A C++ wrapper for HDF5

A new approach to an old problem

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HELMHOLTZ
ASSOCIATION

DESY

Motivation

Why C++?

- High performance
- No garbage collection due to destructors
- Type safety due to static typing
- Highly portable

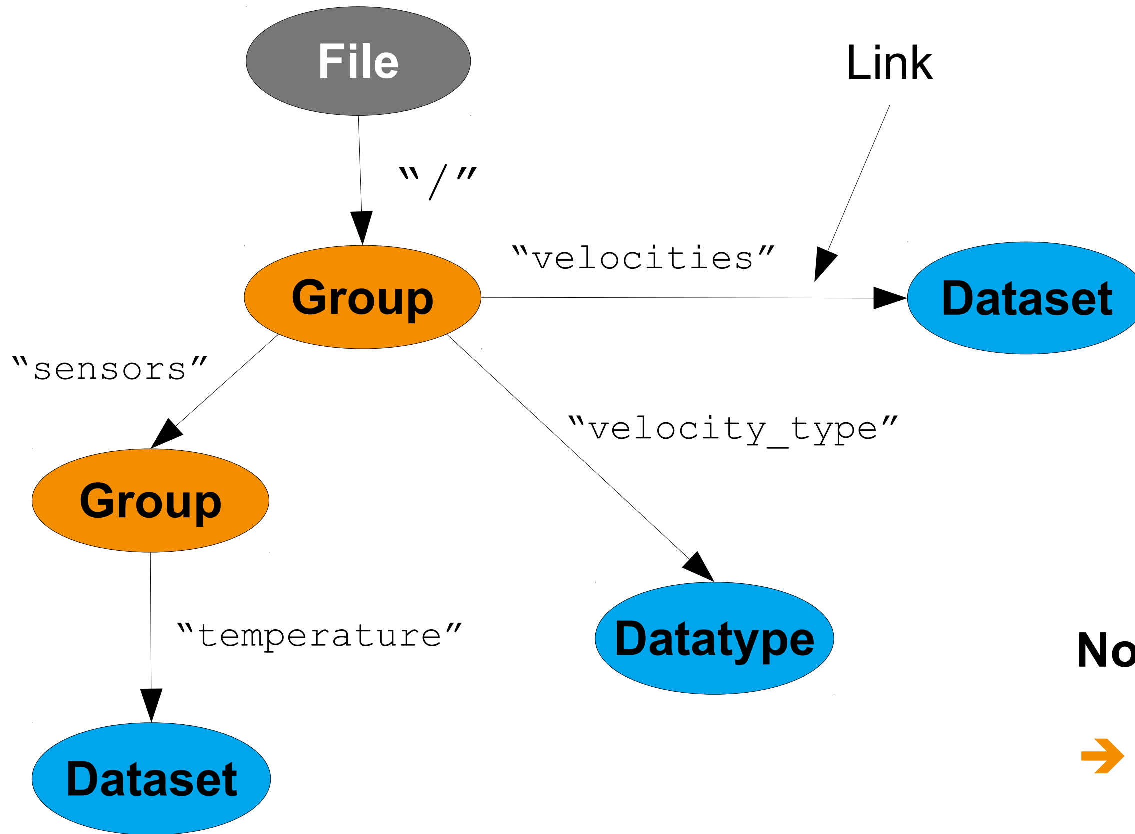
Why a new C++ wrapper?

- The current implementation is not complete
- Current wrapper is standard C++ 2003 at best
- The HDF group has to remain a stable interface for their contractors
- Not STL compliant

Design goals

- Complete functionality (on the long run)
- **STL compliant interfaces**
- Easy to use (*keep simple things simple and make complex possible*)
- High performance
- Supported platforms: Windows, Linux, macOS
- **Avoid handler leaks**
- **Easy to extend** (user defined data types while keeping type safety)
- **Preserve the access history of an object**
- Provide facilities for signal handling
- Keep thread safety in mind

A very high level view on HDF5



Nodes:

- **Group**
- **Dataset**
- **Commited Datatype**

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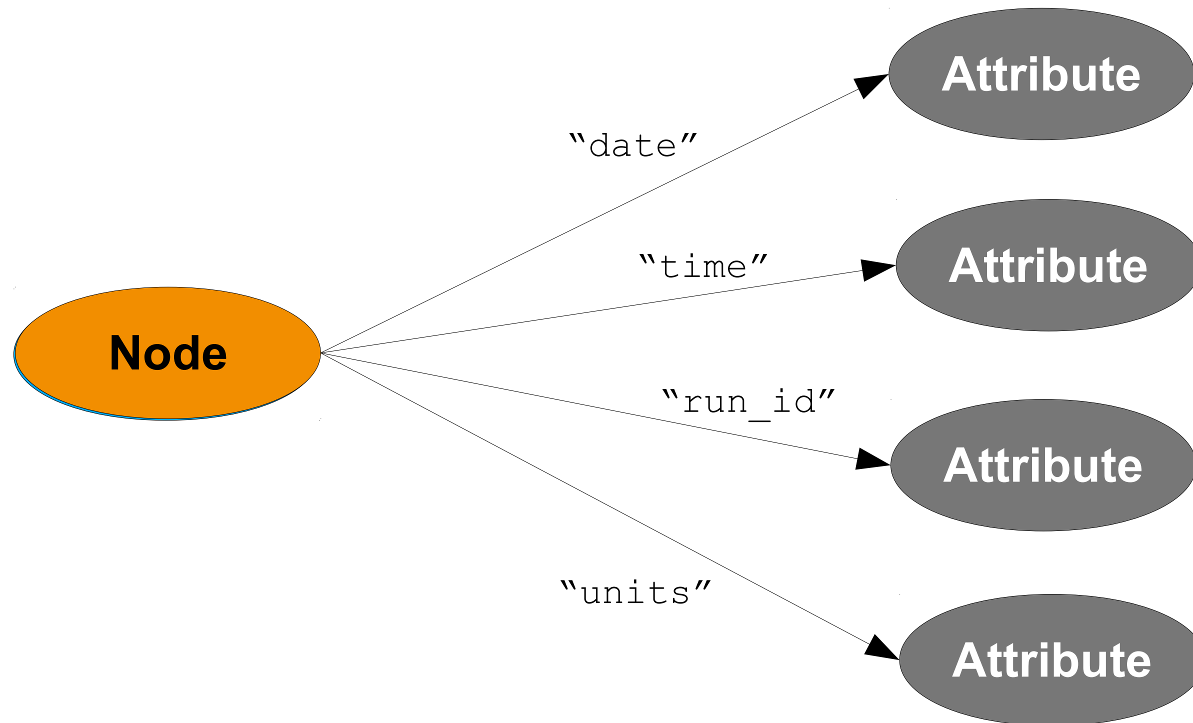
Adding metadata with attributes



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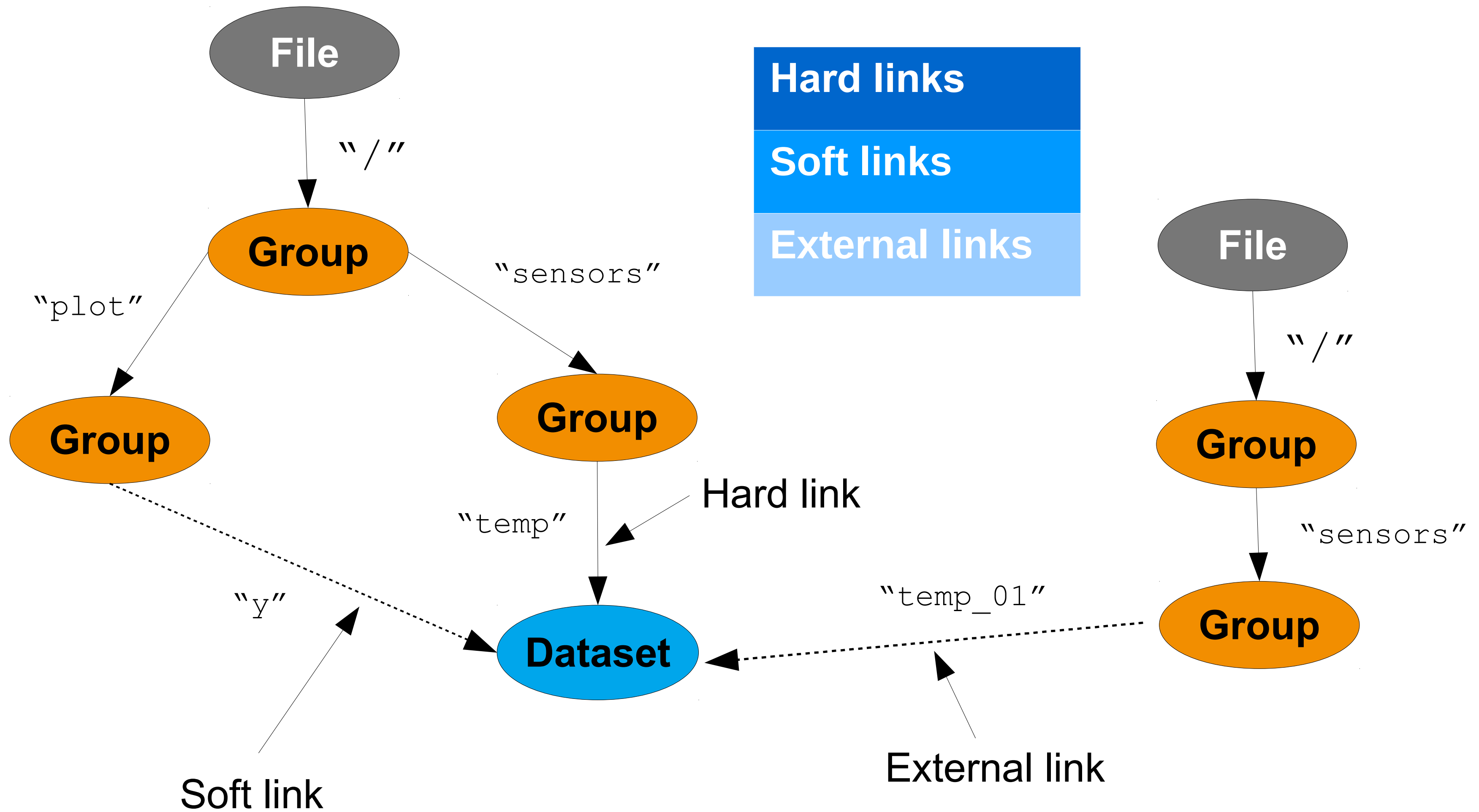
Three kinds of links



A node path

Path := a ‘/’ separated *list* of *link names* used to access a particular node

File

"/"

The root group link has the special name ‘/’

Group

"plot"

"sensors"

Path = /plot

Group

Group

Hard link

"temp"

Dataset

Path = /sensors/temp

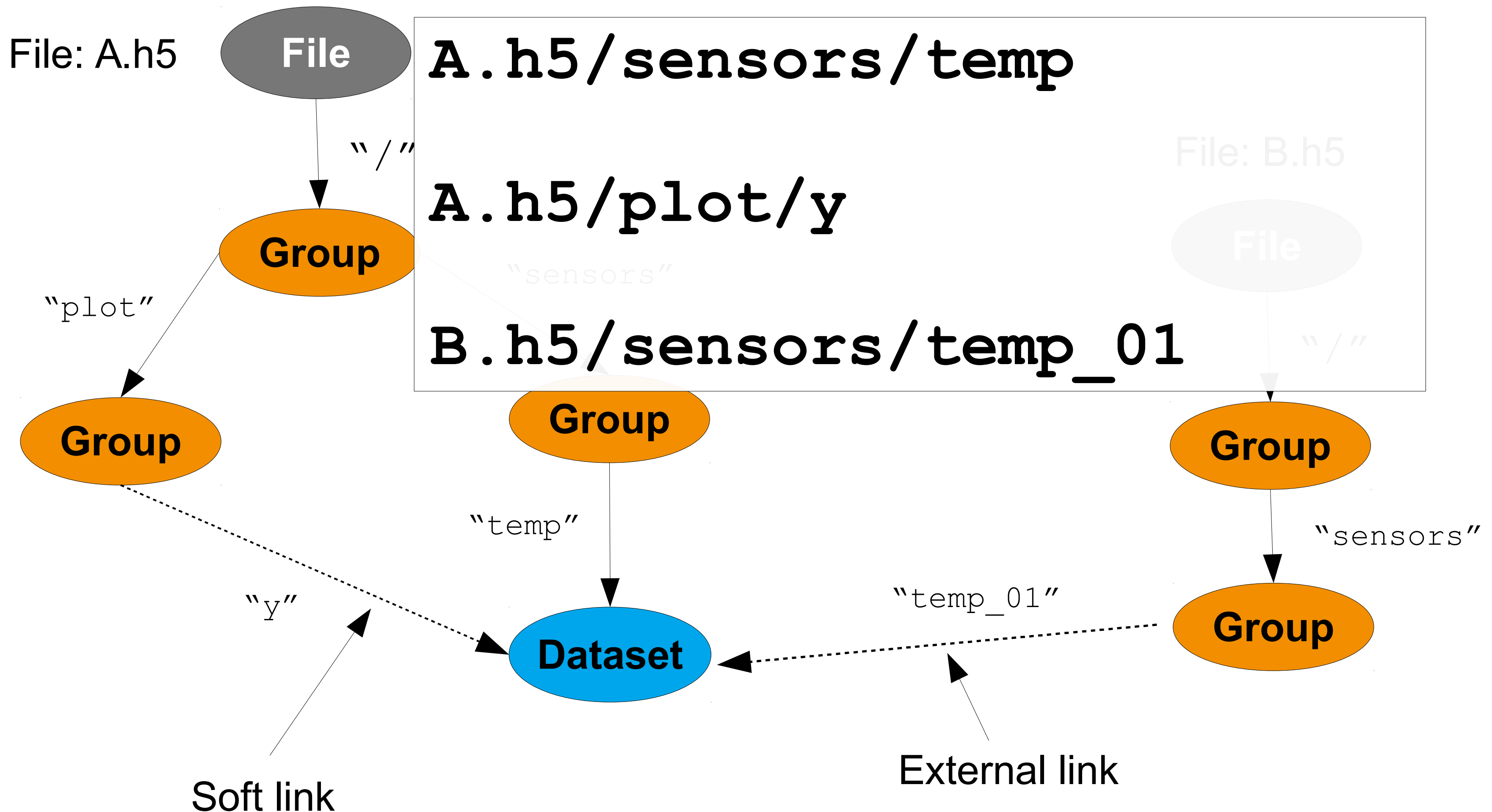
Every node can be accessed by following the links mentioned in its path!

We end up with two problems

I. What's the path of a node?

II. How to avoid accessing a node multiple times during iteration?

The name problem – whats the name of the dataset?



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The name problem – its getting worser!

There is not solution:

all three names are equally valid and can be used to access the same object!

Consequences:

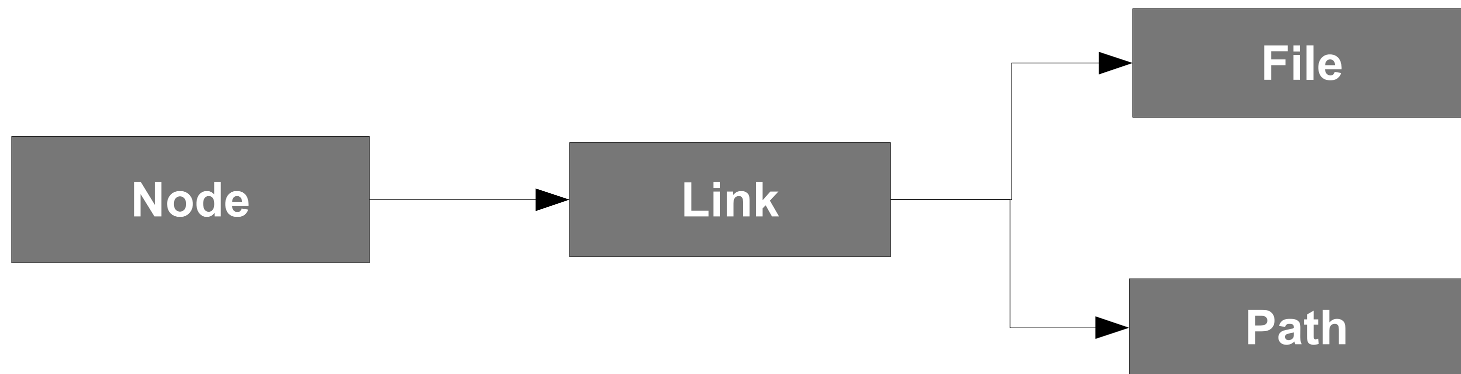
1) We cannot ask a node for its path!

2) Thus we cannot ask a node for its parent!

3) A path does not uniquely identify an object!

The name problem – a pragmatic solution!

- When asking a node for its path we expect to get the path used to access the node
- When asking for the nodes parent we expect to get the top level group of the final link used to access the object



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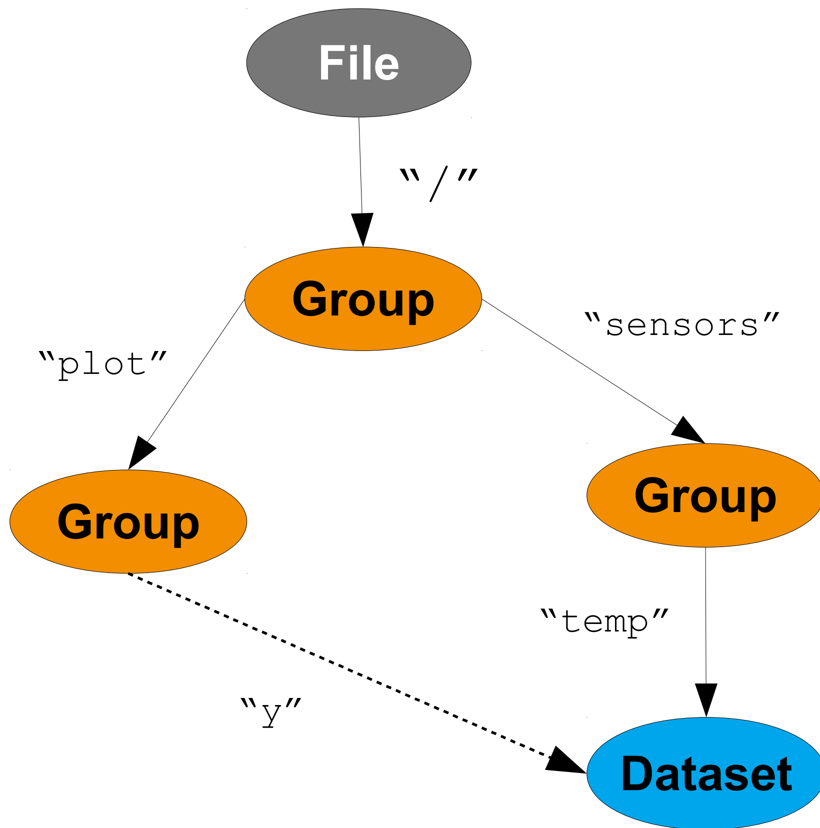
The unique ID problem



When iterating recursively over all nodes in below the root group we get two references to the same dataset!

1) /sensors/temp

2) /plot/y

This is bad!

DESY

The ObjectId class

```
namespace hdf5 {
namespace node {

class DLL_EXPORT Node
{
  public:

    Node(ObjectHandle &&handle,const Link &link);
    Node();
    Node(const Node &);
    Node &operator=(const Node &node);
    virtual ~Node();

    Type type() const;

    ObjectId id() const;

    explicit operator hid_t() const
    {
      return static_cast<hid_t>(handle_);
    }

    bool is_valid() const;
    const Link &link() const;
    attribute::AttributeManager attributes;

  private:
    ObjectHandle handle_; //!< access handle to the object
    Link link_;           //!< stores the link to the object
};

DLL_EXPORT bool operator==(const Node &lhs, const Node &rhs);
DLL_EXPORT bool operator!=(const Node &lhs, const Node &rhs);

} // namespace node
} // namespace hdf5
```

```
namespace hdf5
{

class ObjectId
{
  public:
    ObjectId();
    ObjectId(hid_t object);

    bool operator== (const ObjectId& other) const;
    bool operator!= (const ObjectId& other) const;
    bool operator< (const ObjectId& other) const;
    …
  private:
    …
};
}
```

ObjectId **allows to uniquely identify an object within a program context!**

Avoiding handler (hid_t) leaks

```
namespace hdf5
{
class DLL_EXPORT ObjectHandle
{
  public:
    enum class Type {…};

    enum class Policy
    {
      WITH_WARD = 1,
      WITHOUT_WARD = 2
    };
  private:
    hid_t handle_; //!< ID of the object

    void increment_reference_count() const;
    void decrement_reference_count() const;
  public:
    explicit ObjectHandle(hid_t id,Policy policy=Policy::WITH_WARD);
    explicit ObjectHandle() noexcept;
    ObjectHandle(const ObjectHandle &o);
    ObjectHandle(ObjectHandle &&o) noexcept;
    ~ObjectHandle();

    ObjectHandle &operator=(const ObjectHandle &o);
    ObjectHandle &operator=(ObjectHandle &&o) noexcept;

    explicit operator hid_t() const
    {
      return handle_;
    }

    void close();
    bool is_valid() const;
    ObjectHandle::Type get_type() const;
    int get_reference_count() const;
    ObjectHandle get_file() const;
};
} // namespace hdf5
```

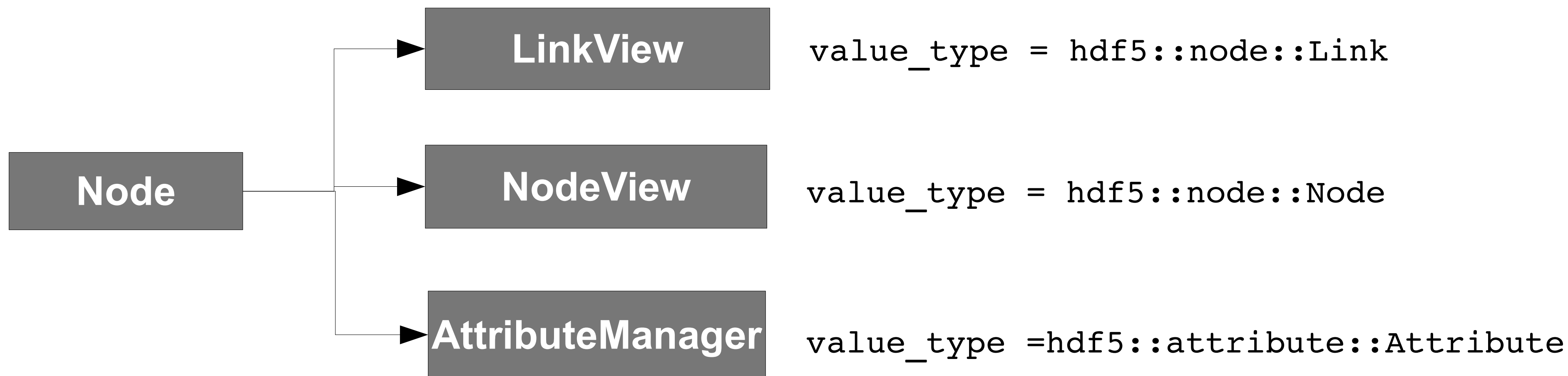
- Access to an object in HDF5 is provided via a handler (hid_t)
- When handlers are not closed the file an object belongs to is not closed

=> very hard to debug failures!

ObjectHandle **is a guard object which ensures that a handler gets destroyed whenever it looses scope!**

STL compliance

We want to use all the algorithms provided by the STL to search through an HDF5 tree.



The LinkView interface

```
namespace hdf5 {
namespace node {

class Node;
class NodeIterator;

class DLL_EXPORT NodeView : public GroupView
{
  public:
    using value_type = Node;
    using const_iterator = NodeIterator;

    NodeView() = delete;
    NodeView(const NodeView &) = default;
    NodeView(Group &node);
    ~NodeView();

    Node operator[](size_t index) const;

    bool exists(const std::string &name,
                const property::LinkAccessList &lapl =
                property::LinkAccessList()) const;

    Node operator[](const std::string &name) const;

    const_iterator begin() const;
    const_iterator end() const;
};

} // namespace node
} // namespace hdf5
```

```
namespace hdf5 {
namespace node {

class DLL_EXPORT NodeIterator : public Iterator
{
  public:
    using value_type = Node;
    using pointer = value_type*;
    using reference = value_type&;
    using difference_type = ssize_t;
    using iterator_category = std::random_access_iterator_tag;

    NodeIterator() = delete;
    NodeIterator(const NodeIterator&) = default;
    NodeIterator(const NodeView &view,ssize_t index);

    explicit operator bool() const
    {
      return !(index()<0 || index()>=view_.get().size());
    }

    Node operator*() const;
    Node *operator->();

    NodeIterator &operator++();
    NodeIterator operator++(int);
    NodeIterator &operator--();
    NodeIterator operator--(int);

    NodeIterator &operator+=(ssize_t i);
    NodeIterator &operator-=(ssize_t i);
    bool operator==(const NodeIterator &a) const;
    bool operator!=(const NodeIterator &a) const;

  private:
    std::reference_wrapper<const NodeView> view_;
    Node current_node_;

};

} // namespace node
} // namespace hdf5
```

Examples

Where are we today – what is implemented

- Classes for virtually all property lists
- File class
- Attribute facilities are complete
  - Attribute
  - AttributeManager
  - AttributeIterator
- Node classes
  - Dataset (currently no partial IO)
  - Group
  - NodeView
  - LinkView
- Datatype
  - Integer
  - Float
  - Compound
- Dataspace
  - Scalar
  - Simple
- Utility classes
  - Path
  - ObjectHandle
  - ObjectId

Todo

For the first milestone 0.0.1

- Link creation functions
- Partial IO for Datasets
- String Datatype (in all favors)

In general

- Documentation update (user manual)
- Implement better error management
- Signal handling support
- Test coverage
- Utility functions to access nodes and links

Collaboration

EUROPEAN
SPALLATION
SOURCE

- ➔ **Martin Shetty**
- ➔ **Jonas Nilsson**

Science & Technology Facilities Council
ISIS

- ➔ **Matthew Jones**

Github Project of the HDF5 C++ wrapper