

Data Consistency and Fault Management in Local Sensor Networks used for Landslide Surveillance

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Abstract – In this paper we are presenting a data consistency and fault management architecture, developed for a local embedded sensor network used for landslide surveillance. Landslide sensor responses measured from multiple points are used by our software architecture to compute a local landslide displacement and orientation. Landslide sensors are checked by our architecture for data consistency and fault management. Our approach implements a fault tolerant architecture, where a measurement point that is identified, tested and verified to be faulty is removed from the list of addressed sensors in order to ensure data integrity. Fault tolerant architecture is integrated at node level, where possible diagnostic fault codes received from measurement points are managed. Decisions to exclude measurement points from the network are made based on the occurrence and persistence of specific diagnostic fault codes.

Keywords – embedded sensor network, fault management, data consistency, landslide surveillance.

I. INTRODUCTION

Fault management and data consistency have key roles in the network management strategies of advanced sensor networks. The rapid growth of wireless sensor networks emphasize even further the importance of an efficient management mechanism because of their applications in harsh environments that could easily have a negative impact in the overall data flow of the network. In order to address the issues related to network performance and data consistency a series of strategies have been developed that detect faults and integrate fault recovery mechanisms to maintain network operability and efficient data flow [1-2]. One method of dealing with fault situations is to implement a management system that is fault tolerant [3]. Faults can be caused by electromagnetic interferences, component failure, and elevated temperatures but also by natural phenomenon within the working environment [4]. Our work proposes a fault management and data consistency mechanism that could be used in landslide surveillance sensor networks [5]. Our

method combines centralized [6-7] and distributed [8] approaches for fault management in order to take advantage of the features provided by these implementations.

II. LOCAL EMBEDDED SENSOR NETWORK

In order to survey a landslide prone area we have developed a local embedded network comprised of a local network node that manages the data acquisition and fault detection process from multiple measurement points. Landslide activity is measured by a landslide measurement point (MP) that uses an in depth landslide sensor (LS). Measurement point activity is supervised by a microcontroller that acquires data from the landslide sensor. Network activity is coordinated by the local network node which communicates with the measurement points by means of a serial RS-485 interconnecting cable. The local embedded sensor network architecture, proposed by our approach is described in Fig. 1. The local network node is part of a wireless sensor network that uses NXP JN5148 modules. The embedded measurement point contains the following hardware components: sensor signal conditioning circuit (SC), signal generator (SG), programmable gain amplifier

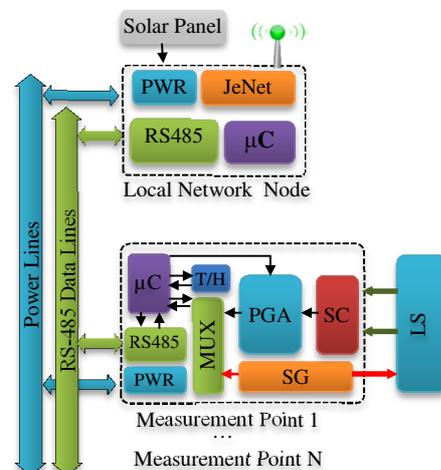


Fig. 1. Architecture of the local embedded sensor network

(PGA), analog signal multiplexer (MUX), temperature and humidity sensor (T/H), microcontroller (μC), full duplex RS-485 transceiver (RS485) and a power converter circuit (PWR). Sensor response is preprocessed by the SC and then is amplified by PGA using a software computed gain. The μC acquires the landslide data by controlling the MUX to feed the two sensor response signals and the excitation signal to the ADC. Landslide data is transferred to the local network node using the RS-485 integrated transceiver.

III. NETWORK NODE MANAGEMENT COMPONENT

The specific data consistency and fault management procedure presented in this paper was intended to be used in an embedded concept system aiming to implement a landslide measurement and monitoring system. Our approach proposes a distributed mechanism for data consistency and fault management that focuses his actions on the local embedded network. The fault management and data consistency mechanism is coordinated by the network measurement node. Nodes are able to detect error sources, identify malfunction scenarios and ensure data consistency for each subsidiary measurement point by controlling the acquisition time.

Measurement points were addressed by unique identifiers, and respond with predefined status messages, diagnostic fault codes (DFC) and data formats. The software architecture implements two main tasks. The first task consists in sending normal data requests to measurement points, receiving data, computing landslide parameters and analyzing data in order to identify triggers and possible alerts. The second task implements the sensor response test mode that aims to identify and eliminate faults that could corrupt data consistency of the response received from each measurement point. Diagnostic fault codes are used to signal a fault situation.

Local node software starts by initializing the node peripherals and communication modules. Next a real time clock synchronization (RTC sync.) message is send to the measurement points of the embedded network. After the synchronization process network points are addressed one by one using their unique identifier (ID). Measurement points are added to the network when they respond affirmative to the interrogation message send by the node. In case an addressed point does not respond to the node request that point is not considered as part of the embedded measurement network. A valid identification response is followed by transmission of any existing diagnostic fault codes. Next the operation mode for that specific point is selected. If any fault codes are received the network point mode of operation is switched to test.

A. Centralized fault detection mechanism

The test mode is used to find the source of any faults

that influence the measurement point acquired data. A test command is send to the specific point containing the test mode identification and the time delay between two consecutive sensor tests (Δt). The targeted point is bound to respond with possible fault codes and operating status. In case the point response contains a fault code a new test is requested for that specific network point. A set of five consecutive failed tests, acknowledged by an error status renders the measurement point as faulty and is further ignored by the network. For this fault case the point ID is eliminated from the list of functional network points and the DFC and time stamp are stored for future reference.

If after a new series of tests the sensor response does not contain the initial DFC and the status is favorable then the code is cleared, the point ID is refreshed and the point is again part of the embedded sensor network. Next if any fault events have occurred they are stores and the following network measurement point is addressed.

B. Centralized data consistency mechanism

The normal functioning mode is selected for a specific network point if no diagnostic fault codes were detected. A normal mode command is send to a specific network point containing the normal mode identification and the time delay between two consecutive sensor readings of sensor responses. As a response to this command the network point sends his unique ID and status. Once a validated point ID and status was received the point starts to send the data stream to the local node.

The node receives the measured landslide sensor responses and computes the landslide orientation (LSO) and the landslide displacement (LSD). Computed values of the newly determined LSD and LSO are first stored and then compared with previews values. In the process of analyzing the evolution of the LSD and LSO data the time stamp of each computed value has a key role.

Particular faults or landslide events could be characterized by their own distinct time stamps and could be used to issue warnings or alerts related to landslide developments. Based on the evolution of the LSD and LSO locally computed data there are two possible situations that could result from the warning mechanism.

First situation refers to the case when a possible landslide triggering event could occur. If this situation is triggered then our data consistency mechanism computes a new target time delay and adjusts the acquisition frequency of sensor data by decreasing the time between two sensor readings. After sending the adjusted time delay to a specific network point a landslide possible trigger event (LsPT) is recorded. In the case when multiple trigger events are recorded over a predefined time frame and measured data presents an ascendant trend this means that the landslide activity registers important changes shown by the persistent events and a possible landslide alert is created (LsPA). Previews issued landslide alerts are cleared if the triggering conditions are

not persistent. In the event when a possible landslide trigger is recorded once and the landslide data does not causes the event to reappear this event is cleared and interpreted as non-persistent. The computed LSD and LSO describe the general landslide activity sensed by our local embedded sensor network. This activity characterizes the vertical profile of soil layers in one specific spot from the landslide prone area.

IV. NETWORK POINT MANAGEMENT COMPONENT

The distributed architecture of our data consistency and fault management mechanism, implemented at the level of each embedded network measurement point is described in Fig. 2. The mechanism proposed for fault management at measurement point level contains a localized component. At the level of measurement points, test mode operation runs a pseudo independent testing component that checks if the points present any DFC.

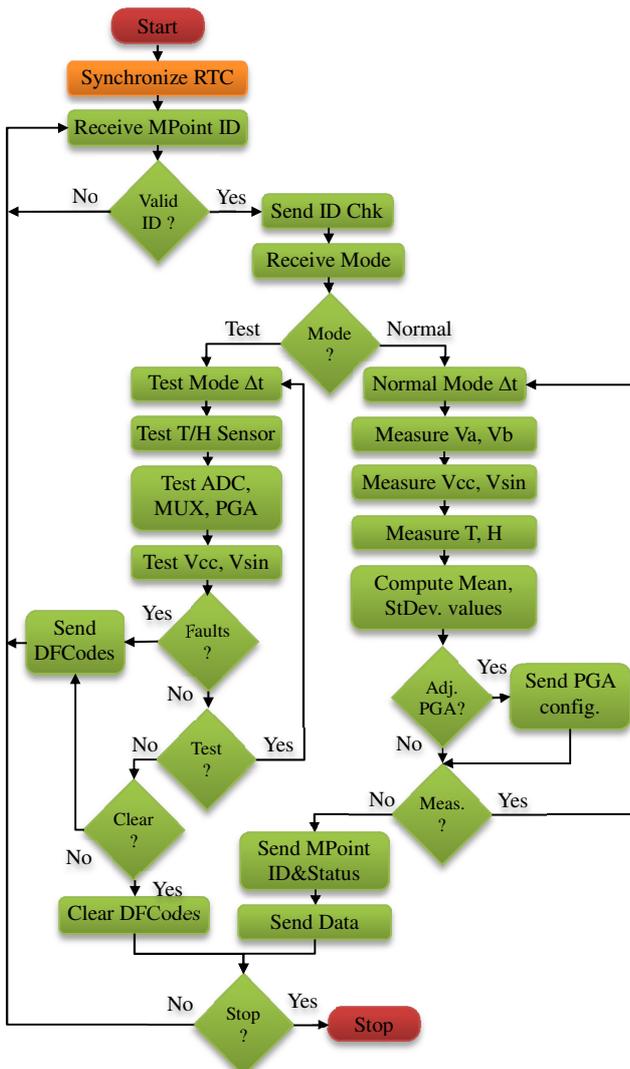


Fig. 2. Software architecture of a measurement point

This assures a localized mechanism used in case of fault detection to identify the source of the fault and to take corrective actions. First the measurement point is synchronized with clock of the central node using the received time stamp. After a successful synchronization, the data time stamp will be accurate and reliable. Time stamps are used by the fault management mechanism to identify discrete events that have occurred in the landslide monitoring process. At this point the measurement point awaits a request from the central node. The node addresses measurement points by the unique identifier attributed to each point of the network.

Identifiers are validated by the corresponding points and then a confirmation (ID Chk) is send to the coordinator node. After receiving the confirmation message the node sends the mode of operation to the specific network measurement point. The received mode of operation is decoded and a decision is made to run in test mode or to continue in normal operation mode. The two modes of operation are used for continuous monitoring of landslide sensor response and to implement of fault management.

A. Local fault detection

In test mode of operation a series of tests are run to evaluate the response of various hardware system components. Tests are aimed at identifying malfunctions in important hardware system components that could produce false sensor response and corrupt the data consistency. For each test case a unique DFCODE is generated to identify specific fault scenarios. If a fault is found the code is send to the central network node for troubleshooting. In case a fault only appears one time a decision is made internally to test again the system components and if the test results do not indicate an error then the DFC is cleared.

B. Local data consistency

Landslide continuous monitoring is achieved when the measurement points of the local network run in normal mode. Data acquisition is scheduled at precise moments by controlling the time delay (Δt) between two consecutive sensor reads. First a value for Δt is received from the central node that is used to initialize the data acquisition. In certain cases, for example if a trigger is issued, the central node decreases the time between two sensor reading in order to achieve a better time accuracy for the landslide monitoring. Measured data is sent as a time stamped data pack to the central node for storage and analysis. Measured values are used to compute the mean and standard deviation that describes the trend of the acquired data. Based on these computations a decision is made to adjust the gain of the PGA that preprocesses the sensor response in order to be measured within the correct range. Normal mode of operation completes when

the measurement point identifier, status and time stamped data pack are sent to the central network node.

V. RESULTS AND DISCUSSION

The experimental results reported concern the behavior of our concept measurement sensor presented in Fig.1. We have analyzed the sensor response provided by our system in two experimental situations. The first

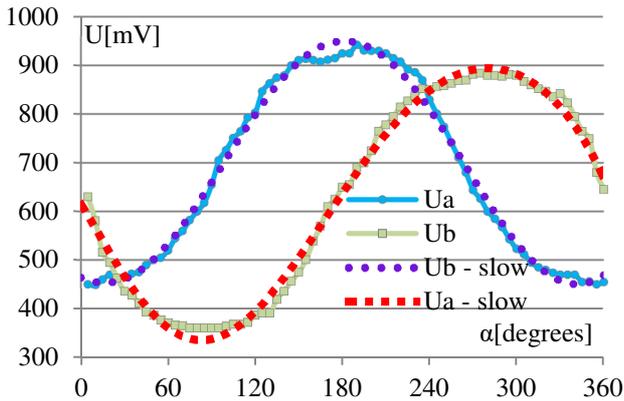


Fig. 3. Measured landslide sensor responses caused by slow and fast changes in the measured data trend.

situation manages the surveillance of landslide activity with a slow evolution with a value of parameter $\Delta t = 5$ seconds. In this case a landslide displacement with constant amplitude is slowly applied to the sensor at orientations from 0 to 360 degrees. The second scenario uses the same amplitude and orientations but this time the speed of variation is increased. Fig. 3 presents the measured sensor responses in the two experimental scenarios. The two measured potentials U_a , U_b characterizing the sensor bridge were ranging from 200 mV to 900 mV and were relating data about the displacement and the orientation. One can observe by analyzing the measured data that the frequency of acquisition has increased from the first to the second scenario. This increase in the number of samples acquired in a specific time frame is caused by the node that adjusts the value of parameter Δt to about 1 second. The data flow corresponding to the fast landslide evolution increases with about 40 % through the network. In normal surveillance mode, when slow landslide movements are evaluated the data flow reaches 10 % of the network transfer capacity. Results from experimental trials show that our implementation is able to cope with increases in landslide dynamics without reaching the maximum transfer rate of the network.

VI. CONCLUSION AND FUTURE SCOPE

In this paper we present a data consistency and fault management procedure applied in an embedded sensor

network used for landslide surveillance. Our approach integrates two management components. The distributed management component is localized at the level of each network measurement point and deals locally with faults and corrects erroneous data. A high level centralized management components functions at node level and deals with malfunctions of the measurement points by eliminating them from the network in order to ensure data consistency. Network central node analyses the trend of the computed landslide parameters and modifies the data acquisition rate in order to maintain an adequate time resolution in case of landslide events. The evolution of landslide data is continuously surveyed by the management mechanism that could signal possible triggers and issue landslide alerts. Further development of the work presented in this paper consists in scaling up our method to cope with the data flow and fault situations of a wireless sensor network used in continuous monitoring of landslide activity over large areas.

VII. ACKNOWLEDGMENT

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REFERENCES

- [1] M. Yu, H. Mokhtar, and M. Merabti, "A survey on Fault Management in wireless sensor network," in *Proceedings of the 8th Annual PostGraduate Symposium on The Convergence of Telecommunications, Networking and Broadcasting Liverpool, UK, 2007*.
- [2] M. Z. Khan, M. Merabti, and B. Askwith, "Design Considerations for Fault Management in Wireless Sensor Networks," in *PGNet 2009 Liverpool, 2009*.
- [3] L. Paradis and Q. Han, "A Survey of Fault Management in Wireless Sensor Networks," *Journal of Network and Systems Management*, vol. 15, pp. 171-190, 2007.
- [4] L. B. Ruiz, I. G. Siqueira, L. B. Oliveira, H. C. Wong, J. M. S. Nogueira, and A. A. F. Loureiro, "Fault management in event-driven wireless sensor networks," in *MSWiM'04 Italy, 2004*.
- [5] M.V.Ramesh, "Design, development, and deployment of a wireless sensor network for detection of landslides", *Ad Hoc Networks*, vol. 13, Feb. 2014, pp. 2-18.
- [6] N. Ramanathan, K. Chang, E. Kohler, and D. Estrin, "Sympathy for the Sensor Network Debugger," in *Proceedings of 3rd ACM Conference on Embedded Networked Sensor Systems, San Diego, California, 2005*, pp. 255-267.
- [7] J. Staddon, D. Balfanz, and G. Durfee, "Efficient Tracing of Failed Nodes in Sensor Networks," in *First ACM International Workshop on Wireless Sensor Networks and Applications USA, 2002*.
- [8] W. L. Lee, A. Datta, and R. Cardell-Oliver, "Network Management in Wireless Sensor Networks," in *Handbook of Mobile Ad Hoc and Pervasive Communications: American Scientific Publishers, 2006*.