The Role of Distributed Wireless Sensor Network Systems in Industrial Automation

Case Study: Hydraulic Fracturing for Pre-conditioning of Underground Mines

Amirali Sorouch, Ph.D. & Vincent Mow & Sam Cantrill | 27 October 2019
Who are we? **CSIRO**

- Conduct and encourage the uptake of world-class scientific research
- We deliver on this objective through our Business Units and Future Science Platforms

### Business Units
- Agriculture and Food
- Data61
- Energy
- Health and Biosecurity
- Land and Water
- Manufacturing
- Mineral Resources
- Oceans and Atmosphere

### Future Science Platforms
- Active Integrated Matter
- Artificial Intelligence and Machine Learning
- Deep Earth Imaging
- Digiscape
- Environomics
- Hydrogen Energy Systems
- Precision Health
- Probing Biosystems
- Space Technology
- Synthetic Biology
CSIRO invented **Wi-Fi!**

Dr O’Sullivan et. al. CSIRO Astronomy, 1996

Summary

• Introduction to Hydraulic Fracturing
  • What is hydraulic fracturing?
  • Modelling, laboratory experiment, and, field operations
  • CSIRO’s Hydraulic Fracturing team

• Hydraulic Fracturing Monitoring Automation
  • Distributed Wireless Sensor Network Systems for tilt monitoring
  • Open-source electronics platform

• Hydraulic Fracturing Automation
  • Wi-Fi Network for operation automation

• Conclusion and Future Works
Section 1:
Introduction to Hydraulic Fracturing
What is Hydraulic Fracturing?
What is Hydraulic Fracturing?

Hydraulic Fracturing or “fracking,” involves the injection of more than a million gallons of water, sand and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layer to crack. These fissures are held open by the sand particles so that oil from the shale can flow up the well.

Source: goodyearlake.org
Vertical vs Horizontal HF
How it is done?
Applications of Hydraulic Fracturing?

- Oil & Gas Industry
  - Well stimulation technique for unconventional resources

- Mining Industry
  - Mine Preconditioning
  - Seismic mitigation
  - Gas drainage
Who are we?

• Five Research Scientists
• Four Experimental Research Engineers
• Four Research / Fieldwork Technicians
What we do?

- Hydraulic Fracturing Modelling
  - Numerically model hydraulic fracture growth in complex systems
  - Interpret and analyse fracture growth monitoring data

*Figure 1. Cohesive zone hydraulic fracture model (After Chen (2012)).*
Understanding HF growth?

Pay zone coverage

What we want

What we get?

Or

Multizone coverage

What we want

What we get?

Fracture length

What we want

What we get?

Payzone

Horizontal well trajectory

What we want

What we get?

Payzone

800 ft

300 ft
What we do?

- Laboratory Experiments
  - Design and conduct hydraulic fracture growth laboratory investigations
  - Develop and deploy data measurement and analysis tools

350mm x 350mm x 60mm sample in cell with confining stress of 20MPa and vertical of 10MPa

Polyaxial cell (true triaxial cell)
Laboratory experiments?

Blue food dye visible in fracture fluid as fracture grows

Glass sample containing hydraulic fracture

Labscale hydraulic fracture experiments in Glass
What we do?

- **Field Operations**
  - Conduct hydraulic fracturing fieldwork at client sites in Australia and internationally
  - Grow, monitor and analyse hydraulic fracture treatments
Field operation?

Hydraulic Power Pack and Priming Pump

Site shed

Injection Line to Borehole

Fracturing Pump

Water Tanks
Why pre-conditioning?

Longwall Underground Mine

MINE BLAST

Four miners killed in Australian mine disaster

By Terry Cook
2 December 1999

The accident that claimed the lives of four mine workers on November 24 at the Northparkes copper and gold mine near Parkes, in central west New South Wales, again focuses attention on the issue of safety standards in the mining industry.
Why pre-conditioning?

Subsidence of the surface

Caving process underground

Block cave Mine
Caving hazards

'Will I have existed?' The unprecedented plan to move an Arctic city

Kiruna's new City Hall, lower right, by Henning Larsen architects, sits about 3km from the world's biggest iron mine, top left. Photograph: Peter Rosén/LapplandMedia

The world's biggest iron ore tunnel mine is about to swallow the Swedish city of Kiruna. The company's answer? Move the city
Field operation?

**Preconditioning**
- Fractures placed near or in ore body
- Reduces waiting events
- Improves crushing requirements by reducing rock size
- **Applicable to:** Block cave mining, Long wall mining

**Gas Drainage**
- Fractures placed in coal
- Improve gas drainage through small propped controlled openings
- **Applicable to:** coal mining (deeper than 400m)

**Seismic Mitigation**
- Removing material during mining changes local stress regime
- Hydraulic fractures used to change rock strength to relieve stresses
- **Applicable to:** All mines (700+m deep)
HF team’s field operations worldwide

A$10M revenue in the last 4 years
Section 2: Hydraulic Fracturing Monitoring Automation
How hydraulically induced fractures are identified / monitored?
Hydraulic fracturing monitoring?

- What is HF monitoring?
  - identify the extent and directions of hydraulically induced fractures

- How is it done?
  - Micro-seismic monitoring
  - Tilt monitoring
Tilt monitoring of hydraulic fractures
What is a tiltmeter?

- Tiltmeters monitor small-scale changes in surface tilt (uplift) caused by injection of a volume of fluid or gas.
- Data is analysed to provide location and volume information on injected material.
- Precision tilt sensors (with nanoradian resolution) sense angular movement in two orthogonal vertical planes.

1 μm = 1 nanoradian = 1 km
Commercial tiltmeters

- **Lily Borehole Tiltmeter**
  - Resolution < 5 nanoradians
  - Price: AUD $30K each
  - Output: ASCII via RS232 or RS485
  - Installed in 10~15 [m] deep boreholes
  - The borehole is sanded to create coupling

<table>
<thead>
<tr>
<th>Specifications</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Channels</td>
<td>X tilt, Y tilt, azimuth, temperature</td>
</tr>
<tr>
<td>Resolution</td>
<td>&lt; 5 nanoradians</td>
</tr>
<tr>
<td>Repeatability</td>
<td>Same as resolution under static conditions</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>±330 µradians</td>
</tr>
<tr>
<td>Self-Leveling Range</td>
<td>±10 degrees</td>
</tr>
<tr>
<td>Non-Linearity</td>
<td>0.2% of full span</td>
</tr>
<tr>
<td>Frequency Resonse</td>
<td>&lt; 1 Hz</td>
</tr>
<tr>
<td>Ks Temp Coefficient (%/°C)</td>
<td>±0.02%/°C</td>
</tr>
<tr>
<td>Kz Temp Coefficient (bias/°C)</td>
<td>±3 µradian/°C</td>
</tr>
<tr>
<td>Azimuth detection</td>
<td>On-board magnetic compass, 0° to 360° output</td>
</tr>
<tr>
<td>Output</td>
<td>RS232 and RS422 standard (user selectable)</td>
</tr>
<tr>
<td>Baud rate</td>
<td>9600, 19200 (default), 28800, 57600, 115200, 230400</td>
</tr>
<tr>
<td>Sample rate</td>
<td>User programmable from 10 samples/sec to 1 sample/day</td>
</tr>
<tr>
<td>Output Format</td>
<td>NMEA XDR, Trimble TCM, Ashtech, Simple (Timestamp, X, Y, Temp, Compass, S/N)</td>
</tr>
<tr>
<td>On-board Memory</td>
<td>2 Megabytes nonvolatile Flash memory (64,000 samples)</td>
</tr>
<tr>
<td>Real-time Clock</td>
<td>Accurate to 10 minutes/year or better</td>
</tr>
<tr>
<td>Power</td>
<td>7 to 28 VDC @ 30 mA (&lt; 10 mA sleep); 250 mV ripple max., reverse polarity protected</td>
</tr>
<tr>
<td>Environmental</td>
<td>-25°C to +85°C operational, -30°C to +100°C storage. 3000 psi</td>
</tr>
<tr>
<td>Weight</td>
<td>4.5 kg (10 lb)</td>
</tr>
<tr>
<td>Materials</td>
<td>304 stainless steel, nonmagnetic (6Al-4V Titanium available on request: to +5000 psi)</td>
</tr>
</tbody>
</table>
HF monitoring in the field

T : Tilt Hole
F : Fracturing Hole
—: Injection Line

CSIRO’s Preconditioning Site and Tilt Monitoring Array
LKAB Iron Ore Mine, Malmberget, Sweden, July 2017
Fracture Growth Map

Figure 1: Injection History

Figure 2: Tilt Vectors - Measurements vs Predictions
Several Components of the System

• **Sensor**
  - Ultra-high resolution tiltmeter (1 nanorad as compared to commercial 5 nanorad)
  - Low cost (reduce the purchasing cost by 70%) and low power consumption (solar powered)
  - State of the art electronics and robust mechanical design

• **Wireless Sensing Technology**
  - Novel long-range (~10 [km]) Distributed Wireless Sensor Network (DWSN)
  - Bi-directional communication for real-time monitoring of tilt data and sensor health, as well as remote sensor calibration
  - Flexible and can be integrated with any digital and/or analog sensors on site

• **Real-time Display**
  - Innovative tailor-made real-time dashboard
  - Intelligent monitoring, preliminary processing, QC/QA, sensor control and alarms
  - Real-time analytics and advanced visualization for on-site decision making
HF monitoring architecture

Real-time Fracture Propagation & Growth Map

Data QC/QA
Sensor Control
Visualization
Analytics / Modelling

Real-time Display

Distributed Wireless Sensor Network (DWSN)

Hardware
Firmware

Tiltmeter

Mechanical Components
Electronics

Signal Conditioning/Levelling

Distributed Wireless Sensor Network

Electronics Design
Mechanical Design
Laboratory Testing

Sensors
Data Logger
CAN bus
Hardware
Firmware
Wi-Fi
DigiMesh

QC/QA
Visualization
Data QC/QA
Analytics / Modelling
Real-time Display
Real-time Fracture Propagation & Growth Map

What is FracSense?
Real-time Display
Visualization
Data QC/QA
Analytics / Modelling
Sensor Control

Real-time Fracture Propagation & Growth Map

Hydraulic Fracturing Monitoring and Control System

Real-time Equipment Monitoring System

Tiltmeter
Distributed Wireless Sensor Network

Electronics
Mechanical Components
Signal Conditioning/Levelling

Created by Unlicensed Version

Created by Unlicensed Version

Created by Unlicensed Version
What is a Distributed Wireless Sensor Network system?

- Monitor and control various physical and environmental parameters in real-time such as temperature, humidity, air pollutant, etc.
- Continuously collect data and transfer them to a central aggregation point (base station) over radio frequencies
- Plug & play, low maintenance, minimum user interference, low cost
Commercial DWSN systems

• What is available in the market at the moment?
  • Offered by several companies
  • Specs vary significantly from one product to another
  • Limited flexibility

• Cost (50 Nodes + Gateway)
  • ~20k to 75k
  • License Renewal
Way to go?

• **Design and Development by an External Company**
  • ~20K for PCB Design & Firmware
  • Additional Costs for Development
  • No Control over the Firmware
  • Extra Costs for Future Upgrades

• **In-house Design and Development**
  • Open Source Electronics / Microcontrollers
  • Capability Development
  • Full control over Hardware / Firmware
Required DWSN system

- **Necessary Specifications**
  - Long Range, non L.O.S Environment
    - ~1 [km]
  - Analogue & Digital Input
  - Clock Synchronisation / GPS
  - Two-way Communication / Sensor Calibration
  - On-board Memory / Data Security
  - Low Power Consumption / Solar Power
  - Mesh Network / Self Healing
  - Durability (heat, moisture, etc)
Overall DWSN system architecture
Choice of microcontroller

Arduino Due
SAM3X8E Microcontroller

<table>
<thead>
<tr>
<th>OVERVIEW</th>
<th>TECH SPECS</th>
<th>DOCUMENTATION</th>
</tr>
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<tbody>
<tr>
<td>Microcontroller</td>
<td>AT91SAM3X8E</td>
<td></td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>3.3V</td>
<td></td>
</tr>
<tr>
<td>Input Voltage (recommended)</td>
<td>7-12V</td>
<td></td>
</tr>
<tr>
<td>Input Voltage (limits)</td>
<td>6-16V</td>
<td></td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>54 (of which 12 provide PWM output)</td>
<td></td>
</tr>
<tr>
<td>Analog Input Pins</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Analog Output Pins</td>
<td>2 (DAC)</td>
<td></td>
</tr>
<tr>
<td>Total DC Output Current on all I/O lines</td>
<td>130 mA</td>
<td></td>
</tr>
<tr>
<td>DC Current for 3.3V Pin</td>
<td>800 mA</td>
<td></td>
</tr>
<tr>
<td>DC Current for 5V Pin</td>
<td>800 mA</td>
<td></td>
</tr>
<tr>
<td>Flash Memory</td>
<td>512 KB all available for the user applications</td>
<td></td>
</tr>
<tr>
<td>SRAM</td>
<td>96 KB (two banks: 64KB and 32KB)</td>
<td></td>
</tr>
<tr>
<td>Clock Speed</td>
<td>84 MHz</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>101.52 mm</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>53.3 mm</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>36 g</td>
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</tr>
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</table>
Choice or radio transceiver

Digi XBee-PRO 900HP
~ 9 [km] LOS range

<table>
<thead>
<tr>
<th>SPECIFICATIONS</th>
<th>Digi XBee-PRO® 900HP</th>
<th>Programmable Digi XBee-PRO® 900HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>HARDWARE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROCESSOR</td>
<td>ADF7023 transceiver, Cortex-M3 EFR32G130 @ 28 MHz, Programmable includes: Freescale HC0508QE.32</td>
<td></td>
</tr>
<tr>
<td>FREQUENCY BAND</td>
<td>902 to 928 MHz, software-selectable channel mask for interference immunity</td>
<td></td>
</tr>
<tr>
<td>ANTENNA OPTIONS</td>
<td>Wire, U.FL and IPFS/ASA</td>
<td></td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF DATA RATE</td>
<td>10 Kbps or 200 Kbps</td>
<td></td>
</tr>
<tr>
<td>INDOOR/URBAN RANGE*</td>
<td>10 Kbps: up to 2000 ft (610 m); 200 Kbps: up to 1000 ft (305 m)</td>
<td></td>
</tr>
<tr>
<td>OUTDOOR/LINE-OF-SIGHT RANGE*</td>
<td>10 Kbps: up to 9 miles (14.5 km); 200 Kbps: up to 4 miles (6.5 km) (with 2.0dB dipole antennas)</td>
<td></td>
</tr>
<tr>
<td>TRANSMIT POWER</td>
<td>Up to 24 dBm (250 mW) software selectable</td>
<td></td>
</tr>
<tr>
<td>RECEIVER SENSITIVITY</td>
<td>-101 dBm @ 200 Kbps, -110 dBm @ 10 Kbps</td>
<td></td>
</tr>
<tr>
<td>FEATURES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DATA INTERFACE</td>
<td>UART (3V, 5V)</td>
<td></td>
</tr>
<tr>
<td>GPIO</td>
<td>Up to 15 Digital I/O, 4 10-bit ADC inputs, 2 PWM outputs</td>
<td></td>
</tr>
<tr>
<td>NETWORKING TOPOLOGIES</td>
<td>DigiMesh, Repeater, Point-to-Point, Point-to-Multipoint, Peer-to-Peer</td>
<td></td>
</tr>
<tr>
<td>SPREAD SPECTRUM</td>
<td>FHSS (Software Selectable Channels)</td>
<td></td>
</tr>
<tr>
<td>PROGRAMMABILITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEMORY</td>
<td>N/A</td>
<td>32 KB Flash / 2 KB RAM</td>
</tr>
<tr>
<td>CPU/CLOCK SPEED</td>
<td>N/A</td>
<td>HCS08 / Up to 50.33 MHz</td>
</tr>
<tr>
<td>POWER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUPPLY VOLTAGE</td>
<td>2.1 to 3.6 VDC</td>
<td>2.4 to 3.6 VDC</td>
</tr>
<tr>
<td>TRANSmit CURRENT</td>
<td>215 mA</td>
<td>229 mA</td>
</tr>
<tr>
<td>RECEIVE CURRENT</td>
<td>29 mA</td>
<td>44 mA</td>
</tr>
<tr>
<td>SLEEP CURRENT</td>
<td>2.5 μA</td>
<td>3 μA</td>
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<td>REGULATORY APPROVALS</td>
<td>FCC (USA)</td>
<td>MCQ-XB900HP</td>
</tr>
<tr>
<td></td>
<td>IC (CANADA)</td>
<td>1846A-XB1000HP</td>
</tr>
<tr>
<td></td>
<td>C-Tick (AUSTRALIA)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>ANATEL (BRAZIL)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>IDA (SINGAPORE)</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Integration of various components

Digi XBee-PRO 900HP
~ 9 [km] LOS range

Arduino Wireless SD Shield
Compatible with XBee modules

Arduino Due
SAM3X8E Microcontroller
Sensor node layout

- Flow-meter
- Voltage Scaler
- Lemo Connector
- Arduino Due Board
- GPS Module
- GPS External Antenna
- microSD Card
- XBe RF Transceiver
- Wireless SD Shield
- RS-232 to TTL Converter
- DB9 Male Connector for RS-232 Input
- RS-485 to TTL Converter
- DB9 Female Connector for RS-485 Input
- Power Jack
- USB Programming Port
- Reset Button
- High Gain Antenna
Receiver Layout

XBee RF Transceiver

Mini USB-B to USB-A cable

Reset Button

Xbee Explorer USB

High Gain Antenna
Firmware development

/* 17 Feb 2017

This is a firmware for Hydraulic Fracturing Wireless Sensor Network for Tiltmeter array.
Developed by Amirali Soroush for Arduino Due boards
Version 1.0
The code is able to read data from Lily and Lippmann tiltmeters and also send commands to both sensor types
*/

#include <XBee.h>
#include <SD.h>
#include <TinyGPS++.h>

// create the XBee object
// TX
XBee xbee = XBee();
// RX
XBeeResponse response = XBeeResponse();

// Payload size for Lippmann Tiltmeter
// uint8_t payload[60];

// Payload size for Lily Tiltmeter
// uint8_t payload[62];
uint8_t payload[65];

// Payload size for Ublox Neo-6M GPS
// uint8_t payload[64];

static const uint32_t GPSBaud = 9600;

// The TinyGPS++ object
TinyGPSPlus gps;

const int chipSelect = 4;

char in_byte;
char inbyte1;
Prototyping

Laboratory Design, Development and Testing January-February 2017
Prototyping

First Prototype March 2017
Prototyping

Radio Module Box – Hardware cost: 250 AUD per node
Development of 50 radio box modules - April 2017
Updates and revisions

- **Hardware**
  - Replaced MAX RS422 chip for better performance
  - Replaced GPS chip to reduce power consumption

- **Firmware**
  - Optimised the code to minimise current draw
  - Added the ability to update the firmware over the air

---

**Sensor node power consumption before and after optimization**

- **Before:**
  - Arduino Due: 61%
  - RS485 module: 16%
  - XBee module: 21%
  - GPS module: 2%
  - Savings: 1%

- **After:**
  - Arduino Due: 59%
  - RS485 module: 23%
  - XBee module: 9%
  - GPS module: 8%
  - Savings: 1%
Field deployment

Real-time Dashboard
## Real-time Dashboard

![Real-time Dashboard Image](image-url)

**Summary:**

- 20 out of 34 tiltmeters in good condition.

### Tilt Data Table

<table>
<thead>
<tr>
<th>MAC Address</th>
<th>ID</th>
<th>Last received</th>
<th>TiltX (μrad)</th>
<th>TiltY (μrad)</th>
<th>Voltage</th>
<th>°C</th>
<th>Last data</th>
</tr>
</thead>
<tbody>
<tr>
<td>D013A20040D91A9F</td>
<td>M1012</td>
<td>&lt; 5s ago</td>
<td>-3.859</td>
<td>-47.671</td>
<td>14.20</td>
<td>18.61</td>
<td>13:57:30</td>
</tr>
<tr>
<td>D013A20040D91A9F</td>
<td>M1013</td>
<td>&lt; 5s ago</td>
<td>-93.466</td>
<td>-6.468</td>
<td>14.10</td>
<td>26.33</td>
<td>13:57:30</td>
</tr>
<tr>
<td>D013A2004154D64E</td>
<td>M1056</td>
<td>&gt; 15s ago</td>
<td>19.988</td>
<td>0.094</td>
<td>14.13</td>
<td>16.88</td>
<td>13:37:31</td>
</tr>
<tr>
<td>D013A20040D91A9F</td>
<td>M1072</td>
<td>&gt; 15s ago</td>
<td>34.373</td>
<td>63.676</td>
<td>13.98</td>
<td>15.61</td>
<td>13:57:23</td>
</tr>
<tr>
<td>D013A200415B7E7F</td>
<td>M1078</td>
<td>&lt; 5s ago</td>
<td>1.862</td>
<td>24.039</td>
<td>13.71</td>
<td>24.21</td>
<td>13:57:28</td>
</tr>
</tbody>
</table>
Wireless communication quality

XCTU software for monitoring the connection quality of XBee radio transceivers.
What was delivered?

- **Hardware**
  - 50 radio modules (sensor nodes) and 8 receivers were manufactured.
  - The radio modules were deployed within the following projects:
    - Whitehaven Coal Mine, Narrabri, NSW (since April 2017, ongoing)
    - LKAB Iron Ore Mine, Kiruna, Sweden (Deployed Underground, May 2017)
    - LKAB Iron Ore Mine, Malmberget, Sweden (Deployed on Surface, July-August 2017)

- **Firmware**
  - Developed the code in C (Arduino IDE Environment)
  - Additional level of data security provided by using on-board memory
  - GPS for clock synchronisation as well as location identification
  - API mode enabled for XBee modules (packets / frames / checksums)
  - Power management system / Sleep Mode

- **Real-time Display**
  - Data visualization, real-time diagnostics, quality control, sensor calibration
Section 3: Hydraulic Fracturing Automation
Hydraulic Fracturing Equipment

• Provide high-pressure and flowrate for injection into the borehole.

• Traditionally operator sits in a drivers cabin or stands next to the pump.
Current Issues

• Too many parameters for a single person to watch & react to in case of an error.

• Damaged equipment results in high cost due to downtime and repairs.

• Operators must be next to the equipment to operate it.
Value of Equipment Management System

• Remote monitoring of operational parameters can catch these issues & trigger safety system.

• Less cost & downtime for repairs & maintenance.

• Increased safety of operators.
Equipment Management System

- No single solution exists on the market that suits our needs.

- Pre-existing platforms exuberantly expensive.

- Develop a remote monitoring solution in-house harnessing open source electronics.
Instrumentation

• Operational information used directly by the operator using the equipment.

• External sensors
  • Magnetic flowmeters, pressure transducers, proximity switches.
Instrumentation

- Diagnostic information used to diagnose the health of equipment in real-time.

- CAN Bus & external sensors.
  - Engine & Transmission ECU’s, pressure and temperature transducers.
Data Acquisition

• Identify sensor outputs and design appropriate input interfaces.
  • 4-20mA analog signal
  • 0-24V digital logic signal
  • 0-180Ω resistive load

• Consider data acquisition requirements.
  • Resolution, Samples Per Second
  • Noise & Filtering
Wireless Network Hardware

- Identify wireless network requirements
  - High-throughput, low-range requirements and ensure delivery of data packets.

- XBee S6B Wi-Fi modules
  - Connect to existing 802.11b/g/n networks
  - Setup Adhoc and Infrastructure networks.
Wi-Fi Network

• DHCP allows networks to be setup dynamically without additional configuration of the modules.

• TCP protocol ensures delivery of data and in correct sequence.

• Through-put and interface data rates meet requirements.
Data Acquisition Boxes

• Open source electronics & libraries allowed rapid development of prototypes.

• Arduino platform provides a lot of support and comes with well vetted software and libraries.
Data Acquisition Boxes

CAN Bus
- Transmission ECU’s
- Engine ECU’s

External Sensors
- Flowrate Sensor
- Pressure Transducers
- Temperature Transducers
- Fuel Level Sensors
- Proximity Switches

Data Acquisition/Interface Board
- Onboard low & high resolution ADCs
- Signal conditioning circuitry

Data Acquisition Node
- Seeed Tech CAN Bus Shield
  - CAN Bus Interface
  - SD Card Slot
- XBee S6B Wi-Fi Module
- Arduino Due
  - SAM3X8E Microcontroller
Control Panel

- Data is accumulated at a central point by the LabVIEW control panel program.

- Converts data from the sensors and CAN bus to meaningful values.

- Incorporates data visualisation, data logging, alarm systems, & safety systems.
Equipment Management System

- Data acquisition system allows collection of various operational & diagnostic parameters.
- Wi-Fi modules allow data to be transmitted remotely.
- Control Panel running on a remote computer receives and displays the data. Implemented alarm and safety systems.
Preventative Control

• Monitoring system can catch issues and alert the user to take action.

• Some safety systems need to be activated immediately.

• Remote control of relays, allowing the equipment to be thrown into neutral mode.
Predictive Maintenance

- Currently planned & corrective maintenance largest factors for downtime.
- Apply machine learning techniques to analyse anomalies in equipment operation
  - Perform maintenance as needed.
Automating/Optimising Fracturing Treatments

- Implement control systems to automate the fracturing process.
- Designing fracturing treatments beforehand.
- Optimise breakdown process & fracturing treatments for each borehole.
Section 4: Conclusion and Future Works
Conclusion

• Over a period of two years, the system successfully monitored the placement of more than 2000 hydraulically-induced fractures in real-time.

• The DWSN system provided an average packet delivery success rate of more than 99.995%.

• The DWSN system reduced the time required for sensor calibration from days to minutes.

• The DWSN system improved the quality of the recorded tilt data significantly by minimizing data loss across the network and removing data access latency limitations.

• The DWSN system demonstrates the advantage of developing in-house low-cost (250 AUD per node) and low-power data collection system using open-source electronics platforms with modular components.
Future Works

• Reducing the system bandwidth (a potential 70% reduction) by replacing the system data encoding format with binary

• Further reducing system power consumption

• Adding a Wi-Fi module to the node for rapid downloading of microSD data

• Implementing LoRa wireless communication technology in underground conditions
Underground HSE hazards

Tilt-meter, electronics enclosure, radio module and battery buried under tones of rock.

LKAB Underground Iron Ore Mine, Kiruna, Sweden, May 2017
Thank you

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