Bedřichov Tunnel – Continual Automated Measurement of Physical Quantities

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Abstract. *The paper presents a solution for continual measurement of physical quantities proposed for Bedřichov tunnel site situated in granite massif in Jizera Mountains. The solution consists of a set of sensors placed at important points in the tunnel as well as on the surface, which are connected by wired RS 485 line or by wireless communication. The communication chain contains also GPRS module for the transfer of measured data to a dedicated server.*

Keywords: Remote Continual Automated Measurement

1. Introduction

One of the issues of the nuclear power engineering is the storage of used radioactive material. Current standard solution accepted in most countries all over the world is a geological disposal – a repository several hundred meters deep, in stable rock, providing isolation properties. Granite massifs are studied as a possible host environment.

The research in some countries is based on underground laboratories like Aspo in Sweden and Grimsel in Switzerland built fully or partly for research purposes. In the Czech Republic we use existing underground constructions – an example is the Bedřichov waterworks tunnel (**Fig. 1**) (Jizera Mts. approx. 120 km North from Prague), an industrial analogue with a lot of options how to observe a long-term response of the rock massif to the excavation [1]. Similar to the laboratories abroad, the research site is related to generic properties of the host rock and exploration methods and it is not the place considered for real repository. Several institutions have participated in the research since 2003.

One of the main issues is how to monitor various physical quantities without a need for manual measurement in the tunnel (formerly within interval of 14 days). Between quantities being currently monitored belong flowrate in water springs (inflow to the tunnel), temperature (both water and rock massif), pH, conductivity, redox potential, fracture displacements and seismic activity [2]. One of the requirements is a possibility to add new sensors on the fly. The data from sensors must be accessible 24 hours a day, 365 days in a year.

Fig. 1: Situation in the tunnel with combined blasted or bored parts [1]

2. Building Infrastructure and Sensor Placement

At the beginning there was no infrastructure in the tunnel available. The first step was to build wired infrastructure consisting of RS485 (12-24 V). The wired line was built up to 890 meters from the tunnel entrance and the remaining length of tunnel will be covered by wireless or laser communication technology, as building wired infrastructure was shown to be very expensive. In **Fig. 2** you can see the tunnel situation and examples of sensors installed.

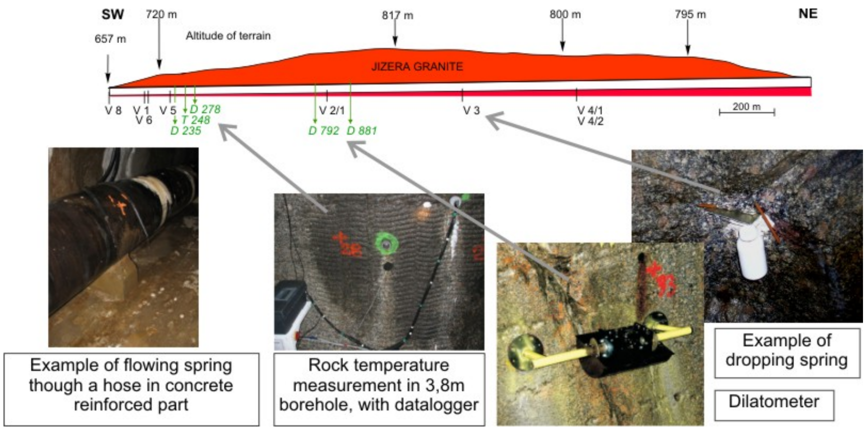

Fig. 2: Scheme of the tunnel and sensor placement

3. Data Gathering and Transmission to Persistent Storage

Proposed communication network (see **Fig. 3**) consists of sensors placed in the tunnel communicating with a microchip module at the tunnel entrance, which is responsible for data transmission over wireless line (currently GPRS) to a dedicated database server. Measured data are stored in a structured way in a relational database. Database scheme was wittingly proposed in Boyce-Codd normal form, which ensures no data redundancies coming from functional dependencies. No redundancy is important as it simplifies (in some cases allows) various queries on stored data (like fetch all temperatures within predefined time period, fetch inflow from the whole tunnel, etc.).

The first version of communication network relied on the fact that microchip module is able to reconstruct measured data coming directly from sensors based on their internal format into a structure that corresponds to the database schema. Java application (see **Fig. 3**) running on the server was intended to communicate with the dedicated database server and to reconstruct data from simple communication protocol defined over TCP/IP. Experiments revealed that such configuration is not appropriate, as some sensors used in the tunnel cannot send all data needed by database structure (a sensor placement, unique identifier of sensors, etc.) and such missing data has to be calculated/inferred based on sensors metadata stored in the database. Unfortunately calculations/inferences are too complex to be done by microchip module (omitting the fact that the microchip ought to communicate with a database server when accessing sensor metadata).

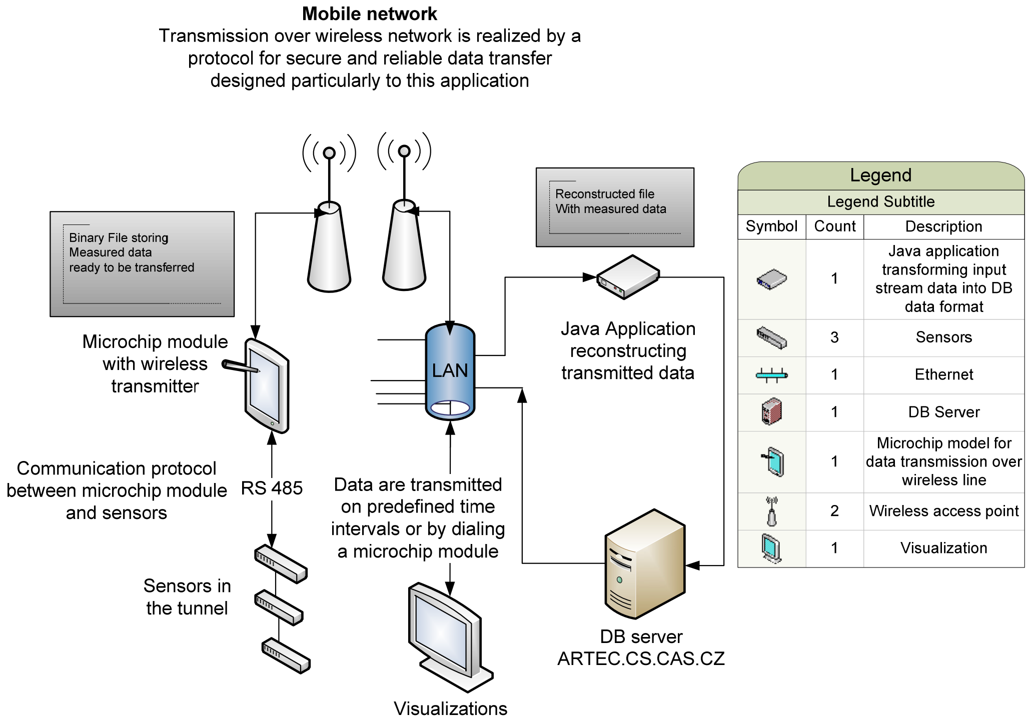

Fig. 3: Communication Network

Consequently, in the second version the communication network was redesigned. The need for calculations/inferences comes from the fact that some sensors are very different from each other (in terms of data structures storing measured data) and therefore it is impossible to cover all of them by a functionality included directly in a Java application (we will call it RemoteDataReceiver). The proposed solution makes use of plug-ins (so called DLLs). For each sensor in the tunnel, there must exist a plug-in ~~being~~ responsible for reconstructing data to a form acceptable by the database. Plug-ins are loaded on fly from predefined directory, so it is easy to implement functionality of a new sensor. Another issue identified is the fact, that debugging plug-ins may be very hard, as the microchip module installed in the tunnel sends all data to just one IP address. In order to overcome this issue, a simulation of tunnel traffic is included in RemoteDataReceiver. It allows to send randomly generated data to arbitrary IP address (localhost for instance) and to debug a plug-in in "offline" mode (by offline is meant a situation where there is no traffic coming from the tunnel and input data are generated artificially). Moreover, the currently developed version of the RemoteDataReceiver allows forwarding traffic coming from the tunnel to arbitrary IP address(es).

4. Conclusions

The communication network proposed for Bedřichov tunnel, excavated in granite massif, provides online measurement of physical quantities. Several new sensors have been designed to achieve desired measurement; the diversity of measured quantities requires combination of different sensor types and manufacturers. Especially the commercially available intelligent sensors often use digital output with closed (unknown) communication protocol; moreover they do not include all data required by a database scheme, so it was necessary to propose a slightly modified version of the communication network.

Storing measured data in relational database is also possible, but with respect to a proper database schema engineering. From our experiments it comes out that Boyce-Codd normal form is appropriate as lower normal forms do not prevent inconsistencies. Storing data in improper database relation or storing unstructured data results in inability to extend set of acceptable queries, impossibility to reuse stored data, etc.

Our experiments further showed that automated measurement of physical quantities in adverse conditions of underground tunnel requires building of reliable communication network, that can be based on existing technologies, but with stress on industrial technologies (like RS 485 bus) rather than technologies commonly available for laboratories (LAN network).

Moreover, supporting communication by dedicated microchip communication device is also possible, but such device should be used only for forwarding measured data to higher level application that ought to be responsible for all calculations/transformations.

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