TELEMETRIC SYSTEM FOR GEOMAGNETIC FIELD MONITORING

Peter Kraker, Andrej Štern, Janez Bešter
University of Ljubljana, Faculty of Electrical Engineering
Trzaska 25, 1000 Ljubljana, Slovenia
peter.kraker@ltfe.org, andrej.stern@ltfe.org, janez.bester@ltfe.org

Rudi Cop
University of Ljubljana, Faculty of Maritime Studies and Transport
Pot pomorscakov 4, 6320 Portoroz, Slovenia
rudi.cop@fpp.edu

ABSTRACT

Measurements of changes in the geomagnetic field in Slovenia were concluded in 1989. They have been renewed through the scientific research project which began in August 2007. In line to this project it was necessary to define a location on the territory of the Republic of Slovenia which could be used as a starting point for geomagnetic measurements. Such a location, chosen as the starting point for geomagnetic measurements in Slovenia, is expected to be the location for the construction of a Geomagnetic Station. The measurement results from this Geomagnetic Station would be collected and processed in a geomagnetic laboratory.
This paper describes the design and installation of a telemetric system for transmitting the measured geomagnetic field data to a distant laboratory in order to meet the INTERMAGNET's requirements of accuracy and timing. The described monitoring site was positioned in harsh environment with low and predictable magnetic interference, thus far from emitting communication infrastructure. Several issues had to be solved before the design of such a sensitive system began, including link reliability and availability, error prevention, detection and possible correction, data processing, temperature stability and low power consumption. The architecture of installed communication and data retention system is focused on wired and wireless connections, embedded computer and possible environmental sensor extensions.

Keywords: telemetry, measurement, architecture, communication, embedded computer, sensor

1 INTRODUCTION

The relative daily change in the geomagnetic field, its disturbances and pulsations, are measured at a geomagnetic observatory on the basis of the normal value of the Earth's magnetic field. The cause of the above-mentioned phenomena is a change in solar activity. Our civilization has become dependent on technology to a high degree. Mobile telephones, power lines and electrical transformers, aircraft and the Earth's artificial satellites are strongly influenced by solar winds and the resulting changes in the Earth's magnetic field.

Two of the six world data collection centres or Geomagnetic Information Node operate in Europe and their task is to collect the results of geomagnetic measurements which are carried out almost in real time. Through these centres more than 80 geomagnetic observatories around the world are connected through the INTERMAGNET project (International Real-time Magnetic Observatory Network). This international project, which has been operating since 1991, enables data collection, storage and analysis. The data is sent from devices for geomagnetic field measurement, which measure changes in the geomagnetic field at different points over the Earth's surface.

2 STATION FOR GEOMAGNETIC MEASUREMENTS IN REPUBLIC OF SLOVENIA

Measurements of changes in the geomagnetic field in Slovenia were concluded in 1989. They have been were renewed through the scientific research project M4-0225 which is carried out by the public Agency for Research of the Republic of Slovenia (ARRS). The project began in August 2007 and it will continue till the end of 2009. Its aim is to measure the size of the magnetic declination in Slovenia and also to offer a comparison with global models of the geomagnetic field. In line with this project it was necessary to define a location on the territory of the Republic of Slovenia which could be used as a starting point for geomagnetic measurements as well as a point for calibration of the measuring devices. Such a location, chosen as the starting point for geomagnetic measurements in Slovenia, is expected to be the location for the construction of a Geomagnetic Station. The construction of Geomagnetic Station is the part of the Experimental Setup Application (ESA) project for geomagnetic field measurements in the Republic of Slovenia. The ESA project is an upgrade of the current research project M4-0225. It may be carried out together with the M4-0225 project but it will start with a minimum delay of one year. It is expected that the ESA project will last more than three years.

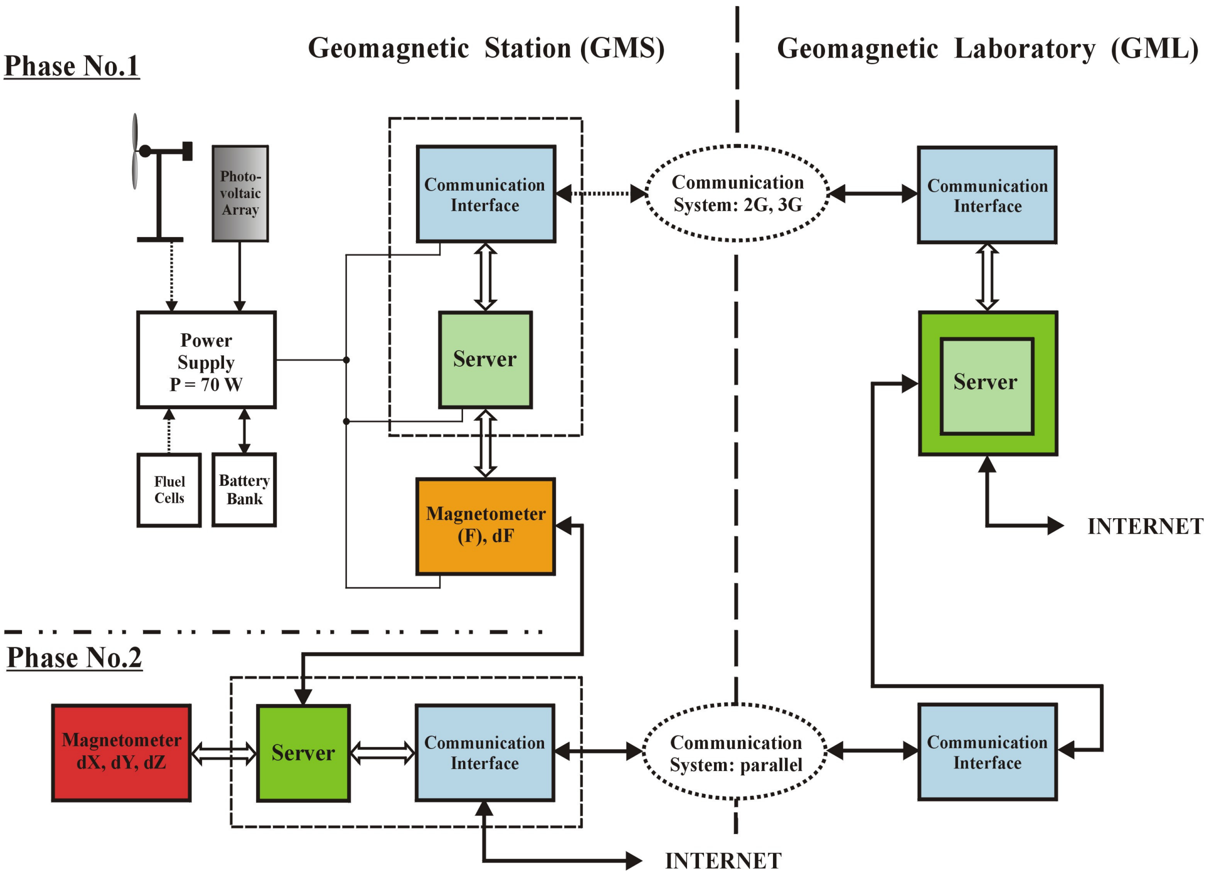

Figure 1: Measuring and telemetric system for geomagnetic field measurements in the Republic of Slovenia

The measurement results from this Geomagnetic Station would be collected, processed in a geomagnetic laboratory and broadcast worldwide (Figure 1). This laboratory would be included in the INTERMAGNET project and would also prepare further research into weak magnetic fields and could be included in domestic and international projects in this area. Its tasks would also include data collection and processing for the needs of Slovenian users. Such data are the basis for navigation and cartography as well as for research into the ionosphere and the biosphere. In fact, measurement data on changes in the geomagnetic field are the basic data for interdisciplinary studies in meteorology, seismology and medicine, as well as for research into the quality of the environment, drinking water and food.

3 TELEMETRIC SYSTEM DESIGN ISSUES

The telemetric part of geomagnetic field monitoring side starts at a point where measurements data is being sent from a magnetometer to an outer world.

3.1 Communication from a distant measurement site

Before transferring data, the serial port of magnetometer must be properly configured. There are two possible ways how to handle the output streams, either in real time transmission or after the survey. In our case it was a clear decision to make it in near real time intervals since embedded computer is capable of temporary storing and relaying the data of large quantities. The serial communication speed has to be calculated within the data quantity demands and minimum of 19200 bps (2.4 kBps) suited us well.

Using serial connections is commonly known as semi-robust way of transporting the data. Due to relatively low transmission speed it performs better than parallel or modern USB interfaces. The RS-232 standard claims the maximum cable length is 15 meters (50 feet), or the cable length equal to a capacitance of 2500 pF. So using a cable with low capacitance allows us to span longer distances without going beyond the limitations of the standard. If a common Ethernet cable is used with a typical capacitance of 55 pF/m, the maximum allowed cable length is 45 meters at 19200 bps. Halving the maximum communication speed would increase the cable length by a factor of ten.

To avoid the interference the core of telemetric unit must be positioned in a distant location at least 100 meters away from the magnetometer's position. This represents the barrier in serial linking and requires an upgrade of classic serial line. Most common solution is using the differential balanced line in a form of RS-485 or RS-422 standard which specifies only electrical characteristics of the driver and the receiver without any data protocol. They offer high data rates while spanning large distances (100 kbps at 1200 m). Another solution with several advantages like low electromagnetic emission, low attenuation and high grade of stability is optical line with serial-to-optical converters. Despite higher initial costs, the choice of using 1 Mbps with multimode fiber for 2 km might be an excellent solution. All these upgrades must be properly powered while simple RS-232 link does not need any additional supply. Although the presumption of low error probability, it is desired that origin serial data contains error protection or detection mechanisms like parity bits or checksums. Similar to GPS reception, every packet of data on the magnetometer's site shall be equipped with a byte or two values that do not match with calculated checksum in case of an error appearance.

3.2 Telemetric unit

These calculations are performed in the telemetric unit, based on a computer module with its peripherals. The decision for the computing power of embedded computer is based on the richness of the operations required to ensure secure, errorless and efficient transmission with some additional features. There is always one compromise that has to be taken: hardware vs. software. Since unit's position isn't near the fixed telecommunication infrastructure, it must be prepared to deal with the wireless network's IP traffic. When using small and costeffective hardware solutions this might be a problem with the missing IP stack. Some GSM/GPRS modules already contain the TCP/IP connectivity and so decrease the demands for software developments but this might be still the solution for series of thousands pieces.

Better choice is a small factor embedded PC platform with possibilities of running widespread operating systems like Microsoft Windows (Embedded) or Linux. Since telemetric tasks are more networking oriented the latter is much better choice. The selection of embedded computer in a range of few 100 MHz processing power, RS-232, USB and Ethernet ports and a solid state storage without spinning disks should be adequate to satisfy the needs. Such a platform is also a guarantee for fast and straight-forward software development.

When developing communications oriented software, the issues of different input and output data rates usually appear. Receiving textual data through serial line and transmitting to the end point using IP protocol might show a difference of 1000 times. So this traffic, especially from faster to the slower side, must be properly buffered and organized. A decision must be taken where and how this buffer is placed. Storing all the buffer data in RAM is the fastest solution but this requires lots of RAM, which quantity is modest in embedded systems. On the other hand, using permanent storage like SD cards might result in a short lifetime of read-write cycles of a flash cell. The only industrially recommended solution is a CF card with certified temperature range. It is capable of reliable buffering or storing the measurements on the site for several months. This comes truly handy when the wireless communication is down due to some failure.

3.3 Wireless communication

Since the measurement site is positioned in a location where only wireless wide area networks are available, the GSM/GPRS solution is the simplest one regarding availability and price-performance ratio. Other possible communications are satellite links over different providers (e.g. Globalstar), special purposed radio links in GHz wavelengths or optical communication using lasers. They all require the line-of-sight to the receiver site.

In GSM/GPRS networks several mechanisms exist that enable secure and reliable transfer. The data sent over a wireless link to the mobile network's base station is encrypted using standard GSM standard cryptography. The most vulnerable part of the communication path is the Internet connection from mobile operator to the observatory data server. The data can be altered by malicious users causing irregularities at server's site. So this part has to be additionally secured by establishing a virtual private network from the operator to the observatory's intranet. This is usually done by requesting a purposed APN (Access Point Name) from a mobile operator. When end-to-end security is a must, an enough powerful embedded system should establish a full-path IPSec connection.

Additional issues in wireless communication field reside from antenna placing and minimizing the electromagnetic interference to the measurements.

3.4 Other issues

Other basic issues are related to environmental conditions, power management and system redundancy.

Every electronic part must be placed in a proper environment. The parameters like humidity, temperature, vibration and sterility must be respected. Significant improvements can be achieved when using industrial enclosures. The IP (International Protection) Code classifies the degrees of protection provided against the intrusion of solid objects, dust, accidental contact, and water in electrical enclosures.

Strict power management is a major concern of all autonomous systems. Since the measurement site is placed far from electricity source all the components of system architecture must respect the limits set by the power generators. It is desirable to use low power modes in the computer when idle and configure the wireless transmissions in a way that maximizes useful data versus high power signaling.

When the system is installed correctly, many things still can go wrong during long usage periods. Establishing a redundant system with automatic switch-over is desirable in combination with auto-diagnostic tools. Simple monitoring applications on the redundant intra-connected embedded computers can be observed by a remote link, so the low-power states, failures and harsh environmental conditions can be detected and solved as soon as possible.

4 TELEMETRIC SYSTEM IMPLEMENTATION

The implementation of telemetric system is a result of combining hardware and software part into one unique telemetric solution.

4.1 Telemetric unit's hardware

Telemetric unit is based on highly integrated low power computing platform and capable of running PC-compatible software without any modifications, making this hardware an ideal choice for development of telemetric services with high degree of complexity and modularity.

Figure 2: Telemetric unit dimensions

Larger amount of RAM and Compact Flash memory is available with several connectivity extensions like USB, RS-232, Ethernet and some internal industrial buses. A VGA port for connecting standard video display is also available for local administration when needed. The wireless connectivity part consists of GSM/GPRS module in form of internal miniPCI card with external antenna or external USB-powered GSM/HSDPA communication module.

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4.2 Telemetric unit software implementation

Primary functional requirement for telemetric unit software system is capturing the magnetometer data and it's short-term retention. The captured data is sent to Observatory Data Server where it can be processed and forwarded to one of the INTERMAGNET's Geographic Information Nodes (GIN).

Direct maintenance of the unit is possible through system shell and web browser interface. Access to archived magnetometer data is available. The retention interval is limited by available storage and configured quota for storage allocation.

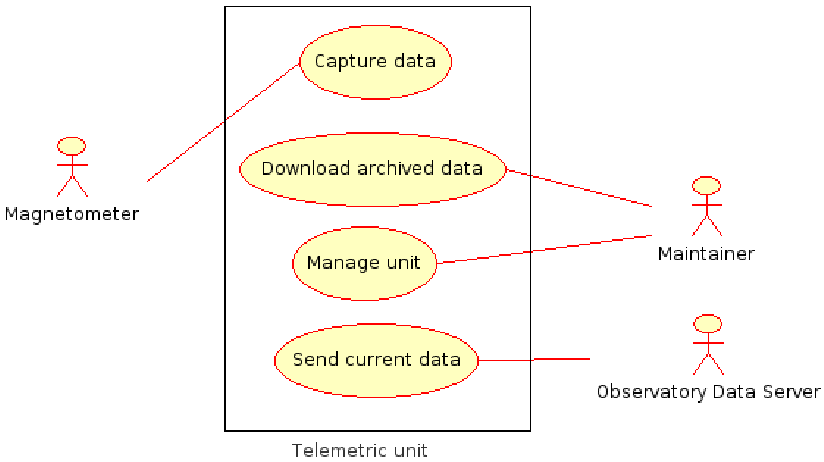

Figure 3: Functional requirements – magnetometer data

Telemetric unit has access to environmental data from external sensors such as environmental temperature and humidity. It can also acquire battery state data from connected Smart UPS and monitor operating system state.

If system determines environmental or system condition is not within boundaries of normal operation, it will send an alert to Observatory Data Server and the administrator. The annual summary of system health information will also be sent.

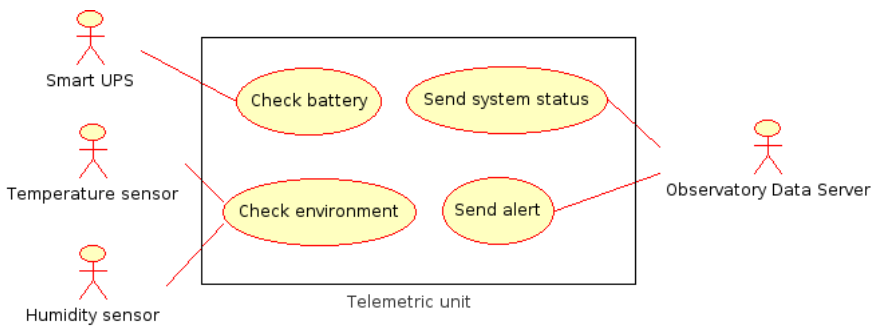

Figure 4: Functional requirements – System health and environmental data

4.2.1 Implementation and architecture

During implementation care has been taken to keep application portable to most popular operating systems, which excludes access to external sensors and Smart UPS. Consequently software system is written in Python 2.4 with portable serial communications library „pyserial“, used for magnetometer data capture. Ubuntu Linux Server edition was used for the final deployment.

Software application was designed as multithreaded application performing magnetometer data acquisition, communications and system health estimation in three distinct threads:

- main thread (data acquisition and aggregation)
- communications thread
- environment and system health evaluation thread

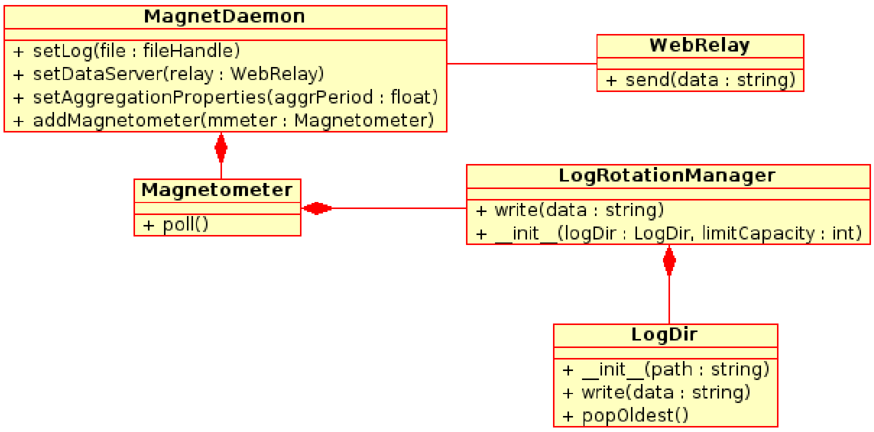

Figure 5: Simplified software system class diagram

4.2.2 Magnetometer data acquisition

Magnetometer provides the measurements to telemetric unit through serial connection and the serial port. The data records are received as string of bytes with endline characters at the end.

Records are collected once per second and written into current day log immediately, thus solving short term data retention requirement. Logging of magnetometer data is limited by system storage and application parameter for storage quota limit. This limit is "soft" by nature, since it allows current day's log to grow without limitations.

Aggregation of data allows us to collect data by given time frames (ie. every 5 minutes), with intent to reduce communication's overhead.

4.2.3 Communication

Communication's thread contains simple queue, where aggregated data is kept until it is sent successfully. Connection is kept up by a separate system process, which takes care of dial-up procedures and authentication to network service provider.

4.2.4 Environment and system health evaluation

System health thread polls external sensors and collects UPS battery data according to configured time period to determine if environment and system state is within configured parameters. System summary is sent to Observatory Data Server every day, while alarms are sent as soon as network connection is available.

4.3 Observatory Data Server

Observatory Data Server (ODS) receives and stores telemetric unit data therefore providing long term storage of magnetometer data. This data is available for review and processing, before data is sent to INTERMAGNET's GIN. ODS consists of Web server with PHP scripting support and relational database management system.

Data between telemetric unit and ODS is transferred in form of messages as defined by HTTP protocol. "Push" mechanism is used communications, where unit initiates session with ODS's web server, sends data and waits for a reply.

There are three types of messages, unit can send to ODS:

- Magnetometer records message, which consists of magnetometer identification and magnetometer data.
- Telemetric unit status summary, which consists of magnetometer identification and system state summary information.
- Alarm message, which consists of magnetometer identification and alarm information.

5 CONCLUSION

Current testing has verified basic functionalities, which encompass data capture on classic EIA-232 serial communications connection, magnetometer data storage and communication with ODS using GPRS connection. The results have confirmed worthiness of system design and that reliable near-realtime availability of magnetometer data can be guaranteed.

Biggest issue to be solved in the future remains assurance of data integrity of captured serial magnetometer data, which currently doesn't contain checksum. Further improvements will deal with data compression both for stored data and data transferred to ODS. This will increase unit's capability to store magnetometer data for longer durations and will potentially reduce used communications bandwidth. Due to low communication bandwidth available on chosen site, security will remain weak, which can consist only of basic HTTP digest access authentication without encryption.

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