



## **FINAL REPORT DMQ1 WORK PACKAGE**

**Connect instruments and sensors effectively to  
the network.**

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# Executive Summary

The work package DMQ1, “effectively connect sensors to the network” has been one of the most complex work packages undertaken in the DART project. The project involved developing and deploying a marine sensor network on Davies Reef, about 100 kilometres offshore of Townsville. The collaborative partners included Queensland Cyber Infrastructure foundation (QCIF), funding infrastructure, and the Australian Institute for Marine Sciences (AIMS), engineering and deployment resources, as well as resources from James Cook University not related to the DART project, microwave and engineering expertise. This work package provided one platform for the ACQUISITION work in the DART Project as it dealt with real sensors on the Great Barrier Reef, the other being crystallography.

There were two primary outcomes from this work package in the original documentation:

1. Policies for Sensors formulated; and
2. Security Layer mapped

The first milestone was achieved by formulating policies that govern the connection of instruments and sensors to the network. DMQ1 leveraged the significant work completed in DMQ2 to create a new paradigm for the management of instruments from micro sensors to large instruments with a single consistent framework. A set of policies were developed for the deployment of the initial set of sensors on Davies Reef. These policies are continuously evolving and are integral to the software that supports the sensor arrays.

The second milestone was achieved by developing a security model that supported user authentication and authorization requirements at storage and compute facilities and role-based authorization requirements for instrument facilities. The security requirements for the sensor layer were also investigated. It was determined that these requirements may be abstracted to higher level of the software stack, the work performed in DMQ2, ensuring effective and reliable connection of selected instruments and sensors to storage repositories.

The software developed to implement the policies evolved into a concept known as the Sensor Abstraction Layer (SAL) and this was an additional outcome for the project above, and in addition to, the original milestones.

The DART requirements were not only fulfilled but exceeded by the DMQ1 Work Package. The work on SAL needs to be extended to ensure effective and reliable connection of selected instruments and sensors to storage repositories. SAL will be further developed and be integrated with the Distributed Integrated Multi-Sensor and Instrument Middleware (DIMSIM), planned for the ARCHER project.

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# 1 Introduction

This document reports on the work undertaken to complete the DART work package DMQ1. This work package's main goal was to "effectively connect sensors to the network". There were two primary outcomes from this work package in the original documentation:

3. Policies for Sensors formulated; and
4. Security Layer mapped

Whilst this may appear to be an academic exercise, DMQ1 not only developed policies and developed the security layer but subsequently implemented the findings in operating sensor networks. This work package provided one platform for the ACQUISTION work in the DART Project as it dealt with real sensors on the Great Barrier Reef, the other being crystallography. The sensor network is connected to a tower on Davies Reef and information is fed back to the mainland via microwave operating in the humidity duct above the ocean.

DMQ1 is at the first layer immediately above instruments and is of primary importance as it allows the rest of the architecture to communicate with the instruments. To achieve the outcomes it was important that the work package provide the software and hardware resources required to:

- physically attach sensors to a platform,
- recognise and configure sensors,
- access and program sensors.

A demonstrator for the technologies developed in DMQ1 was constructed utilising complimentary work from other JCU DART work packages. This demonstrator is a portal that provides real time information Sensor Gateway deployed on Davies Reef. Progress in the deployment of this demonstrator is covered in this report.

## **2 Project Milestones**

The DMQ1 project achieved the two project milestones and subsequently implemented the findings in the real system. The first milestone was to formulate policies that govern the connection of instruments and sensors to the network. The second was to develop a security model that supports user authentication and authorization requirements at storage and compute facilities and role-based authorization requirements for instrument facilities.

### **2.1 Policies for Connection of Instruments and Sensors to the Network**

There is a large variety of instruments and sensors that have an equally large variety of communication and interfacing protocols. While it may be practical to write custom interfaces for large, specialized instruments for example the Instrument Representatives in CIMA, it is not practical for smaller scale instruments and sensors. DMQ1 focuses on these small-scale instruments and sensors.

DMQ1 is at the first layer immediately above instruments and is of primary importance as it allows the rest of the architecture to communicate with the instruments. The policies governing sensor networks is an ongoing process as the policies form an integral part of the management software for the sensor network. The policy framework has been implemented in the Sensor Abstraction Layer (SAL) which is described later in this document. SAL was a significant outcome of DMQ1 as it abstracts the policies governing the sensors to a network level.

### **2.2 Security Model**

The security policies were investigated to determine the applicable level of security at the sensor layer. After investigation of the risk and threat matrix and technical cost of potential solutions it was determined that security would be best achieved through obfuscation of sensors and implementation of a security management layer at the higher levels of the software. This is explained in further detail below.

### **2.3 Development of Sensor Abstraction Layer (SAL)**

The development of the Sensor Abstraction Layer was an additional outcome for the project above, and in addition to, the original milestones. SAL's genesis and development from the original project outcomes is described in the next section.

### **3 Project Outcomes**

This work package has addressed its initial requirements with the development of initial software (SAL and others) with an embedded policy framework to run a sensor network. It has also investigated the security requirements for the sensor layer and how this may be abstracted into higher level of the software stack, the work performed in DMQ2, ensuring effective and reliable connection of selected instruments and sensors to storage repositories.

A Sensor Gateway has been deployed on Davies Reef as a demonstrator for the technologies developed by this work package.

#### **3.1 Development of a Policy Framework**

DMQ1 has leveraged the significant work completed in DMQ2 to create a new paradigm for the management of instruments from micro sensors to large instruments with a single consistent framework

A set of policies were developed for the deployment of the initial set of sensors on Davies Reef. These policies are continuously evolving and are integral to the software that supports the sensor arrays. The latest version of the sensor management layer software has been renamed the sensor abstraction layer (SAL) to reflect its function within the wider Instrument Middleware Architecture.

#### **3.2 Security Layer Mapped and Operational**

The security policies have been developed utilising an agile process. Initially the intention was to protect instruments via conventional protocol encryption, however, risk and threat assessment revealed that the initial instruments would unlikely to be subject to an 'active' attack and that obfuscation of the sensors is sufficient to provide the necessary protection. The security is implemented in the high layers of the software stack, DMQ2, where the cost of protocol overhead is not so great and the value of the data is significantly greater. This situation may change depending on the instruments and the location of the deployment. Currently the security layer is being implemented in the Distributed Integrated Multi-Sensor and Instrument Middleware (DIMSIM), part of the ARCHER project.

#### **3.3 Sensor Abstraction Layer (SAL)**

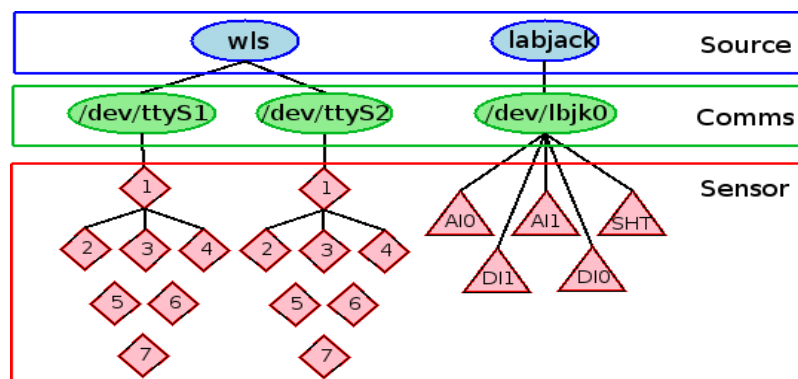
Through the course of our review of the methods available to implement policies in sensor and instrument networks and to have a standardized method of connecting sensors to a network, it became clear that a single API needed to be developed. This became the focus of this work package and was necessary to support work package DMQ2.

In order to present a single API to access a variety of sensors, SAL has to solve three major issues;

1. Different transport mechanisms (connection media) can be used to connect sensors to a computer. Common transport buses supporting hot-swappable devices include USB (one-wire bus [1]), Firewire (CCD sensor), serial [2], parallel and Ethernet (SNMP-enabled devices). The sensor gateway must be able to handle communications over each of these media;

2. Assuming the link between the sink and the sensor is functional, SAL must know about the protocol used to access and communicate with a sensor. Both of these issues require SAL to have access to the appropriate hardware and software drivers; and
3. SAL has to provide a consistent naming scheme to uniquely reference a sensor in the architecture. Depending on the sensing technology, this may be already implemented at the hardware level as in the one-wire bus technology. [1] In addition, the following desirable features have also been implemented in SAL; as far as possible the addition and removal of a sensor is automatically detected by the operating system and passed on to SAL, provided that the underlying transport bus allows it. On other buses, constant polling can be used to pick up changes in the number of sensor nodes.

When a new sensor is detected, no extra configuration steps are required (at the SAL level) in order to communicate with it. Sensors managed by SAL are organised in a hierarchical tree spanning three layers (fig 1 below). The sensor layer at the bottom layer contains the sensors themselves. As seen on figure 1, each sensor is reference by its intrinsic name, as recognised by its driver. The intermediate communications layer creates trees of sensors by grouping them according to their transport bus and communication protocol. Nodes at this level, called ports, identify the physical port and bus used to connect to a sensor tree, as well as the protocol used to communicate with them. The source layer at the top creates sources of sensed data by aggregating multiple sensor trees under a single name. Sources can be arbitrarily created. There are no rules enforcing their creation, and all ports can be grouped under a single source.



**Figure 1:** Internal layered representation of sensors within SAL

By organising sensors this way, SAL solves the issues mentioned previously. The communications layer takes care of loading the appropriate drivers to communicate with the hardware. It is worth mentioning that pseudo sensors can be created from existing sources of information available on the sensor gateway itself. A small stub that adds specific functionalities to the communications layer can turn counters including, but not limited to, operating systems statistics into pseudo sensors that behave just like any existing physical sensors. For instance, the current implementation created pseudo sensors to track the amount of available memory and the load average of the sensor gateway.

### **3.3.1 Current implementation**

The sensor gateway runs Linux Fedora Core version 6. Most of SAL's components have been implemented either as C programs or shell scripts. Current supported sensing technologies are:

- one-wire bus over a USB or serial connection [1]
- Ambient Systems wireless sensors (software version 1.96) over a serial connection [2]
- PL40 Battery controller via a PLI interface over a serial connection [3]
- Labjack A/D converter over a USB connection [4]
- Any SNMP device network reachable by the sensor gateway
- Remote controlled switch board over a parallel connection
- Any Linux operating system provided counters

In the current stable implementation of SAL, all functionalities listed in 3.2.1 have been implemented except the automated configuration of sensors. Focus was put on supporting as many transport media and sensing technologies as possible. At this stage, the process of adding new sensors or removing existing ones involves some configuration steps that can easily be performed using a web interface.

### 3.4 Davies Reef Demonstrator

A Sensor Gateway has been deployed at Davies Reef to provide a real world demonstrator in the area of sensor networks. This has been a complex undertaking with power and communication systems needing development in addition to the sensor system. The goal of this demonstrator was to understand the requirement of sensor networks from the connection of sensors to the network (DMQ1), connecting sensors to storage repositories (DMQ2), ensuring data from instruments and sensors is of sufficient quality for curation (DMQ3), remote control of instruments (DMQ4) and data processing (DMQ5).



**Figure 2:** Davies Reef Weather Station

#### 3.4.1 Sensor Gateway

The sensor gateway is the point at which all sensors in the Davies Reef Sensor Network are aggregated. This is the point at which SAL resides, abstracting the sensors and presenting them on the network. A IEI Nano 7402 all-in-one computer is used in this case because of its low power consumption. The computer is running Linux Fedora Core version 6, and is using a store and forward mechanism based on rsync to transfer data to a MySQL database. The data is served from the database as a web service. This data transport architecture fulfils the basic requirements of the system while a CIMA implementation is developed. The data is available in near real time while the sensor gateway is connected to the network.

#### 3.4.2 Microwave Link

To get data back to the mainland, a microwave data link is being used that provides transfer speeds in the order of 10Mb/s. Davies Reef is approximately 100km east north east of Townsville. A typical microwave link over such a distance requires both ends of the link to be mounted at high elevations to allow a free space path between them because of the Earth's curvature. This is not possible in this case. Instead, we are relying on the propagation of radio waves along the evaporation duct that occurs close to the surface of the ocean. This allows the two ends of the link to be located several metres above sea level. We believe that this will be the first operational installation of the kind anywhere in the world. The presence of evaporation duct is dependant on environmental conditions; however, the link is expected to have an availability of over 95%.

This system is still undergoing commissioning and should be operational by mid 2007. This process has been complicated by the lack of access to Davies Reef and some equipment failures.

### 3.4.3 Power System

The power requirements of the sensor gateway and microwave systems at Davies Reef are in the order of 3000 kWh per day. In order to provide this power a hybrid system has been designed and installed. This system has a 500 Watt photovoltaic array, an AirX Marine wind turbine capable of producing 400 Watts, and six 100 Ah low maintenance batteries. This system was designed with the assistance of the HOMER [5] micro-power modelling software package. This software allows various scenarios to be compared, such as different power generation and storage devices, and local wind and solar irradiance patterns. The system as deployed will be able to fully power the system for around 98% of the year. Intelligent monitoring of the power system through the sensor gateway will allow a power conservation mode to be entered to ensure that data continues to be collected and stored if not transmitted in real time.

### 3.4.4 Sensors

Several recent sensing technologies have been tested at JCU and deployed at Davies Reef.

The one-wire technology allows hundreds of sensors to be connected to a single length of cable up to 300 metres. One wire buses can then be attached to a computer through either a USB or a serial port. The computer then drives the bus, polls and pilots sensors. At Davies Reef, two one-wire buses have been deployed. The first one is an underwater temperature string tied along the south-eastern leg of the tower, made of 7 temperature sensors equally separated, from which the water column temperature profile can be derived. The second one has several combined temperature-humidity sensors, and gives the temperature/humidity profile above sea level. A wind instrument (wind direction and speed) is also attached to it.

The battery charge controller (PL40 [4]) has also been turned into several sensors reporting various current and voltage measures related to the charge and load levels of the batteries.

Lastly, several sensors monitoring the microwave link have also been created from parameters accessible through the microwave link modem, providing examples of SNMP-enabled sensors.

## 3.5 Architecture Issues

The initial implementation of SAL is on a Linux platform. As part of ARCHER, SAL will be rewritten in Java (along with DIMSIM) to allow it to be platform independent.

## 3.6 Collaborations

The major hardware components for the ReefGrid demonstrator were funded by QCIF. AIMS has provided logistic support. Graham Woods from the School of Engineering at James Cook University is the lead investigator on the deployment of the microwave data link.

## 4 Archival Storage of Project Deliverables

The software produced by this work package, the initial version of Sensor Abstraction Layer (SAL) will be zipped up and shipped to Monash University for archival storage with the other software artefacts from the DART Project.

## 5 Recommendations

The DART requirements were not only fulfilled but exceed by the DMQ1 Work Package. The work on SAL needs to be extended and integrated with the work from the DMQ2 work package, ensure effective and reliable connection of selected instruments and sensors to storage repositories, to provide the basis for development of a Distributed Integrated Multi-Sensor and Instrument Middleware (DIMSIM), planned for the ARCHER project.

## 6 Terms of Reference

### 6.1 Glossary

Acronym	Definition
AIMS	Australian Institute of Marine Science
DIMSIM	Distributed Integrated Multi-Sensor and Instrument Middleware
QCIF	Queensland Cyber Infrastructure Foundation
SAL	Sensor Abstraction Layer, hides the complexity of various sensing technologies under a single API.
SNMP	Simple Network Management Protocol, allows monitor stations to query devices via the network.

### 6.2 References

[1] One wire interface overview, Maxim – Dallas semiconductors, [http://www.maxim-ic.com/appnotes.cfm/appnote\\_number/3989](http://www.maxim-ic.com/appnotes.cfm/appnote_number/3989)

[2] uNode, Ambient Systems, <http://www.ambient-systems.net/ambient/download/Ambient%20uNode-product%20sheet.pdf>

[3] PL charge controllers, Plasmatronics <http://www.plasmatronics.com.au/common/pl204060.html>

[4] Labjack corporation - <http://www.labjack.com>

[5] HOMER - <http://www.nrel.gov/homer/>

## 7 Report Signoff

It is agreed between

Franz Eilert, Cameron Huddleston-Holmes and Gilles Gigan

and

Associate Professor Ian Atkinson

and

Dr Andrew Treloar

That the **Final Report Document** for the DART DMQ3 – ‘Ensure that data from instruments and sensors is of sufficient quality to warrant curation’, gives a full account of the work undertaken for the DART Project.

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- has been read and reviewed by all parties,
- shows that the DART DMQ3 – ‘Ensure that data from instruments and sensors is of sufficient quality to warrant curation’ has been completed satisfactorily,
- clearly outlines the deliverables stated in the DMQ1 requirements documentation have been met.

Dated this 25<sup>th</sup> day of May 2007

\_\_\_\_\_  
Signed  
Associate Professor Ian Atkinson  
Chief Investigator

\_\_\_\_\_  
Signed  
For and on behalf of DART by the  
Project Director Andrew Treloar