifier: ***Facility / Device / Location / Property***

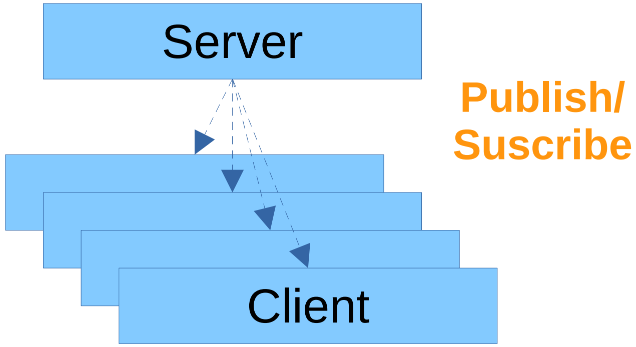
Server interfaces

Server interfaces

- Server core API implemented as **C++ library**
- Follows a **client-server** model
- **Multi-threaded** with update threads, interrupt handlers, …



- Network communication based on **RPC** with XDR data model
  - Additional interfaces (hardware, protocols) as separate libraries
- **ZeroMQ** protocol added in v24.1
  - Zero-broker message queue library
  - Request/Reply pattern → same functionality as RPC
  - Publish/Subscribe pattern → distribute data to subscribed clients

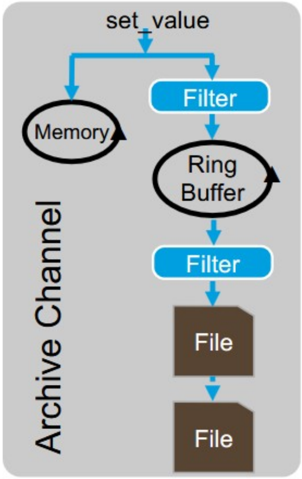


Server interfaces

- **Configuration** stored in local file, with **save & restore** functionality
- Locations & properties can be added/removed **on-the-fly**

- Extended **archiving** functionality
  - Histories stored locally on server, no network required
  - Access through regular server API

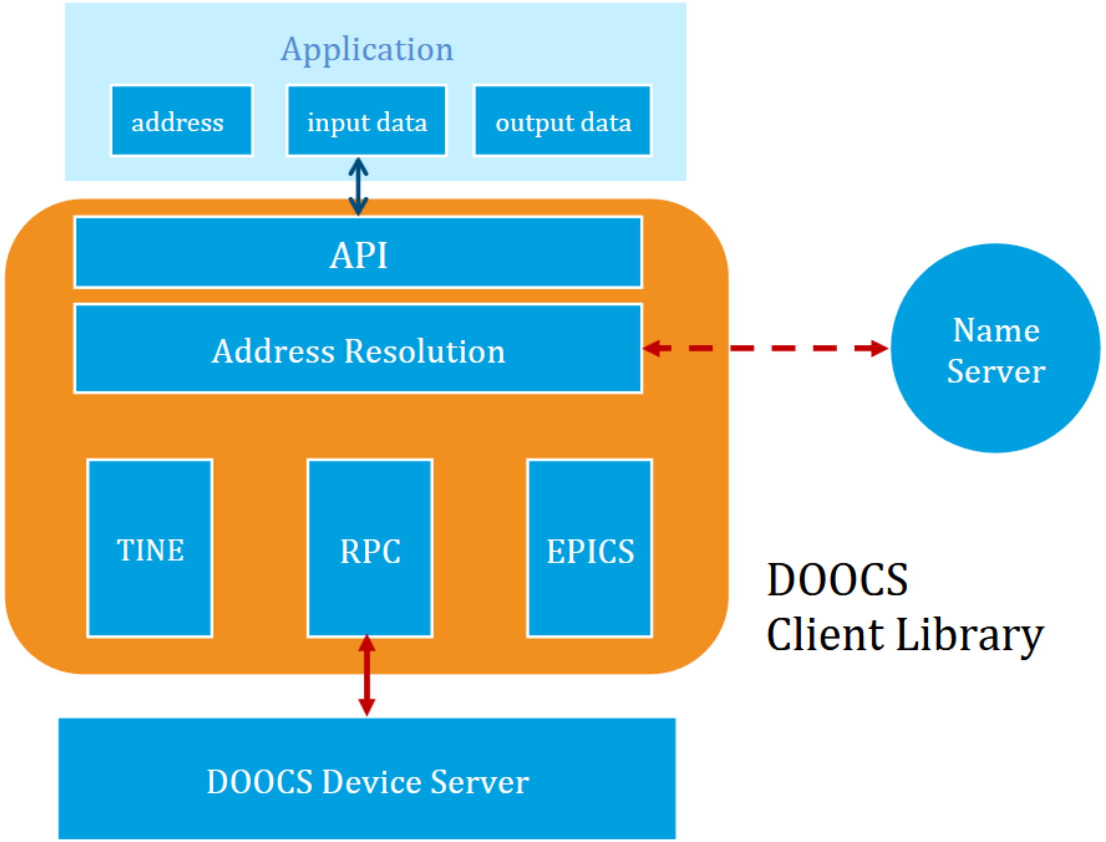
- Server **access authorization**
  - Basic access levels via UNIX user + group id lists (per server)
  - Fine-grained access control (on property level) via XML file



Client interfaces

Client interfaces

- Client API library written in **C++**
- Core features:
  - Unified addressing of **devices** & their **properties**
  - Universal **data** exchange independent of data type
  - Protocol-independent **access** to devices:
    RPC, ZMQ, TINE, EPICS
- DOOCS servers must be registered at dedicated **name server** for address resolution
- Some **high-level control** libraries exist in C++
  → provide commonly used features, similar approach as pyAML



Client interfaces – C++ API

- **EqCall** class
  - Represents client interface to DOOCS
  - **`get()`** + **`set()`** calls read/write device data on server
  - **`names()`** call to retrieve list of devices/locations/properties
  - Updates (reads) in background loop through **`get_monitor()`**
  - With ZeroMQ: asynchronous **`subscribe()`** / **`unsubscribe()`**
- **EqAdr** class
  - Parameter address, allows DOOCS/TINE/EPICS schemes
- **EqData** class
  - Main class to implement all DOOCS data types + getters/setters
  - Stores additional info like timestamps, error codes

```cpp
#include <iostream>
#include <eq_client.h>

int main(void) {

    int return_code = 0;
    EqCall eq;          // Equipment function call object
    EqAdr ea;           // Equipment address object
    EqData src;         // Equipment data object to be sent to server
    EqData dst;         // Equipment data object returned data is stored to

    // Set the address of a DOOCS channel
    ea.adr("XFEL.DIAG/TOROID/TORA.25.I1/CHARGE.SA1");

    // A TINE channel address would be set up as
    // ea.adr("tine:/device context/device group/device server/device property");
    // e.g. ea.adr("tine:/TEST/LxSineServer/SineGen0/Amplitude");

    // And an EPICS channel as
    // ea.adr("epics://host_ip/epics_channel_name")
    // e.g. ea.adr("epics://my_epics_ioc/test:sine");

    // Make the call
    return_code = eq.get(&ea, &src, &dst);

    if (return_code) {
        std::cout << "Error code: " << dst.error() << std::endl;
    } else {
        std::cout << "Data is: " << dst.get_string() << std::endl;
    }

    return 0;
}
```

Client interfaces – C++ API

- Supported data types:
  - Simple **scalars**:
    BOOL, SHORT, USHORT, INT, UINT, LONG, ULONG, FLOAT, DOUBLE
  - Compound scalars:
    IIII (= 4x INT), *IFFF* (= INT + 3x FLOAT), *TTII, USTR, XY, XYZS,*
    IMAGE, SPECTRUM, GSPECTRUM
  - Scalar **arrays**:
    A_BOOL, A_SHORT, A_USHORT, A_INT, A_UINT, A_LONG, A_ULONG,
    A_FLOAT, A_DOUBLE, STRING, TEXT, XML
  - Compound arrays:
    A_USTR, A_XYZS, A_BYTE, A_XY
  - Multi-dimensional arrays:
    MDA_FLOAT, MDA_DOUBLE
  - **Structured** data

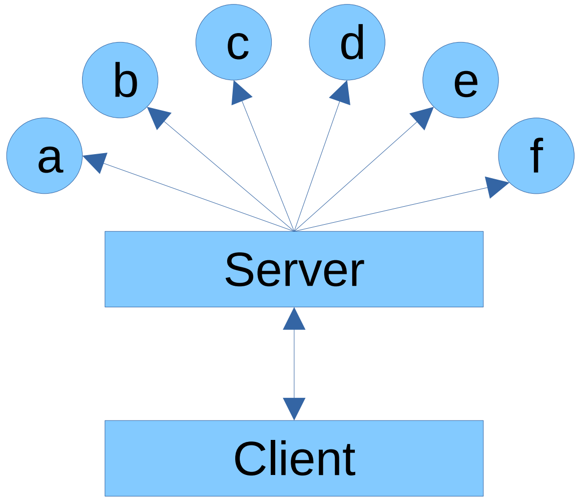
Client interfaces – Python API (doocs4py)

DOOCS4PY.

- **doocs4py** is a new approach to Python 3 bindings
  - Older implementation exists with PyDOOCS → *not covered here*
- API to write **clients** and **servers** with a single library
- Attempts to *completely* wrap the client & server API
- Direct interface to EqCall, EqAdr, EqData classes
- Supports all calls as **wrappers** to C++ methods:
  `get()` `set()` `names()` `get_monitor()` `subscribe()`
- Allows to write & run purely-Python server classes

```python
from doocs4py import set, get, names
from doocs4py.types import IIII

# --- names --- request names from doocs domain

location_list=names("TEST.DOOCS/UNIT_TEST_SUPPORT/*") # Make a list of locations
property_list=names("TEST.DOOCS/UNIT_TEST_SUPPORT/DOOCS4PY/*") # Make a list of properties

# --- set --- sets data to a Property from the server

set("TEST.DOOCS/UNIT_TEST_SUPPORT/DOOCS4PY/BOOL", False) # Set the value

#For scalar data types, the value can be set directly. For more complex data types, the type object must be created first.
#There is no need to create the data object first, it is created automatically when the value is set.

my_iiii = IIII(1, 2, 3, 4) # Create an object
set("TEST.DOOCS/UNIT_TEST_SUPPORT/DOOCS4PY/IIII", my_iiii) # Set the value in the property

# --- get --- Gets the data object from a Property from the server

my_bool = get("TEST.DOOCS/UNIT_TEST_SUPPORT/DOOCS4PY/BOOL") # Get the Data object
back_iiii = get("TEST.DOOCS/UNIT_TEST_SUPPORT/DOOCS4PY/IIII") # Get the Data object
print(f"my_iiii: {back_iiii.value.get_data()}") # Print the data stored in the object
print(f"my_bool: {my_bool.value}") # Print the value stored in the object
```

Special feature: Wildcard in addresses



- DOOCS does not support full **async/await** mechanism for calls
- However, one can use **star operations** (wildcards) in addresses:

  `PETRA/BPM/*/ORBIT`
- In this case, all locations/proprties are evaluated on the **server side**
- Aggregated results are returned to client in a **single data transfer**

- This only works for `get()` calls
- Not possible to `set()` variables at different addresses simultaneously

Single device server

Facility / Device / Location / Property

- Asynchonuous call feature is planned for a future release!

Comparison to TANGO and EPICS

- DOOCS implements **device servers**
- Most DOOCS calls are **synchronous**
- **LDAP** name service to locate servers by DOOCS address
- Similar n**aming scheme** to TANGO: Facility / Device / Server / Property
- **TANGO** uses broker system as name/communication service
- **EPICS** traditionally uses internal database (IOC)
  - Modern Process Variable Access similar to DOOCS
- DOOCS supports direct communication with EPICS servers
- Structured data in DOOCS is compatible with EPICS

Summary

- DOOCS is a **control system framework** for accelerators
- Written in **C++**, interfaces to **Python** / Java / MATLAB
- **Client-server** model with **devices** as main entities
- Device **properties** reflect control system **parameters**

- Network communication over **RPC**+XDR or **ZeroMQ**
- Most calls are **synchronous**
- ZeroMQ adds publish/subscribe mechanism

- **doocs4py** is the new interface for Python 3

Thank you.

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- **Original paper of the overall DAQ concept (slightly out-of-date):**
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