BEDŘICHOV TUNNEL – AUTOMATED MEASUREMENT OF PHYSICAL QUANTITIES

BEDŘICHOVSKÝ TUNEL – AUTOMATICKÉ MĚŘENÍ A PŘENOS FYZIKÁLNÍCH VELIČIN

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Abstract

We present a concept of field measurement and data transfer adjusted to underground locations with unique features like modular structure, combination of different sensors, and database storage. The solution has been tested and implemented within Bedřichov tunnel site situated in granite massif in Jizera Mountains. The system consists of a set of sensors placed at selected points in the tunnel as well as on the surface, which are connected by wired EIA-485 line or by wireless communication technology. The communication chain also contains a GPRS module for the transfer of measured data through the internet to a database on a dedicated server.

Abstrakt

Článek popisuje návrh a realizaci komunikačního řetězce, který umožňuje měření fyzikálních veličin v prostředí podzemní laboratoře situované v Bedřichovském tunelu v Jizerskohorském žulovém masivu. Řetězec rovněž řeší přenos naměřených dat a jejich uložení do relační databáze. Přenosový řetězec obsahuje jak autory navržené senzory tak i komerčně dostupné senzory. Komunikace uvnitř tunelu je řešena pomocí EIA-485 nebo pomocí bezdrátové komunikační technologie a přenos dat na databázový server je řešen pomocí GPRS modulu.

Keywords

Remote Continual Automated Measurement, telemetry, database, deep geological repository, wireless communication

1 Introduction

Field measurement of physical phenomena is important in many applications, especially in geotechnics and hydrogeology. Particular interest is the measurement in underground constructions which can give the knowledge about the behaviour of geological materials “from inside”.

The development of electronics and information technology allowed more and more efficient collecting of measured data in the last decades. The current trend is e.g. a change of interest from data-loggers with local storage to online data transfer mainly with the availability of GSM networks. Standard commercial solutions include fully functional complete systems of sensor networks, data transfer and storage but are limited to sensors and other components of particular manufacturer and proprietary software for processing data.

The existing projects of online measurement in underground in the Czech Republic are the Josef gallery [5] and Jeronym mine [2]. The system developed for Bedrichov tunnel in contrast with those cited is projected for conditions without full electricity and data wires infrastructure, together with up-to-date information technology tools, with packet transfer (IP protocol) via GSM/GPRS network and organization of sensors and data to database [1].

The motivation for measurement in Bedřichov tunnel is its role as industrial analogue of the projected deep geological disposal of spent nuclear fuel [3, 4]. Even if its maximum depth below surface approx. 140 m is less than the expected repository and less then dedicated underground laboratories abroad, it has exceptional geological conditions and is important in context of Czech geological disposal program as well as general knowledge of geological processes from scientific point of view [3]. The tunnel length is 2600 m, diameter 3.6 m and consists of two parts with different excavation methods – tunnel boring machine and drill-and-blast (Fig.1).

The existing and planned measurement in Bedrichov follows the geological research and former manual data collection [1, 4]. We can sort the data according to physical quantities as follows:

Fig. 1 Situation in the tunnel with combined blasted or bored parts [3]

- Flow-rate in selected underground water spring (tunnel inflow) of very different magnitude, flow-rate in the several places in water collecting channel
- water quality of the inflows: temperature, pH, conductivity, redox
- rock and air temperatures (cooperation with Institute of Geophysics, Acad.Sci. of Czech Rep.)
- triaxial fracture displacement and seismic activity (cooperation with Inst. of Rock Structure and Mechanics, Acad.Sci), continual record but without full online transfer due to large data volume
- surface conditions: air temperature, precipitation, soil temperature, infiltration and soil humidity

Besides the online measurement there are still many data sampling running but not planned for online measurement: e.g. water chemical analysis, natural isotope tracer sampling, resistivity and seismic tomography in selected profiles. Some of the possible interpretations of particular measurement or combination of more data are already present in the reports [1, 4] and others are processed for new publications in preparation.

The following list summarizes the basic requirements on the online measurement solution [1]:

- combination of classical analogue sensor (thermometers, electrochemical electrodes) and "intelligent" sensors with digital output (ultrasonic water level, TDR),
- sensors resistible to high humidity, low temperatures;
- sensors of low power consumption;
- sensors using wired as well as wireless technology (only part of the tunnel close to the entrance is covered by a wired infrastructure);
- a possibility to add sensors on fly;
- an open infrastructure and communication protocol providing possibility of future upgrades of technology and also placement of novel sensors and integration of formerly installed measuring systems and data-loggers
- both online transfer and local data storage as backup.

2 Building Infrastructures and Sensor Placement

Since the tunnel was excavated in order to provide shelter for a water pipe carrying drinking water for more than 100,000 people, there was no infrastructure available within the tunnel. Thus, between the first steps belonged building of basic wired infrastructure. It was proposed to be accessible and resistible to most of distraction coming from the fact that tunnel goes through granite massif with water pipe.

Between solutions taken in mind belonged wire network and an industry available standard consisting of EIA-485 (RS485) wiring. The technology was shown not to be the best solution for an underground laboratory with a lot of noise and quite hard condition with low temperatures and high humidity. Therefore an industry standard proposed for such tough environments was chosen as the best technology providing reliable and robust communication infrastructure being capable of powering sensors. The wired line was built up to 890 meters from the tunnel entrance, where enough space on flat surface of TBM was available. The remaining length of the tunnel will be covered by sensors using wireless or laser communication technology.

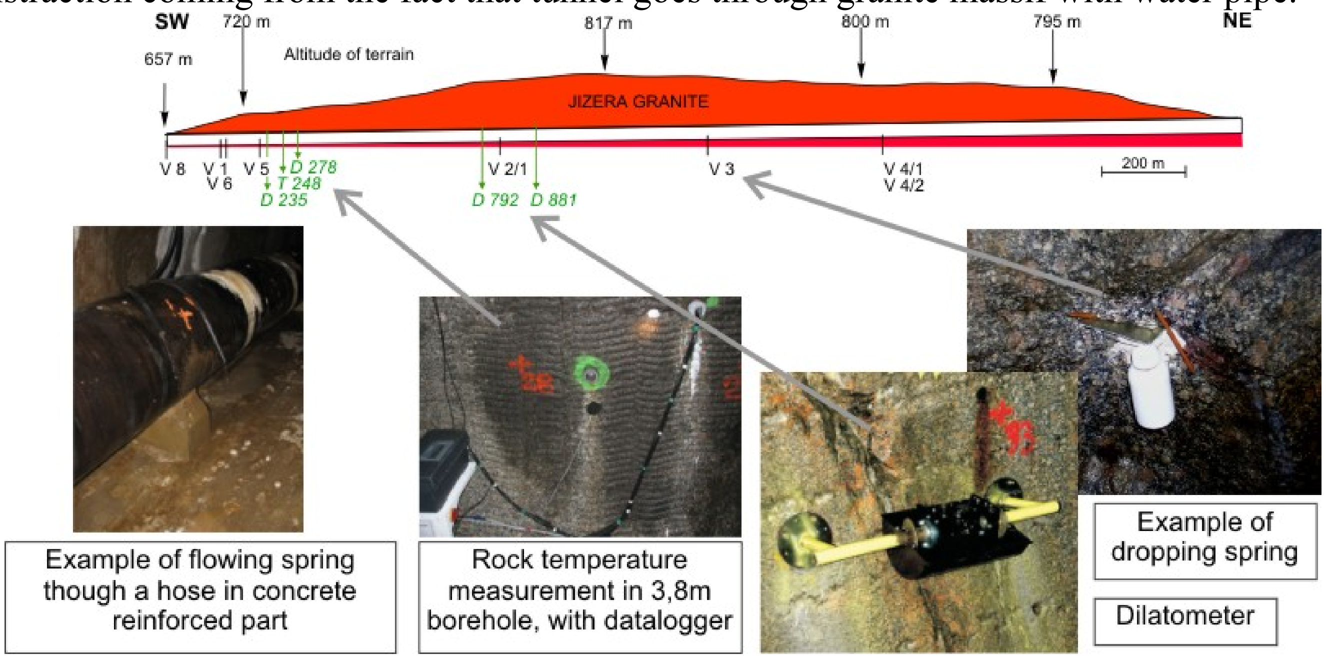

Fig. 2 Scheme of the tunnel with examples of sensors

Currently most of the sensors are placed in this part closer to the tunnel entrance, but coverage of whole length to get representative data is planned in the future. In Fig. 2 you can see the tunnel situation and examples of sensors being currently installed.

3 Gathering Data and Data Transmission to a Persistent Storage

For the purpose of gathering data in the tunnel a communication chain was proposed. The proposal consists of:

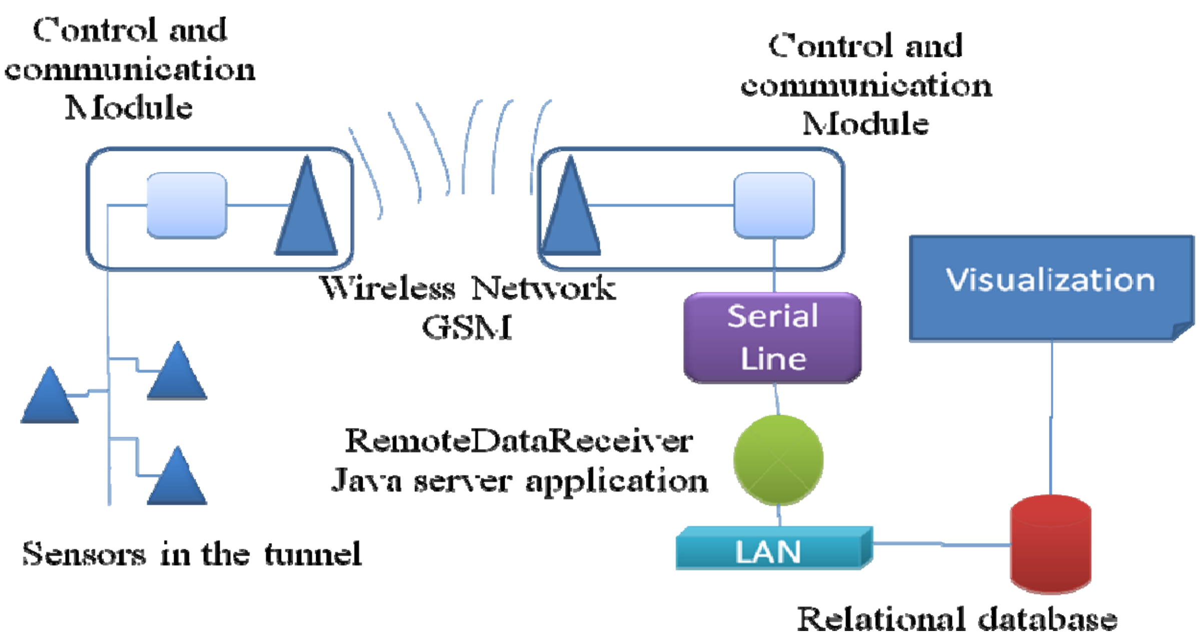

Fig. 3 The first version of the Communication Chain

- sensors placed in the tunnel;
- a control and communication system with low power microcontroller and GSM cellular module at the tunnel entrance communicating with placed sensors and transmitting gathered data over wireless line (currently GPRS data transfer technology);
- a java server application (called Remote Data Receiver) being responsible for:
- receiving of TCP/IP packets;
- extracting measured data stored within EPSNet packets (the original packets used for a communication within the tunnel);
- decoding data from EPSNet packets and storing them to a structure of proposed relational database.
- a dedicated database server storing measured data in a structured way in a proposed 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.).

3.1 Proposing and Modifying of the Communication Chain

The first version of communication chain (see Fig. 3) used a microcontroller and GSM cellular module at server site to receive and GSM cellular module at server site to receive and deconstruct data from Bedřichov. Furthermore it sends raw data to *Remote Data Receiver* that extracted measured data and stored them to relational database. . Experiments revealed that such configuration is not appropriate, as some sensors used in the tunnel cannot send all data needed by the 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 operation requiring communication over a secure channel with a database server to be done by microchip module. Furthermore, the microchip module receiving data over wireless transmission was shown by experiments to be unstable losing occasionally connection to s network.

The second version (see Fig. 4) was a slight modification of the first version avoiding communication of a microchip module with a database. The main modification was a movement of all functionality provided by receiving microchip towards the *Remote Data Receiver*. This allowed us to provide reliable and efficient communication infrastructure with most of the application logic placed on a server side of the communication chain.

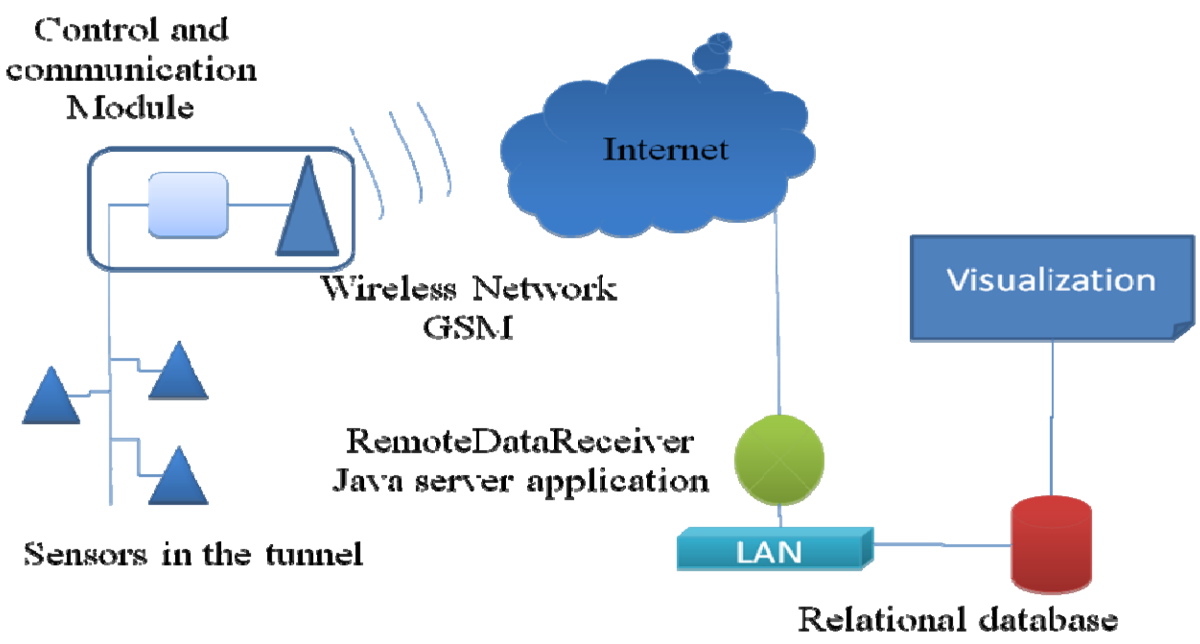

Fig. 4 The second modified version of the Communication Chain

The third version (see Fig. 5) was proposed to overcome the fact that commercially available sensors do not follow the proposed open communication chain. Experiments showed that commercially available sensors use their own (commonly closed) communication protocol packing data within EPSNet packet in many different ways.

Thus a new modification of the communication chain making use of plug-ins (so called DLLs) for each sensor in the tunnel was proposed. The plug-ins are realized as standalone JAR files implementing predefined interface accepting raw data and returning a list of data in structure acceptable by the relational database. Plug-ins is loaded automatically on fly from predefined directory, so it is easy to implement functionality of a new sensor.

Another identified issue 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 simulator of tunnel traffic is included in the *Remote Data Receiver*. It allows to send randomly generated data to arbitrary IP address (*local-host* 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 *Remote Data Receiver* allows forwarding traffic coming from the tunnel to arbitrary IP address.

4 Designing Database

Database schema (see Fig.6) was wittingly designed to be at least in Boyce-Codd normal form providing no redundancies coming from functional dependencies.

Based on several meetings with colleagues the main criteria for design database schema was to allow simple extraction of data based on various filtering criteria.

The following list shows basic objects of the database:

- Points of interest - points where an measurement takes place (point relation);
- Type of measurement (measurement);
- Measuring device (device);
- Magnitudes (magnitude);
- Sensors (header);
- Measured data (header-record).

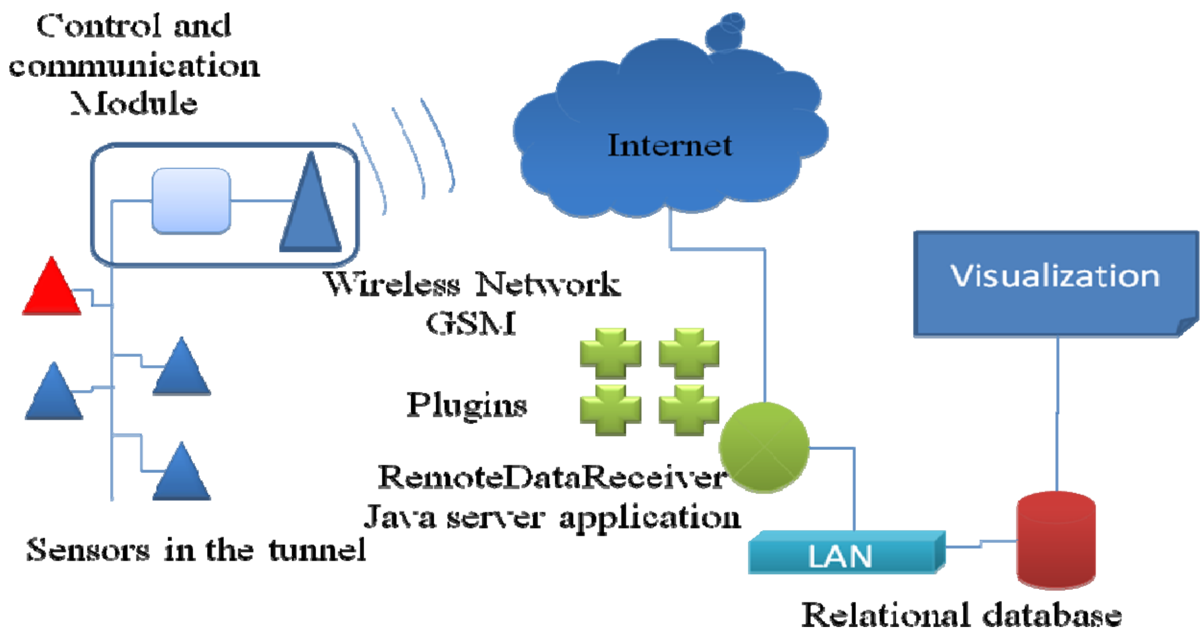

Fig. 5 The final version of the Communication

Such scheme allows simple and efficient extraction of desired data. For example, it is possible to extract all data within a time interval from a selected point of interest, select total inflow in the tunnel, etc.)

Conclusions

The communication network proposed for the Bedřichov tunnel, excavated in granite massif, provides online measurement of various 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 the proposed database scheme, so it was necessary to propose a slightly modified version of the communication network.

Storing measured data in relational database is possible and efficient, but with respect to a proper database 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 a reliable communication network, that can be based on existing technologies, but with stress on industrial standards (like EIA-485) rather than technologies commonly available for indoor and 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.

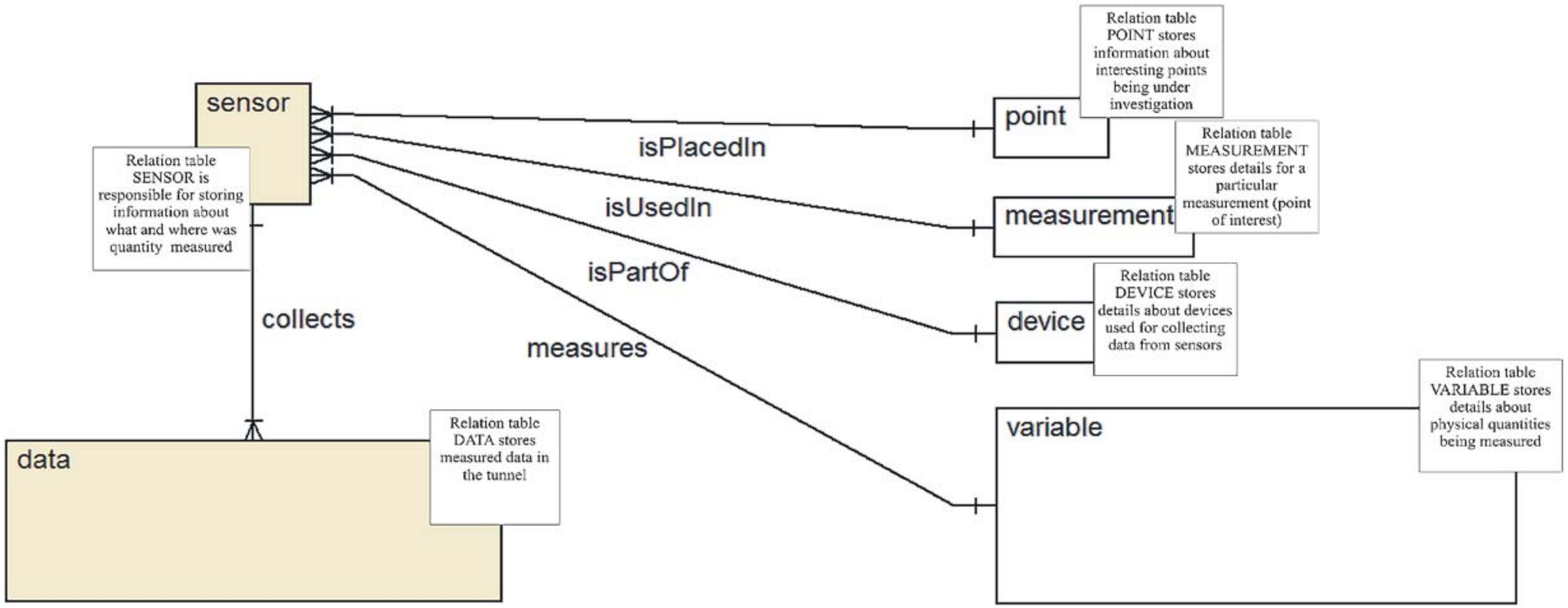

Fig. 6 Proposed database schema

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