The IoT Rockbolt

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***Abstract*—The use of rock bolts in the mining industry is a widely used approach for increasing mine stability. Here we demonstrate an IoT rockbolt with strain and accelerometer sensors. By utilizing the real-time monitoring capabilities of a network of IoT rockbolts, open up for drastically improve monitoring of mining activities and thereby providing real time logistics and operational information while at the same time provide working safety information.**

I. Introduction

One of the most commonly used techniques for stabilizing tunnels in mines is the use of rock bolts. In the US alone, more than 100 million rock bolts are installed every year, as reported by Spearing et al. [1]. A rock bolt is a long metal rod which increases stability by transferring load from the outer layer (which has been damaged by mining activities such as blasting and drilling) to untouched rock several meters into the wall.

Rock bolts can become damaged by seismic activities or movements within the rock, and thus lose their loading capacity. Therefore, there is a clear need of monitoring solutions for strain and thereby stress, as well as seismic and microseismic activity. Strain measurements on single rock bolts have previously been investigated by Schroeck et al. [2]. Currently no technology is available for continuous and simultaneous monitoring of all rock bolts in a mine tunnel.

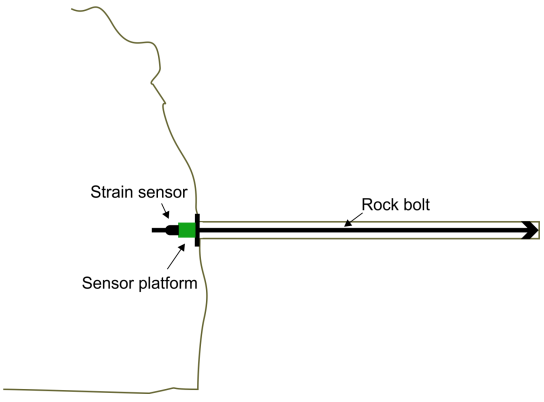

Fig. 1. Intelligent rockbolt in mine tunnel

In this paper, a novel method for mine monitoring is presented. The method is based on equipping standard rock bolts with Internet of Things technology, i.e. embedded electronics with the rock bolt as shown in Fig. 1. This approach enables real-time monitoring of each individual rock bolt in near real time. The IoT rockbolt are using the Arrowhead Framework [6] to provide SOA services.

II. Background and Related work

The mining industry have over time initiated a number of smaller projects to test the function of rock bolts. This has lead to some functional rock-bolt monitoring specifications [3], [4].

A necessity is that IoT rockbolt can be integrated to a process automation systems used in industry. The use of IP-based networked sensor and actuator devices with vertical integration into traditional industry systems is currently being investigated in some of Europe's largest automation projects such as the R&D projects FP7 IMC-AESOP [5] and Artemis Arrowhead [6].

III. Architecture

A. IoT rockbolt

The current proposed design of the IoT rock bolt is a standard rock bolt, which is equipped with measurement electronics. The core of the electronic system is the Mulle platform from Eistec AB [7], [8]. The Mulle is a low-power sensor node designed for Internet of Things applications. The measurement system consists of a strain sensor and an accelerometer. The accelerometer is mounted on a printed circuit board (PCB) while the strain sensor is external to the PCB, i.e. mounted inside the rock bolt's head.

B. Internet of Things networking stack

The current communication stack is based on previous work from several research projects. Other research projects that have been developing the Mulle architecture are EU FP7 IMC-AESOP and I2Mine and Artemis Arrowhead. The current version of the Mulle's communication stack is based on the IEEE 802.15.4 standard, and uses IPv6 and RPL over 6LoWPAN. Data is normally transmitted using SenML encoded using XML (with optional EXI-compression by the EXIP parser [9]) over CoAP. Figure 2 shows the Mulle's communication stack.

The software side of the strain and acceleration measurements were implemented as CoAP [10] services. A CoAP service is easily accessible through a web browser that supports it. This provides simplicity in monitoring and configuring the

rock bolts as it can be done through a standard web interface over the Internet. CoAP is a protocol designed to be used on resource-constrained, low power electronic devices.

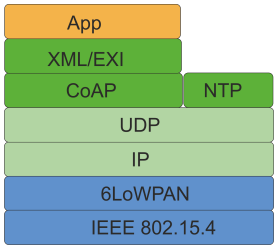

Fig. 2. Rock bolt communication stack

IV. Test and Results

Several different experiments were conducted in the mine in order to collect as much relevant data as possible.

To test the linearity of the strain sensor, different torques were applied to the strain simulation device. Four different boards and sensors were tested, labeled 2, 3, 4 and 5 and the strain output as a function of applied torque were recorded. The measurements were taken at torques of 0, 40, 50, 70 and 80 Nm. The resulting plots are shown in Figure 3.

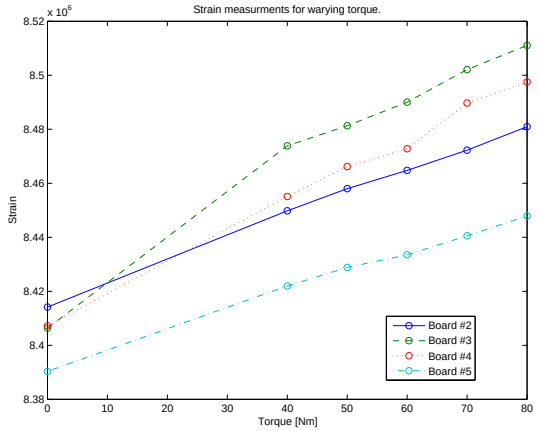

Fig. 3. Strain measurements for varying torque

A. Drill test

A mine-based test was performed in order to investigate if a rock bolt's vibration sensor can be used to detect mining-related activities such as drilling. A mobile top hammer production drill rig, located approximately 25-30 meters from the installed rock bolts, was used as a vibration source.

It is clearly seen in the IoT data when the drilling machine drills, takes a short pause to insert a new rock tool, and starts drilling again. This indicates that a rock bolt can be used to detect drilling activity in close proximity, and even count how many drill holes that have been drilled.

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V. Conclusion

This paper presents concrete test results from a mine-based field test of IoT rockbolts. Results from the tests indicates that a traditional rock bolt can be equipped with sensors, and that the sensors are capable of detecting mining-related activities.

Test results also show that successful integration between low-power electronics and a standard rock bolt is feasible. When all results presented in this paper are summarized, it is clear that intelligent rock bolts can be used within the mining industry to improve production efficiency and OEE while at the same time produce a better and safer working environment.

Acknowledgment

The authors would like to express their gratitude toward Agnico Eagle's Kittilä mine for allowing us to perform our experiments there. The work has been by the I2Mine and Arrowhead projects.

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