High-performance scalable Information Service for the ATLAS experiment

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1. The ATLAS Online Monitoring System

The Atlas experiment

ATLAS is one of the four major experiments in the Large Hadron Collider accelerator at CERN.

The ATLAS Trigger/DAQ System

The ATLAS Data Acquisition (DAQ) system transports event data from the 1600 detector read-out links to the mass storage.

The ATLAS Online Monitoring System

The Online Monitoring system is responsible for real-time checking of the full spectrum of operational conditions of the ATLAS data taking, including physics events analysis and data quality assessment. Online Monitoring system is operating in highly-distributed multi-partition computing environment.

The ATLAS Information Service

The core of the Online Monitoring system is the Information Service which provides highly-scalable, fast, distributed persistent information storage for all the varieties of the online monitoring information in the ATLAS experiment.

The ATLAS TDAQ system consists from about 10000 processes, each of them publishing some information to the IS. The minimal information, which is published by any single process reflects the process' state. In addition to that many applications are publishing quite a few additional information objects which represent for example the status of the hardware those processes are controlling or the quality of the collected physics data. In the end the total amount of information available in the IS for an average data taking session is at the order of few tens Gigabytes. This information is periodically updated with the update period varying from 5 to 100 seconds for different information types.

2. The Information Service

The Information Service Design

The Information Service is using the client-server architecture with the Information Repository acting as a server to hold information provided by ATLAS software applications. Currently the Information Repository is implemented by a number of processes, called IS Servers, which are distributed over several computing nodes in a location transparent way. Each server has a unique identifier, which a client application is using to communicate with this server.

The IS Communication Model

Information Providers can add information to the IS repository as well as update or delete already existing information. Information Readers can retrieve the value of an information from the repository while Information Subscribers can subscribe for the repository to be notified about any changes in it. Each time Provider creates, updates or deletes an information the Subscriber will be informed.

The Object Identification

Each information object has a unique name in the IS repository. In the current implementation, the name is a character string which must have the following format:

InformationName::=ServerName<.>ObjectName

The IS Meta-Information

The Information Service implementation provides access to the description of the information object classes at run-time as well as allows manipulating information whose type is not known at compilation.

The Inter-process Communication Technology

The actual IS implementation is based on the Common Object Request Broker Architecture (CORBA) standard. The C++ implementation is done on top of the omniORB CORBA broker and Java implementation is using the JacORB one. However both C++ and Java IS APIs are fully independent of the underlying communication layer, thus allowing to change to a different communication technology without affecting the IS client applications.

The IS API

The IS Application Program Interface (API) is available in C++, Java and Python.

3. IS C++ API

```
ISInfoDictionary d;

// Create the instances of the information to IS
// that will be published, and initialize them
ISInfoInt voltage( 220 );
ISInfoFloat temperature( 22.3 );

// Publish information to the MyServer IS server
d.checkin( "MyServer.MyDeviceVoltage", voltage );
d.checkin( "MyServer.MyDeviceTemperature", temperature );
```

Publishing Simple Information to IS

```
ISInfoDictionary d;

// Create the instances of the information
// that will be published, and initialize them
ISInfoInt voltage;
ISInfoFloat temperature;

// Read information from the MyServer IS server
d.getValue( "MyServer.MyDeviceVoltage", voltage );
d.getValue( "MyServer.MyDeviceTemperature", temperature );
```

Reading Simple Information from IS

```
ISInfoDictionary d;

// Declare arbitrary information object
ISInfoDynAny any;

// Read information from the MyServer IS server
d.getValue( "MyServer.MyDevice", any );

// Extract attributes values by their position
int voltage = any.getAttributeValue<int>(< 0 );
float temperature = any.getAttributeValue<float>(< 1 );
std::vector<ISInfoDynAny> connected = any.getAttributeValue<std::vector<ISInfoDynAny>> (< 2 );
```

Reading Arbitrary Information from IS

```
class Device: public ISInfo {
public:
    int voltage;
    float temperature;
    std::vector<std::string> logs;

private:
    void publishGuts(ISostream & out) {
        out << voltage << temperature << logs;
    }
    void refreshGuts(ISistream & in) {
        in >> voltage >> temperature >> logs;
    }
};
```

Declaring complex Information Class

```
ISInfoDictionary d;

// Create the instances of the information
// that will be published, and initialize them
Device device;
device.voltage = 220;
device.temperature = 22.3;

// Publish information to the MyServer IS server
d.checkin( "MyServer.MyDevice", device);

// Information value is being changed
d.logs.push_back("Device is connected");

// Inform IS about information changes
d.checkin( "MyServer.MyDevice", device );
```

Working with Complex Information

4. WWW interface for IS

Web IS provides generic WWW interface to the Information Service. Each object in IS has a unique URL associated with it, e.g.:

<https://atlasop.cern.ch/info/current/ATLAS/is/RunParams.RunParams>

A GET request for such URL returns the value of the respective IS object in XML format.

This is a generic facility which is used to construct complex WEB based GUIs using CSS, JavaScript, Java applets, standalone Java applications.

For histograms the Web IS interface can do the rasterization of images using the ROOT libraries and return those in a number of standard formats (PNG, JPEG, GIF, SVG, etc.). Therefore there is no need for any HEP specific software on the client machine. This design allows users to present the information they are interested in their preferable form.

The latency to access an item is determined by the HTTP access, typically in the order of 100 ms if one is outside of CERN. There are limits on the maximum number of concurrent requests, enforced by the servers to control the load on the online monitoring system, which might impact data taking.

5. IS Streaming and Remote Monitoring

IS Streaming

IS provides the Streaming functionality. This feature streams all changes in the information held by the main IS to the secondary service, which is running in the CERN Global Public Network. The streaming works in real-time mode, thus assuring that the information content is properly synchronized at any given moment. The average time for mirroring an information item is at the order of a few microseconds.

Remote Users

Any ATLAS member who has an active Remote Shifter role, can open X (NX) session on one of the "ATLAS Remote Monitoring" nodes and run the same GUI displays as in the ATLAS Control Room. Those GUIs will be taking information from the IS Mirror with no impact on the data taking activity per se.

Scalability

This approach scales to a very large number of remote users by simply adding extra levels of the information mirroring. The information from the "Primary IS mirror" service can be streamed to the "Secondary IS mirror", which in turn can stream to the "Tertiary IS mirror", etc.

6. IS Performance measurements

A performance analysis of IS was conducted on the same standard hardware that was used by the ATLAS online infrastructure for the physics data taking. The IS server was running on a host with two 4-core Intel Xeon E5420 CPUs.

Message delivery rate was measured for IS, Qpid and ActiveMQ. The delivery rate is the sum of messages received by the subscribers per second.

All systems have been tested in saturation mode, i.e. when maximum delivery rates was reached. For the different systems, to reach the maximum rate a different number of senders and receivers has been used:

System	Senders	Receivers
IS	12	44
Qpid	35	18
ActiveMQ	12	15

Message delivery rate in case of a slow receiver. In this problematic case, one of the subscribers is accepting messages at a much lower rate than the rest. This forces the messaging server to retain the undelivered messages until it reaches a certain queue size limit, at which point a certain policy of flow control will be enforced.

All three systems, IS, Qpid and ActiveMQ use a similar implementation of this policy – they are dropping those messages which do not fit to the fixed size queue.

The latency, i.e. the time of passing message from the source to all receivers, was measured only for IS. A fixed configuration of 100 receivers and a single sender emitting messages at a rate of 100Hz was used for the first test.

The Latency vs. Number of Receivers was measured for the messages of the size of 9Bytes.