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CERN SUPERVISION, CONTROL AND DATA ACQUISITION SYSTEM FOR RADIATION AND ENVIRONMENTAL PROTECTION

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Abstract

The CERN Health, Safety and Environment Unit is mandated to provide a Radiation and Environment Supervision, Control and Data Acquisition system for all CERN accelerators, experiments as well as the environment.

The operation and maintenance of the previous CERN radiation and environment supervisory systems showed some limitations in terms of flexibility and scalability.

In order to face the increasing demand for radiation protection and continuously assess both conventional and radiological impacts on the environment, CERN developed and deployed a new supervisory system, called REMUS - Radiation and Environment Monitoring Unified Supervision.

REMUS design and development focused on these desired features. REMUS interfaces with 75 device types, providing about 3,000 measurement channels (approximately 600,000 tags) at the time of writing.

This paper describes the architecture of the system, as well as the innovative design that was adopted in order to face the challenges of heterogeneous equipment interfacing, diversity of end users and continuous operation.

INTRODUCTION

CERN HSE Unit is in charge of providing Radiation Protection and Environmental Impact Monitoring to CERN facilities and immediate surroundings. This constant surveillance ensures:

- Workplace safety for CERN personnel and external visitors.
- Quick and appropriate response to any unplanned release of potential pollutants or ionizing radiation.
- Reporting to the authorities the nature and the quantities of emitted ionizing radiation.
- Reporting to the authorities of any release of potential pollutants.

In order to fulfil these missions, CERN has set up numerous and diverse monitoring equipment across the organization and its surroundings.

In addition, CERN HSE Unit provides a Supervision, Control And Data Acquisition (SCADA) system able to gather remotely all the relevant data in the domains of Radiation Protection and Environmental Impact Monitoring.

Between 2005 and 2016, HSE operated a supervisory system named RAMSES (RAdiation Monitoring System for the Environment and Safety) [1], which was in charge of the data acquisition, control/command and supervision of 50 device types, allowing the remote supervision of 1,500 channels.

This system allowed, for the first time at CERN, to supervise the majority of HSE relevant equipment in a consistent manner. However, it had some limitations in terms of scalability and evolutivity, making it unsuitable for longer-term use. For instance, some monitoring equipment were not remotely supervised, due to the high cost of interfacing them through the supervision. Some others where remotely controlled by proprietary supervisors, such as Berthold MEVIS, which constrained final users to use different software to operate them.

In 2012, HSE started the development of a new supervisory system, REMUS (Radiation and Environment Monitoring Unified Supervision) that would tackle those limitations. In particular, this system would:

- Interface with all the equipment that were interfaced with RAMSES system.
- Allow quick interfacing of new type of monitoring equipment, in order to unify the supervision and integrate stand-alone devices, most of them being COTS (Commercial Off-The-Shelf) products.
- Provide a reliable, scalable and cost-effective system.
- Use common CERN software, WinCC OA (WinCC Open Architecture) [2], and JCOP framework (Joint COntrols Project) [3].
- Reduce the delay and the cost of declaring and displaying new devices of known types in the supervision.
- Provide light and fast clients, tailored to the needs of diverse end-users.
- Reduce the overall maintenance and user support effort necessary to maintain the system in operation.

REMUS founded its evaluation of scalability and performance on the study performed by CERN engineering department [4]. The technologies used are commonly employed in large SCADA systems supervising the LHC (Large Hadron Collider) such as the LHC Quench Protection System Supervision or CERN Electrical Network Supervision.

For its development, REMUS applies the same International Standard IEC 61508 [5] that was set up during the development of RAMSES.

CORE FUNCTIONALITIES

Project Objectives

The REMUS project aims at developing a universal software for supervision, control and data acquisition for

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the entire suite of monitoring stations covering all radiological and environmental parameters that can potentially be affected by the operation of the facilities of CERN.

Functionalities

The main functions of the system (See Fig. 1) are:

- Data acquisition of measurements and events coming from the instrumentation.
- Display of near real-time measurements, alarms and operational states of instrumentation through customizable user interfaces composed of synoptic, widgets and alarm screens.
- Remote sending of commands and operational parameters to the instrumentation.
- Display of archived and near real-time measurements and events coming from the instrumentation, through a data visualisation tool, ERGO (Environment and Radiation Graphic Observer).
- Publishing of alarms and faults to the CERN central alarm system, LASER (Lhc Alarm SERvice) [6].
- Publishing of measurements to other systems via the CERN Data Exchange system, DIP (Data Interchange Protocol), built on the top of DIM (Distributed Information Management) [7].
- Publishing of measurements to CERN shared MDB (Measurement DataBase) [8].

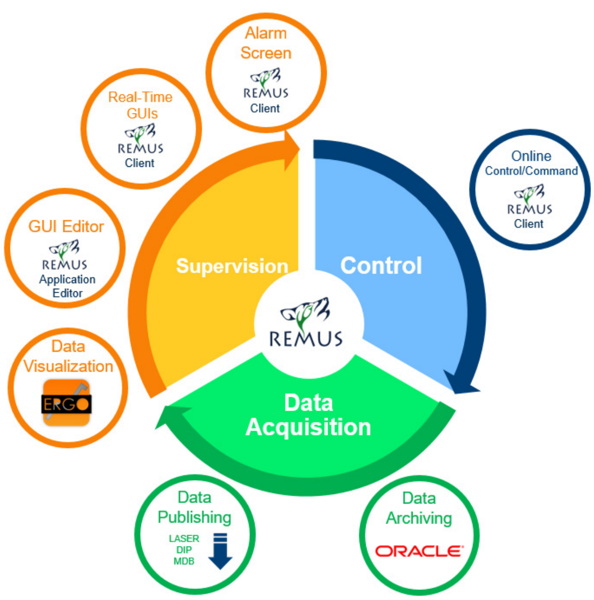

Figure 1: REMUS functional diagram.

The system shall monitor the instrumentation 365 days a year, 24/7 and ensure the data acquisition of measurements and system events in case of network outages.

HETEROGENEOUS DEVICE TYPES INTEGRATION

Problem Statement

CERN has set up, over the years, numerous and diverse monitoring equipment across the organization and its surroundings, in order to efficiently monitor ionizing radiation and environmental impact.

The first driver of this heterogeneity is the wide scope of measurements to acquire, ranging from weather conditions, useful to predict the dispersion of pollutants in the environment, to gamma ionizing radiation.

Another driver is the long lifetime and consequent cost of such monitoring equipment. As a result, monitors are not necessarily replaced all at once when a newer generation of the same type of monitor is available on the market and selected by CERN for installation. They are gradually replaced over the year, duplicating the number of different monitors to interface with the supervisory system. This heterogeneity creates challenges on the SCADA side.

The first challenge is the obsolescence of the firmware and protocol used by such devices, which generally happens before the obsolescence of the electronics. The use of obsolete technologies and protocols make the integration with modern network infrastructure and SCADA troublesome.

Another challenge is the increased complexity of the system as a whole. The SCADA shall make abstraction of heterogeneity for the end user, whose attention should be targeted on the data produced by the instrumentation rather that its technical specificities.

Abstraction by Modelling

REMUS took the approach of making abstraction of the instrumentation by modelling it with simple and generic concepts:

- Channel: An abstract entity representing a geographic point of measure, or a functional position (e.g. “Valve pressure of equipment X”). It allows REMUS to identify every data streams. It is associated to a device.
- Device: A piece of equipment of a determined type (Electronic boards, PLCs, Ionization chambers …) holding its own parameters, possibly connected to other devices and channels.
- Monitoring Station (MS): An encapsulation of a set of devices and associated channels, connected to the system through the network infrastructure.

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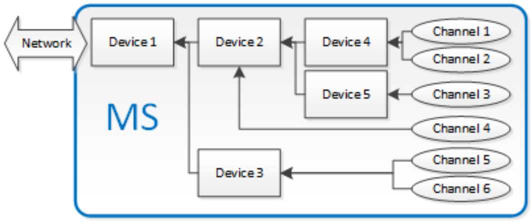

Figure 2: REMUS Instrumentation Model.

Each type of Monitoring Station to interface is modelled in a relational database, using those concepts (See Fig. 2). Usage of abstract concepts homogenizes the software, makes most of source code reusable and simplifies the development process, from analysis to tests and validation.

In addition, it provides REMUS users with what appears to be a uniform instrumentation, easier to comprehend and operate.

DIVERSITY OF USERS

Problem Statement

Radiation Protection and Environmental Monitoring data are of interest for many different type of users at CERN. REMUS shall provide interfaces for operators of the different CERN accelerators and experiments, radiation protection engineers, environmental engineers, physicists, maintenance teams and the CERN fire brigade. The user interfaces shall be easily editable, and as close as possible to the users' needs in term of data and its presentation.

Editable Graphical User Interfaces

REMUS allow trained users to design their own Graphical User Interfaces (GUI), encapsulating all the widgets and synoptic they may need for them and their teams. The GUIs are called *REMUS Applications*, and consist solely of a descriptive xml file, that can be uploaded to the REMUS Server (See Fig. 3). Applications can be created and updated through a user friendly interface, the *Application Editor*. The applications have specific access control, and a dedicated alarm screen. All the applications can be updated at run-time, and the updates are propagated to all the clients simultaneously.

Today, REMUS has 18 distinct Applications, such as Large Hadron Collider Radiation overview, used by CERN Control Center (CCC), or Water conventional monitoring, used by the CERN Fire Brigade.

The advantages of this strategy are multiple:

- Users can focus on devices they are interested in (only a sub-set of the total instrumentation).
- The performance of the clients is improved, as only the variables displayed in the current Application are fetched from the servers.
- The maintenance effort is distributed among several *Application Administrators*, close to the needs of the users.

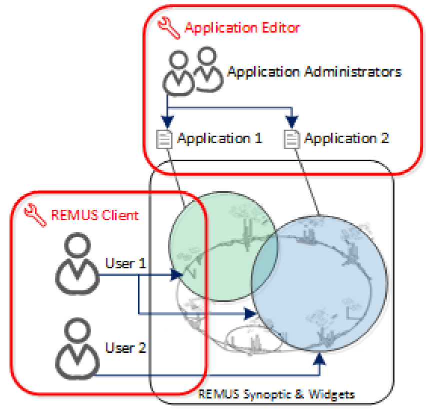

Figure 3: REMUS Application definition and usage.

ARCHITECTURE

Interfacing with Instrumentation

REMUS currently implements five different ways to interface the instrumentation, depending on the protocols implemented by the device firmware:

- WinCC OA native driver (Modbus, S7)
- WinCC OA CERN driver (Controls MiddleWare)
- In-house driver developed on top of WinCC OA API
- File exchange system
- OPC

Data Acquisition & Archiving

The instrumentation connected to REMUS provide about 1,000 measurements to archive every second.

All the devices produce homogeneously formatted measurement files, at the lowest possible level (Firmware, Driver or Supervision), that are later injected into REMUS Oracle database through Oracle SQL*Loader.

This mechanism allows capable devices and intermediate file servers to buffer the measurement data in case of network outages in order to ensure the availability and recovery of the data.

Real time Animation Graphical User Interfaces

The drivers connected to instrumentation send about 1,800 data point updates requests to the central servers every second. The redundant central servers then proceed with the update, and replicate their respective internal databases. The cross-platform Client GUI (remote UI in WinCC OA terminology), running on Linux or Windows, requests all the data needed to animate the tailor-made GUIs either by systematic polling at defined intervals or driven by notifications of updates.

Animation of the alarm screens are working in a similar fashion, with the exception that the alarms meta information is pre-computed on the server side in order to minimize the data exchange between the clients and the redundant servers.

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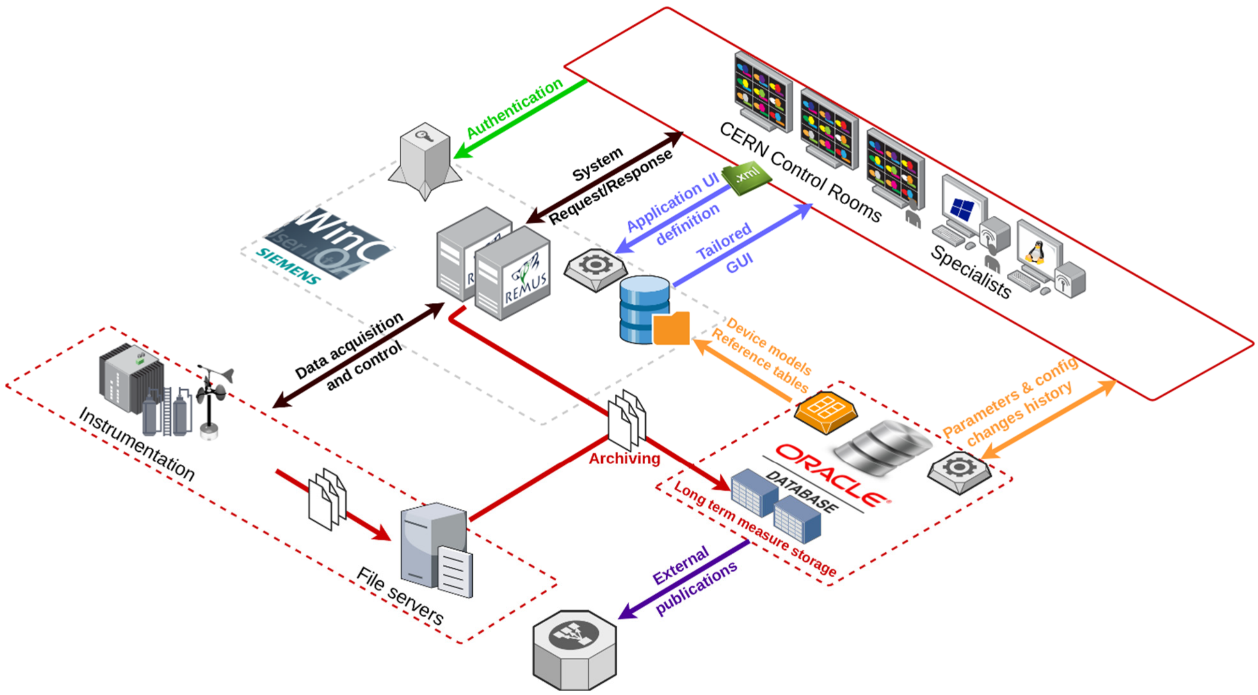

Figure 4: REMUS architecture.

Control/Command

Dedicated UI panels are available from the client GUIs in order to send commands to the instrumentation. Commands and change of parameters requests are encapsulated into formatted messages, *System Requests*, to the central servers, which forward them to the selected device. Once the command has been acknowledged by the device, the change of parameters is recorded in the REMUS Oracle database for future reference and audit trailing.

CONTINUOUS OPERATION

Radiation and Environmental impact monitoring are equally important during operation or shutdown of the accelerators. While the run phases of the accelerators shall naturally be closely monitored, the shutdown periods are typically a time when underground access is more frequent, and when the personnel have more exposure risks. As a result, REMUS needs to be available 24/7, 365 days a year.

REMUS architecture (See Fig. 4) has been designed to be as resilient as possible, in order to ensure its continuous operation.

In addition, all maintenance and support operations have been designed to be executable at run-time, making a 0% downtime objective nearly achievable. Between 2013 and 2018, the availability of the system surpassed 99.998% (20mn of planned down time due to servers Operating System change and 15mn unplanned downtime due to power or network cuts).

This high availability figure has been made possible by implementing the following features.

Run-time Declaration of New Devices

REMUS offers the possibility to users having the necessary access rights to declare new devices to interface directly from the client GUI.

Users select a known device type from the list of available models, a driver and an address. The supervision will add all the internal variables and necessary connections.

Combined with the possibilities of tailoring the GUIs, a new device can be added and have its data shared to all the concerned users in minutes. All this without any interruption of the supervision.

Server Redundancy

REMUS core consists of two redundant synchronized servers, playing interchangeably the roles of *Active* and *Hot Standby* (See Fig. 5). This redundancy has two major advantages:

- The *Hot Standby* server can take over the operation of the core in case of network or power outage of the *Active* server.
- All maintenance operations can be carried on the *Hot Standby* server, transparently for the users.

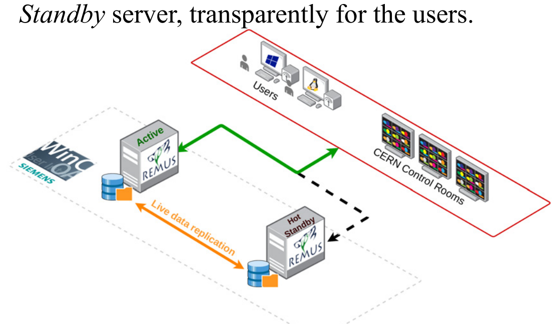

Figure 5: REMUS redundancy.

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CONSIDERED EVOLUTIONS

REMUS succeeded in all its initial objectives, and is now the unique supervision of more than 3,000 measurement channels, monitoring 75 types of monitoring equipment in charge of the surveillance of Radioactivity levels and environmental impact.

Since REMUS is in production, in 2013, the amount of single measurements archived by HSE supervisory systems jumped from 15 billion to 30 billion a year, and the number of monitored channels from 1,700 to 3,200. This dramatic increase generated new needs from Environmental and Radiation protection specialists. New tools and features are required in order to allow efficient data analysis.

High Resolution Measurement Storage

In order to guarantee low latency when accessing data for a long period, archived REMUS data are reduced after a defined time, following algorithms defined for each type of measurements. In most common cases, the measurements are reduced to one minute resolution after 15 days, and with the best available resolution around specific events (i.e. exceeded thresholds).

However, radiation protection specialists are interested, in some cases, to be able to keep the best available resolution for a longer period of time. NoSQL (Not Only SQL) ecosystems could offer such high resolution measurement service, at the cost of a higher latency on data retrieval.

Both services could be made available from the data visualisation tool, in order to be able to switch from a low latency/low resolution service to a high latency/high resolution one (See Fig. 6).

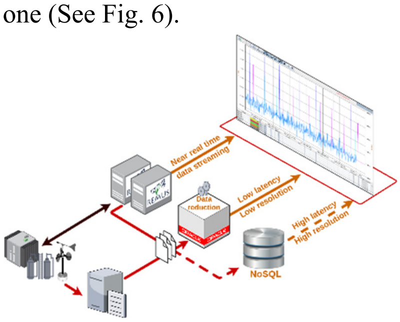

Figure 6: REMUS future data service architecture.

Data Streaming

REMUS users are gaining interest on accessing REMUS real time data on mobile terminals, for on-site operations.

The emergence of big data technologies has brought new possibilities regarding reliable and scalable data streaming services. At the time of writing, REMUS relies on a CERN-developed protocol for streaming data in near real time to its data visualisation tool.

A modernisation of REMUS data streaming service could be an opportunity to both increase its efficiency and allow the development of web and mobile applications.

CONCLUSION

The CERN Health, Safety and Environment Unit succeeded in the development and deployment of a new Radiation and Environment Supervision, Control and Data Acquisition system.

This supervisory system, called REMUS - Radiation and Environment Monitoring Unified Supervision - is now the unique supervision for all radiation and environmental monitoring equipment at CERN.

Its cost-effectiveness, reliability and scalability makes it suitable for long term use at CERN, and opened the possibility of collaboration with other laboratories and industrial partners.

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