Technical Data Server: A Large Scale Supervision System

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Abstract

CERN’s Technical Control Room (TCR), is responsible for the overall surveillance and control of its technical infrastructure covering systems such as cooling, air conditioning, electric power distribution, control and safety systems. In order to prepare this supervision for the era of CERN's future accelerator, the Large Hadron Collider (LHC), we have developed, extensively tested and installed the Technical Data Server (TDS): an event-driven, distributed, real time information system which can interface to different types of equipment data.

To achieve our objectives of an efficient and maintainable supervisory system with very limited human and financial resources, we based our development on three concepts: rigorous application of software engineering standards, use of a commercially available middleware package and integration of various industrial control systems via a commonly accepted communication standard.

The project adhered fully to the PSS-05 Software Engineering Standards and its life-cycle approach as conceived and published by the European Space Agency (ESA), though some of the technical and managerial documents had to be tailored to the particular context of a CERN in-house project. Throughout the development we focused specifically on quality factors such as: reliability, testing, programming standards and configuration management. A dedicated simulator was built and the TDS underwent systematic tests which covered the maximum load that it is required to handle.

The TDS has been developed on top of the commercial middleware package RTworks. This product is specially designed for the building of large scale applications, offering high speed inter-process communication, scalability, reliability and fault tolerance.

With the TDS we have successfully implemented a new type of industrial system integration at the TCP/IP level. The generic TDS equipment access protocol (GTEAP) fully defines the asynchronous data exchange with the equipment level, providing a clear partition of responsibilities between the global technical supervision and the local process controls.

The first technical system and the large scale tests has shown the TDS to behave as a reliable and robust supervisory system. A further seven new systems representing 10,000 tags are being integrated and will be ready for December 1997.

1 Introduction

At CERN, the Technical Control Room (TCR) monitors data coming from the electrical distribution, cooling water, air conditioning, vacuum, cryogenics, safety and other systems.

In this context, a Technical Data Server (TDS) has been defined and implemented. It provides data collected from equipment using a standard TCP/IP interface to the high level control software such as Human Computer Interfaces (HCI), a Data Logging System (DLS) and a Central Alarm Server (CAS). It performs real time data storage and distribution, alarm filtering, data archiving and playback, and command management in a distributed, multi-platform environment. Technical infrastructure data are used by other CERN control rooms and by those responsible for equipment. The TDS is now operational and several thousand tags are under integration.

The intention of this paper is to summarise the concepts and performance of the TDS, the experience gained using RTworks and the applicability of the ESA PSS-05 Software Engineering Standards at CERN.

2 Motivation for the project

The TDS objectives are to provide: a fast and reliable channel for data diffusion (states, alarms, measurements and command), alarm filtering, an efficient and unique equipment access method, a common application programming interface and a reduced maintenance effort. The TDS shall provide the permanent availability and high reliability required by the TCR.[1]

The TDS has superseded the traditional Request-Reply method of acquiring and managing data, where HCI and logging data are obtained by polling equipment and alarm data are event-driven, by the modern Publish and Subscribe paradigm.

3 Volume of work

The development of the TDS represents a six man/year effort from the user specification up to the delivery of the product in operation. Five hundreds pages of documentation and 80 000 lines of code have been produced.

4 Environment

The environment consists of a three-layer architecture: the Control Room layer, the Front-End layer and the Equipment Control layer.

The Control Room Layer consists of HP servers (HCI, alarms, logging) and Xterminals.

The Front-End layer consists of standard VME racks powered by PowerPC processors running LynxOS interfacing various fieldbuses (MIL1553, GBUS, BITBUS, JBUS), HP servers interfacing Programmable Logic Controllers (PLC) via the Siemens protocol SINEC H1, and manufacturer specific gateways connectable to the backbone via TCP/IP[2]. The top two layers communicate via a 100 Mbit/s FDDI backbone via switching devices.

The Equipment Control layer consists of CERN built devices and PLCs from various manufacturers.

5 Off-the-shelf product: RTworks

The TDS has been designed on top of a middleware product: RTworks from Talarian Corporation (USA). RTworks is a suite of software development tools for building time-critical monitoring and control system applications. It consists of separate processes for data acquisition, data distribution, real-time inferencing, and graphical user interface building. RTworks is specially designed for building applications where large quantities of data must be acquired, analysed, distributed, and displayed in real time. It offers high speed inter-process communication, scalability, reliability and fault tolerance.

The major RTworks components are:

RTserver - information distribution server.
RTie - expert system builder
RThci - graphical user interface builder.
RTdaq - data acquisition interface.
RTarchive - intelligent information archiver.
RTplayback - information playback module.

6 Supervision principle

The Publish and Subscribe paradigm of RTworks fits very nicely to the event driven model defined for the TDS. The RTworks processes communicate via a dedicated message server. Applications can run on a single workstation or can be distributed across multiple processors in a heterogeneous network.

Equipment data are sent by their control devices using drivers (e. g. SINEC H1, CERN SL Equip) to an Equipment Controller (EC) which converts them to the TDS tag format and forwards them to the TDS using the Generic TDS Equipment Access protocol (GTEAP).

The tags are then stored in the TDS's local real-time databases (RTdaq) and are published to the subscribing applications. The client applications receive the data by subscribing to particular data sets called datagroups. All data arriving in the TDS are archived for 72 hours (allowing post-mortem analysis of incidents). Archive data can be played back in client applications just like the real-time data. The alarms are sent to the expert system (RTie) using the RTworks Guaranteed Message Delivery (GMD) mechanism which ensures that no data is lost even in the case of network or server unavailability. The expert system performs alarm deduction, filtering and alarm burst detection.

A special mechanism informs in real-time the relevant client applications of any non-availability of an element (RTdaq, EC..) in the data transmission chain. All commands sent using the TDS are identified, logged and their execution status is checked. The TDS application programming interface (GTAAL) allows any client application to exchange data with the TDS. It is based on the reception of pre-defined messages handled as application call-backs.

Tag definition and system configuration data are held in a reference database providing a totally data driven system.

The TDS supervision module monitors the overall system and centralises the errors treatment.

An anti-flooding mechanism has been implemented whereby only tags different from their default values are transmitted at initialisation thus optimising system performance.

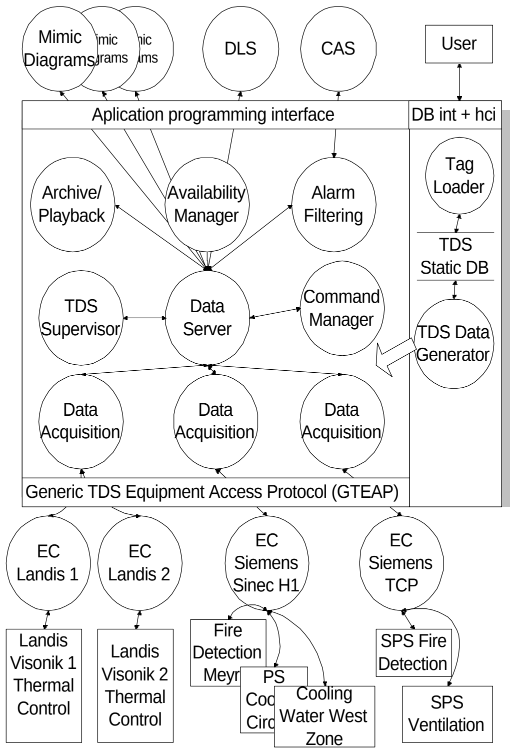

Figure 1 - TDS Logical Model

7 Performance

The performance requirement where:

- average transmission time EC- to client: 1 s
- maximum transmission time: 30 s
- system capacity: 100,000 tags
- reliability: no data lost in transmission

A simulator tool was built in order to test the most extreme operational conditions expected:

- 12 client applications
- 6 RTdaq
- 42 Equipment Controllers sending 10 tag/s each,
- 1 RTserver and
- 105.560 tags loaded.
- 2 multi-user HP servers

The following tests results were obtained:

- average transmission time EC- to client: 200 ms
- maximum transmission time: 10 s
- system capacity: passed
- reliability: passed

During a 1 minute avalanche, where 45.000 tags were sent, the transmission time rose to 10s without data loss. Within 1 minute the system was back to its normal transmission rate.

The test sessions have demonstrated that the TDS has met its requirements in terms of reliability (no data loss in extreme situations), long term stability, nominal and avalanche transmission speed, as well as ability to monitor the required number of tags. The modularity and scalability of the system does not limit the system to the 100.000 tags initially foreseen.

8 Industrial control integration

With the TDS we have successfully implemented a new type of industrial system integration at the TCP/IP level. The generic TDS equipment access protocol (GTEAP) fully defines the asynchronous data exchange with the equipment level. It is based on TCP/IP socket streams. It provides a clear partition of responsibilities between the global technical supervision and the local process controls. To ensure the system integrity the equipment data has to be defined as TDS tags in the TDS reference database (TDrefDB) along with the TDS topology which hosts this new interface.

At the TDS level, the RTdaq processes have been linked with the GTEAP library for protocol handling. The RTdaq is able to manage the connection with several ECs. We have experience with ECs on PC/OS2, PowerPC/Lynx OS, HP/HPUX.

When integrating a new system within the TDS, the local control system provider will deliver its EC according to the GTEAP specification and the requirements for monitoring by the CERN/SL network management system [5].

9 Benefits

The large scale tests and the first system migrated show the following benefits:

- improved response time of the human computer interface for equipment survey (HCI)
- data integrity and coherence between all the TDS client applications: UMMI, DLS, and CAS
- robustness and reliability of all the processes
- no more data loss, handling of alarm burst
- the equipment layer devices are not linked any more to the client applications
- software maintenance process is improved
- the TDS being fully documented its maintenance could be easily outsourced
- all new modules will adhere to the message based and event driven concepts
- single interface for industrial system integration
- the definition of the overall system (equipment data and TDS configuration) in a reference database ensures its permanent integrity.

10 Software engineering

In order to achieve the proposed goals, and to limit the risk due to the limited experience of the manpower resources assigned to the project, we adopted the ESA PSS-05 Software Engineering Standard [3]. This standard has been tailored with the help of the Danish software company CRI to the CERN context, needs, and resources available for the project.

The ESA PSS-05 Software Engineering Standard was used for the technical, managerial and administrative tasks (configuration management and project management). Writing the technical documentation following the standard was essential to the successful management of the project. However, in order for documentation to be of a high standard and to be kept up to date with the evolution of the project it should be carried out either by specifically trained staff or developers with significant experience. Mechanisms for ensuring the validity of the documents with respect to the software also need to be adopted. Nevertheless, the standards enabled the team to focus in details to all aspects of the software life cycle. We used the waterfall for development and the V model for verification and validation.

The managerial and administrative tasks of the ESA PSS-05 organise the contractual relations between the customer and the software provider and impose additional paper work which is not adequate for internal CERN development. For the data integration phase we are testing the Goal Directed Project Management (GDPM) method from Erling S. Anderssen & all [6]. It is found less administrative and more efficient in terms of team motivation and project controls.

11 Present situation

A further seven systems representing 10.000 tags are being integrated and will be ready by December 1997 (CERN fire and gas detection, cooling water West zone, PS cooling water, PS ventilation, computer center iced water, heating plant Meyrin and Prevessin, co-generation plant, SPS ventilation).

12 Conclusion

The TDS has been developed using modern software engineering methods and standards. Its uplish and subscribe” paradigm provides excellent performance and scalability for integration in CERN she distributed environment of the CERN CERN sdistributed control environment. The choice of RTworks from Talarian seems highly satisfactory in terms of performance and reliability (mission critical applications). The TDS design effort saves resources: no programming is required to supervise new equipment which only requires data definition, EC integration, system configuration and HCIs design. The maintenance of the overall supervisory system is drastically simplified.

Nevertheless a 5 man year effort was required to complete the project. We had to interface all existing equipment, control rooms applications and redefine the control system structure.

The project development was a fruitful experience of a CERN-industry integrated team, were the CERN participants learned much from industrial pragmatism and methods.

The first technical systems to be integrated and the large scale tests have demonstrated the reliability and the robustness of the TDS supervisory system. The integration of the remaining and forthcoming systems bring other challenges, particularly in the data management area. The next development effort in the supervision of CERN'S technical services will focus on a new generation of human computer interfaces based on JAVA and fourth generation web server technology to integrate the object oriented definition of equipment supported by the TDS.

Reference

[1] 'The Technical Data Server for the control of the 100 000 points of the Technical Infrastructure at CERN', P. Ninin & all, Icalepcs 95.

[2] 'Industrial Control Systems at CERN', P. Ninin, E. Cennini, P. Sollander, Icalepcs 97.

[3] 'Software Engineering Standards', ESA Board for Software Standardisation and Control, 1994

[4] 'TDS Interface Control Document', April 1996, P. Ninin & all

[5] 'Data Communication Infrastructure Available at CERN for Interconnection of Industrial Control Systems', Robin Lauckner, Patrick Lienard, Raymond Rauch, CERN-SL 97-14 CO, March 1997.

[6] 'Goal Directed Project Management', Erlking S Andersen, Kristoffer V Grude, Tor Haug, Coopers & Lybrand